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32nd Annual New Mexico Water Conference

Ground Water Management

New Mexico Water Resources Research Institute
Box 30001, Dept. 3167
Las Cruces, NM 88003-0001

GROUND WATER MANAGEMENT

PROCEEDINGS OF THE
32ND ANNUAL NEW MEXICO WATER CONFERENCE

HOLIDAY INN PYRAMID
ALBUQUERQUE, NEW MEXICO
NOVEMBER 5-6, 1987

New Mexico Water Resources Research Institute
New Mexico State University
Las Cruces, New Mexico

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PREFACE

To complement last year's conference which focused on managing the surface water of the Rio Grande, this year we explored the topic of ground water management. The management of New Mexico's ground water reflects the growing concern for the quality of the water in our aquifers and private wells that provide over 1,200,000 New Mexicans with their water supply. Augmenting our water supply by recycling water for recharge into aquifers is proving to be one way to provide an adequate supply of water for future use. Also, we need to better understand the legal and administrative implications involved in water planning activities. With these concerns in mind, the 32nd Annual New Mexico Water Conference dealt with the topic of "Ground Water Management."

The first session of the conference highlighted ground water quality programs at the federal, state, and local levels. In addition, we learned about the 1986 Arizona Environmental Quality Act, a model for establishing an aquifer protection program. Governor Carruthers, during his luncheon address, set priorities for the state of New Mexico in ground water and emphasized the need to identify and clean up contaminated sites.

Ground water recharge was the topic of session II with several speakers describing ongoing recharge demonstration projects as well as research in the area of recharge. The last session dealt with strategies for protecting ground water quality for current and future users. The effects and interrelationships of federal and state laws upon water management were examined.

This year's water conference confirmed the need for careful, comprehensive planning for the future use of ground water in our state. As in the past, the conference provided a forum for water experts, policy makers and interested citizens to come together and discuss the current and future state of water in New Mexico. This year, Governor Carruthers asked for guidance and advise from the attendants for protecting New Mexico's water resources.

Special thanks should go to the Water Conference Advisory Committee for suggesting the theme of this conference and providing the support to make it a success.

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Funds for the proceedings publication were provided by registration fees, the U.S. Department of the Interior and by state appropriations to the New Mexico Water Resources Research Institute.

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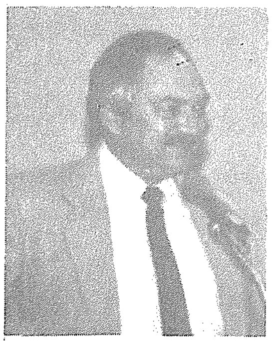

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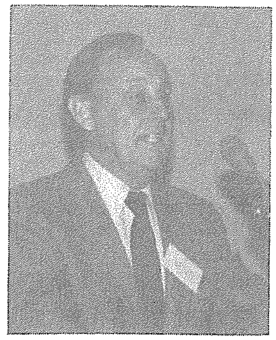

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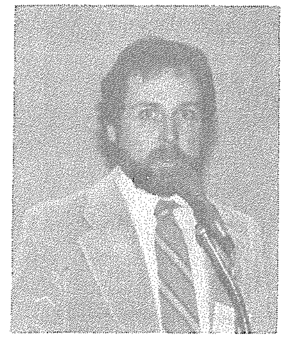

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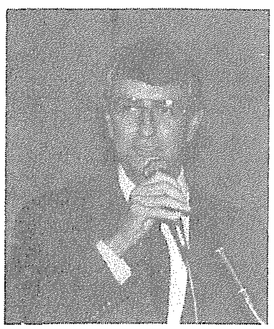

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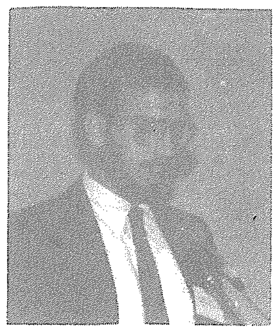

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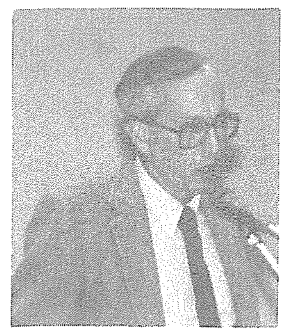

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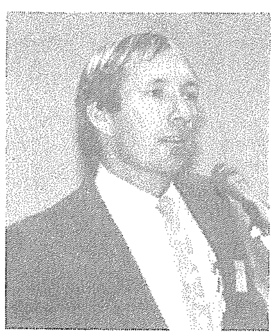

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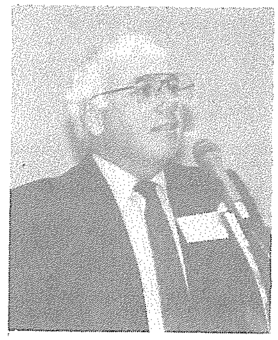

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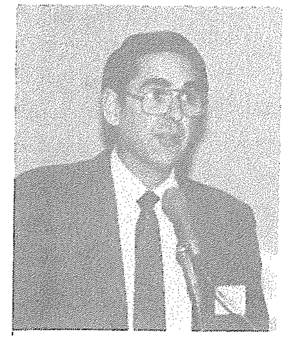

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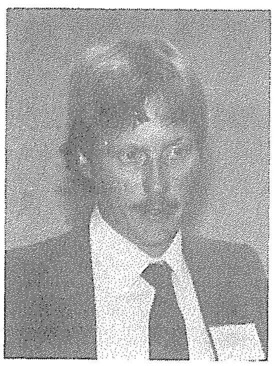

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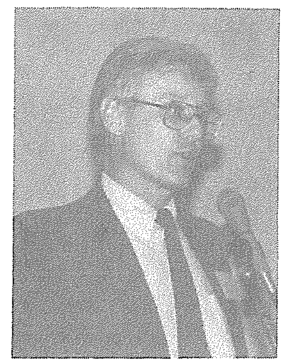

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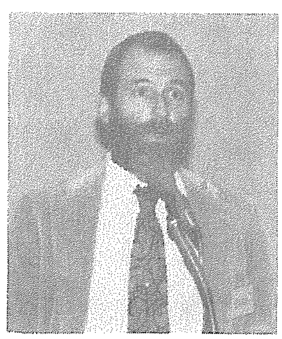

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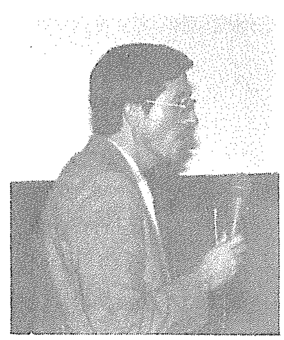

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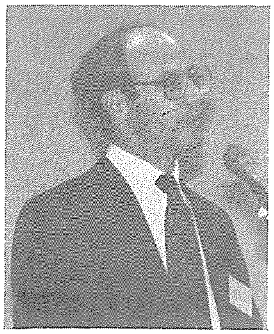

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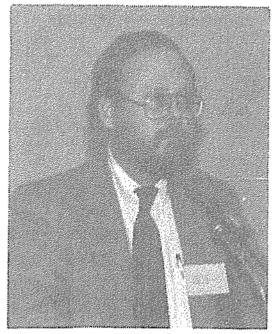

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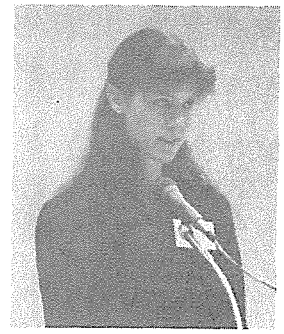

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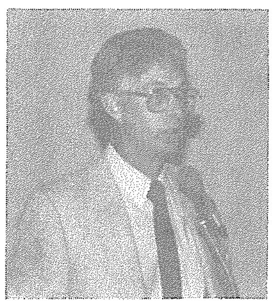

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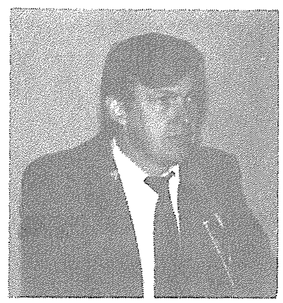

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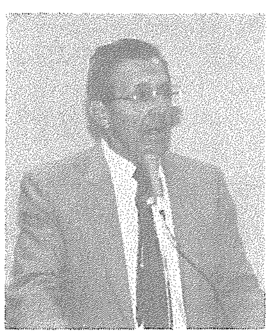

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SPEAKERS PREVIEW

TOM BAHR is the secretary of the Energy, Minerals and Natural Resources Department. His current interests focus on recent water court cases and their implications to water and natural resource policy and management in the western United States. Prior to his cabinet appointment, he was director of the New Mexico Water Resources Research Institute. He previously served as director of the Interior Department's Office of Water Policy under the first Reagan administration. He is a native of Wisconsin and received his undergraduate degree from the University of Idaho and a master's and doctorate from Michigan State University.

HERMAN BOUWER is the director of the U.S. Department of Agriculture's Water Conservation Laboratory in Phoenix. He is leader of a subsurface water management research group, whose main projects deal with renovation of sewage effluent by ground water recharge and effects of irrigated agriculture on ground water. He has written about 180 research publications, the textbook Groundwater Hydrology, and 10 book chapters. In 1985, he received the Scientist of the Year Award from the USDA. He received B.S. and M.S. degrees in land drainage and irrigation from the National Agricultural University of Wageningen, The Netherlands, and a Ph.D. in hydrology and water management from Cornell University.

DAVID G. BOYER is the environmental bureau chief for the New Mexico Oil Conservation Division where he is responsible for the permitting of gas plants and refineries, the regulation of surface disposal of oil production wastes, and the investigation of oil-related ground water contamination. Previously he was with the New Mexico Environmental Improvement Division where he was in charge of the EPA's Surface Impoundment Assessment and Underground Injection Control Program. He received his B.S. and M.S. degrees in hydrology from the University of Arizona and has conducted hydrogeological investigations for the Arizona Water Resources Research Center and the Office of Arid Lands Studies.

GARREY CARRUTHERS, the 24th governor of New Mexico, began his political career in 1959 as state president of the Future Farmers of America. In 1974, he became a White House Fellow under President Gerald Ford and in 1981 he was appointed assistant secretary of the Interior Department. After earning bachelor's and master's degrees at New Mexico State University and a doctorate in economics from Iowa State University, he returned to NMSU to teach agricultural economics and agricultural business. His association with the university continued until 1985 when he resigned to run for governor. From 1976 to 1978, he was the acting director of the New Mexico Water Resources Research Institute. He grew up on a farm in Aztec, New Mexico.

PETER V. DOMENICI, JR. is an attorney with the law firm Civerolo, Hansen & Wolf, P.A. specializing in water and related resources, water pollution, and water allocation and distribution. He has been counsel in complex water resource and pollution litigation, including Pueblo of Acoma and Pueblo of Laguna v. City of Grants, et al. He is co-author of "Indian Water Rights Expanded," published in the August 1987 issue of the New Mexico Business Journal. He holds a bachelor's degree from the University of Virginia and a J.D. from the University of New Mexico School of Law.

DOUGLAS EARP is a geohydrologist with the City of Albuquerque Environmental Health Department where his main responsibilities include development of a ground water quality monitoring program, periodic monitoring of existing wells, design and construction of additional monitoring wells, computer modeling, and data base development and management. For five years he worked in the surface water and ground water programs of the New Mexico Environmental Improvement Division. He holds a bachelor's degree in biology from the University of New Mexico and a master's degree in hydrology from the University of Arizona.

BRUCE GALLAHER is a program manager with the Ground Water Bureau of the New Mexico Environmental Improvement Division where his responsibilities include conducting field investigations of landfills, identifying hazardous waste programs in the state, and developing New Mexico's ground water protection strategy. He has a bachelor's degree in mathematics from Eastern New Mexico University and a master's degree in hydrology from the University of Arizona. He was born and raised in New Mexico.

BRUCE GLENN is a general engineer with the U.S. Bureau of Reclamation Engineering and Research Center, Denver. His career spans 26 years with the bureau as a planner evaluating and reviewing planning studies. His special assignments include conducting a short course in water resources planning in the Philippines and reviewing the Three-Gorges Project in China. He also has served on various committees implementing national water policy. He is currently the program manager of the High Plains States Groundwater Recharge Demonstration Program. He holds a B.S. in civil engineering from Cornell University, an M.S. in engineering economics from Stanford University and an M.S. in policy analysis, also from Stanford University.

MAXINE S. GOAD is a water resources specialist and has been working in water pollution control for the State of New Mexico Environmental Improvement Division since 1974. She was principal draftsperson and one of the principal developers of the New Mexico Water Quality Control Commission regulations to protect ground water quality. As program manager for the Ground Water Section she was responsible for the implementation of these regulations from their adoption in 1977 until 1985. Ms. Goad's present duties include working on coordination of ground water regulatory programs and being a major participant in the development of the New Mexico Ground Water Quality Protection Strategy being prepared as required by the EPA. She received B.S. and M.S. degrees in physics from Stanford University in California.

KEN KIRKPATRICK is the deputy director, Water Management Division, Office of Ground Water, U.S. Environmental Protection Agency, Region 6, Dallas. His 26 years with the federal government include more than a dozen positions concerned with managing air and water quality. Recently he served a two-year intergovernmental assignment from the EPA as deputy director for the Arkansas Department of Pollution Control and Ecology. He is a registered professional engineer and a member of the Texas Society of Professional Engineers and the Water Pollution Control Federation. The Kansas native holds a B.S. in civil engineering from Colorado State University and an M.S. in civil engineering from Oregon State University.

DANIEL B. KNORR is vice president of Parkhill, Smith & Cooper, Inc., El Paso, Texas. Since joining the firm in 1971, he has had a major role in the planning and design of several major projects for El Paso's Public Service Board, including El Paso's $30 million Northeast Treatment Plant. In conjunction with this project, he designed a sewage drinking water treatment plant required for a full scale aquifer recharge project in El

Paso. His involvement in this project has brought him national recognition as one of the foremost designers of advanced wastewater treatment facilities in the United States. He grew up in Artesia, New Mexico and graduated from New Mexico State University with a B.S. in civil engineering.

DENNIS MCQUILLAN is a water resources specialist with the Ground Water Bureau of the New Mexico Environmental Improvement Division. He conducts regional and local investigations of ground water quality and contaminant discharges, provides technical assistance to other agencies, local governments and citizens, oversees several cleanup efforts, and maintains an inventory of ground water contamination in the state. He received a B.S. in geology from the University of New Mexico and has more than eight years of ground water quality experience.

SUSAN CHRISTOPHER NUNN recently joined the faculty of the Department of Economics at the University of New Mexico where she teaches water policy, water quality management and natural resources economics. She was previously with the Department of Hydrology and Water Resources at the University of Arizona. She currently works in the area of rural/urban water transfer policy and serves on several state and local committees in Arizona. She was co-organizer of a conference on "Water Transfers and the Quality of Rural Life" in April 1987. She received her Ph.D. from the University of Wisconsin-Madison.

WILLIAM H. OTTO is assistant director of the Public Works Department, city of Albuquerque, where he is responsible for planning the city's transportation, drainage, wastewater and water supply systems. His career spans 25 years devoted to planning, design, construction, operation and maintenance of public works. He spent 15 of those years specializing in the field of water works, primarily involving Albuquerque's water supply system. He holds a B.S. in civil engineering from the University of New Mexico.

RICHARD PERKINS is a water resources specialist with the New Mexico Environmental Improvement Division where he is currently developing the New Mexico Ground Water Quality Protection Strategy. Previously at the EID he managed the state's liquid waste program and ground water quality surveillance program. Before coming to New Mexico, he was an assistant professor of biology at the University of Kansas. He holds a B.S. in biology from the University of California, an M.S. in zoology from the University of Georgia and a Ph.D. in ecology, also from that university.

FRED M. PHILLIPS is an associate professor of hydrology at the New Mexico Institute of Mining and Technology where his research interests include ground water dating, paleoclimatic reconstruction from ground water geochemistry, and paleohydrology of quaternary "pluvial" lakes. His research has been published in several journals, proceedings and technical reports. He is the co-author of the Handbook of Environmental Isotope Geochemistry. He is a native Californian and a graduate of the University of California at Santa Cruz. He also holds an M.S. and a Ph.D. in hydrology from the University of Arizona.

DAN SHEIN is a research analyst with the Arizona House of Representatives where he is on the staff of the Natural Resources and Energy Committee and the Agriculture Committee. His responsibilities on the Natural Resources Committee include preparing issue papers and analysis of legislation relating to those areas under the committee's responsibilities. Previously he was a consultant in public policy, research and analysis. He has also worked as a planner with the Energy Division of the Arizona Office of

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JAY F. STEIN is an attorney with the law firm Civerolo, Hansen & Wolf, P.A., specializing in environmental litigation. He was the lead counsel to the New Mexico Water Quality Control Commission in the case of Pueblo of Acoma and Pueblo of Laguna v. City of Grants, et al. From 1977 to 1985, he was counsel to the State Engineer Office and the Interstate Stream Commission. During that time he handled interstate litigation and intrastate water adjudications, including Colorado v. New Mexico and the Hondo adjudication involving the claims of the Mescalero Apache tribe. He has a J.D. degree from the University of New Mexico School of Law.

JANE G. WELLS is a hydrologist with the Bureau of Indian Affairs, U.S. Department of the Interior, Albuquerque. She serves as a Principal Professional Technical Consultant in the development and implementation of a nationwide water quality control program for the BIA. She is also responsible at the BIA for providing expert witness testimony for Indian water quantity adjudications, providing the BIA and Indian tribes with information on new EPA water regulatory programs and overseeing ground water exploration contracts. Her responsibilities also include collecting and interpreting other geohydrologic data for court work or Indian water management purposes. She graduated with honors from the University of New Mexico in 1977 and is a Certified Professional Geological Scientist.

MODERATORS

BOBBY J. CREEL is the acting director of the New Mexico Water Resources Research Institute. Dr. Creel's extensive experience in resource economics includes more than 25 research projects. He also holds the position as college associate professor in the Agricultural Economics and Agricultural Business Department at New Mexico State University. Dr. Creel holds bachelor's and master's degrees from New Mexico State University and a doctorate from the University of New Mexico in resource economics. He is a native New Mexican who grew up on a ranch near Ruidoso, New Mexico.

CHARLES T. DUMARS, professor of law at the University of New Mexico, recently served as chairman of the New Mexico Water Law Study Committee. He is the author of numerous articles on water law and water rights and is the co-author of Economic Impact of Alternative Resolutions of New Mexico Pueblo Indian Water Rights. He is a member of the Western States Water Council, the Board of Trustees of the Rocky Mountain Mineral Law Institute, and the American Bar Association Natural Resources Committee. He received a bachelor's degree from the University of Oregon and a law degree from the University of Arizona.

JOHN HERNANDEZ has wide ranging administrative and research experience including positions as dean of engineering at New Mexico State University and deputy administrator of the U.S Environmental Protection Agency. During a recent sabbatical he worked in the Technical Division of the New Mexico State Engineer Office on ground water basin studies. He also helped plan a proposed update of New Mexico's water resources assessment. He holds degrees from Harvard University, Purdue University and the University of New Mexico.

WALTER A. WEBSTER is senior vice-president of Leedshill-Herkenhoff, Inc., which conducts water resources development for municipalities in New Mexico. He has been with the firm since 1954. Before that, he was with the U.S. Army Corps of Engineers, Albuquerque District. He is a member of several professional organizations including the American Water Works Association, the American Society of Civil Engineers, the American Consulting Engineers Council of New Mexico and the American Consulting Engineers Council. He holds a B.S. in civil engineering from the University of New Mexico.

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FEDERAL GROUND WATER QUALITY PROTECTION PROGRAMS

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Dallas, Texas

Thank you for the invitation to meet with you today. I have spoken here before, enjoy the association and always learn a great deal about water in New Mexico. It also provides an opportunity to visit New Mexico and its scenic mountains. I would like to take a moment to introduce Lee Harris and Kathy Hollar from the Office of Groundwater in Region VI. Kathy manages the ground water protection programs in New Mexico, working closely with the New Mexico Environmental Improvement Division. Lee is the Chief of the Office of Groundwater.

We recognize that in New Mexico, pollution of shallow ground water has the potential to contaminate private drinking water wells. The environmentally sensitive river valleys and floodplains, which often contain shallow aquifers, are the focus for high density populations in New Mexico. Among the five states covered by our regional office, (Louisiana, Arkansas, Oklahoma, Texas, and New Mexico), New Mexico is of particular interest to us with regard to ground water contamination because of the strong dependence on ground water here and because the area's geology renders the limited ground water supplies vulnerable to contamination.

Approximately 87% of the population in New Mexico depends on ground water for drinking water and it is the only source of water in many parts of the state. Compare this to approximately 50% in Arkansas, 69% in Louisiana, 41% in Oklahoma, 47% in Texas, and it is easy to understand the importance of ground water in New Mexico.

The Environmental Protection Agency (EPA) has awarded grants to the New Mexico Environmental Improvement Division for developing and implementing ground water protection programs. Since 1985, a total of just under $300,000 has been allocated to the state for ground water protection.

With respect to ground water protection in the United States today, it is clear that a complex network of federal, state, and local agencies are sharing the responsibility, based on their particular authorities and abilities. Some of these agencies have had a role in ground water protection for many years, while other agencies have only recently added ground water protection to their other responsibilities. In some states, new agencies have even been established to handle the protection of ground water. New Mexico took the initiative to protect ground water resources a decade ago when the New Mexico Water Quality Control Commission adopted a comprehensive set of state ground water protection regulations. New Mexico's regulatory program for the protection of ground water quality is well established, workable and effective. The ground water laws of some sixteen states reflect New Mexico's influence.

Legislation that protects ground water is found at all levels of government; however, there is no single, overriding ground water statute at the federal level. Instead, fifteen separate laws address ground water in some way (see Figure 1). Many of these federal statutes control specific contaminants and sources of contamination, while others establish programs to preserve or restore the ground water.

Historically, states have had the principal ground water protection responsibility. Although federal source-related statutes have been enacted, no overriding federal legislation similar to that for surface water or air exists for ground water. While some groups are calling for omnibus legislation, the EPA administration has taken the position that states should retain the primary responsibility.

At the federal level, eleven separate agencies have some jurisdiction over ground water (see Figure 2). Of these agencies, EPA has the lead responsibility for ground water quality and implements regulatory and research programs designed to protect ground water. Some of the other federal agencies that also play major roles in the protection of ground water include: land management agencies within the Department of Interior and the United States Department of Agriculture; source control agencies such as the Nuclear Regulatory Commission and the Department of Defense; and, finally, scientific agencies such as the United States Geological Survey which characterizes the ground water resource and conducts broad-based site-specific research aimed at understanding the sources, movement, and fate of both natural and man-made chemicals in ground water, and the United States Department of Agriculture which conducts research on the agricultural aspects of ground water.

Within EPA, ground water protection has become an integral part of many programs which were originally established to meet other objectives. The organization chart in Figure 3 shows the EPA offices with ground water responsibilities at the national level. The organization chart in Figure 4 shows the offices and programs with ground water responsibilities for Region VI. For the most part, these programs address one or more discrete sources of ground water contamination. For example, programs originally established to promote waste recycling and recovery, in order to reduce health risks from

STATUTES

Atomic Energy Act
Clean Water Act
Coastal Zone Management Act
Comprehensive Environmental Response, Compensation, and Liability Act
Federal Insecticide, Fungicide, and Rodenticide Act
Federal Land Policy and Management Act (and associated mining laws)
Hazardous Materials Transportation Act
National Environmental Policy Act
Reclamation Act
Resource Conservation and Recovery Act
Safe Drinking Water Act
Surface Mining Control and Reclamation Act
Toxic Substances Control Act
Uranium Mill Tailings Radiation Control Act
Water Research and Development Act

Source: Office of Technology Assessment, Protecting the Nation's Groundwater from Contamination (Washington, D.C.: U.S. Congress, Office of Technology Assessment, 1984), p. 65.

Figure 1. Federal Laws Related to the Protection of Ground Water Quality

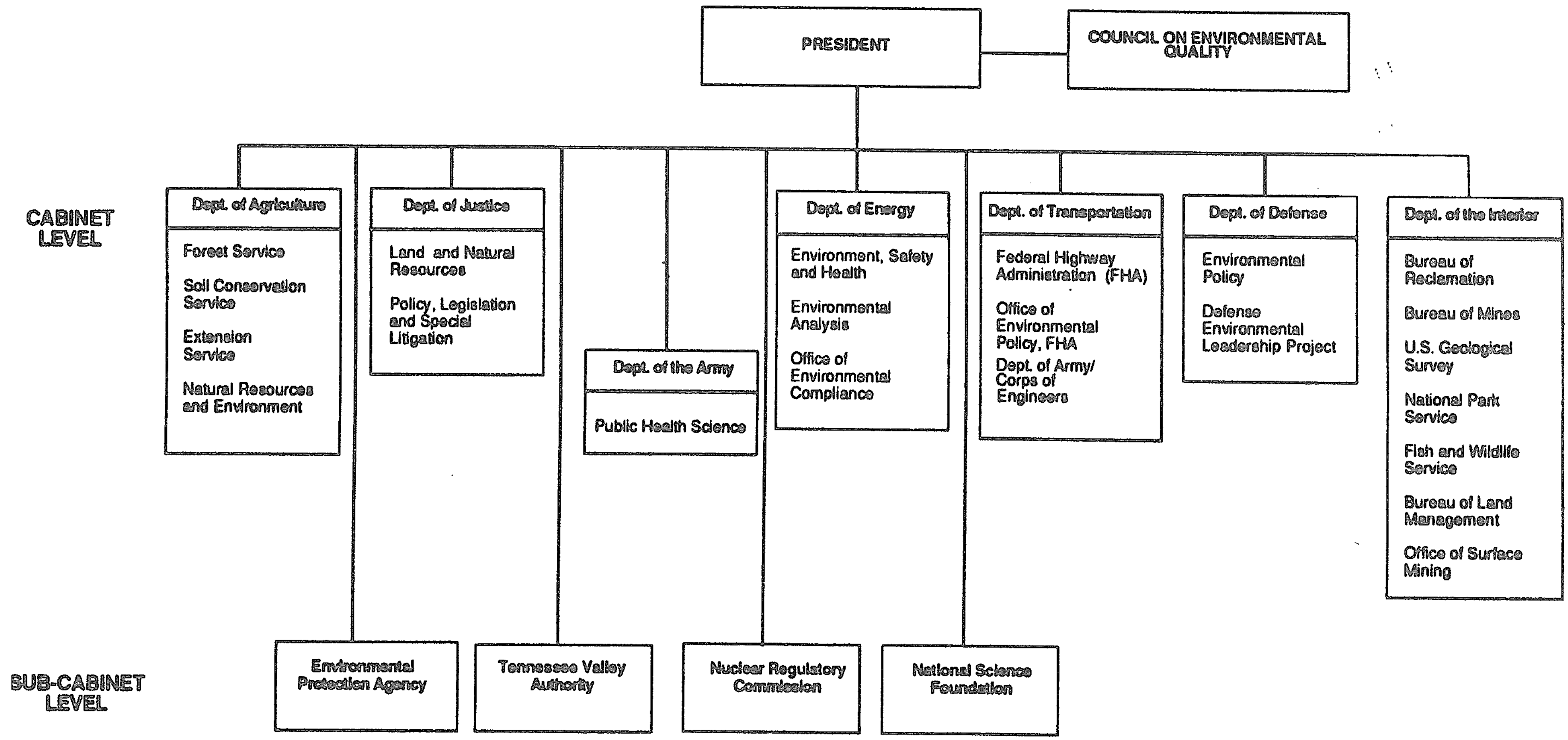

Figure 2. Federal Agencies with Ground Water Protection Roles

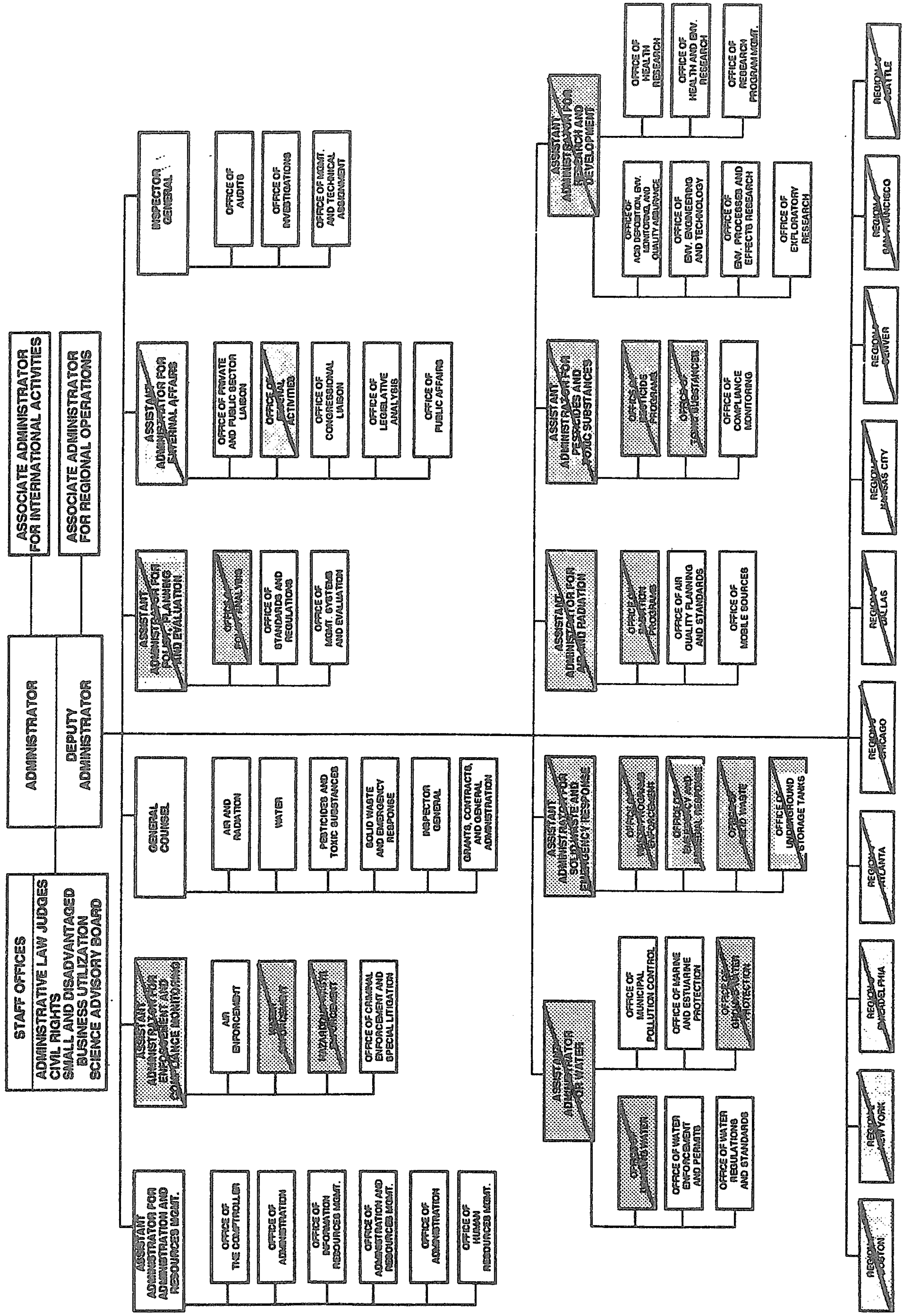

Figure 3. Organization of the U.S. EPA

Source: U.S. Environmental Protection Agency

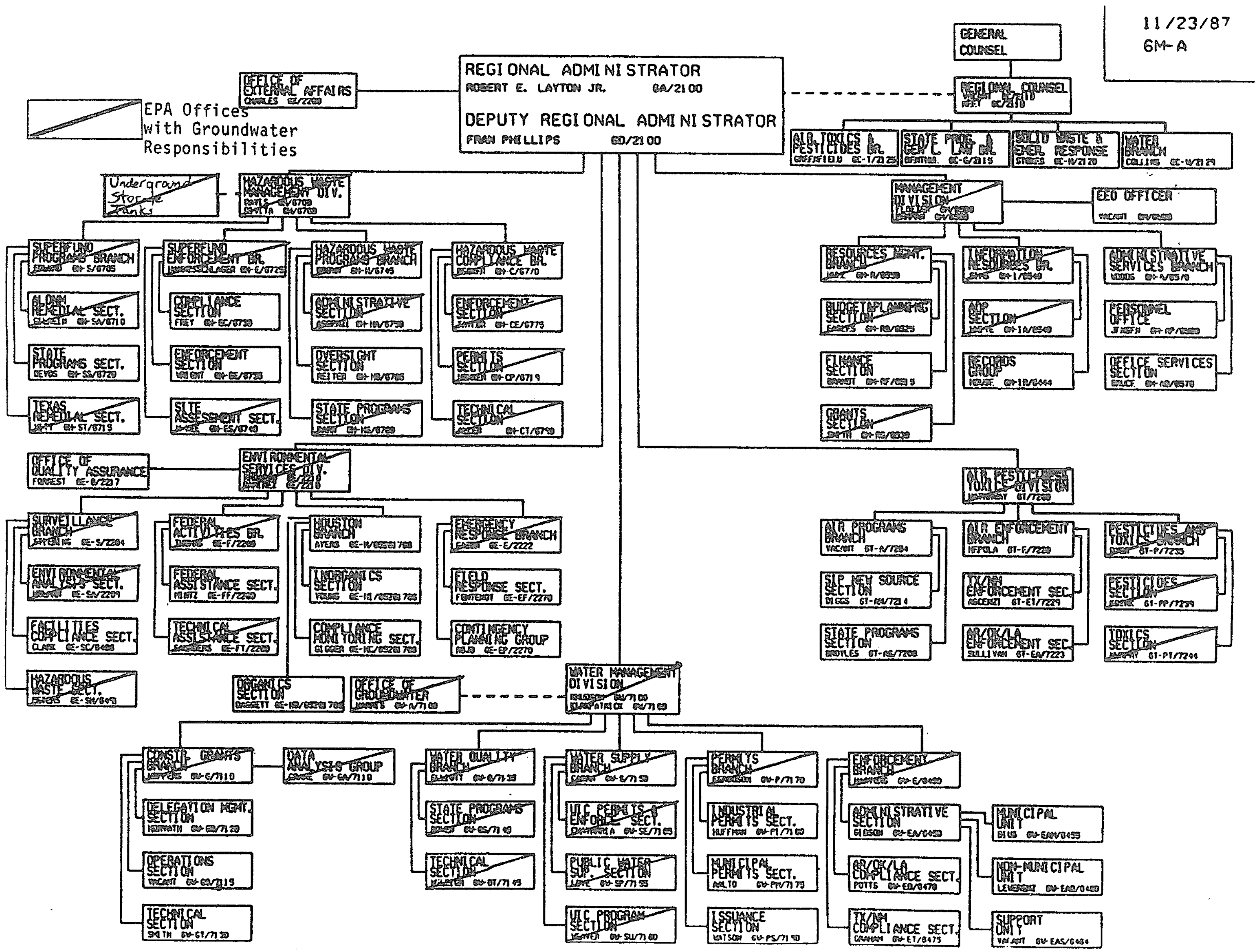

Figure 4. Region 6 Organization Chart

dumps, municipal landfills, lagoons, and other waste repositories, now have a predominant ground water protection orientation.

Ground water protection is one of the EPA's top priorities. Many of our major programs and a large percentage of our budget directly support the protection, maintenance, and restoration of ground water quality. Protecting the vital ground water resource is also one of the agency's most complex environmental issues since it involves potentially millions of individual sources of contamination and an enormous array of domestic, commercial and industrial practices. On a national scale, protecting ground water involves addressing about 1500 hazardous waste land disposal facilities, 951 Superfund sites, (only 4 in New Mexico) thousands of non-hazardous waste disposal facilities, hundreds of thousands of injection wells, over a million underground tanks, 23 million residential septic systems, and the use of millions of pounds of pesticides and millions of tons of fertilizers. The potentially regulated community encompasses not only a few large industries and businesses, but also small businesses, individual homeowners and farmers.

Several important statutes administered by the EPA deal with various aspects of ground water protection and cleanup. The Resource Conservation and Recovery Act of 1976, as amended, prevents contamination of ground water from hazardous waste facilities, municipal landfills, impoundments, and underground tanks. The Comprehensive Environmental Response, Compensation and Liability Act (Superfund) provides the EPA with major authorities and resources to compel or carry out the cleanup of prior and current releases of hazardous substances to the environment. Through the Federal Insecticide, Fungicide and Rodenticide Act, the EPA controls the availability and use of pesticides which may leach into ground water. Under the Safe Drinking Water Act, the EPA sets drinking water standards used in ground water protection decisions and controls the injection of fluids into the underground.

The EPA also provides assistance to states in the development and implementation of ground water protection strategies through the Clean Water Act (CWA). In addition, under the Safe Drinking Water Act Amendments of 1986, the EPA is providing guidance to assist states in protecting the ground water entering the wellhead areas of all public water wells. The agency provides, through these and other statutes such as the Toxic Substances Control Act and the Atomic Energy Act, a wide range of standard setting, institution building, technical assistance, compliance enforcement, research, monitoring and other activities geared toward protecting ground water.

Escalating public concern over ground water contamination has prompted environmental and health officials to apply existing authorities more explicitly for ground water protection. In the last few years, there has been a gradual recognition throughout the United States of the need to move toward protection of the resource itself, rather than focusing regulatory efforts on discrete sources of contamination. Some progress toward that goal has been realized since 1984. Under the agency's <u>Ground Water Protection Strategy</u>, the EPA has: promoted the use of consistent policy for prevention and cleanup of ground water contamination; strengthened its internal organization for protecting groundwater; and, begun to address a broader range of sources.

A central feature of EPA's Ground Water Protection Strategy is a policy framework for agency programs according different levels of protection to ground water based on its use, value to society, and vulnerability to contamination. The strategy divides ground water into three classes:

- -Class I: Ground waters are given special protection because of their vulnerability and their value as a drinking water source or their value to sensitive ecological systems.
- -Class II: Ground waters are current or potential sources of drinking water or have other beneficial uses. They would receive a baseline level of protection consistent with current protection under the EPA programs.
- -Class III: Ground waters are not considered potential sources of drinking water and are of limited beneficial use.

This classification system began its first circulation in draft form for internal review of technical and policy issues in October of 1984, and the final draft for public comment was released in December 1986. We expect another draft of the classification this month and a high level review in December, 1987.

Ground water classification has the potential to impact many EPA programs, for example: the hazardous waste, Superfund, and the pesticide programs; the Underground Injection Control program; and the National Pollution Discharge Elimination System permits program. This classification system is designed as a site-specific system to be used for individual localities. The general intention is that it will be used in EPA's regulatory programs for such action as permitting or enforcement at existing or proposed sites. We will be holding training sessions for state personnel and our own program personnel as soon as the classification system is launched next year.

In order to provide a focus for activities related to ground water protection, the EPA established offices of ground water protection in our headquarters office in Washington and in each of our ten regional offices. In Region VI, the Office of Groundwater manages the ground water protection portions of the Section 106 and Section 319 programs of the Clean Water Act as well as the Sole Source Aquifer (SSA), the Sole Source Aquifer Demonstration (SSAD), and the Wellhead Protection (WHP) Programs in Texas, New Mexico, Oklahoma, Arkansas, Louisiana and Indian lands belonging to the sixty-eight tribes in Region VI. I would like to elaborate on these programs.

Since 1985, states have been eligible for grant money to develop and implement state ground water protection programs under Section 106 of the Clean Water Act. Ground water protection by most states under Section 106 is largely a result of EPA policies described in the EPA Ground-Water Protection Strategy published in 1984. One of the major goals expressed in that strategy is that EPA assist states in developing their own ground water protection programs and state strategies. Recognizing that each state or region of the country has a different set of ground water problems to face, a different philosophical and institutional framework, and a different set of measures already in place to protect ground water, the EPA has allowed a great deal of flexibility to the states in designing their ground water protection programs.

Section 319 of the Clean Water Act as amended this year gives new direction and authorizes significant federal financial assistance for the implementation of state non-point source programs. The Water Quality Act gives states the opportunity and flexibility to design and implement non-point source programs for both surface and ground water.

The Sole Source Aquifer Program was created in 1974 with the passage of the Safe Drinking Water Act. Upon receipt of a complete petition, the EPA may designate the petitioned aquifers or aquifer systems as sole or principal source aquifers which provide 50% or more of the drinking water for a particular area. Following such designation, the EPA reviews proposed federally funded projects in the Sole Source Aquifer area and may prevent funding or require redesigning of a project if the project has the potential to contaminate the aquifer. Designation has no effect on proposed projects which do not receive federal financial assistance such as projects funded by state, local, or private concerns. As a ground water protection program, the Sole Source Aquifer program primarily ensures that the federal government will not support projects which can contaminate unique water supplies. Nationwide, there are currently twenty-one designated sole source aquifers. The Edwards Aquifer in the San Antonio, Texas area is the only one in our five state region to date; however, we have several petitions under review.

The Sole Source Aquifer Demonstration (SSAD) Program was part of the 1986 Amendments to the Safe Drinking Water Act. The purpose of the SSAD program is to establish demonstration programs for Critical Aquifer Protection Areas (CAPAs) within designated sole source aquifers. The EPA issued a rule outlining criteria for identifying these critical areas that considers aquifer vulnerability, population using ground water for drinking purposes, and the economic, social, and environmental benefits and costs of ground water protection. Protection of critical aquifers will occur through the development and implementation of a comprehensive management plan ensuring maintenance of ground water quality for protection of human health, environment and ground water. All or part of an aquifer must be a designated sole source aquifer and meet CAPA criteria to be included within the demonstration program. The aquifer could be an existing designated sole source aquifer or be designated by June 1988. The SSAD Program is a limited one and may entitle successful applicants to receive matching grants. The total amount of the grant cannot exceed $4 million per aquifer per year as authorized by law; however, Congress has not appropriated any SSAD funds for FY88 at this time.

The Wellhead Protection Program, scheduled to begin next year, will develop and implement programs to protect public water supply wells. In New Mexico, the Environmental Improvement Division has been designated by the governor to administer the program. The program is intended to prevent contamination of ground water in the vicinity of public water supply wells by controlling activities which are located within certain distances of each well. The state will be responsible for deciding how large the protected areas around each well should be, and what types of controls will be applied within those areas. Unlike the other federal environmental programs, this one will not set requirements the states must meet. Rather, the EPA will provide leadership by setting some broad goals and in helping states meet those goals. We have been advised that the house appropriations subcommittee has recommended no funding for the program in FY88, although the President's budget included $8 million dollars. I might add that a state is not required by the Safe Drinking Water Act to implement a wellhead protection program. Unlike other EPA programs, it is optional.

Those of you who are municipal officials may be asking, what interest do I, as a municipal official, have in this program ... it sounds like most of the action will be at the state level. First and foremost, the Wellhead Protection Program is designed to protect <u>your</u> drinking water - whether you buy water from another source or control the source yourself. The law itself encourages public participation, and there are several areas where you may want to have input. For example, you will want to work with the state to identify municipal versus state responsibilities. You will want to help identify potential sources of contamination in your area. You certainly want to be aware of the impacts emergency contingency plans may have on you. Will you be called upon to provide water to neighboring cities in an emergency basis? Also, if you anticipate ever constructing new wells, you will want to have a say in any siting and construction requirements developed. On a local level, you may want to consider zoning ordinances to protect your water supply. The Wellhead Protection Program is a good example of how local officials can make the state aware of local problems. I encourage you to let your state agency officials know of your interest in the program and to take advantage of all opportunities for public participation.

In summary, ground water quality protection at the federal level is a complex matrix of different statutes, agencies, and programs. There are currently in the United States Congress several different bills under consideration involving further ground water protection. There is a great challenge ahead for all of to ensure that our future generations have an adequate supply of safe ground water for the many purposes it serves. Thank you for your attentiveness and the privilege to be here with you today.

GROUND WATER CONTAMINATION IN NEW MEXICO
1927-1986

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INTRODUCTION

More than one million New Mexicans rely totally upon aquifers for their water supply. Approximately 200,000 residents use private water wells. Unlike public water systems which are tested routinely pursuant to the federal Safe Drinking Water Act, private wells are tested rarely, if at all.

For the purpose of this document, ground water contamination is defined as a result of human activity involving either the increase in concentration of aqueous solutes or the introduction of unnatural material (dissolved, emulsified, immiscible or suspended). Ground water contamination most frequently occurs in "vulnerable" aquifer areas where the water table is shallow (see Figure 1). (See Figure 2 for general map of New Mexico.)

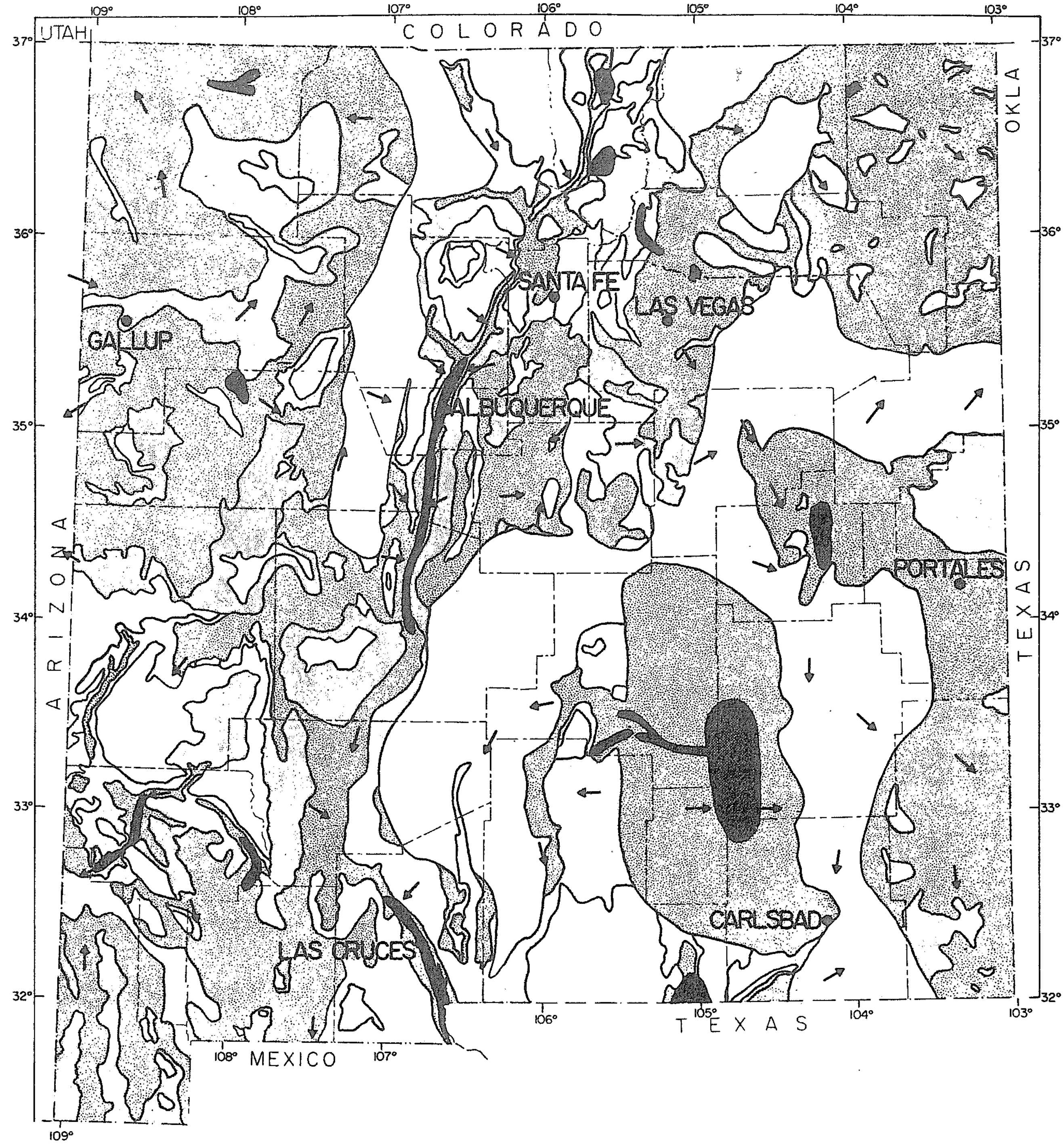
At least 883 incidents of ground water contamination have been documented in the state from 1927 to 1986 (see Figure 3). These cases have contaminated 80 public water supply wells, most of which have been shut down and abandoned (see Figure 4). To date, 54 cases have received or will soon receive some degree of remediation (see Figure 5).

Slightly more than one half of all cases of ground water contamination in the state have been caused by non-point sources, predominantly household septic tanks or cesspools (see Figure 6). Non-point source contamination is caused by diffuse sources such as large numbers of small septic tanks spread over a subdivision, residual minerals from evapotranspiration, urban runoff or widespread application of agricultural chemicals.

Point-source contamination categories are shown in Figure 7. These sources are predominantly industrial in nature; other sources include publicly owned sewage treatment plants or landfills. Virtually all such cases result from:

* historical disposal practices;
* accidental discharges; or
* current unpermitted discharges.

In fact, only 5 of the 412 discharges permitted by N.M. Water Quality Control Commission regulations have caused ground water contamination. None of these cases



HIGHLY VULNERABLE (shallow water table or highly fractured vadose zone)

MODERATELY VULNERABLE (water table less than 200 feet below surface)

LESS VULNERABLE (water table 200 to 500 feet below surface)

RELATIVELY PROTECTED (deep water table; artesian; saline; poor yield)

Figure 1. Relative Vulnerability of New Mexico Aquifers to Contamination from Surface Discharges

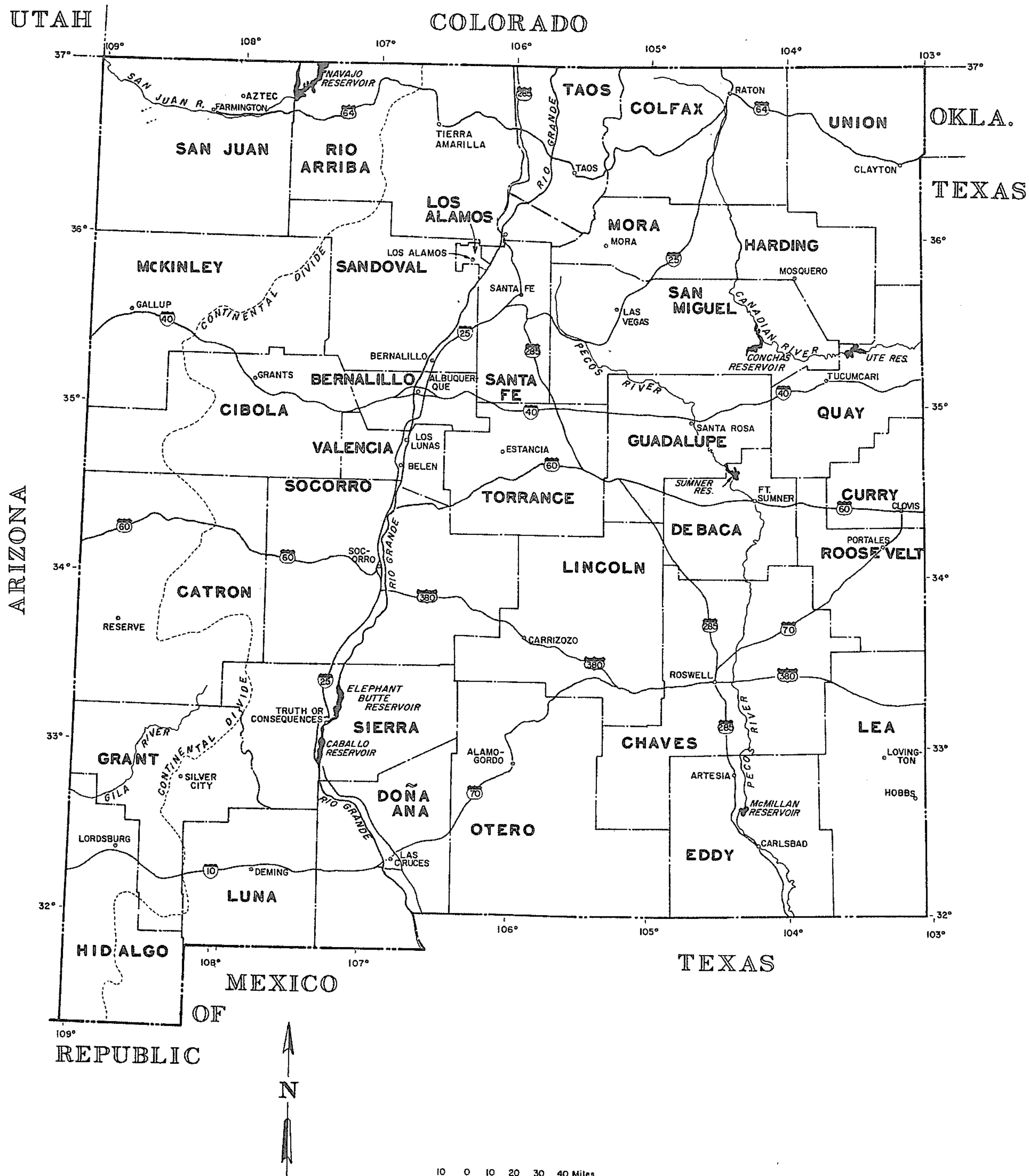


Figure 2. Map of New Mexico

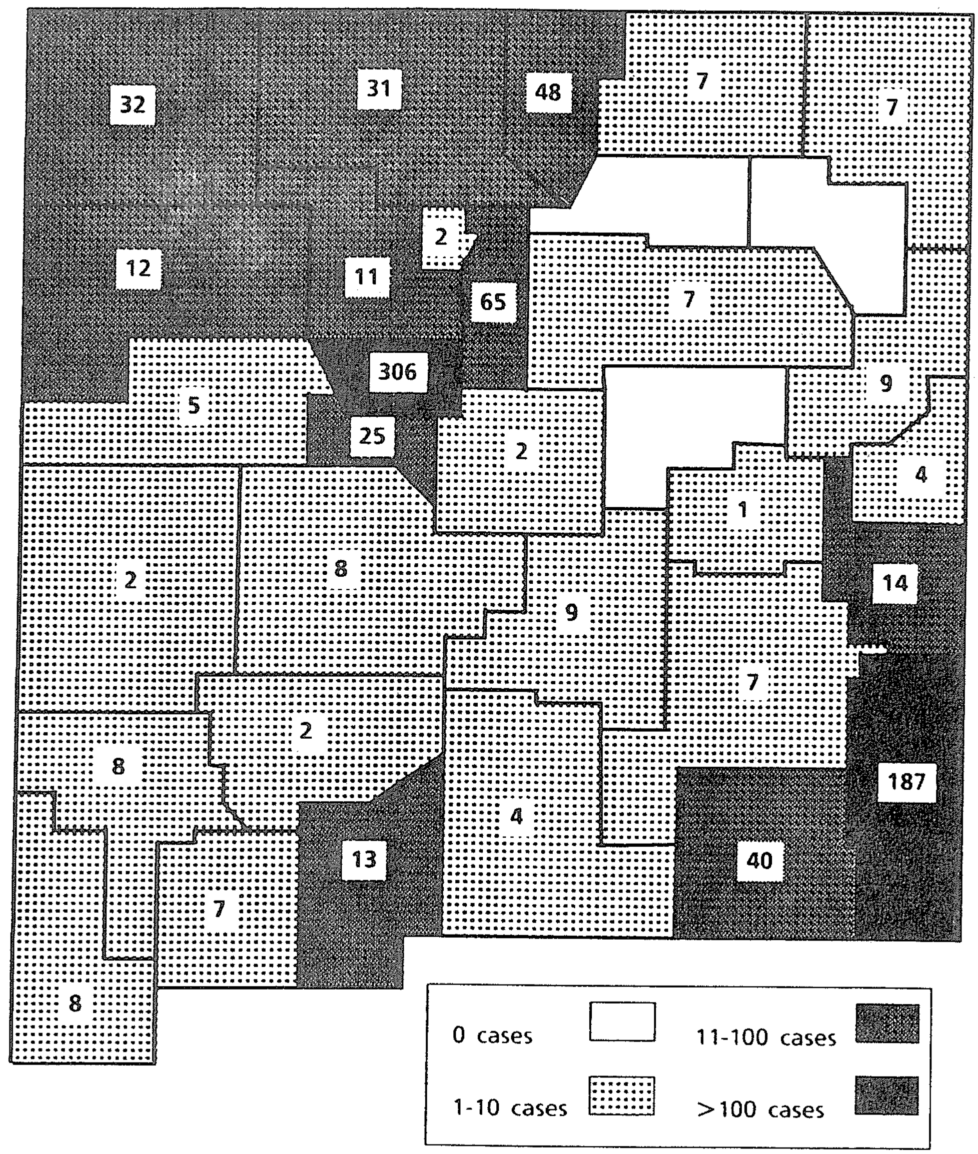


Figure 3. Ground Water Contamination

883 cases distributed by county

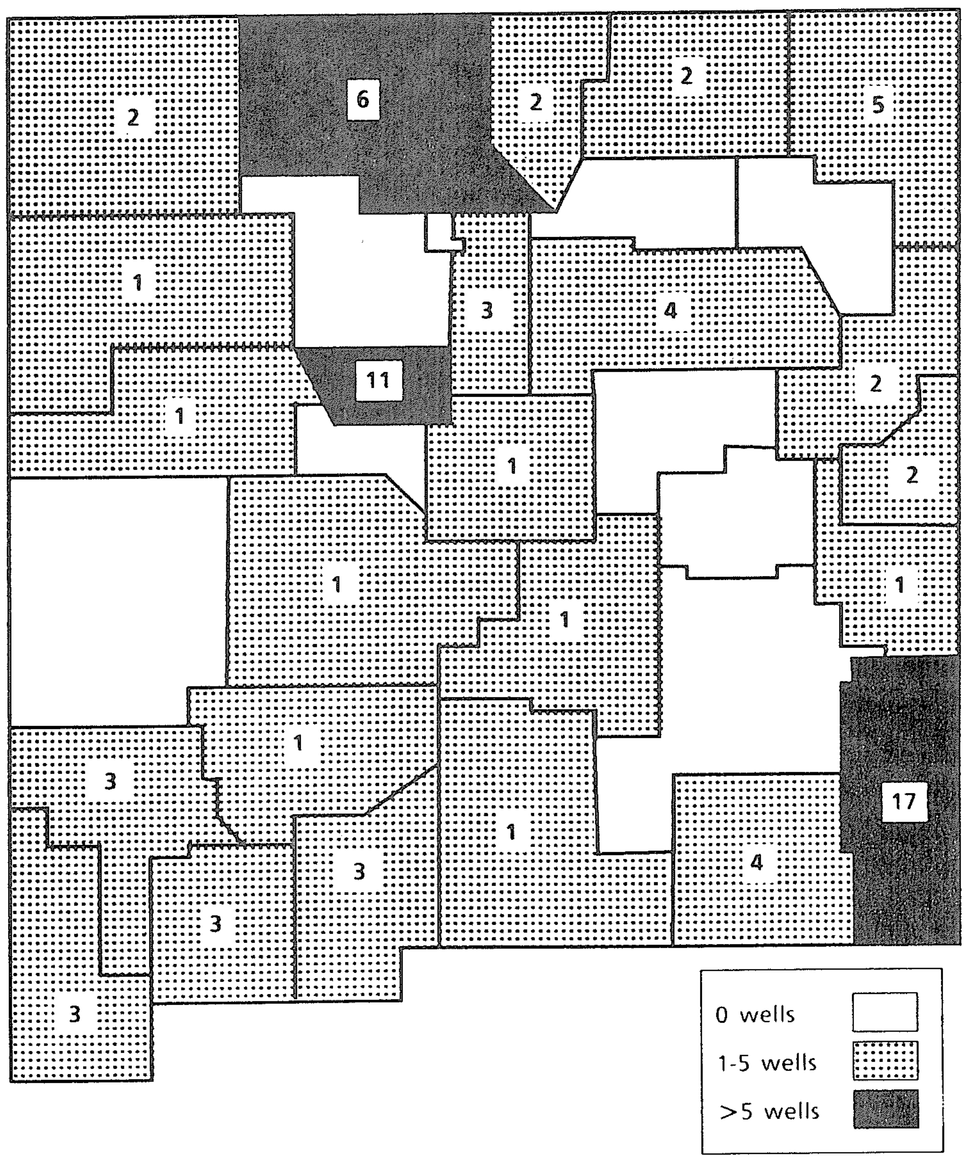


Figure 4. Contaminated Public Water-Supply Wells

80 wells distributed by county

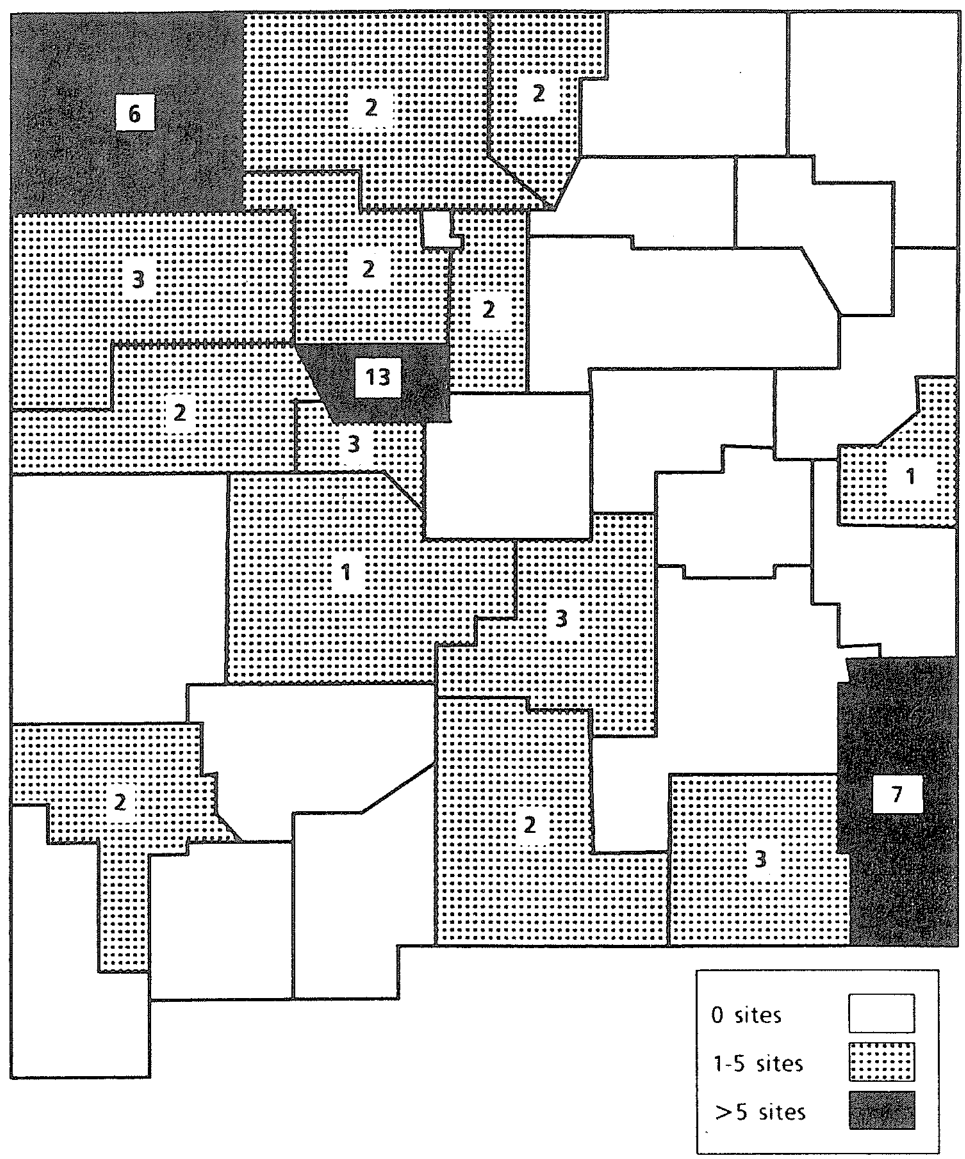


Figure 5. Remediation of Ground Water Contamination

54 sites distributed by county

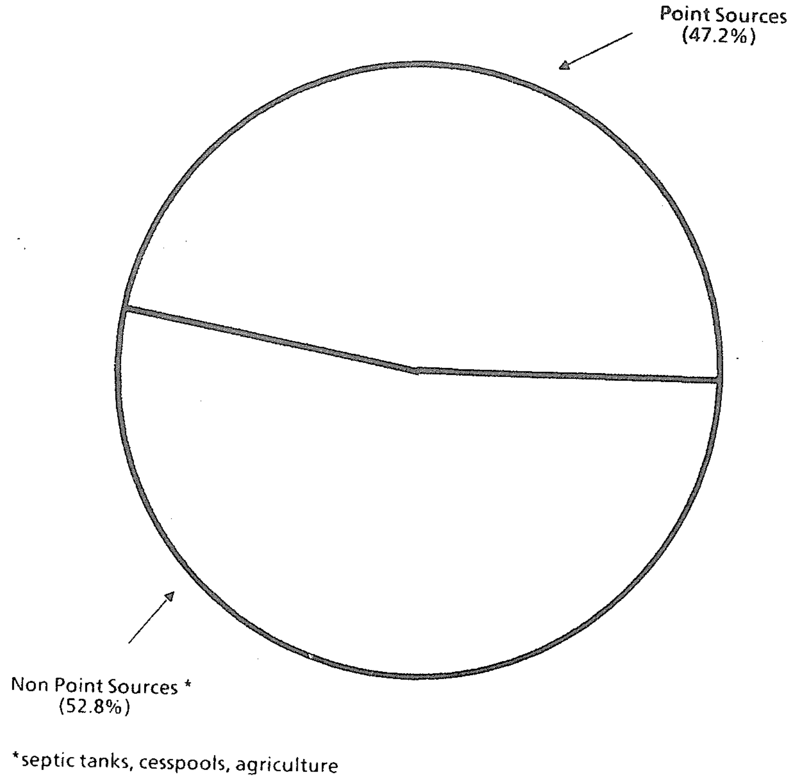


Figure 6. Total Ground Water Contamination Cases

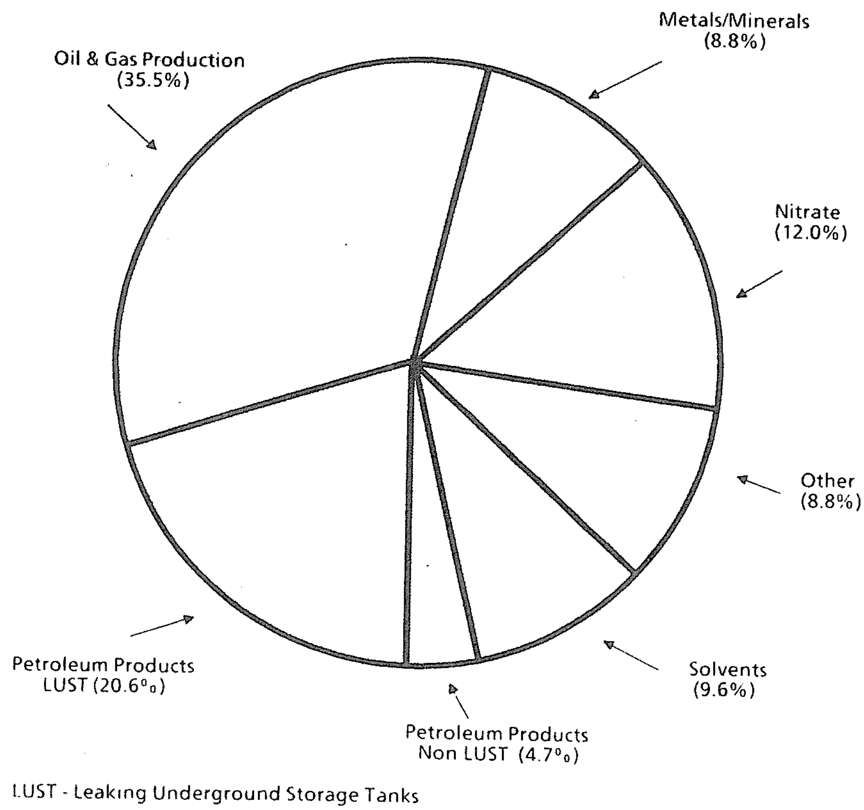


Figure 7. Point Sources of Ground Water Contamination

has impaired the beneficial use of ground water. No water-supply wells, public or private, have been contaminated by permitted discharges. Contamination has been documented only in monitoring wells.

NON-POINT SOURCES OF CONTAMINATION

Household Septic Tanks and Cesspools

An estimated 135,000 household septic tanks or cesspools in the state discharge approximately 25 million gallons per day of waste water to the subsurface. In shallow water-table areas, the effluent percolates rapidly to underlying aquifers. These systems can pollute ground water with the following contaminants:

* iron, manganese and sulfides (anoxic contamination);
* nitrate;
* potentially toxic organic chemicals; and
* bacteria, viruses and parasites (microbiological contamination).

Anoxic contamination causes taste and odor problems, and can stain laundry or porcelain, but it is not known to be hazardous to human health. Nitrate contamination, on the other hand, typically lacks such aesthetic problems, but can cause methemoglobinemia, a rare but potentially serious and sometimes fatal disease affecting infants. Questions have been raised as to whether nitrate can cause cancer in healthy adults. Ground water nitrate levels resulting from household septic tank contamination can be as high as 30 mg/l as N, three times the health standard.

Conditions of severe anoxic and nitrate contamination are mutually exclusive due to differences in the oxidation-reduction potentials of the ground water involved. Organic chemicals and disease-causing microbes, however, can occur in conditions of both anoxic and nitrate contamination.

Many household products, especially cleaners, contain organic chemicals. Trichloroethylene, in particular, is a well-known ground water contaminant released by septic tank discharges.

Microbiological contamination of ground water has caused outbreaks of shigellosis, gastroenteritis, viral hepatitis and paratyphoid fever in other states (Craun, 1984). An investigation of enteric illness in Albuquerque's South Valley, however, did not identify consumption of private well water as a risk factor for these diseases among residents (Gallaher, et al., 1987).

Household septic tanks and cesspools constitute the single largest source of ground water contamination in the state. Widespread nitrate contamination and/or anoxic conditions have been documented in Albuquerque, Belen, Bernalillo, Bosque Farms, Carlsbad, Corrales, Espanola, Hobbs, Los Lunas, Lovington, Santa Fe and Tesuque.

Proper septic-tank maintenance requires that accumulated solids periodically be removed. The disposal of this material, known as septage, is discussed in the point-source section below.

Agriculture

Evapotranspiration (ET) is a process in which water vapor enters the atmosphere either by direct evaporation or by transpiration from living plants. Residual minerals can increase the TDS of shallow ground water and form alkali deposits.

In the Rio Grande valley, for example, irrigation canals have diverted river water for hundreds of years. Percolating irrigation water has caused the shallow water table in many valley areas to rise and be more vulnerable to ET. This problem can be remedied by the construction of drains to lower the water table, as was done in Albuquerque in the 1930s.

Approximately 70 pesticides or pesticide decomposition byproducts have been detected in the nation's ground water (USEPA, 1986a,b). Seventeen such pesticides have contaminated ground water as a result of "normal" application practices (ibid).

Fumigant pesticides, halogenated methanes, ethanes and propanes, are common ground water contaminants in other states, but have not been used heavily in New Mexico. Fumigants are included in routine volatile organics analyses performed on ground water samples, but have not been detected in the several thousands of such analyses that have been conducted to date on New Mexico ground water.

Carbamate pesticides such as aldicarb, carbaryl, carbofuran and methomyl have caused ground water contamination in other states and are used in New Mexico; aldicarb and carbofuran have been used heavily in certain areas. New Mexico recently developed the capability to test for carbamates in water; the Environmental Improvement Division and the N.M. Department of Agriculture are conducting a cooperative reconnaissance program for carbamates in ground water. Heavy application areas located in shallow water-table environments have been identified and the first samples will be collected from shallow existing water wells later this year.

Urban Runoff

Very little monitoring of the ground water quality impacts of urban runoff has been conducted in New Mexico. At one site in Albuquerque, however, several pesticides were detected in both the sediments of a flood-control channel and in shallow ground water adjacent to the channel. The pesticides detected, relatives of DDT and Lindane at low ug/l levels, were accompanied by dissolved petroleum products. It appears that the petroleum hydrocarbons had a mobilizing effect on these normally hydrophobic pesticides due to the cosolvency phenomenon.

POINT SOURCES OF CONTAMINATION

Oil Field Sources

The most common cause of oil-field contamination is the past practice of produced-water disposal to unlined pits. Other causes include leaks of crude petroleum and/or produced water from pipelines and well casings.

Produced waters, often brines, can gravitate to the basal part of a fresh-water aquifer and migrate along a hydraulic gradient different from that of the aquifer. In addition to inorganic contaminants, such as chloride, most produced waters contain aromatic hydrocarbons that also can contaminate ground water. At the present time, 90% of the approximately 300 million barrels of water produced annually in the state is injected into deep wells for the purposes of secondary recovery, pressure maintenance or disposal.

Crude oil and natural gas condensate, if discharged in the liquid phase, will float atop the water table and their water soluble constituents will dissolve into ground water. Oil field contamination has been a more serious problem in southeastern production areas than in those in the northwest. This is due to the larger quantity and generally poorer quality of water produced in the southeast, as well as the relative vulnerability of southeastern aquifers (e.g. the Ogallala).

Refined Petroleum Product Sources

The most common cause of petroleum-product contamination in the state is leaky underground storage tanks (LUSTs). It is estimated that between one tenth and one third of the 14,000 underground storage tanks in the state are leaking. In cases where the cause of leaks has been determined, the following conditions have been identified:

CAUSE	% OF CASES KNOWN
faulty installation	37.3
tank corrosion	33.3
line corrosion	29.4

In addition to ground water contamination, LUSTs can cause explosive hazards when product vapors migrate to basements and utility corridors (see Figure 8).

Other sources of refined petroleum-product contamination include leaks and tank-bottom water discharges from above-ground storage tanks, leaks and hydrostatic test water discharges from pipelines, transportation accidents and waste oil disposal.

Nitrate Sources

Point sources of nitrate contamination include sewage treatment plants, dairies, slaughterhouses, explosives manufacturing or handling facilities, other industrial facilities and septic tanks serving restaurants, mobile home parks, etc. Industrial nitrate contamination, such as from explosives, can result in considerably higher concentrations (e.g. 500 mg/l as N) than those resulting from household septic tanks, which seldom exceed 30 mg/l as N (the health standard is 10 mg/l).

Solvent Sources

Halogenated or aromatic solvents are used by many different industries such as machine shops and electronics firms, and also occur in a variety of household products. The most common solvents being detected in the state's ground water are benzenes and chlorinated methanes, ethanes, ethylenes and propanes.

Metals/Minerals Sources

Contamination by metals and/or minerals is caused by mining and milling and by other industrial activity. Common contaminants include sulfate, TDS, heavy metals, radionuclides and other trace elements.

Ore refining mills produce large quantities of tailings, the raffinate of which typically contains elevated levels of metals/minerals. Due to engineering convenience and economic advantages, tailings impoundments are often located in alluvial valleys close to the mill, frequently causing ground water contamination.

Other Sources

Other point-source contaminants include microbes, oxygen demanding substances, pesticides, explosives and other synthetic organic chemicals.

Some point-sources of contamination may contribute various contaminants to ground water. Landfills and septage disposal are examples of such multi-contaminant sources.

Public Landfills

Concern about the potential for landfills to contaminate ground water has grown in recent years. Very little is known about the composition of wastes buried in landfills in the state. Constituents known to occur in landfill leachate include

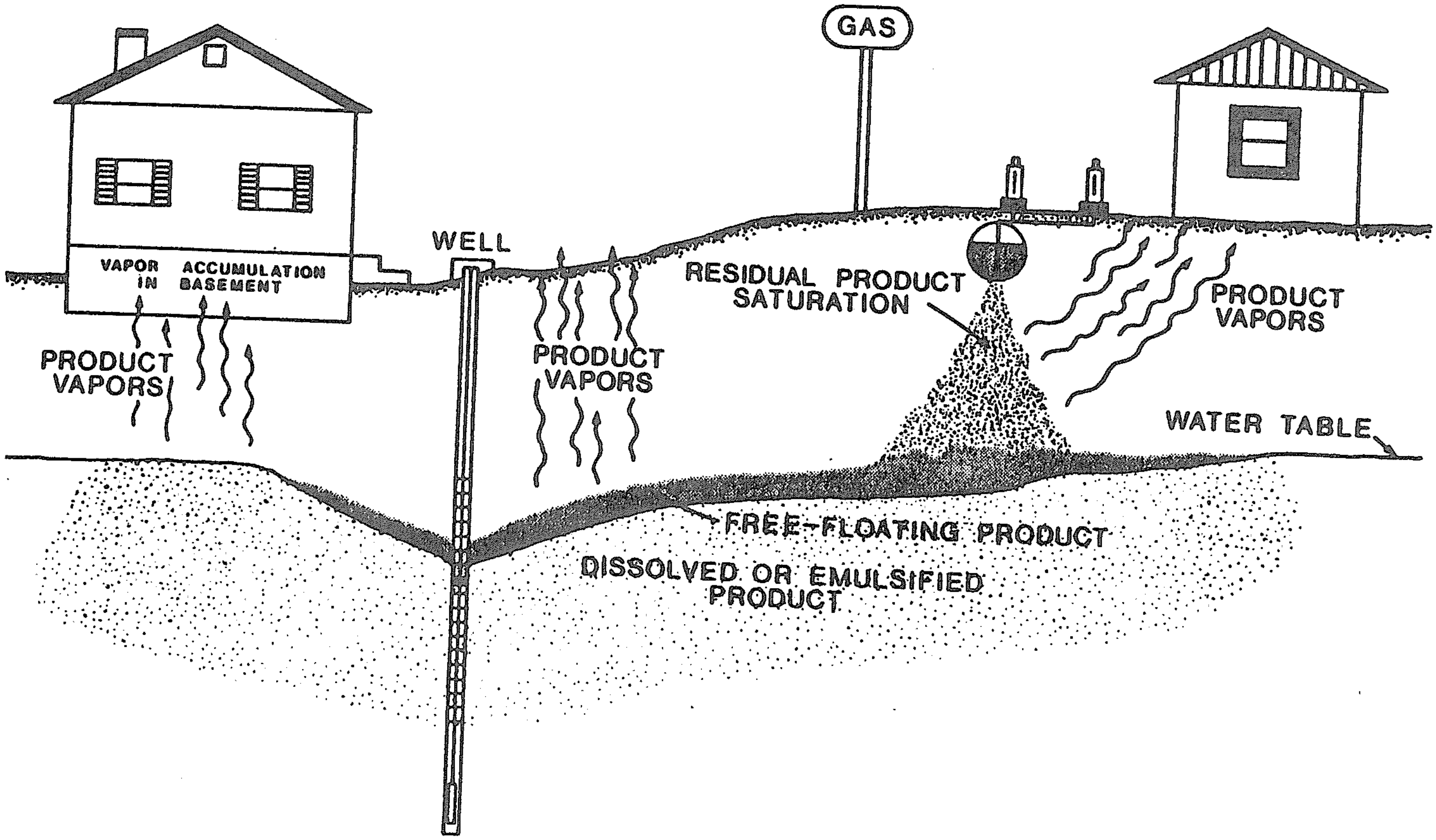


Figure 8. Overview of Underground Petroleum-Product Leakage and Subsurface Impacts

chloride, nitrogen species, solvents and a large number of other organic contaminants.

Household wastes alone contain a large number of leachable constituents. In Oklahoma, for example, more than 40 organic compounds, including phthalates and alkylbenzenes, were detected in ground water contaminated by a landfill that did not receive appreciable amounts of industrial waste (Robertson, et al., 1974). In an Albuquerque survey of household hazardous waste, more than 50% of the wastes identified were disposed of in area landfills, including more than 53,000 gallons of used motor oil per year (Salas, et al., 1983).

Large quantities of septage (solids and liquids pumped from septic tanks periodically) have been discharged to unlined pits at several landfills in the state. The septage in several cases has been comingled with industrial wastes such as produced water, waste petroleum products and chlorinated solvents.

The Environmental Improvement Division is conducting a limited study of the ground water quality impacts of landfills in the state. Ground water contamination has been documented at two landfills thus far.

Septage Disposal

Vacuum truck operators provide a vital service to septic tank owners by periodically removing accumulated solids. However, in many areas of the state, operators do not have a legal and environmentally sound mechanism to dispose of septage. Several septage disposal sites have been found to contain petroleum products, metals, minerals and solvents.

EXAMPLES OF GROUND WATER CONTAMINATION

Many population centers in the state have developed in vulnerable aquifer areas such as the Rio Grande valley (see Figure 2). Additionally, a number of mineral resource development areas also coincide with vulnerable aquifer regions. Not surprisingly, these areas have a high incidence of ground water contamination. The following examples have been selected to illustrate various kinds of problems.

Albuquerque South Valley

(from Gallaher, et al., 1987)

Albuquerque overlies one of the most precious fresh-water aquifers in New Mexico. Several thousand feet of fresh-water saturation reside within the Rio Grande valley fill. This aquifer is the city's sole source of drinking water and is highly vulnerably to contamination in the valley area. While humans have contaminated only a small fraction of ground water, recent trends suggest that the nature and extent of contamination may become more severe in the next decade due to increased industrialization and population growth.

A long history of human activity in a shallow water-table zone has left the Albuquerque valley with ground water contamination dating back to at least 1927. All known cases of ground water contamination in the South Valley are shown in Figure 9.

Two types of contamination exist in this area:

* regional contamination with anoxic conditions and/or elevated salinity and hardness; and

* numerous localized contamination cases involving constituents of health concern such as nitrate, gasoline, chlorinated solvents and pesticides.

Many valley areas were developed originally with private wells and septic systems and were later provided with municipal water and sewer facilities after contamination problems became evident. Septic tank and cesspools are major contributors to the problem of widespread anoxic conditions. Even if remaining areas were sewered immediately, it might take decades for natural purification processes to eliminate the contamination caused thus far. Septic tanks also are responsible for doubling and tripling nitrate levels in two areas west of Coors Boulevard since 1977.

Petroleum products have contaminated ground water in at least 20 sites in the South Valley. A soil gas survey along Isleta Boulevard (see Figure 9) showed evidence of gasoline contamination at 6 of the 17 underground storage tank facilities surveyed.

The San Jose area (see Figure 9) is one of New Mexico's four active Superfund sites. In this shallow water table environment, a city well field was developed in the 1930s. Industrial development (manufacturing industries, petroleum product and chemical handling) began in this area in the 1950s prior to the development of New Mexico's ground water protection program. In 1980, two city wells in this field were shut down after the detection of several chlorinated solvents in the wells. Subsequent investigations have identified multiple sources of contamination.

Historically, ground water contamination in the South Valley has been limited to depths of 100 feet or less below the land surface. It appears, however, that contaminants in the shallow zone are being drawn to greater depths by the pumping of deep wells. At one location, hazardous substances have been found at a depth of 220 feet below the surface. This vertical migration presents a long-term threat to all deep wells located in the valley, including those used by the City of Albuquerque for municipal water supply.

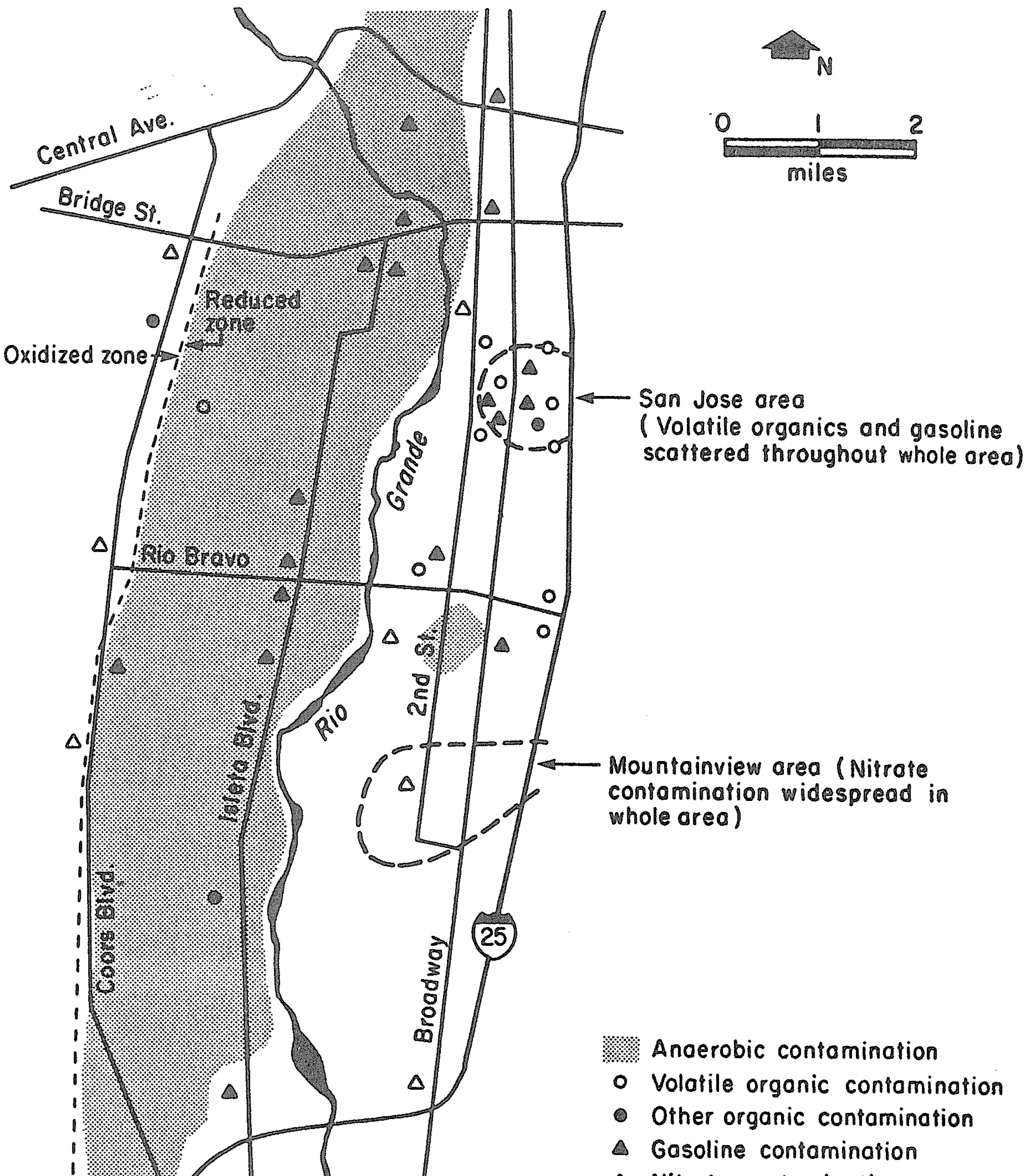


Figure 9. Ground Water Contamination in the Albuquerque South Valley

Espanola Valley

The Espanola area also is located in the Rio Grande valley and is similar in many ways to the Albuquerque valley. Espanola is far less populated and industrialized than Albuquerque, however, and contamination problems are less numerous and less severe.

Nitrate contamination and anoxic conditions have been caused by septic tank discharges in several areas (see Figure 10). Additionally, at lease two cases of LUST gasoline contamination are documented (see Figure 10).

It appears that more serious ground water contamination can be prevented if approriate safeguards are enacted. A number of rural areas, however, are currently undergoing rapid development with private wells and septic tanks upon minimal lot sizes and this may add to ground water contamination problems.

Lea County

The Ogallala Formation, composed of unconsolidated sand and gravel, is the principle fresh-water aquifer in this region. The depth to water ranges from 30 to 250 feet, with a maximum saturated thickness of 200 feet.

Lea County has been a major petroleum-producing area since the early part of this century. Large quantities of saline water are co-produced with the petroleum. The produced brine was commonly discharged to unlined pits prior to the 1960s when this practice was prohibited. Well casing leaks began to be discovered and repaired at least as early as 1934.

Oil-field contamination of fresh ground water resources became evident in the early 1950s (McGuinness, 1963). Cases of known and suspected contamination are shown in Figure 11. Documented contamination mechanisms include discharges to unlined pits and leaks from well casings and pipelines.

Nitrate contamination from septic tanks also has occurred in several areas of Lea County; anoxic conditions resulting from septic tank discharges have not been documented. Additionally, a variety of industrial facilities have contaminated ground water with nitrate, gasoline, waste oil, solvents and other organic contaminants.

Extensive ground water contamination has occurred in Hobbs, the largest city in Lea County (see Figure 12). Oil field contamination with brine, crude oil and natural gas exists in the western and southern areas of the city. In one area, more than 300,000 barrels of crude oil, lost from leaky production well casings, have been recovered from windmills and other shallow wells. Widespread nitrate contamination from septic tanks exists in the residential areas of northern Hobbs. Nitrate contamination also has occurred

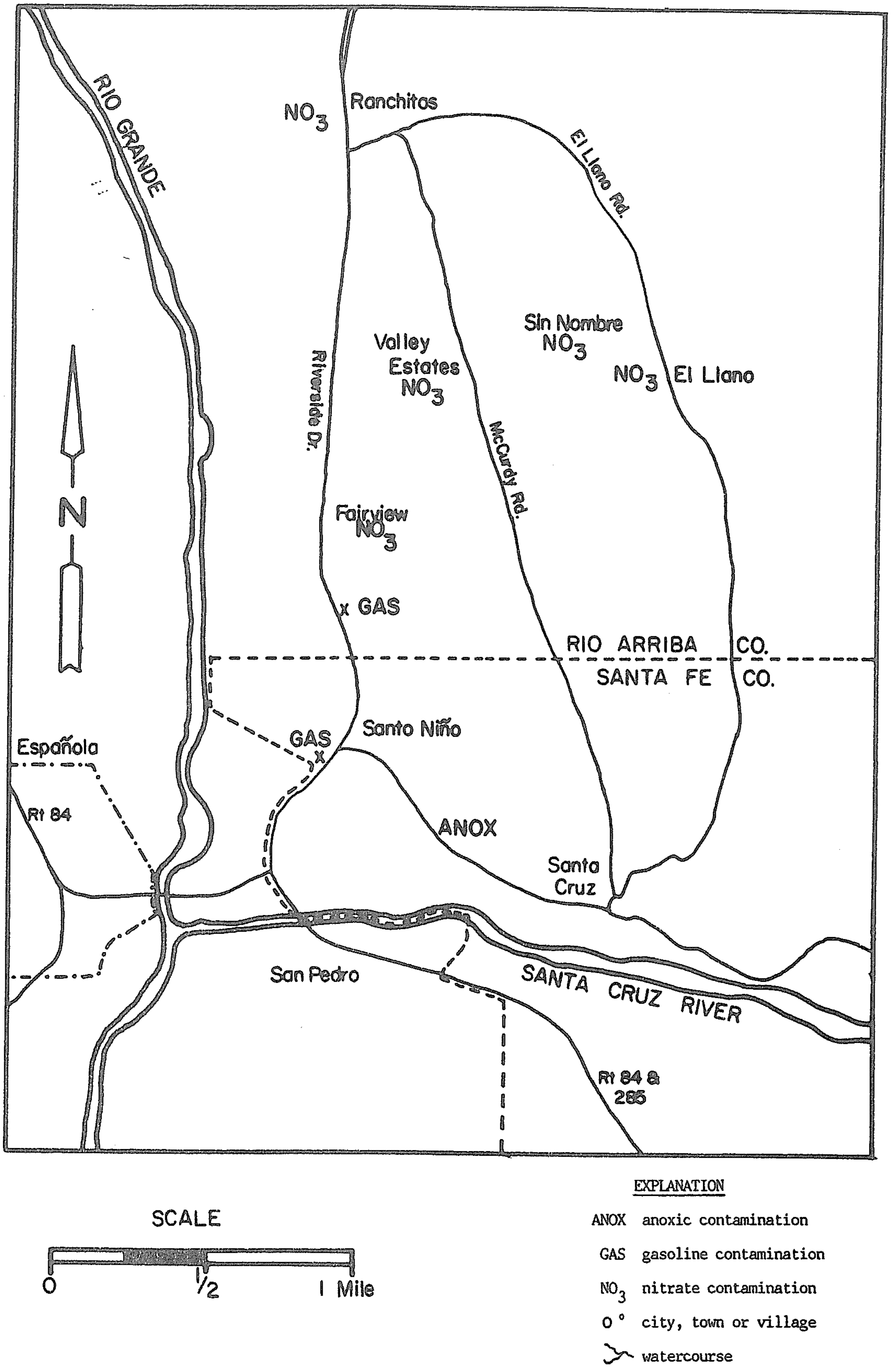


Figure 10. Ground Water Contamination in the Espanola Area

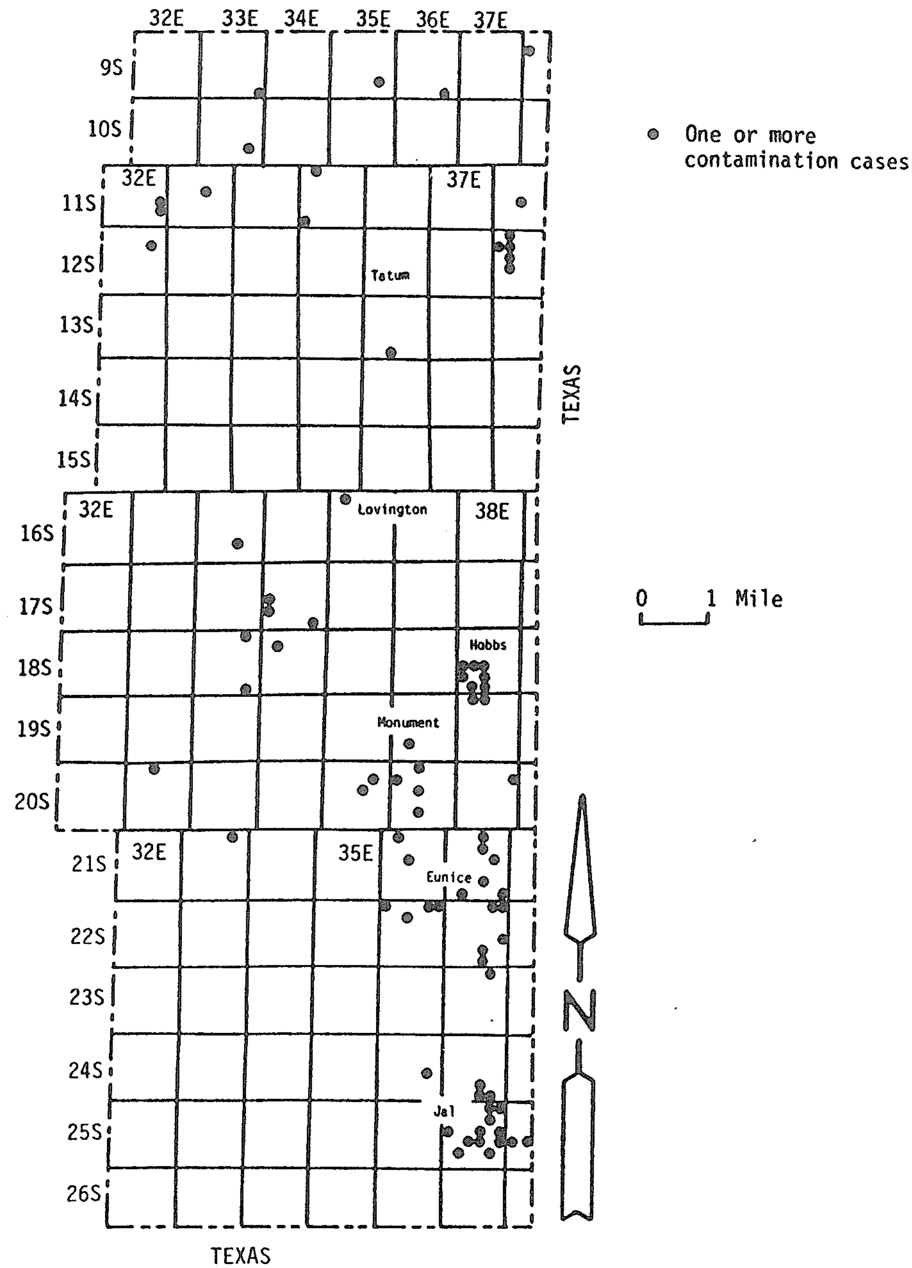


Figure 11. Known and Suspected Ground Water Contamination by Oil Field Activities in Lea County, New Mexico*

*Contaminants include crude oil, natural gas and produced water.

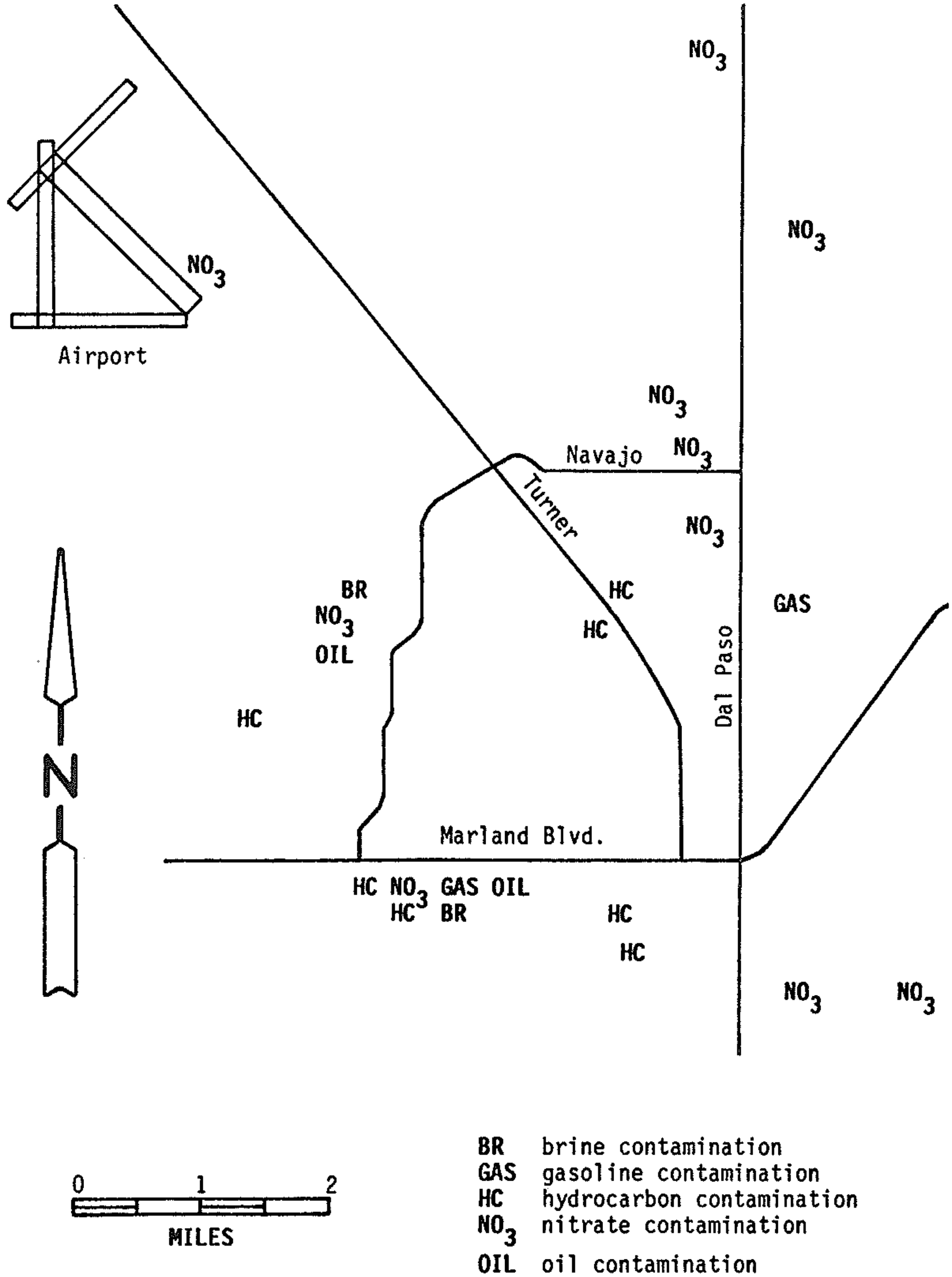


Figure 12. Ground Water Contamination in the Hobbs Area
Lea County, New Mexico

at an explosives manufacturing plant, a sewage treatment plant and a slaughter house. Two cases of gasoline contamination, one caused by a LUST, also have been documented.

GROUND WATER POLLUTION CONTROL

New Mexico's authority to protect and maintain ground water quality is discussed in the paper by Maxine S. Goad, *Historical Overview of New Mexico Ground Water Quality Protection Programs.* Additionally, several federal statutes provide ground water protection in the state. These include:

1) the Comprehensive Environmental Response, Compensation and Liability Act (commonly called Superfund);
2) the Resource Conservation and Recovery Act;
3) the Uranium Mill Tailing Radiation Control Act; and
4) the Safe Drinking Water Act.

REMEDIATION OF GROUND WATER POLLUTION

For the purpose of this report, remediation is defined as either:

* removal of polluted ground water for beneficial use or recycling;
* removal of floating hydrocarbons; or
* purification of polluted ground water followed by recharge or diversion.

The above activities have occurred in the past, occur now or are expected to occur in the near future. To date, 68% of these activities are being done under the authority of the N.M. Water Quality Act (see Figure 13) and negotiated settlements that provide for a phased schedule of investigation and mitigation.

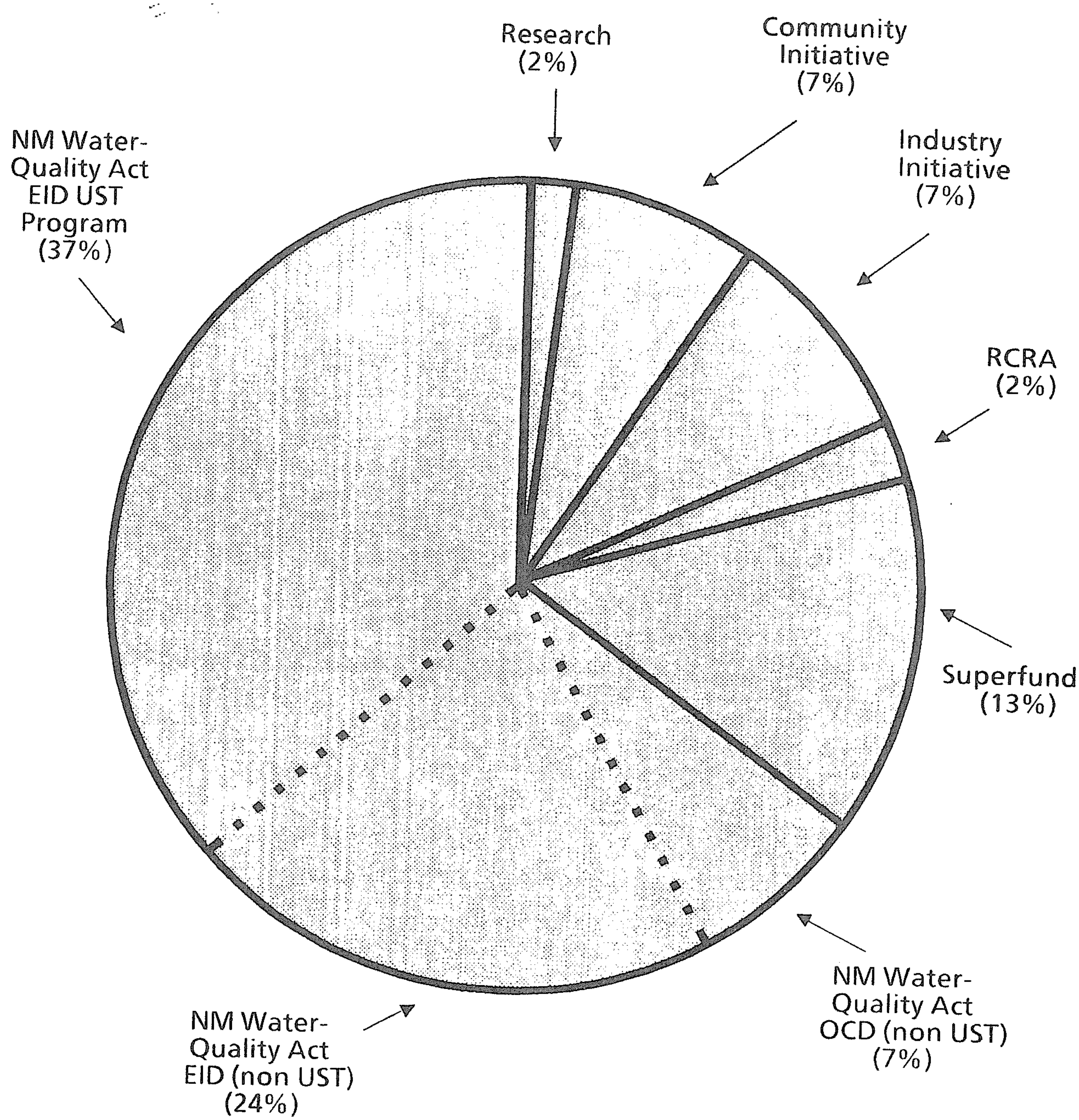


Figure 13. Remediation of Ground Water Contamination: by Regulatory Program or Initiative

REFERENCES

Craun, G.F. 1984. Health Aspects of Ground Water Pollution. In Ground Water Pollution Microbiology, ed. G. Bitton and C.P. Gerba, pp. 139-155. Wiley-Interscience Publications.

Gallaher, B.M., McQuillan, D.M., Chavez, L.D., Hull, H.F. and Eidson, M. 1987. Ground Water Quality and Public Health, Albuquerque South Valley. New Mexico Health and Environment Department Publication EID/GWH-87/1, p. 24.

McGuinness, C.L. 1963. The Role of Ground Water in the National Water Situation. U.S. Geological Survey Water-Supply Paper 1800, p. 564.

Robertson, J.M., Toussaint, C.R. and Jorque, M.A. 1974. Organic Compounds Entering Ground Water from a Landfill. U.S. Environmental Protection Agency Report EPA-660/2-74-077, p. 47.

Salas, A., Gordon, L.J. and Anglada, R. 1983. City of Albuquerque, Residential Hazardous/Toxic Waste Survey. Albuquerque Environmental Health and Energy Department, p. 32.

United States Environmental Protection Agency (USEPA), 1986a. Pesticides in Ground Water: Background Document. Office of Ground Water Protection, (WH-550G), p. 72.

USEPA, 1986b. State Program Briefs, Pesticides in Ground Water. Office of Ground Water Protection (WH-550G), p. 93.

HISTORICAL OVERVIEW OF NEW MEXICO GROUND WATER QUALITY PROTECTION PROGRAMS

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In New Mexico, much of which is arid, water has historically been recognized as a resource which is limited, critical and basic. Article XVI of the State Constitution, adopted in 1911 in preparation for statehood, deals with water, stating that beneficial use shall be the basis, the measure and the limit of the right to the use of water, and that priority of appropriation shall give the better right. This appropriative doctrine was followed by custom and court declaration in New Mexico for many years before it was enunciated in the State Constitution and in the surface water codes of 1905 and 1907 (when New Mexico was still a territory) and the ground water statutes of 1927 and 1931 (Hale and others, 1965). The state engineer has the authority to administer water rights permits.

NEW MEXICO WATER QUALITY ACT

In recent decades concern about water quality has been added to the early concern about water quantity. The New Mexico Water Quality Act, adopted by the State Legislature in 1967, addressed water pollution more specifically than earlier general public health and public nuisance statutes. It established the Water Quality Control Commission (WQCC) and authorized it to adopt standards and regulations to prevent and abate water pollution from all types of activities, with the exception of oil and gas exploration and production which were already controlled under the Oil and Gas Act. The Water Quality Act defines the water to be protected as including both surface and subsurface water.

In the early 1970s, it became apparent that a specific regulatory program to protect ground water quality should be developed under the authority of the Water Quality Act. The need for such specific regulation was clearly illustrated when a serious ground water pollution problem was discovered in the southeastern part of the state. The State of New Mexico won a suit brought against the discharger on the basis of public nuisance, but the case demonstrated that public nuisance was a difficult, expensive and unwieldy legal means of addressing ground water pollution problems and did not prevent those problems from arising. Prevention of ground water pollution is particularly important in New Mexico where 85% of the water used in municipal water supply systems comes from ground water sources, and in many areas of the state the only source of water is ground water. In addition, experience has clearly shown that once polluted, ground water is extremely difficult and expensive to clean up. Prevention of pollution is much more economically and technically feasible than remedial action.

WATER QUALITY CONTROL COMMISSION REGULATIONS

Formal efforts to develop specific ground water regulations under the Water Quality Act began in 1974. The Water Quality Control Commission, which is made up of a representative of each of eight constituent state agencies (the director of the state agency or his designee) plus a representative of the public named by the governor, directed the Environmental Improvement Division (EID) to draft proposed regulations. Various proposals were discussed at numerous commission meetings from 1974 through 1976 and were also discussed at meetings of the technical advisory committee organized by EID for this purpose. The technical advisory committee included representatives of industry (including mining and milling), agriculture, municipalities, and environmental organizations.

In June 1976, a four-day public hearing was held with the full commission sitting in attendance to hear the extensive testimony and question witnesses. The ground water standards and regulations, suitably reworded in light of evidence presented at the hearing, were adopted by the commission on January 11, 1977 and became effective on February 18, 1977. They appear as Part 3 of the Water Quality Control Commission Regulations (WQCC, 1987) and are entitled, "Regulations for Discharges Onto or Below the Surface of the Ground."

On February 17, 1977, the new ground water standards and regulations were appealed by nine uranium companies, but they were not stayed by the courts and they remained in effect and enforceable throughout the appeal process. The New Mexico Court of Appeals largely upheld the ground water quality regulations on December 19, 1978. On November 16, 1979, the New Mexico Supreme Court also largely upheld them, except for the definition of "toxic pollutant" which the court found to be unconstitutionally vague. The commission subsequently deleted that definition and in 1981 adopted a new, narrower definition for "toxic pollutant" which has since been upheld by the courts. One particularly important aspect of the 1979 New Mexico Supreme Court decision was that it upheld the placement of the burden of proof upon the discharger to demonstrate that the discharge would not pollute ground water. A more detailed account of the development and adoption of these regulations can be found in "New Mexico's Experience in Setting and Using Ground Water Quality Standards" (Goad, 1982).

The state-wide program for the protection of ground water quality adopted by the Water Quality Control Commission in 1977 has two basic aspects: (1) setting ground water standards (as of 1987, 47 numerical standards plus a generic "toxic pollutant" provision have been adopted); and (2) requiring by regulation that a discharger demonstrate in a "discharge plan" that those standards will not be violated at any place of present or foreseeable future use. The stated purpose is to protect all ground water that has an existing concentration of 10,000 mg/l or less total dissolved solids, and to protect those segments of surface waters which are gaining because of ground water inflow. The requirements apply to a wide variety of types of discharges of effluent or leachate onto or below the surface of the ground, including well injection, seepage from surface impoundments and leach fields, land application of industrial, municipal and other wastes, and any other "point source" discharges which may impact ground water except those specifically exempted. Certain oil, natural gas, carbon dioxide gas, geothermal and coal mining discharges and small individual home septic tank systems are specifically exempted from the requirements of Part 3 and are covered by other statutes and regulations. Also exempted are most discharges due to natural infiltration of precipitation and to irrigated agriculture. All facilities new or newly modified since 1977 are covered by these regulations, and older facilities can be required to submit discharge plans at the discretion of the constituent agency. However, these regulations do not require remediation of historical pollution problems existing before 1977.

Each proposed numerical ground water standard must be supported by substantial evidence at a public hearing before being adopted by the commission. Twenty-seven numerical standards, almost all for inorganic contaminants, were adopted in 1977 as part of the original standards and regulations, and eight toxic organic compounds were added in 1982 as a result of public hearings held in 1981. Subsequent monitoring in the state identified ground water quality problems with additional toxic organic compounds (McQuillan, 1984; Jercinovic, 1984). The commission held a public hearing in September 1985 on proposed additions and amendments to the numerical ground water standards, with opposition testimony presented by representatives of the oil and gas industry. Twelve new standards, and two amendments to make previous standards more stringent, were adopted for toxic organic contaminants, and became effective March 4, 1986. The interests opposing the new standards at the hearing appealed them and asked that they be stayed during the appeal process. The Court of Appeals rejected the request for stay and on March 25, 1986 issued its formal opinion in this matter clarifying, for the first time, the standards and procedures to be used in requests for stay of administrative regulations promulgated in New Mexico (WQCC, 1986). In December 1987, the Court of Appeals upheld the new standards. In January 1988, appellant's petition for writ of certiorari asking the Supreme Court of the State of New Mexico to consider this matter was denied. Thus, the new standards have been firmly upheld by the courts.

Ground water monitoring has shown that these commission regulations have been very successful in preventing new ground water pollution problems from facilities to which they apply which were new or newly modified since their adoption in 1977 (WQCC, 1986). They have also been effective in requiring that old pollution problems not be allowed to spread or get worse. An inventory of ground water pollution problems in New Mexico from 1927 to 1987 (McQuillan and Keller, 1987) indicates that slightly more than half of the documented pollution incidents were due to non-point sources, predominantly household septic tanks and cesspools, discharges not covered by the commission regulations. Virtually all of the point source contamination incidents were due to historical disposal practices occurring before either Water Quality Control Commission or Oil Conservation Division current regulations were in effect, to accidental discharges, or to current unpermitted discharges.

In addition to discharge plan requirements, the cleanup regulation, Section 1-203, is the other important tool for control of ground water pollution under Water Quality Control Commission regulations. Section 1-203 requires reporting and cleanup of spills, leaks, and other discharges not done in conformance with commission regulations. The majority of incidents handled under this regulation have been petroleum product spills and leaks, both leaks from underground storage tanks and surface discharges and spills.

OTHER PROGRAMS AFFECTING GROUND WATER QUALITY PROTECTION

Ground water quality protection in New Mexico has local, state and federal aspects. While the major law dealing with water quality management at the state level is the New Mexico Water Quality Act, other state laws and broad local authorities are also involved since so many different activities may affect water quality. Please see the attached table "Summary of New Mexico State and Local Government Authorities to Control Pollution of Ground Water - 1987." This table gives information on those authorities which are specifically directed toward protection of ground water quality, such as the Water Quality

Control Commission regulations. It also gives information on those regulatory authorities mainly directed toward other issues but having relevance to ground water protection (e.g. Solid Waste Management Regulations; State Fire Board Rules and Regulations Relating to Flammable and Combustible Liquids). Some of these authorities have been designed to make the state eligible to assume primary enforcement authority over federal programs (e.g. Hazardous Waste Management Regulations; Surface Coal Mining Regulations). A brief description of most of these authorities can be found in New Mexico's latest biennial report to Congress, Water Quality and Water Pollution Control in New Mexico, 1986 (WQCC, 1986), and additional information will be included in the 1988 version of this report.

FROM THE PAST TO THE FUTURE

Much of New Mexico's state ground water protection program was well established before most of the federal legislation and regulations addressing ground water quality were adopted. State regulations controlling the disposal of oil-field brines in order to protect ground water quality have been in effect since 1969. The Water Quality Act was adopted in 1967 and, as described above, a comprehensive ground water quality program applicable to a broad range of discharges was in effect by 1977. One challenge to New Mexico has been, and continues to be, to incorporate into its programs beneficial aspects of federal programs without disruption of state programs already in place. The state has sought and obtained primary enforcement authority over various programs mandated by federal legislation, including the underground injection control program established by the Federal Safe Drinking Water Act and the hazardous waste management program established by the Federal Resource Conservation and Recovery Act.

While New Mexico now has in place an effective program for control of many sources of ground water pollution, serious challenges remain. These include the need to better address (1) non-point source contamination such as that from large numbers of small septic systems in residential areas; (2) disposition of septage (pumpage from septic tanks) and other vacuum truck effluents; (3) landfill problems and how to comply with new federal criteria; (4) leaks, spills and unpermitted discharges; (5) contamination due to historical practices which are no longer allowed; (6) the possibility of pesticide problems; (7) meeting new federal criteria including wellhead protection requirements; (8) improving coordination efforts; and (9) setting appropriate priorities to balance the need for continued support of existing effective programs (especially preventive programs) with the need to solve new problems. Many of these challenges cannot be met without substantial local effort. City and county governments and local citizens must all be involved; public education is essential for their understanding of the problems and of their options for action.

REFERENCES

Goad, M.S. 1982. New Mexico's experience in setting and using ground water quality standards. Sixth National Ground Water Quality Symposium, presented at the September 1982 meeting.

Hale, W.E., Reiland, L.J., and Beverage, J.P. 1965. Characteristics of the water supply in New Mexico. Technical Report No. 31, New Mexico State Engineer, Santa Fe, New Mexico.

Jercinovic, D.E. 1984. Petroleum-product contamination of soil and water in New Mexico. New Mexico Environmental Improvement Division, Santa Fe, New Mexico.

McQuillan, D.M. 1984. Organic water contaminants in New Mexico. New Mexico Environmental Improvement Division, Santa Fe, New Mexico.

McQuillan, D., and Keller, N.S. 1987. Ground-water contamination in New Mexico, 1927-87. New Mexico Environmental Improvement Division, Santa Fe, New Mexico (in preparation).

New Mexico Water Quality Control Commission (WQCC). 1986. Water quality and water pollution control in New Mexico, 1986. Santa Fe, New Mexico.

_______. 1987. Water quality control commission regulations (as amended through February 17, 1987). Santa Fe, New Mexico.

Summary of New Mexico State and Local Government Authorities to Control Pollution of Ground Water-1987
(Table prepared by Maxine S. Goad, Environmental Improvement Division)

DIVISION OR SUBDIVISION OF NEW MEXICO STATE GOVERNMENT AUTHORIZED TO ADMINISTER REGULATIONS CONTROLLING POLLUTION OF GROUND WATER	AUTHORIZING STATUTES	ADOPTED REGULATIONS/CODES OR PROCEDURES	TYPES OF FACILITIES, ACTIVITIES, AND SOURCES OF GROUND WATER CONTAMINATION ADDRESSED BY AUTHORIZED DIVISION OF STATE GOVERNMENT
Environmental Improvement Division of the HEALTH AND ENVIRONMENT DEPARTMENT	WATER QUALITY ACT 74-6-1 through 74-6-13, NMSA 1978	Water Quality Control Commission Regulations	Industrial (except oil and gas production and refinement) Mining, milling and smelting (except coal mining)
	HAZARDOUS WASTE ACT 74-4-1 through 74-4-13, NMSA 1978	Hazardous Waste Management Regulations Asbestos Management Regulations	Municipal sewage and sludge Private domestic sewage including septic tank systems Hazardous waste generation, handling and disposition, including asbestos disposition
	EMERGENCY MANAGEMENT ACT 74-4B-1 through 74-4B-11, NMSA 1978	Hazardous Materials Emergency Response Plan	Underground Storage Tanks Agricultural (except those irrigation practices which pose no threat)
	ENVIRONMENTAL IMPROVEMENT ACT 74-1-1 through 74-1-10, NMSA 1978	Solid Waste Management Regulations Liquid Waste Disposal Regulations Water Supply Regulations	Leaks and spills (except from oil and gas production and refinement)
	RADIATION PROTECTION ACT 74-3-1, through 74-3-16, NMSA 1978	Radiation Protection Regulations	Landfills (except landfills for oil and gas production and refinement wastes)
	PUBLIC NUISANCE STATUTE 30-8-1, 30-8-2 and 30-8-8, NMSA 1978		

Summary Table Continued - page 2

SUBDIVISION OF NEW MEXICO STATE GOVERNMENT	AUTHORIZING STATUTES	ADOPTED REGULATIONS/CODES OR PROCEDURES	TYPES OF FACILITIES AND ACTIVITIES ADDRESSED
Oil Conservation Division of the ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT	OIL AND GAS ACT 70-2-1 through 70-2-38, NMSA 1978 WATER QUALITY ACT 74-6-1 through 74-6-13, NMSA 1978 GEOTHERMAL RESOURCES CONSERVATION ACT 71-5-1 through 71-5-24, NMSA 1978	Oil Conservation Division Rules and Regulations Water Quality Control Commission Regulations Geothermal Resources Rules and Regulations	Oil and natural gas production and transportation through refinement, including disposition of produced water and drilling fluid Oil field servicing companies Refineries Natural gas processing plants and transmission after refinement Carbon dioxide facilities Geothermal facilities
Mining and Minerals Division of the ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT	SURFACE MINING ACT 69-25A-1 through 69-25A-35, NMSA 1978 ABANDONED MINE RECLAMATION ACT 69-25B-1 through 69-25B-11, NMSA 1978	Surface Coal Mining Regulations New Mexico Reclamation Plan for Abandoned Mine Lands	Surface and underground coal mining Abandoned mines (coal mines and under certain conditions other mines)
STATE ENGINEER OFFICE	72-2-1, 72-13-4, 72-13-6, 69-3-6 and 70-2-12.B. (15) NMSA 1978 72-12-1 through 72-12-28, NMSA 1978 New Mexico Supreme Court Decisions in City of Roswell v. Reynolds, 86 N.M. 249, 522 P. 2d 796 (1974); Heine v. Reynolds, 69 N.M. 398, 367 P. 2d 708 (1962); and Stokes v. Morgan, 101 N.M. 195, 680 P. 2d 335 (1984)	State Engineer Rules and Regulations Governing Drilling of Wells and Appropriation and Use of Ground Water in New Mexico State Engineer Order #25A 1950 (Estancia Basin)	General supervision of waters of the state Plugging of mine discovery or drill holes Drilling, casing and plugging artesian wells to prevent commingling Pumpage control to prevent salt water encroachment Designation of aquifers to be protected by the Oil Conservation Division

Summary Table Continued - page 3

SUBDIVISION OF NEW MEXICO STATE GOVERNMENT	AUTHORIZING STATUTES	ADOPTED REGULATIONS/CODES OR PROCEDURES	TYPES OF FACILITIES AND ACTIVITIES ADDRESSED
Division of Agricultural and Environmental Services of the NEW MEXICO DEPARTMENT OF AGRICULTURE	PESTICIDE CONTROL ACT 76-4-1 through 76-4-39, NMSA 1978	Regulatory Order Number 5 under the Board of Regents of New Mexico State University	Agricultural pesticide application
State Fire Marshal's Office of the STATE CORPORATION COMMISSION	FLAMMABLE LIQUIDS STATUTE 59-17-13 through 59-17-26, NMSA 1978	State Fire Board Rules and Regulations Relating to Flammable and Combustible Liquids (incorporates National Fire Protection Assn. (NFPA) 30, 1984 Edition, NFPA 385, 1979 Edition)	Transportation, marketing, distribution, handling and use of flammable liquids
Motor Transportation of the STATE CORPORATION COMMISSION	MOTOR CARRIER ACT 65-2-80 through 65-2-127, NMSA 1978 Constitution of the State of New Mexico Article XI, Section 1 through 18, NMSA 1978	New Mexico Motor Carrier Rules and Regulations, Rules of Procedure Rule 40 - Governing Transportation of Explosives and Inflammables, Section 1 (applicability of federal Department of Transportion Regulations)	Transportation by motor carrier of hazardous materials including petroleum products
Pipeline Division of the STATE CORPORATION COMMISSION	PIPELINE SAFETY ACT 70-3-11 through 70-3-20, NMSA 1978 Constitution of the State of New Mexico Article XI, Section 1 through 18, NMSA 1978	Rules and Regulations of the Corporation Commission of the State of New Mexico Relating to Pipelines Transporting Oil (Order No. 401) Rules and Regulations for the Transportation of Natural and other Gas by Pipeline-Minimum Standards	Transportation of petroleum and petroleum products by intrastate transmission pipelines

Summary Table Continued - page 4

SUBDIVISION OF NEW MEXICO STATE GOVERNMENT	AUTHORIZING STATUTES	ADOPTED REGULATIONS/CODES OR PROCEDURES	TYPES OF FACILITIES AND ACTIVITIES ADDRESSED
Construction Industries Division of the REGULATION AND LICENSING DEPARTMENT	CONSTRUCTION INDUSTRIES LICENSING ACT Section 60-13 NMSA 1978	"Construction Industries Rules and Regulations" (Plumbing Code)	Septic tank construction and function
COUNTIES OF THE STATE	SUBDIVISION ACTS 47-5-1 through 47-6-29, and 3-20-1 through 3-20-16, NMSA 1978	County Subdivision Regulations	Subdivisions, including liquid and solid waste disposal and water supply systems.
	ZONING ACT 3-21-1 through 3-21-26, NMSA 1978	County Zoning Regulations	Location and use of facilities: restrictions to promote health and welfare
	REFUSE ACT 4-56-1 through 4-56-3, NMSA 1978	County Refuse Systems	Collection and disposal of refuse
	COUNTY ORDINANCES ACT 4-37-1 through 4-37-9, NMSA 1978	County Ordinances, and Grant of Same Authorities Granted Municipalities (see below) with Certain Exceptions	Landfills, liquid waste systems, other facilities and activities affecting health and safety in the county.
MUNICIPALITIES OF THE STATE	PLANNING AND PLATTING; MUNICIPAL SUBDIVISION ACT 3-19-1 through 3-20-16, NMSA 1978	Municipal Planning and Platting and Municipal Subdivision Regulations	Municipal planning and regulation of subdivision within municipal planning jurisdiction
	ZONING ACT 3-21-1 through 3-21-26, NMSA 1978	Municipal Zoning Regulations	Location and use of facilities: restrictions to promote health and welfare
	HEALTH; CONTROL OF DISEASE 3-43-1 through 3-43-2, NMSA 1978	Municipal Health Codes	Activities affecting public health

Summary Table Continued - page 5

SUBDIVISION OF NEW MEXICO STATE GOVERNMENT	AUTHORIZING STATUTES	ADOPTED REGULATIONS/CODES OR PROCEDURES	TYPES OF FACILITIES AND ACTIVITIES ADDRESSED
MUNICIPALITIES OF THE STATE (continued)	WATER FACILITIES 3-27-1 through 3-27-9, NMSA 1978	Control of Municipal Potable Water Supplies	Protection of municipal water supply sources within and without municipal boundaries
	SEWAGE FACILITIES 3-26-1 through 3-26-3, NMSA 1978	Sanitary Sewer Authorities	Sewage collection, treatment and disposal
	REFUSE ACT 3-48-1 through 3-48-7, NMSA 1978	Authority to Regulate Refuse	Refuse collection and disposal
	POWERS OF MUNICIPALITIES 3-18-1 through 3-18-29, NMSA 1978	Municipal Ordinances	Facilities and activities within the jurisdiction of a municipality

GROUND WATER QUALITY PROTECTION AND MONITORING PROGRAMS IN ALBUQUERQUE

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Albuquerque and surrounding communities have a combined population in excess of 500,000 people. Municipal, public, and private wells in these communities extract water from the underlying alluvial aquifer system. The alluvial aquifer is the only source of potable water throughout most of the Albuquerque-Belen basin and is consequently an irreplaceable resource.

Federal, state, county, and local governments share responsibility to protect the ground water resource, to develop a thorough understanding of interactions between ground water and surface water within the basin, and to monitor chemical quality of water at the wellhead and at strategic points within the system. These responsibilities have historically been addressed, with various levels of effort, through a diverse assortment of programs and activities. Efforts are currently underway to develop a comprehensive regional water resource management program. Ground water quality monitoring will constitute a vital part of the program.

This paper contains an overview of many existing and planned programs and activities which relate to the protection of the ground water resource. This discussion is presented from the perspective of the City of Albuquerque, the major user of the ground water resource. Federal, state, and county programs are also discussed to present a comprehensive picture of related programs and activities.

HYDROGEOLOGIC SETTING

Albuquerque is located near the center of the Albuquerque-Belen basin. The basin is about 90 miles long, is 25 to 40 miles wide and encompasses approximately 2700 square miles. The basin is bounded on the east and west by a series of generally north-south trending faults which separate unconsolidated, relatively transmissive sedimentary deposits within the basin (technically termed a graben) from consolidated, relatively impermeable rocks on either side. Total depth of sediments filling the graben exceeds 20,000 feet in some places. Faults along sides of the basin converge to form the San Acacia Constriction, the southern end of the basin. The north end of the basin is less clearly defined, but roughly corresponds to the southern flank of the Jemez Caldera and Santa Ana Mesa.

The Albuquerque-Belen basin is generally arid. Mean annual precipitation varies from 8 to 24 inches depending on altitude and proximity to major topographic features.

Principal surface water features include the Rio Grande, Rio Puerco, and Jemez River. In addition, valley areas near the Rio Grande are served by an elaborate network of irrigation canals and drains. Numerous arroyos enter the basin from adjacent mountains and flood-control canals direct runoff toward the Rio Grande. Each of these natural and man-made features has an effect on the dynamics of ground water flow in the basin. Interactions between surface water and ground water are complex and often not well understood.

The basin fill consists of unconsolidated sediments (interbedded alluvial and flood plain deposits) and volcanics. These sediments are saturated through most of their thickness and constitute the principle aquifer of the area. Hydraulic properties of the basin-fill deposits vary considerably, both vertically and areally. Chemical characteristics of ground water contained in these deposits also vary spatially.

Recharge to the aquifer occurs as underflow from the north, infiltration from the Rio Grande, arroyos, and other major surface water features and from irrigation activities within the inner valley. Relative importance of these recharge components varies on seasonal and long-term bases.

Movement of water within the aquifer is controlled by hydraulic properties of the basin-fill materials and by the hydraulic head distribution within the aquifer. The historical direction of regional ground water flow, under undisturbed conditions, was toward the south. The flow direction has changed in many areas owing to irrigation and drainage activities, pumping by domestic wells and, particularly in recent decades, to pumping by high-capacity municipal wells. Strong vertical gradients and flow components are present in many areas.

Ground water levels and flow directions also vary on a seasonal basis. For example, water levels in irrigated portions of the inner valley generally rise during the irrigation season (late spring and summer). Conversely, water levels near municipal well fields drop during the summer months due to peak demand during that time of year. Water levels near municipal wells recover somewhat during the winter months whereas water levels in agricultural areas generally drop.

The complexity of the geologic setting and the seasonal and longer-term changes in natural and induced recharge, irrigation activities, and pumping by municipal wells have profound implications for ground water quality monitoring. Regional-scale monitoring is necessary to determine natural variability in chemical characteristics of ground water and to monitor long-term changes. Preliminary site-specific monitoring is typically required to ascertain local components of flow (vertical and horizontal) prior to final design of local ground water quality monitoring programs and effective contaminant-removal programs. References listed at the end of this paper give more detailed information about the geology and hydrology of the basin.

PREVENTION PROGRAMS AND ACTIVITIES

Prevention of future contamination is of great importance and is a method by which tax dollars can be effectively used to protect the ground water resource. Prevention programs are receiving increased attention at all levels of government. The following summary emphasizes activities at the local level.

Three agencies within Albuquerque city government are involved in ground water protection programs. The Public Works Department (PWD) operates the municipal water-supply system and the wastewater-treatment system. They consequently have primary responsibility for ensuring a perpetual supply of potable drinking water and for minimizing potential adverse environmental impacts related to wastewater collection and treatment. The Albuquerque Environmental Health Department (AEHD) is responsible for regulating eleven non-municipal public-water-supply systems within the city (e.g. the University of New Mexico, several hospitals, several mobile home parks, and others) to ensure that they provide safe water to their customers. AEHD also regulates the installation of on-site liquid waste disposal systems within the city limits. The Planning Department has primary responsibility for developing long-term plans (comprehensive plan, area plans, sector plans) and zoning recommendations, which adequately address concerns related to ground water protection. Since there are overlapping responsibilities, concerns and areas of expertise within these three departments, there is an ongoing need for active communication and cooperation among management and staff.

Underground Storage Tank (UST) Program

The AEHD has recently become actively involved in the remediation of leaking underground storage tanks (LUSTs) in Albuquerque. This involvement is formalized through a Memorandum of Understanding between the city and the New Mexico Environmental Improvement Division (NMEID). The Public Works Department is funding a full-time hydrogeologist position, administratively located within the Environmental Health

Department, to carry out LUST-related activities. The state will also provide some funding assistance and will follow-up on cost recovery against responsible parties.

Registration of underground storage tanks is mandated under Section 9002 of the Resource Conservation and Recovery Act (RCRA). Over 2,400 underground storage tanks located within Bernalillo County have been registered with NMEID. Approximately 700 of these tanks are located in the inner valley area where the water table is shallow and soils are acidic. Using Environmental Protection Agency (EPA) estimates that 5 to 10% of existing tanks are leaking, 35 to 70 inner-valley tanks may pose an immediate threat to ground water.

Initially, the AEHD Underground Storage Tank program will develop nine LUST cases in the Albuquerque area based on a priority rating system. Once a case is technically developed, it will be turned over to NMEID for enforcement by the Health and Environment Office of General Counsel. The city will continue to monitor remediation activities at the sites to assure timely, effective cleanup.

The city has also taken lead responsibility for identifying tanks which were not reported during the registration process. These primarily include abandoned tanks at locations that have changed ownership or have been converted to other uses. Such tanks pose a significant potential threat to ground water in that most are old and many still contained liquids including gasoline, diesel, and dry-cleaning solvents when they were abandoned. To date, 219 potential abandoned tank sites have been identified, primarily through visual surveys along major streets. The status of 159 sites has been determined through more in-depth surveys. Relevant information will be turned over to the NMEID for further action.

<u>Small Quantity Generator (SQG) and Technical Assistance Program</u>

The 1984 Amendments to the Resource Conservation and Recovery Act (RCRA) brought small quantity generators of hazardous waste (generators of 100 to 1,000 kilograms of hazardous waste per month) under federal regulation. Prior to enactment of this legislation, an estimated 590,000 kilograms (1.3 million pounds) of hazardous waste were being improperly disposed of each year by Albuquerque area businesses. Proper management and disposal of these wastes greatly reduces the potential for contamination of ground water resources.

To this end, the Albuquerque Environmental Health Department in 1985 began conducting an education and on-site technical assistance/consultation program for small quantity generators of hazardous waste. The program, which is unique for local governments, has been carried out with funding assistance from EPA. Program activities have included mass mailings of information on new regulations, free seminars on hazardous waste regulations and proper management of hazardous wastes, a one-time hazardous waste collection project and an on-going, on-site technical assistance/consultation program for local businesses. Although quantification is not possible at this time, the improper disposal of hazardous wastes has been significantly reduced through this program.

The Albuquerque Fire Department has a 24-hour hazardous material emergency response capability through which spilled materials are cleaned up, contained and held for proper disposal by the responsible party. AEHD provides technical support upon request from the Fire Department.

Wellhead Protection Program

The Safe Drinking Water Act Amendments of 1986 (Section 1428) provide for the optional development of state/local Wellhead Protection Programs. Protected areas are to include surface and subsurface areas (surrounding a well or wellfield which supplies a public water system) through which contaminants are likely to migrate and eventually reach a well or water supply. The ultimate objective of the program is to control or eliminate potential contaminant sources which are located within the protected areas.

Congress authorized up to $20 million in technical assistance grants to develop state/local programs. However, the House Appropriations Committee failed to allocate money for the program. The future of the program and of New Mexico's and Albuquerque's participation is uncertain at this time.

Sole Source Aquifer Demonstration Program

The Safe Drinking Water Act Amendments of 1986 (Section 1427) also provide for the optional development of Sole Source Aquifer Demonstration Programs. Under these programs, protection of critical aquifers will be achieved through development and implementation of comprehensive ground water management plans for critical areas. Albuquerque will likely develop and implement a comprehensive ground water management plan for the metropolitan area without formally participating in the federal program.

New Mexico Water Quality Control Commission Regulations

New Mexico Water Quality Control Commission Regulations effectively regulate new or newly modified facilities, which may potentially discharge to ground water, by means of the discharge permit program. This program, which is implemented at the state level, has effectively minimized potential contamination related to industrial, agricultural, and waste disposal and treatment activities since 1977.

Other Programs

A complete summary of federal, state, and local regulatory programs related to protection of water resources is included elsewhere in these proceedings in a paper by Maxine Goad (see *Historical Overview of New Mexico Ground Water Quality Protection Programs*).

GROUND WATER MONITORING PROGRAM

Ground water quality monitoring in the Albuquerque area has historically been random and irregular and has been performed by various public and private entities. Water quality data are similarly scattered and are generally not accessible in any single data base. Efforts are currently underway to develop a comprehensive regional ground water quality monitoring program and a central data base for all water quality data (including historical).

City Monitoring Activities

Within Albuquerque city government, responsibility for ground water quality monitoring is shared by the AEHD and the Public Works Department (PWD).

The AEHD presently conducts routine sampling at four dedicated ground water quality monitoring wells -- three at the inactive Los Angeles landfill and one near the inactive Yale landfill. The Los Angeles landfill wells are sampled quarterly for an extensive suite of inorganic and organic chemical constituents.

The Public Works Department currently monitors chemical quality of the municipal water supply as required under the Safe Drinking Water Act. Sampling is performed at selected points within the distribution system. Results consequently represent quality of mixed water from several wells rather than from discrete wells. The Public Works Department also routinely monitors chemical quality of water from four nested-pairs of monitoring wells located adjacent to sludge drying beds at the wastewater treatment plant.

The city currently maintains a computer data base containing water quality data for over 1500 private wells in Bernalillo County, which were sampled between 1960 and 1976.

Bernalillo County Monitoring Activities

Ground water monitoring by the Bernalillo County Environmental Health Department is generally limited by budget constraints to sampling private wells for nitrate and coliform bacteria. Sampling is usually performed at the request of homeowners and mortgage companies. For the last five years, the County Environmental Health Department has also been resampling fifteen private wells near the mouth of Tijeras Canyon on an annual basis in an effort to monitor long-term trends in nitrate concentrations. The county is also cooperating with the NMEID in a nitrate sampling program in the east mountain area, recently funded a study of septage disposal practices and options, and is investigating the possibility of establishing assessment districts as a means for providing community water supplies to outlying communities that are currently served only by private wells.

State Monitoring Activities

State ground water monitoring activities in New Mexico and portions of the Albuquerque metropolitan area are addressed in other papers being presented at this conference (see paper by Dennis McQuillan entitled *Ground Water Contamination in New Mexico 1927-1986* and paper by Bruce Gallaher entitled *Water Quality Problems in Albuquerque's South Valley*). State efforts have included detailed studies of the Albuquerque South Valley (over 370 water quality analyses), participation in the San Jose Superfund-site investigation, numerous LUST contamination investigations, monitoring at facilities to verify compliance with ground water discharge permit limitations, and other general and site-specific investigations. NMEID periodically sponsors "Water Fairs" at which water samples brought in by private well owners are analyzed on-site for a few key indicator chemical parameters. Follow-up sampling by NMEID personnel is performed at wells which showed anomalous results during the initial screening.

Federal Monitoring Activities

The U.S. Geological Survey (USGS) data files (in STORET and WATSTOR) contain water quality data for 265 wells in the Albuquerque metropolitan area dating back to the mid-1940s. The USGS and the Albuquerque Public Works Department are involved in development and performance of several cooperative agreements for work related to evaluation of ground water and surface water resources. Included are projects to:

- Monitor ground water levels in 41 wells scattered throughout the basin. Four wells are equipped with continuous recording devices, 30 are monitored monthly and 7 are monitored twice each year.
- Quantify effects of urbanization on hydrologic processes (ground water and surface water).
- Evaluate surface water and ground water resources of the area and estimate impacts of future demand.
- Develop data bases for water-quality data and geophysical well-log data, which are compatible with the Albuquerque Geographic Information System (AGIS).

The Bureau of Indian Affairs (BIA) recently began monitoring chemical quality of ground water and surface water entering Isleta Pueblo. Data will be used to identify and assess potential contamination entering Pueblo lands from the north. A paper by Jane Wells of BIA entitled *Southwestern Indian Water Resource Management: Issues and Strategies for Assuring Clean Water* is included in these proceedings.

Kirtland Air Force Base monitors water quality in wells which serve the water supply system at the base. An extensive suite of chemical data are available for seventeen wells dating back, depending on the well, to 1959.

FUTURE DIRECTIONS

Additional Monitoring Wells

Ground water monitoring activities in Albuquerque will be significantly expanded in the next two years. The city council has appropriated $142,500 for construction of monitoring wells during the current fiscal year. In addition, the city anticipates receiving some federal LUST Trust funds for construction of additional wells at sites where tank leaks have caused ground water contamination. An undetermined amount of Superfund money is also slated for drilling activities in the Albuquerque area by NMEID.

Taken together, these additional wells will provide valuable information regarding ground water quality near four former landfills, several municipal well fields, one or more industrial facilities, and several LUST sites. In addition, some wells will be designed to provide information of a more general (non-site-specific) nature regarding water quality variations on a regional scale. Inner valley areas having a shallow water table and major aquifer recharge areas will be given top priority in these efforts. Nested wells/piezometers will provide information regarding vertical flow and water quality variations in the vertical dimension.

Other existing wells that are suitable for sampling include USGS's multi-level piezometer nests along Montano Road in the north valley and along Rio Bravo Blvd. in the south valley. Sampling of some of these piezometers is anticipated as a means of determining vertical and regional water quality variations.

Most new wells will be sampled quarterly for the first year, semi-annually during the second year, and on an annual basis thereafter. Chemical analyses will include major inorganic constituents (including ions and trace metals) and selected organic constituents.

Possible uses of water quality data generated through these monitoring efforts include:

- identification of previously undetected contamination problems
- providing background and site-specific data for use by state regulatory agencies in enforcement actions
- siting of new municipal (and other) water supply wells
- supporting sound land-use-management decisions
- guidance to the citizenry and elected officials regarding funding needs and priorities
- guidance to private sector for facility siting
- guidance regarding prioritization of extension of water and sewer facilities
- projecting effects of growth and increased water use on ground water quality

Comprehensive Water Resource Management Plan

Geologic, hydrologic and chemical information gained during construction of new wells and during monitoring of new and existing wells will be used to assist in development of a comprehensive, long-term, regional ground water quality monitoring and management program. This program will be funded primarily through the Public Works Department and will likely be designed by a consultant working in close cooperation with Albuquerque Public Works, Environmental Health, and Planning Departments, and with the U.S. Geological Survey. A more extensive discussion of this program is included in another paper included in these proceedings entitled *Albuquerque's Water Resource Management Program* by William H. Otto.

Albuquerque Geographic Information System (AGIS)

Effective management of water quality data will receive major emphasis during development and implementation of the regional ground water monitoring network. All available water quality data should be assembled in a single location and should be made readily available to all potential users. This is not a simple task, owing to the multiplicity of data sources, formats, and end users.

The City of Albuquerque and the USGS are currently evaluating a geographic information system called ARC/INFO for this purpose. The city manifestation of ARC/INFO is the Albuquerque Geographic Information System (AGIS). AGIS is fully compatible with other ARC/INFO systems such as the one utilized by the USGS.

Geographic information currently resident in the ARC module of ARC/INFO (and AGIS) includes street networks, land parcels (for portions of the city), soil distributions, surface water drainage networks, water table elevations and others. Information which will be added to the system in the near future includes locations of water supply wells, monitoring wells, underground storage tanks, landfills, hazardous waste generators, facilities holding ground water discharge permits, areas of known ground water contamination, and other relevant data. AGIS will readily allow production of maps and overlays of this information, singly or in combination with any other information residing in the system. For example, it will be possible to produce maps showing proximity of potential contamination sources to public or private wells or, conversely, to illustrate proximity of wells to the locations of contaminant spills and releases.

The INFO portion of ARC/INFO (and AGIS) is a powerful and extensive data base, and will provide access to data for any specified point, line or area within the area of coverage. For example, INFO will ultimately contain water quality data for individual wells. Data will be retrievable for any specified combination of chemical parameters, for any specified well or wells located within a designated area, or for virtually any combination of wells and/or chemical parameters.

Taken together, the geographic and data-base features of ARC/INFO (and AGIS) will provide an extremely powerful and useful tool for organizing, analyzing and utilizing geographic information. The area of coverage and the amount and quality of information contained in the system will continue to grow as needs and applications expand.

Information Exchange

It is important that ground water quality data be made available to multiple users. It is equally important that technical and managerial staff of various government agencies keep abreast of related activities being performed by other entities, and that they receive timely updates and interpretations of results.

One important forum for this type of information exchange is the Middle Rio Grande Aquifer Water Quality Steering Committee. Committee members include representatives of virtually all government agencies and institutions which are involved in ground water protection and monitoring in the Albuquerque-Belen basin. Meetings are held six or seven times each year and typically include three or four informal technical presentations on topics of mutual interest.

Other important forums for information exchange include meetings of the New Mexico Chapter of the American Water Resource Association, the New Mexico Hazardous Waste Management Society and the New Mexico Geologic Society.

SUMMARY

Federal, state, county, and local governments share responsibility for protecting the ground water resource upon which Albuquerque and surrounding communities depend for their water supply. Most ground water protection programs originate at the federal and state levels. Albuquerque is actively involved in local implementation of several programs.

Ground water quality monitoring in the Albuquerque area has historically been performed independently by various agencies at all levels of government. Efforts are currently underway to plan, coordinate, and expand monitoring activities through development of a comprehensive regional ground water quality monitoring program. Plans are also being made to consolidate ground water quality data in an integrated database/ geographic-information-system in an effort to facilitate data access, analysis, and presentation. These programs will be vital components of a larger water-resource management plan for the Albuquerque area.

SELECTED REFERENCES

Bjorklund, L.J. and Maxwell, B.W. 1961. Availability of Ground Water in the Albuquerque Area, Bernalillo and Sandoval Counties, New Mexico. New Mexico State Engineer Technical Report 21.

Kelley, V.C. 1977. Geology of Albuquerque Basin, New Mexico. New Mexico Bureau of Mines and Mineral Resources Memoir 33.

Kernodle, J.M., Miller, R.S., and Scott, W.B. 1987. Three-Dimensional Model Simulation of Transient Ground Water Flow in the Albuquerque-Belen Basin, New Mexico. U.S. Geological Survey Water-Resources Investigations Report 86-4194.

Kues, G. 1986. Ground-Water Levels and Direction of Ground-Water Flow in the Central Part of Bernalillo County, New Mexico, Summer 1983. U.S. Geological Survey Water-Resources Investigations Report 85-4325.

Peter, K. D. 1987. Ground-Water Flow and Shallow-Aquifer Properties in the Rio Grande Inner Valley South of Albuquerque, Bernalillo County, New Mexico. U.S. Geological Survey Water-Resources Investigations Report 87-4015.

WATER QUALITY PROBLEMS IN THE ALBUQUERQUE SOUTH VALLEY

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Albuquerque overlies one of the most precious fresh water aquifers in New Mexico. Approximately 300 vertical feet of the Rio Grande Valley-fill strata are saturated with high quality water. This ground water constitutes the city's sole source of drinking water. The resource, however, is highly vulnerable to pollution due to permeable soils and a shallow water table. While only a small fraction of the ground water has been contaminated to date, recent trends suggest that the nature and extent of contamination may become more severe in the next decade, due to increased industrialization and population growth.

DESCRIPTION OF THE SOUTH VALLEY

The Albuquerque South Valley is situated within the Albuquerque-Belen geologic basin. The basin is located in central New Mexico and is approximately 100 miles long and 25 to 40 miles wide. The basin is bounded by mountains to the east and is drained to the south by the Rio Grande and its major tributaries.

As used in this paper, the South Valley is located partly within and adjacent to the city of Albuquerque and is an area of about 50 square miles. It is bounded on the north by Central Avenue, on the east by Interstate 25, and on the south by the Isleta Pueblo grant boundary. The western boundary of the study area extends approximately 1 mile west of Coors Boulevard (see Figure 1).

The Rio Grande is the only perennial stream in the study area. It flows from north to south through the middle of the South Valley. The alluvial flood plain along the river generally extends two to three miles west of the river and one-fourth to one mile east of the river.

Approximately 54,000 people reside in the South Valley, according to 1980 census data. Nearly 39,000 of these reside in the unincorporated areas of the study area. The northern portion of the South Valley is urban and is supplied with water and sewage utilities by the city of Albuquerque. The southern part is rural; water for domestic use generally is obtained from wells that are less than 300 feet in depth and on-site sewage disposal is utilized. The far southeastern area is largely agricultural and relatively few

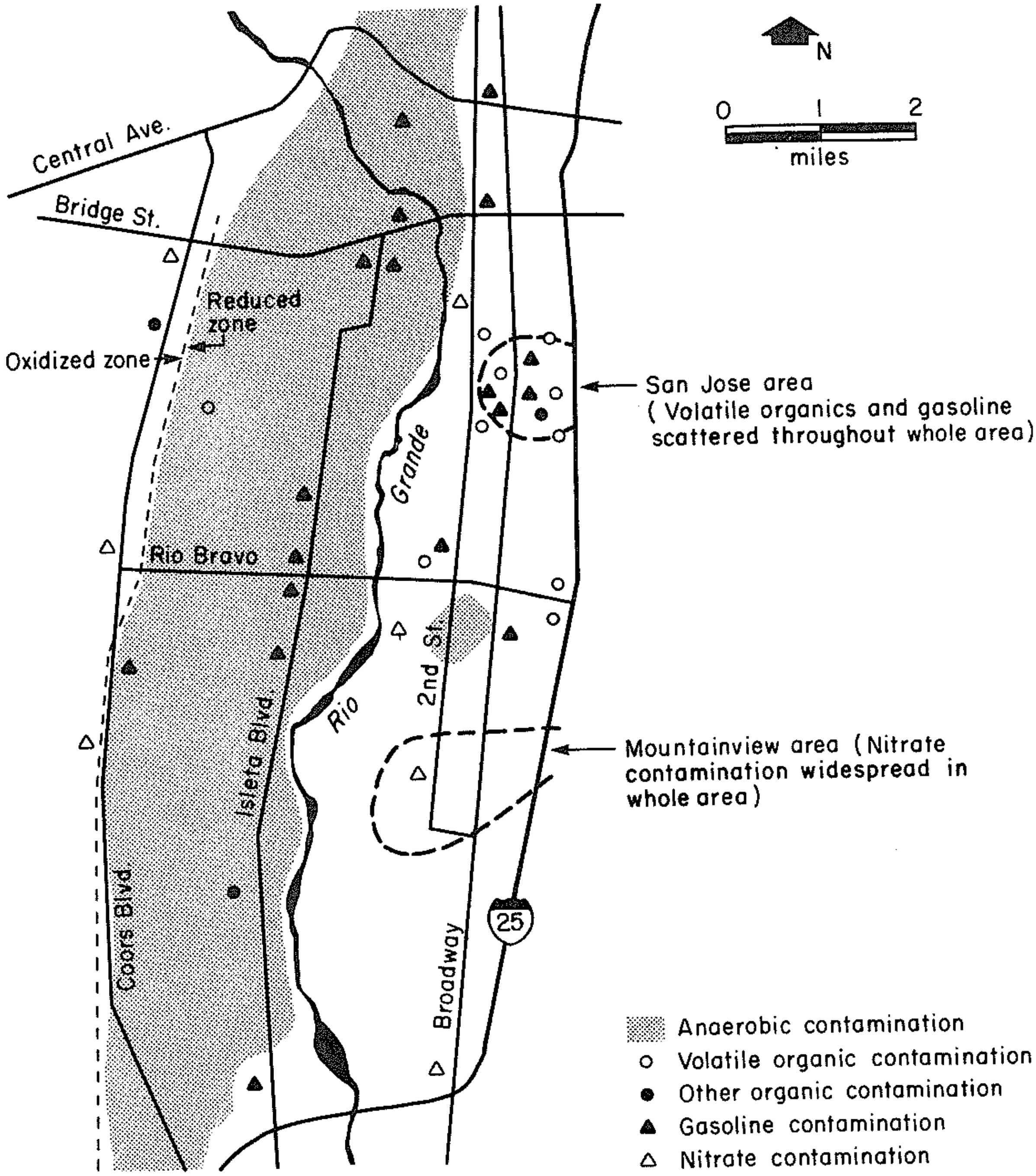

Figure 1. Ground Water Contamination in the Albuquerque South Valley

wells have been drilled. The inner valley within the study area is dissected with canals and drains. The network allows water to be routed throughout urban and rural areas for agricultural use, flood control, and to prevent waterlogging of low-lying land.

POTENTIAL CONTAMINATION SOURCES

In the South Valley, the top three sources of ground water contamination (at least in volume) are agriculture, septic tanks and petroleum product storage facilities.

<u>Agriculture/Evapotranspiration</u>

Irrigation canals have diverted water from the Rio Grande for hundreds of years. Percolating irrigation water caused ground water levels in many valley areas to rise and be more vulnerable to evaporation directly from the soil surface and to transpiration from living plants whose roots tap the ground water. These processes, collectively termed evapotranspiration (ET), cause a gradual build up of salinity in the ground water and form alkali deposits on the soil surface.

In 1919, about 28% of the valley floor was covered by salt grass and alkali or was swampland (Bloodgood, 1930). The Middle Rio Grande Conservancy District designed and constructed drains in the early 1930s to control the waterlogging of irrigated fields. The drains lowered the water table and the croplands were reclaimed.

There are two mechanisms related to irrigated agriculture and evapotranspiration that degrade ground water quality: (1) gradual increase of salinity as relatively pure water evaporates and (2) leaching of alkali deposits as croplands are flushed. Excessive application of irrigation water provides for evapotranspiration and a subsequent increase in the salinity of the shallow ground water once the residual irrigation water percolates downward.

<u>Septic Tanks</u>

About 55% of all housing units in the South Valley dispose of their wastewater using on-site wastewater treatment and disposal systems. There are approximately 9,000 septic tanks/cesspools in use in the area, based on 1980 census data and city and county records. They collectively discharge about 1.4 million gallons of wastewater into the ground daily.

Severe ground water pollution problems can result from the cumulative effects of high density development, improperly treated septic tank effluent, and use of septic tanks in poorly suited areas. In the South Valley, there are several significant existing or potential ground water concerns associated with the use of septic tanks and cesspools.

These include contamination with nitrate and pathogens, and the creation of anaerobic (oxygen deficient) ground water conditions that result in undesirably large concentrations of iron and manganese. The anaerobic conditions occur as a result of biological decomposition of high concentrations of organic material (sewage).

Petroleum Product Storage

Discharges of petroleum contaminants in the South Valley include those resulting from leaking underground storage tanks, accidental spills of liquid products, and the periodic disposal of aqueous contaminants such as tank-bottom water and hydrostatic pipeline-test water. At present, no reliable estimates of total waste volumes of contaminants can be made.

Petroleum products like gasoline, jet fuel, and diesel are complex mixtures of hundreds of organic compounds, many of potential public health concern. Benzenes, 1,2-dichloroethane (EDC), ethylene dibromide (EDB), and polynuclear aromatic hydrocarbons (PAHs) are of primary water quality concern. Elements such as lead, iron, and manganese also may be of concern depending upon site conditions.

CONTAMINATION OF SOUTH VALLEY GROUND WATER

A long history of human activity in a shallow water table zone has left the Albuquerque valley with ground water contamination dating back to at least 1927. Ground water contamination of the Rio Grande Valley-fill aquifer today is typically limited to the upper 200 feet of the aquifer. Deeper waters are generally uncontaminated and are of exceptionally high quality to depths exceeding 3,000 feet.

The contamination in the shallower parts of the aquifer is of utmost concern for two reasons: (1) more than 8,000 households are totally dependent on shallow wells for water supply; and (2) there exists a potential for contamination in the shallower parts of the aquifer to be drawn to deeper zones, ultimately jeopardizing deep municipal and industrial supply wells.

Anaerobic Contamination

Ground water contamination has been documented in virtually every section of the South Valley, as shown in Figure 1. The most common type of contamination in the South Valley is an extensive taste and odor problem involving non-hazardous but elevated levels of salinity, hardness, iron, and manganese in shallow private well waters. Most of these contaminants are ubiquitous within the zone shown as "Anaerobic Contamination".

The manganese and iron problems exist throughout the inner valley except in the largely undeveloped farming areas in the southeast, where residential lot sizes typically are larger than 5 acres (see Figure 2). The elevated levels of manganese and iron appear to be principally attributable to septic tank and cesspool wastewater discharges (Gallaher et al., 1987).

Of much greater public health concern, however, are the presence of several localized contamination problems with nitrate, gasoline, and volatile organic compounds (VOC) such as cleaning solvents. Nitrate and VOC contamination can be insidious in that noticeable tastes and odors are not present until the degree of contamination greatly exceeds health standards.

Petroleum Product Contamination

At least 20 incidents of ground water contamination by petroleum products have been documented by the Environmental Improvement Division from 1970 to 1985 (see Figure 3). A concentration of petroleum contamination occurs in the San Jose area and is associated with the industrial and bulk terminal facilities along 2nd St. and Broadway. Contamination from leaking underground gasoline storage tanks occurs along virtually all of the major streets within the valley. The largest number of the cases are situated along Isleta Boulevard, formerly the major north-south highway through the valley. Most of the petroleum contamination sites are limited in areal extent to a few acres.

West of Coors Boulevard

Relatively isolated cases of nitrate contamination by septic tanks have been observed in a large zone situated generally west of Coors Boulevard. Of fifty wells sampled in this area by the EID, four (8%) had nitrate-nitrogen concentrations greater than the recommended health limit of 10 mg/l (milligrams per liter), and sixteen (32%) exceeded 5 mg/l. Wells with elevated nitrate concentrations are located throughout the zone west of Coors Boulevard, but in all cases are situated in close proximity (less than 500 feet) to large capacity septic tanks.

Mountainview and San Jose Areas

The most severe ground water pollution in the South Valley exists in the Mountainview and San Jose areas shown in Figure 1. Within both areas, wells have been taken out of service due to threats to public health. The respective boundaries of contamination have not been fully determined, but available information indicates that each zone of contamination encompasses an area of at least one to two square miles.

The dangerously large nitrate concentrations detected in Mountainview ground water rank with some of the highest in the United States. Nitrate concentrations at least 50

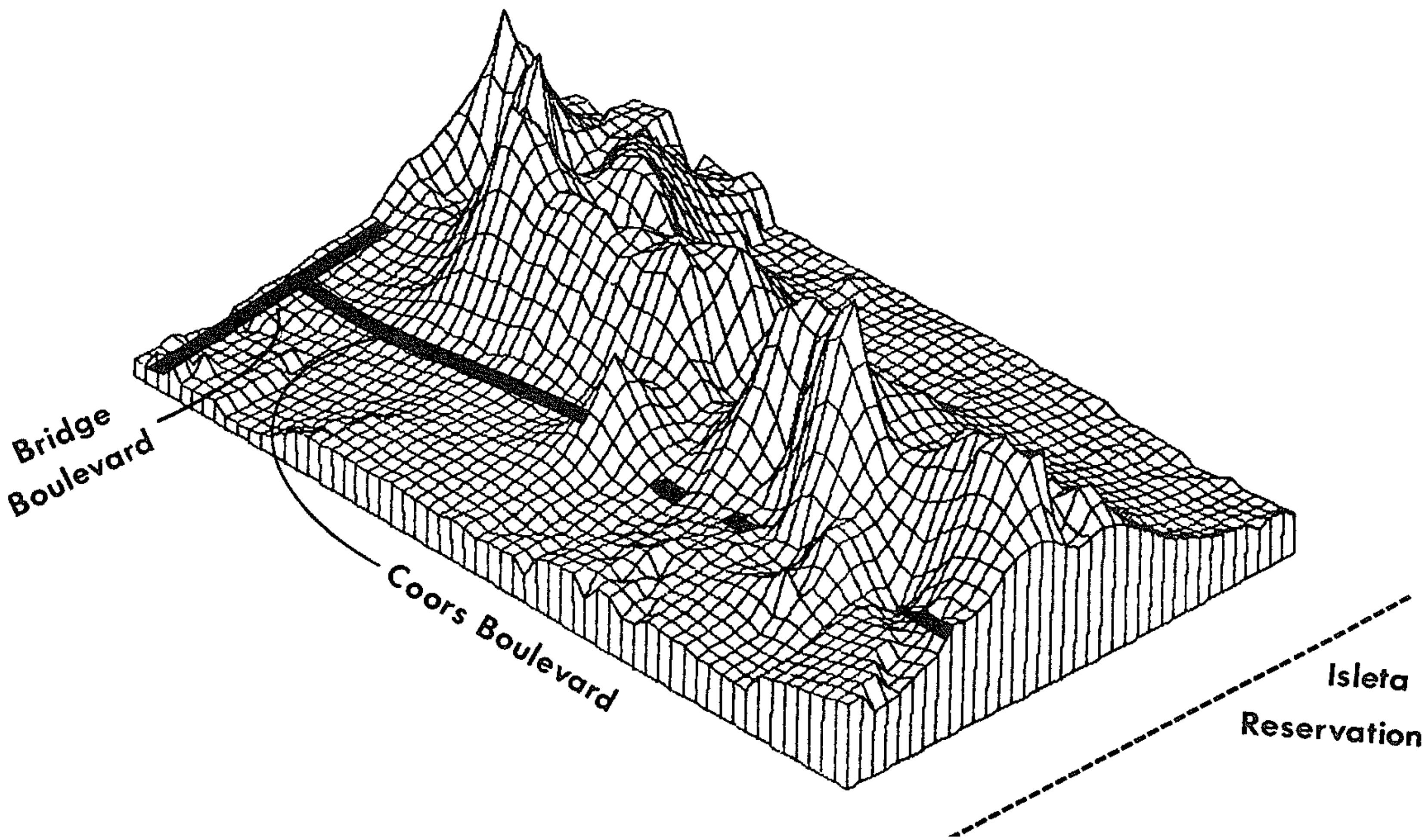

Figure 2. Three-dimensional Perspective of Manganese Concentrations in the South Valley. The "peaks" represent the largest concentrations. View is to the northeast. The widest lines depict the approximate paths of major streets.

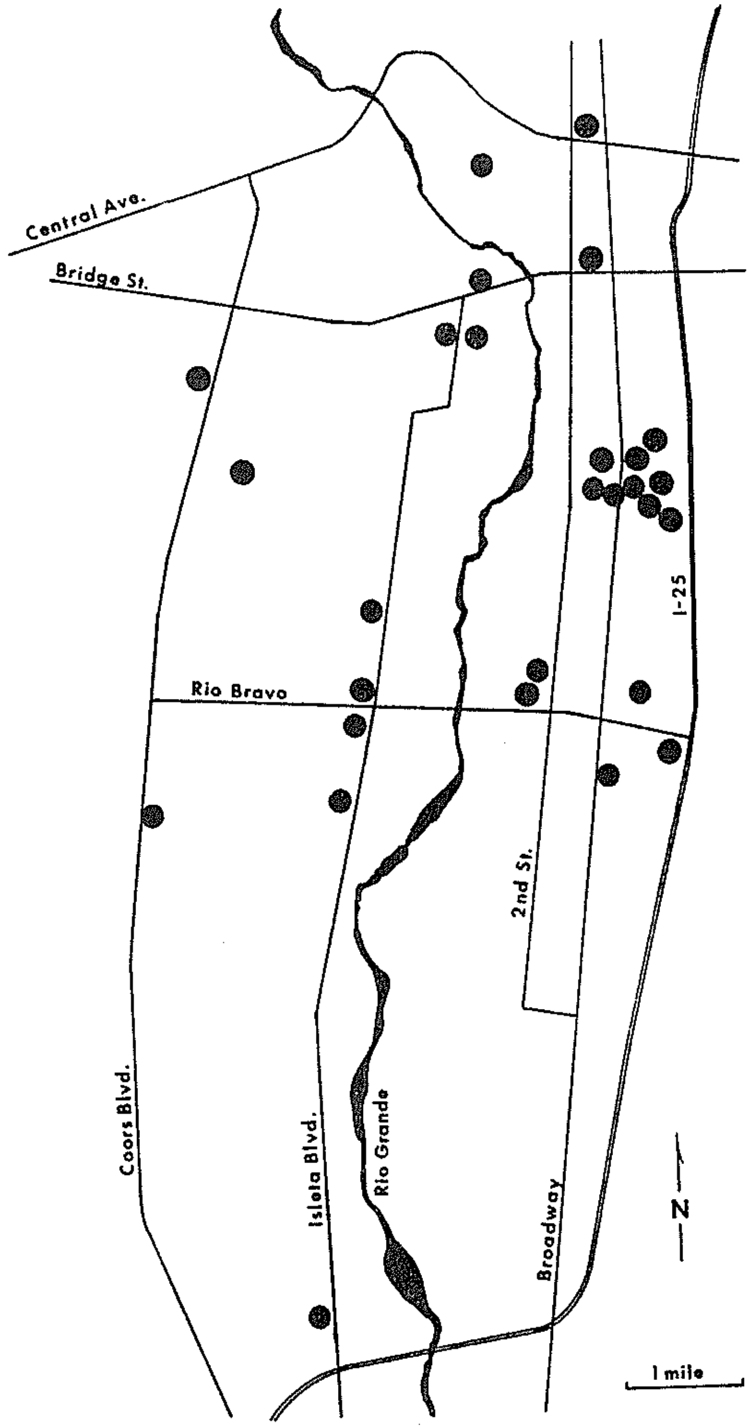

Figure 3. Hydrocarbon Incidents Impacting Ground Water

times higher than drinking water limits have been detected. The specific source of the problem has yet to be determined, though the contamination was first documented in 1961.

A review of available chemical and hydrological information by Gallaher et al. (1987) leads to the conclusion that ground water contamination at Mountainview was probably caused by the discharge of nitrate-rich salts within the Tijeras Arroyo drainage. Such salts are widely used in munitions, explosives pyrotechnics, and commercial fertilizers.

While the possibility exists that other sources may have contributed to the nitrate problem, there is sufficient cause to warrant expanded investigation into the possible relationship between explosives disposal and the Mountainview nitrate contamination. Further work in this area is planned for 1988 by state and federal agencies.

The San Jose area is located within an industrial and residential area in the northeast portion of the South Valley. It has been designated as the state's highest priority "Superfund" site because of the presence of hazardous substances, particularly in the ground water near the city's San Jose well field. Within the site, there are six known or suspected contaminant sources. Figure 4 overviews the general conditions of the site.

Ground water contamination was first generally suspected in 1978 when tastes and odors were noted in a private well near a chemical handling facility. Subsequent sampling showed certain volatile organic compounds were present in two municipal wells. These wells were subsequently taken out of operation by the city of Albuquerque. To date, at least six private, industrial, or municipal supply wells have been impacted by the contamination and subsequently shut down.

Since 1983, the U.S. Environmental Protection Agency (EPA) has directed a remedial investigation at the San Jose area under the auspices of the federal "Superfund" program. Preliminary investigations at the site indicate that ground water contamination exists as deep as 170 feet below the top of the aquifer (200 feet below the land surface), and may encompass an area greater than one square mile. The degree of contamination varies considerably with location but generally decreases with depth (EPA, 1985).

The upper 50 to 60 feet of the aquifer contains aromatic hydrocarbons and chlorinated solvents in concentrations typically less than 40 and 700 parts per billion (ppb), respectively. Maximum detected concentrations, however, are considerably higher (e.g. 55,000 ppb of total hydrocarbons; McQuillan et al., 1982).

Additional field investigations are required to determine if there is or has been any source of soil and/or ground water contamination at any facility within the San Jose area. Possible sources include petroleum handling facilities, solvent handling facilities, flood

This area is complex in terms of both hydrogeology and potential sources or organic contaminants. The direction of ground-water flow appears to have been reversed due to heavy pumpage. At least three of the numerous potential contaminant sources have impacted ground-water quality.

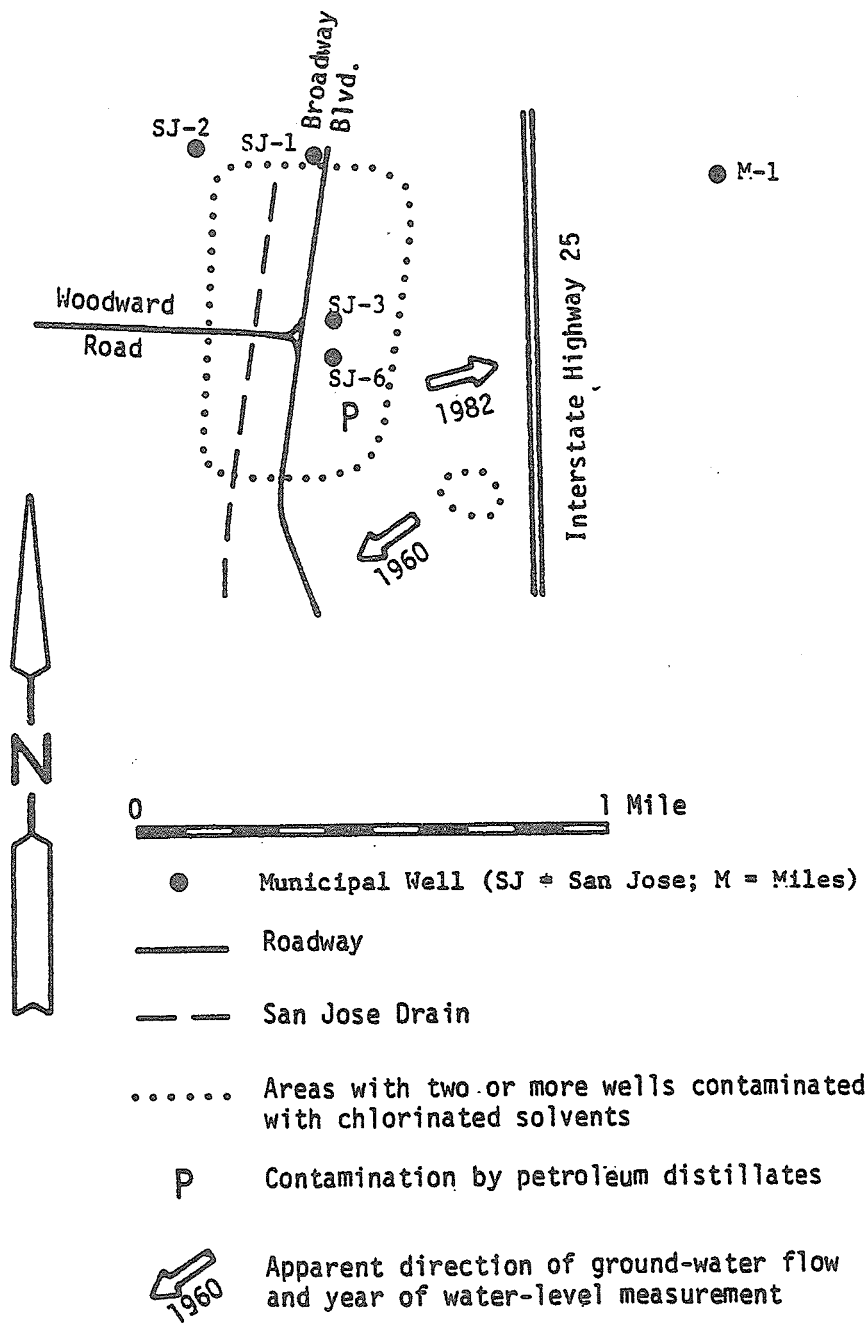

Figure 4. San Jose Area of the Albuquerque South Valley

diversion channels, and municipal sewer lines if leakage from these facilities occurs. As concluded by McQuillan et al. (1982), there appears to be multiple sources which have contributed to the problem.

DISCUSSION AND CONCLUSIONS

For most South Valley residents, there is currently little potential health risk associated with drinking private well water. Severe taste and odor problems are widespread in the inner valley but, on balance, are not hazardous to public health. Potential health hazards caused by nitrate, gasoline, and volatile organics are generally restricted to discrete areas. Epidemiologic studies conducted between 1985 and 1987 indicate that the rates of diarrheal illness, cancer, and childhood leukemia in the South Valley are not significantly different than in other parts of Albuquerque, Bernalillo County, or New Mexico (Gallaher et al., 1987).

Due to increased industrialization and population growth, however, the extent of health-threatening contamination cases will inevitably increase in the next decade. Experience gained indicates that in the inner valley the ground water is exceedingly vulnerable to contamination from spills or wastewater discharges at the land surface. Moreover, it appears that contaminants in the shallow ground water zones are being drawn to greater depths by the pumping of deep wells. This vertical migration presents a long-term threat to all deep wells including those used by the city of Albuquerque.

Development and aggressive enforcement of ground water protection based zoning measures by local governments would greatly minimize this long-term risk. In the light of the demonstrated vulnerability of aquifers to contamination, industrial development in the inner valley may conflict with the goal of protecting municipal and private water supplies. High risk activities should be located, when possible, in areas outside of the valley where the depth to ground water is greater than 300 feet.

REFERENCES

Bloodgood, D.W. 1930. The Ground Water of the Middle Rio Grand Valley and its Relation to Drainage. New Mexico State College, Agricultural Experiment Station, Bulletin 1984, p. 306.

Gallaher, B.M., McQuillan, D.M., Chavez, L.D., Hull, H.F. and Eidson, M. 1987. Ground-Water Quality and Public Health Albuquerque South Valley. New Mexico Health and Environment Department. EID/GWH/87-1, p. 240.

McQuillan, D.M., Oppenheimer, S.J. and Meyerhein, R.F. 1982. Organic Ground-Water Pollutants in the South Valley of Albuquerque, New Mexico. New Mexico Health and Environment Department. p 47.

U.S. Environmental Protection Agency, 1985. Draft Technical Report, Offsite Remedial Investigation, South Valley Site, Albuquerque, New Mexico. Contract No. 53-6111.0, 2 vols.

ARIZONA ENVIRONMENTAL WATER QUALITY ACT OF 1986

Representative Larry Hawke
Arizona House of Representatives

Presented at the conference by
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Arizona House of Representatives

The Environmental Quality Act (HB 2518) was the product of many thousands of hours of time by parties from affected industries and businesses, environmental groups, public interest groups, local governments and state agencies. The bill establishes an aquifer protection permit program, with permits required for any discharge of a pollutant to the land or vadose zone in such a manner that there is reasonable probability it will reach an aquifer. There are specific categories of activities for which a permit is expressly required and there are also specific exemptions. In addition, general permits can be issued for certain classes of activities, including agriculture, urban runoff and small septic systems.

The permit conditions include monitoring requirements, action levels and post-closure plans. Also, there is specific point of compliance defined in the statute.

All aquifers are initially classified for drinking water purposes. The director of the Department of Environmental Quality (DEQ) can reclassify an aquifer for non-drinking water use only if it is not being used for drinking water; it is hydrologically isolated from other aquifers; and, substantial benefits significantly outweigh the costs of allowing degradation. The Environmental Protection Agency (EPA) maximum contaminant levels are adopted by reference as aquifer standards, but the director may adopt numeric limits for additional pollutants. Citizens may petition for additional pollutant limits. The numeric standards must be health based.

A state superfund is established, with a cap of $25 million for remedial action, abatement, and liability provisions similar to CERCLA (Comprehensive Environmental Response, Compensation and Liability Act). The fund may be used for a variety of purposes: to provide state matching money for CERCLA; for costs incurred in remedial actions if a responsible party cannot be identified or refuses to undertake a cleanup; for the costs of monitoring and evaluating threats to the ground water from hazardous substances; and for the costs of conducting site investigations, feasibility studies, health-effects studies and risk assessments.

Six million dollars will be put into the fund every year until the cap is reached. The initial $5 million in the fund was borrowed from the tax protest resolution fund. This loan will be paid off at the rate of $1 million per year during the next five years.

Enforcement of the act is through a variety of measures: administrative orders, injunctions, civil penalties of up to $25,000 per day, and felony penalties for certain knowing or negligent violations. In addition, there is a citizen suit provision to allow for enforcement of statutes, rules, permits and orders. Any person may file a lawsuit against any other person, including the state, for violations of standards, permits, discharge limits, orders or rules. A person may file a lawsuit against the director for failure to perform a nondiscretionary duty. Action may not begin: (1) before the expiration of a 60-day notice period; or, (2) if the attorney general is currently prosecuting an action to require compliance.

Article 6 of the act deals with the regulation of the ground water impacts of pesticides. Generally, the law requires pesticide manufacturers to supply specific data so that the state can determine what the most mobile pesticides are and narrow the regulatory focus to those pesticides.

The approach is patterned after California in order to simplify the Arizona program. In addition to requiring the submission of certain data, the act requires the establishment of numeric value for specified pesticide characteristics and a cancellation procedure in the event a pesticide is found in the ground water or at a designated depth in the soil.

DEQ, in consultation with the Department of Water Resources and the Commission of Agriculture and Horticulture, is required to set specific numeric values. These values have been incorporated into a set of proposed rules (Pesticide Numeric Values) which also contains administration of the ground water protection list and enforcement provisions. The ground water protection list includes those pesticides which have the potential to pollute ground water. Each pesticide on that list which is intended to be applied to or injected into the soil by ground-based application equipment or by chemigation must be regulated. Regulation is also required of pesticides with labels requiring or recommending that the application be followed within 72 hours by flood or furrow irrigation.

Users of pesticides on the list must report usage to DEQ. Pesticide dealers must make quarterly reports to DEQ on the sale of all pesticides.

The cancellation procedure is triggered when any of the following occurs:

1. an active ingredient of the pesticide is found in the ground water, or
2. an active ingredient of the pesticide is found at or below the deepest of the following:

a) 8 feet below the soil surface;

b) below the root zone of the crop; or,

c) below the soil microbial zone.

Registration may be cancelled by the state chemist if the label cannot be modified to prevent ground water pollution. Regardless, no pesticide can be used in the state if it would cause a violation of water quality standards at an applicable point of compliance.

There is an independent process for persons to appeal various portions of the act. Permits and two pesticide issues (numeric values and data-gap information) are directed to a three-member water quality appeals board in the Department of Administration. Also, any person who is or may be adversely affected by an order of the director may request a hearing conducted by an administrative law judge in the Department of Administration. In both instances, decisions are subject to further appeal to a special water judge in the superior court and have precedence over all other civil proceedings.

The functions of the Board of Pesticide Control were repealed and transferred to the Commission of Agriculture and Horticulture, the Industrial Commission and Department of Health Services. All rules and orders adopted by the board relating to pesticide regulation continued in effect, as did all valid licenses, permits and certificates issued by the board until superseded by the new regulations of the Commission and Industrial Commission. (The Commission of Agriculture and Horticulture rules became effective November 22, 1987.)

There are a variety of powers and duties assigned to the commission. It must conduct investigations based on complaints and on its own initiative to determine if violations have occurred. It must take action within certain statutory periods of time to enforce the law. It must publish a list of pesticides which it determines to be highly toxic, odoriferous, or otherwise appropriate for inclusion.

The scheme for establishing and penalizing violations is by a non-exclusive list of acts and omissions which would be either serious, non-serious or de minimus violations. In addition, the commission must establish and use a system to assess violators with points for each violation. Civil penalties are as follows:

non-serious -	not to exceed $500 per violation; license, permit or certificate may be revoked
serious -	not to exceed $10,000 per violation; license, permit or certificate may be revoked

There is also the right of private action or citizen suits. Any person having an interest which is or may be adversely affected may commence a civil action in superior court against any alleged violator or the director of the commission. There are two exceptions to this right: de minimus violations are excluded; and, if the director or attorney general is taking appropriate and diligent action on the matter. In the latter case the suit would be dismissed within 60 days if there were appropriate action.

The act provides for buffer zones around schools, day care centers, health care facilities and residences with distances ranging from 50 feet to one-quarter mile. The distance depends on the type of application (ground or air), the form in which the pesticide is applied (liquid or dust) and whether it is odoriferous.

Two other features of the act are the designation of pesticide management areas which are those close to the urban areas, or other areas where pesticide use may be or has been a source of public complaints. In these areas, the commission must receive advance notice of pesticide applications. The commission is also directed to establish an integrated pest management program. Certain sectors of agriculture have priority for development of the program: (1) cotton, grain forage; and (2) livestock, fruit, nut, vegetable, ornamentals.

There are several means of oversight. A ten-member legislative oversight committee is established to monitor the activities of the four agencies involved with pesticides; the auditor general will contract for an independent performance review to be conducted in FY 89-90 on the pesticide regulatory program established by the act; there is a five-year sunset date on the Commission of Agriculture and Horticulture and, there are various periodic reports which must be submitted to the legislature and governor by all the agencies.

DEQ IMPLEMENTATION

The department is currently developing rules authorized by the EQA and other state statutes. An open public process has been instituted to provide interested parties an opportunity to participate. DEQ utilizes advisory groups, concept papers, public meetings and workshops to facilitate this process. Mediation or "formalized" rule negotiations will be considered when appropriate.

Rule adoption

Three sets of rules have gone completely through the administrative rule-making process: the Water Quality Assurance Revolving Fund (ARS 49-282) administration rules, the Pesticide Dispute Resolution rules (ARS 49-306) and the Aquifer Boundary and Protected Use Classification rules (ARS 49-224).

Interagency Coordination

After the EQA was enacted, management-transition meetings were held with participating state agencies. Memorandums of Understanding have been finalized with the ADHS Division of Laboratory Services and the ADHS Division of Disease Prevention. A Memorandum of Understanding is being negotiated with the Department of Water Resources. Interagency service agreements exist or are pending with the State Chemist's Office, the U.S. Geological Survey, and the Commission of Agriculture and Horticulture.

Water Quality Advisory Council

Since December, 1986, eight meetings of the Water Quality Advisory Council have been held to provide input and advice to the department on discharge limitations, procedures for the reclassification and classification of aquifers, water quality standards, and the establishment of Best Available Demonstrated Control Technology (BADCT) Advisory Group.

The department is currently working with four BADCT advisory groups to develop BADCT guidance documents for municipal and industrial wastewater treatment, mining operations, and landfills. These guidance documents will be available for use by the regulated community and the department to assist in developing and evaluating Aquifer Protection Permit applications.

The Best Management Practice (BMP) advisory committees have begun to meet on feedlot operations and nitrogen fertilizers. These agricultural BMP advisory committees are to make recommendations to the director by October 1, 1988. The director has until July 1, 1989, to adopt rules on agricultural general permits using the recommendations of the committees.

STATE PRIORITIES IN GROUND WATER

Governor Garrey Carruthers
Governor of New Mexico
Santa Fe, New Mexico

It's always a great event to come back to the water conference. This is the 32nd annual meeting since Dr. Stucky invented water conferences 33 or 34 years ago at the Water Resources Research Institute, where I spent a couple of years of my life as an acting director.

The Water Resources Research Institute and its water conference have always been very topical. The institute always manages to anticipate the future of water resources in New Mexico and of course publishes an excellent document as the result of the conference. The proceedings of the conferences, believe it or not, and I have evidence of this, have been used for public policy. Occasionally Steve Reynolds has used them in some of the litigations for which Steve has become famous.

I would suggest to you that the conference theme of underground water resources in the state of New Mexico is once again very topical and that it has been well chosen. It doesn't really hurt to refocus occasionally away from quantity. If Texas would just get off our case, we could really refocus away from quantity and start talking about quality.

We have our own set of problems with ground water quality. It's a little easier to refocus on the question of underground water reserves when the reservoirs are full, and, it's raining, as it is today in Albuquerque. One would begin to believe that perhaps the time is here to look at something else. Unfortunately, when the Water Resources Research Institute's sponsored water conference refocuses, it's oftentimes in anticipation of a major problem. And so I think the conference's theme was chosen well and I commend you for it.

You have anticipated what I believe to be one of the really serious pending problems in the state of New Mexico. I will admit to you that I'm not the kind of water expert that you are. But I do travel the state considerably and have been traveling the state for a number of years, intensively over the last two or three years. I have been serving as governor for these past 10 months, 8 days, 10 hours and 12 minutes. As a consequence of that service, I've discovered an unusual set of complaints about the condition of underground water in New Mexico, and it comes from a variety of places.

Ground water conditions that we sensed at one time would never be a problem in Reserve, New Mexico have now become a problem. I don't think anyone who is familiar with Reserve, New Mexico would anticipate complaints about contamination of underground water reserves, but that is one of the most serious concerns that the people have in that particular county.

I grew up in San Juan County, and I think we did anticipate what would happen in the San Juan Basin due to too many septic tanks in an area that had very high ground water levels. Many of you live in Albuquerque. I've never heard anything but complaints about the conditions of the ground water reserves in the south valley of Albuquerque. We know that we already have existing problems, rather serious problems in the state of New Mexico. I think you rightfully anticipate that we ought to take corrective actions today, that we are going to take care of the problems.

To get into a proper mental state, we should talk about ground water reserves. Of the 1.4 million New Mexicans, I understand that more than one million rely totally upon aquifers for their water supply and about 200,000 New Mexicans use private wells. In terms of our own health and welfare, the condition of the ground water reserves has to be paramount. Contamination of ground water reserves used essentially for domestic consumption has already been reported in 30 of our 33 counties and we already know that there are 80 public water wells that have been contaminated. That is a serious problem in itself. We have several hundred known point source ground water contamination cases and we have managed to move on only 45 of those cases, so we already have a serious problem.

We know the source of the ground water contamination. We know they are buried and as a consequence, in terms of public policy, law, rules, and regulations, it is going to take a variety of approaches.

I think one area of great concern to those of us who are now in public policy are gasoline and other petroleum products that are stored underground in tanks. They have a cute acronym that comes from the federal level called LUST. LUST stands for Leaking Underground Storage Tank and describes the overall program that attends to this problem. LUST is a rather peculiar acronym to talk about a rather serious problem. It is a serious problem in New Mexico because we have a number of things that we haven't been able to identify; where they are and the extent of the leakage. And more than that, we have some concerns in New Mexico about who really is responsible for cleaning them up. We're going to turn that over to the EPA.

The septic tank problem is probably even a more serious problem. In terms of local government, we're going to have to take more aggressive action than we've taken in the past. We know that in New Mexico, we take great pride in private land and the ability to do with private land what we want. I protect that right. Private land is very special to Westerners. But in the process of doing that in some counties, they have allowed overdevelopment of some private land. The only possible way of disposing of some wastes was to use septic tanks and as a consequence, we have some serious problems particularly in the San Juan Basin and the lower valley of Albuquerque.

The solution, however, is very expensive. These people do own their land, they live there, and they do have a septic tank. The solution ultimately, in terms of public policy and public programs, will probably require a much more aggressive program in rural sewage systems, much like the rural water system you see today. The impetus for furthering the cost of rural water systems is in part driven by the fact that once the ground water is contaminated, people can no longer use their own well. Part of the solution has been to put in the rural water systems to take people off of their own wells and put them on a safer drinking source. That still ignores the problem doesn't it? The problem still exists and we haven't taken very aggressive steps to alleviate it. With 90 percent of our population depending upon ground water, it seems to me that we ought to take aggressive steps.

As governor I speak with great confidence and clarity when I know very little about the subject because when I get more into the subject, it becomes complex and I tend to get confused. I will speak with great confidence and clarity since I have my experts here who can explain some of the things that are going on in state government right now. If you have an interest in the rules and regulations that are being promulgated with respect to the leaking tanks and some of the other things, there are some experts here from the EID who can converse with you. However, I am here to talk with you about priorities in ground water in the state of New Mexico.

The priority, of course, is the cleanup of those identifiable sites. We must go out and clean those that we have been able to identify. The cleanup is quite costly. Once a leak has occurred, it can take, in some circumstances I'm told, 20 years to clean it up and can cost from $100,000 to millions of dollars depending on the contaminant.

Some of the contamination occurs very simply because people just drive up and dump stuff and they really don't care whether it is in a properly identified, EID and county sanctioned city land fill. They just care about getting rid of it. Some of our problems will always be complicated by attempting to identify who is responsible for the contamination. Thus we want to identify and assign priority to the cleanup of ground water contamination.

An even more important problem is to discover the extent of the problem. We in state government do not have a full appreciation of this in the state of New Mexico. I would ask representatives of the EPA whether we know the full extent of the problem in the United States. As a consequence, taking inventory will be a priority for the EID. It must be a priority for the EID and the inventorying process is just now getting underway.

The EID is taking some steps, particularly with respect to the leaking storage tanks, to promulgate rules and regulations which I understand will be available at the end of 1987. As a consequence of waiting this long to protect the underground environment in New Mexico, we had put many storage tanks in place that were not properly regulated.

There are other activities in state government which are important but I would suggest to you that they are all along the lines of inventory and cleanup. We will seek some support from the EPA and from a special grant to help identify where the underground tanks are. Also, we need to develop and are in the process of developing some additional stringent language with respect to orphaned underground storage tanks, abandoned tanks. We will seek from the EPA somewhere between $350,000 to $1.2 million to help us on that issue. Most of all, I think we're going to have to come up with some language to assign responsibility to those people who have, in fact, contaminated the environment.

It would not be out of the question it seems to me, for the New Mexico legislature to discuss the possibility of a superfund in New Mexico which would do essentially what the EPA does with their superfund on a national level. The superfund would require that when we identify a responsible party, even though the public has cleaned it up, we would ask that party to compensate the superfund for the cost of the cleanup. Given the proper, legal leverage, I think we could do some marvelous work in cleanup.

I would make one recommendation to the EPA however, and that is in the area of oil field waste. We understand that the EPA is about to declare oil field waste as hazardous waste. The oil and gas industry has been very responsive to state regulations on this issue and we would really rather continue to have the state of New Mexico regulate this matter than to turn it over to the EPA. We will be lobbying with the EPA to let New Mexico take care of its ground water resources as best as it possibly can. Steve Reynolds and others have been very aggressive and forceful over the years in establishing some of the best water laws, both surface and ground water, that we have in all the United States. We are very proud of them. We think that those laws, plus the rules and regulations that are established, implemented, and monitored by the Oil Conservation Division serve us rather well. It is just a matter of giving us the opportunity as a state to practice state's rights and to use our own rules and regulations to define the water quality and the methods of making sure we attain that water quality.

In sum, I would suggest to you as you confer here on underground water, that we may have to take those questions both to the legislature and the private sector. We must, through inventory, discover what kind of problems we have, particularly with the deposition of toxic wastes and other wastes that contaminate the ground water supply. We are ultimately going to have to assign some kind of priority to our revolving fund so that we can make some stronger investments in rural sewage systems. We now have some of those investments in water systems and it seems to me that now we need to focus the community development grants and some of our revolving loan funds to sewer systems. This will begin to remedy the problem of septic tank contamination. Finally, we ask you to continue to reflect scientifically as well as in terms of good public policy, how we can best use the rules, laws and regulations that we have in New Mexico to protect our ground water resources.

I would like to ask Bobby Creel, as representative of this conference and the principal organizer, to synopsize the thinking of this crowd. With respect to underground water resources in New Mexico, particularly the water quality aspect, I am interested in receiving your guidance and advice on the steps we ought to take in the near-term and long-term to protect New Mexico's water resources.

Thank you very much.

BUREAU OF RECLAMATION'S HIGH PLAINS STATES GROUNDWATER RECHARGE DEMONSTRATION PROGRAM

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INTRODUCTION

The High Plains States Groundwater Demonstration Program Act of 1983 directs the secretary of the interior, acting through the Bureau of Reclamation, to engage in a special study of the potential for ground water recharge in the High Plains states (Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas and Wyoming) and other Reclamation Act states (Arizona, Colorado, Idaho, Montana, Nevada, North Dakota, Oregon, Utah and Washington).

The program is being carried out in two phases. Phase I consists of planning, development, and site selection, and Phase II includes design, construction, operation, and evaluation. The legislation established a two-year period for Phase I and a five-year period for Phase II. During Phase I, a detailed plan has been developed to construct demonstration projects. The cooperative non-federal/federal nature of the program has been a key element in the development of the plan. Maximum use has been made of the resources and assistance available from state and local entities. The key non-federal participants are the governors and their designated representatives from each of the 17 western states, as well as various officials from municipalities, irrigation districts and other local organizations.

In addition to non-federal cooperation, Reclamation has worked closely with sister agencies, the U.S. Geological Survey (USGS) and the Environmental Protection Agency (EPA), to formulate the program and evaluate the proposals. The Phase I report recommendations are the result of the active support and participation of the nonfederal interests, the USGS and the EPA.

Under the act, the plan is to contain not less than twelve demonstration sites in the High Plains states and not less than nine sites in the other Reclamation Act states. Demonstration project sites are located in areas having a declining water table, an available surface water supply, and a high probability of physical, chemical, and economic feasibility for recharge of the ground water reservoir.

The major themes of the program are as follows:

1. Operational/Demonstration Projects. The objective of this program is to move from research on ground water recharge to the pilot demonstration phase, and lay the groundwork for larger operational programs. Many technical and research studies have been undertaken; however, Congress, in passing the legislation intended that the emphasis be specifically on demonstration rather than new research. In that regard, maximum use was to be made of existing information, studies and projects.

2. Recharge Orientation. The emphasis of the program is on ground water recharge. Conjunctive use, conservation, and management of existing supplies are important tools in an overall resource management scheme; however, they are not intended to be the primary purpose of this program. Conditions of actual regional declining ground water levels on a long-term basis are considered to be at the heart of the program.

3. Local Supplies. The program expects local surface water supplies to be used in recharging nearby aquifers. Specifically excluded from legislation was the authorization of interbasin transfers of water. In fact, the law prohibits study of use of water originating in the drainage basin of the Great Lakes or from the state of Arkansas. The underlying theme of the Congress was "small and local." This constraint, while clear, limits the practical effect of demonstrating recharge of depleted aquifers on a regional basis. It is unfortunately true that, in the very areas where ground water overdraft and water level decline are most severe, a local surface supply is usually not available or is only available during high streamflows. Often the surface supply is fully appropriated. Nevertheless, demonstrating maximum effective use of all available local water supplies is a cornerstone of the program. Such efforts can make a significant contribution to the arrest of declining ground water situations.

4. Nonstructural. A widely held view that needs to be tested and confirmed is whether ground water recharge is a more economical and environmentally safe way to store water for future use than are massive new dams. These low capital intensive methods of meeting future water needs hold great promise for managing our limited water resources. However, they are not without problems, particularly the need to maintain and protect ground water quality. Addressing these problems is a major goal of the program.

5. Institutional and Legal. The program will examine the institutional and legal aspects of ground water recharge. Recent attempts by states to establish agreements

for managing ground water basins indicate the high level of awareness of the limitations of ground water to fully supplement surface supply. These issues will be explored in a special study during Phase II as part of the overall study.

6. Uniqueness. The authorizing legislation specifically states that the purpose of the plan is to determine whether various recharge technologies may be applied to diverse geologic and hydrologic conditions. During the technical evaluation of the proposals, Reclamation took note of those proposals which provide an opportunity to test technologies under new conditions.

The program officially began with the apportionment of funds by the Office of Management and Budget to the Bureau of Reclamation on December 2, 1985. The authorizing legislation requires a report on Phase I within 24 months of the appropriation of funds. Thus, the goal of Reclamation has been to transmit the Phase I report to Congress by December 1, 1987. The act authorized the appropriation of $500,000 for Phase I and $20 million for Phase II.

Early and active involvement of the 17 western states was the principal way the program was to be accomplished. Accordingly, each governor was asked to designate his representative to work with Reclamation. The state representatives reviewed the concepts included in the site nomination and selection process, and provided ideas and information which were incorporated into the evaluation process.

To ensure that individual state policies and program priorities were recognized in the development of this program, each governor reviewed, prioritized, and submitted their proposals to Reclamation. The governor's transmittal is a critical step in the planning phase as his prioritization of proposals helped ensure that each state's particular program direction was considered in the site selection.

The evaluation process included USGS evaluation of the hydrologic and geologic aspects of proposals including the monitoring plan; EPA review of the plans for monitoring and evaluation of general water quality impacts from artificial recharge; and Reclamation evaluation of engineering, economic, environmental and legal aspects of proposals, and public acceptability.

TECHNICAL EVALUATION OF PROJECT PROPOSALS

Reclamation received 41 proposals involving a wide range of types of recharge project proposals. Some proposals involve using existing recharge projects and increasing the facilities for recharge and/or monitoring. Other proposals plan to use existing conveyance facilities to transport surface water to potential recharge sites; still others propose to use existing pits or ponds to store recharge water supplies and existing or abandoned wells to inject recharge water supplies into the aquifers.

The majority of the proposals however, call for the construction of new facilities. These facilities include channel diversion structures, retention dikes and gates, flushable gravel filters, sediment ponds, dual-purpose (injection and extraction) wells, monitoring systems, spreading mechanisms, percolation ponds, underground barriers, and shallow dry wells. Several ways to obtain the necessary water supplies are proposed. Some proposals are based upon accumulation of snow; some use excess spring runoff; and some use treated effluent. Exchanges of water to obtain a recharge supply also are being considered. Some proposals take advantage of fluctuations in seasonal water supply or demand to obtain water for recharge demonstration purposes. In addition to the objective of increasing aquifer supplies, some proposals would evaluate the reduction or stabilization of land subsidence through injection of water into underlying aquifers. Other proposals would reduce salt-water intrusion into aquifers using injection wells.

Figure 1 shows the location of all 41 proposals. The proposals have been reviewed and evaluated by the three federal agencies, using the procedures and criteria process developed jointly by Reclamation, the USGS, and the EPA. Each proposal was subjected to an initial screening derived from the requirements specified in the act, including a declining water table, an available surface water supply, and a high probability of physical, chemical and economic feasibility for recharge of the ground water reservoir. The specific screening criteria developed were as follows:

Screening Criteria:

- Declining Water Table
- An Available Surface Water Supply
- A Minimum of 20% Non-Federal Cost Sharing
- Lack of Serious Environmental Problems
- Public Acceptability of Proposal
- Received a Priority from the Governor

Figure 1. High Plains States Groundwater Demonstration Program
Location of Proposed Recharge Demonstration Sites

As a practical matter, all proposals received were given a full technical evaluation, since on initial screening all appeared to pass the screening tests. All proposals underwent additional evaluation during which a detailed analysis was made of the following eleven factors.

Geohydrologic Feasibility	Cost Sharing
Engineering Feasibility	Federal Cost versus Total Cost
Cost Estimate	Legal and Institutional Issues
Legal Access	Environmental Issues
Monitoring	Uniqueness
Rehabilitation Plan	

The total evaluation process proved to be iterative in that, in some cases, during the detailed evaluations, additional information was developed indicating serious environmental problems, lack of priority established by the governor, or absence of a declining water table.

RECOMMENDED PLAN

After each project had been technically scored and evaluated, an overall plan was developed. In selecting projects to be included in the final recommended plan, four overall objectives were considered.

-Technical Merit

-Environmental Clearance Requirements

-Requirements of the Act (Public Law 98-434)

-Cost Ceiling Constraints

The process for selecting projects for Phase II considered both quantitative and qualitative or judgmental factors. The four overall objectives had to be balanced and traded off where all four objectives could not be achieved simultaneously. Often constraints imposed by one objective had a very limiting effect on the proposals that would be otherwise selected based on other objectives.

Technical Merit. Technical merit was measured objectively by the overall technical score achieved by each proposal based on Reclamation regional evaluations. Proposals were selected on the basis of technical score, unless constrained by other considerations that could not be included in the eleven technical evaluation factors.

These other considerations included:

-Responsiveness to the intent of the act to recharge aquifers. Even though all proposals passed the screening criteria requiring the existence of a declining water table, some proposals were in areas where the declining water table was very localized, or even seasonal. These proposals dealt with conjunctive use where water was being used more efficiently, allowing for seasonal storage. These proposals, while very meritorious from the standpoint of conserving and managing water more efficiently, are not located in long-term regional declining water table situations.

-Balance in types or recharge projects. Another technical consideration was the goal of promoting the opportunity to develop unique recharge situations and obtaining a balance in the types of recharge technology being tested. Examples of recharge technologies included in the proposals were deep-well injection, in-channel methods, spreading basins and land treatment.

-Uniqueness. Testing diverse and varied recharge technologies was a purpose specified in the act. In making the final selections, a judgment was made on whether to place certain proposals in the recommended plan to achieve a balance in technologies in the program that could not be measured by simply taking the highest score.

Environmental Clearance Requirements. Only proposals for which all environmental compliance requirements are or can reasonably be expected to be achieved are included in the recommended plan. This includes completing requirements of appropriate compliance under the National Environmental Policy Act (NEPA), Fish and Wildlife Coordination Act, Endangered Species Act, Clean Water Act, Safe Drinking Water Act, and National Historic Preservation Act.

Requirements of the Act (Public Law 98-434). The act requires a minimum of twelve projects to be selected in the eight High Plains states and a minimum of nine in the remaining Reclamation Act states. Although not specifically stated, the inference is that the recharge demonstration projects are to be apportioned in a geographically diverse manner among the states.

The act also requires Reclamation to contract with the states to conduct a study to identify and evaluate alternative means by which the costs of ground water recharge projects could be allocated among the beneficiaries of the projects within the respective states and identify and evaluate the economic feasibility of and the legal authority for utilizing ground water recharge in water resources development projects. This program will be carried out in Phase II.

Cost Ceiling Constraints. The act authorizes $20,000,000 at October 1983 prices for Phase II demonstration projects. Adjusted for inflation, this would permit expenditures of $21,125,000 at September 1986 price levels, the date when the proposals were submitted.

In formulating the recommended plan, the authorization ceiling of $21,125,000 (September 1986 prices) was considered a constraint. However, this authorized cost ceiling was not considered a target. Rather, the overriding objective was to meet the goal of selecting a minimum of 21 demonstration projects which were the most technically sound, environmentally safe, and which would contribute the most to new and innovative ground water recharge technology.

The range in costs for the 41 proposals received varied from $80,000 to $3,263,000 (federal project costs). Thus, even though some proposals were very highly rated, the cost of their inclusion could preclude a number of other desirable projects. It was not feasible to quantitatively trade off the specific technical merits of one large proposal versus a number of smaller proposals. Therefore, judgment was used in making the selections by considering the objectives of attaining a balance between recharge techniques, and institutional, geographic, hydrogeologic, and climatic settings.

In the final selection process, only those projects that could be fully certified as environmentally sound at the time of the final Phase I report were selected. This meant that some projects that might significantly contribute to ground water recharge information had to be dropped from consideration. In some cases, those projects have a high probability of eventually meeting environmental compliance requirements. However, due to the complexity of the environmental issues and the time required for environmental compliance, they are precluded from consideration for selection. If recommended projects drop out due to lack of sponsor support or for unforeseen technical or institutional problems, sponsors of the other proposed projects will be contacted about their interest in being reconsidered.

The recommended plan, displayed in Table 1, includes 21 projects in 15 states: 12 projects in the High Plains states and nine projects in the other western states. The location of the recommended projects are shown in Figure 2. Federal costs would be $18,520,400 including costs for the economic study and program coordination. This is below the authorized program cost ceiling (indexed) of $21,125,000. The difference between proposed program costs and authorized ceiling provides for contingencies to allow for future cost escalation or other changes in program costs.

Two states do not have projects in the recommended plan. North Dakota did not submit any proposals. Wyoming, a High Plains state, submitted one proposal; however, the proposal was rated technically deficient on environmental, hydrological, legal, and institutional factors.

Table 1
Recommended Plan

Proposal	Priority State	Priority Regional	Environ. Category	USGS Rating	% Cost Share	Total Project Cost $1000
High Plains States						
Colorado						
Plains-Arikaree	1	3 of 11	4	1.0	20.0	196
Frenchman	2	7 of 11	4	.1	57.0	186
Denver Basin Aquifer	4	2 of 11	4	1.0	53.1	2283
Kansas						
Smoky Hill	1	1 of 11	2	1.0	20.0	890
Equus Beds	1	3 of 7	3	1.0	33.0	3583
Big Bend	2	2 of 7	4	1.0	20.0	133
Nebraska						
York	1	4 of 11	2	.95	20.0	1169
Adams County	2	6 of 11	3	.6	20.0	645
New Mexico						
Alamogordo	1	4 of 7	4	.8	20.0	582
Oklahoma						
Blaine Gypsum	1	6 of 7	3	.4	20.0	896
South Dakota						
Huron	1	9 of 11	3	.4	20.0	1132
Texas						
Hueco Bolson	2	1 of 7	4	1.0	30.4	412
Other Western States						
Arizona						
Rillito Creek	1	2 of 6	3	.5	46.4	2726
California						
Arcade	1	2 of 7	4	.9	20.0	399
Stockton	2	5 of 7	3	.8	20.0	1055
Idaho						
Southwest Irrig. Dist.	1	6 of 7	3	.9	20.0	3028
Montana						
Turner-Hogeland	1	5 of 11	4	.3	20.0	795
Nevada						
Washoe County	1	1 of 6	2	.9	20.0	945
Oregon						
Hermiston	2	3 of 7	4	.75	20.0	952
Utah						
SE Salt Lake County	2	1 of 3	4	.9	56.3	3336
Washington						
Highline Well Field	1	1 of 7	4	.7	20.0	812

Figure 2. High Plains States Groundwater Demonstration Program
Location of Recommended Phase II Recharge Demonstration Sites

CITY OF EL PASO GROUND WATER RECHARGE PROJECT

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INTRODUCTION

In 1986, an average of 4.4 million gallons per day (MGD) of the city of El Paso's wastewater was converted to a potable water resource. This has been made possible by the successful implementation of El Paso's Hueco Bolson Recharge Project, now into its third year of operation. City officials hope to learn more about the benefits of recycling in the coming months and to share this information with others interested in implementing water recharge projects.

The Hueco Bolson Recharge Project began operation in El Paso in May 1985. This project uses the Fred Hervey Water Reclamation Plant to treat wastewater effluent for recharge into the Hueco Bolson aquifer. Experience to date shows that the treatment process used is reliable and can indeed produce a high quality of "product water."

The Hueco Bolson aquifer currently supplies about 65% of El Paso's total water demand of about 100 MGD. Approximately 10% of the city's water supply comes from the Rio Grande and the remaining 25% from ground water sources northwest of El Paso.

Water from the Hueco Bolson is being consumed 20 times faster than its natural rate of recharge. These consumption rates are causing a drop in the water table of between two and six feet per year, depending upon the location in the aquifer.

The Hueco Bolson Recharge Project is viewed as a significant step by the city of El Paso and the city's Public Service Board to use water recycling as a means to guarantee city residents an adequate supply of water for future use. When ultimate design flows are achieved, the project will provide a perpetual water supply for over 50,000 people.

At the time the idea for the Hueco Bolson project was first being evaluated, recycled wastewater was viewed as the least costly large volume supply available to El Paso over the long-term. For this reason, the decision was made to build the Fred Hervey Plant and to use its treated effluent to recharge the dwindling resources of the Hueco Bolson.

PROJECT DESCRIPTION

The project consists of a ten MGD advanced wastewater treatment plant, a pipeline system through the Hueco Bolson and ten injection wells. Wastewater collected in the northeast area of the city is pumped to the treatment plant and subsequently to the injection system. The system layout is shown in Figure 1. The water is injected directly into the fresh water of the Hueco Bolson between existing production wells. A west to east cross section of the bolson is shown in Figure 2.

No special treatment of water produced from the bolson after recharge is planned. As with other water produced from wells, chlorination will be provided prior to the water being released into the city's distribution system.

The Fred Hervey Plant uses technology originally developed to treat industrial wastewater to produce a water meeting drinking water standards. The discharge permit from the Texas Water Commission requires the monitoring of twenty-three parameters, with 30-day average values used on most of these parameters.

Two parallel 5 MGD treatment trains with a 20-step treatment process are used to achieve the required treatment level. Main process units include screening, degritting, primary clarification, flow equalization, two-stage PACT™ treatment, lime treatment, two-stage recarbonation, sand filtration, ozonation, granular activated carbon (GAC) filtration, chlorination and storage as shown in Figure 3.

PROJECT PERFORMANCE

The raw wastewater is processed through convention grit and primary solids removal systems. The primary effluent flow, about 6.6. MGD, is more than can be processed through the aeration system at the present time. Because of this limitation, the PACT system is fed a constant 4.3 MGD. The balance is collected in oxidation ponds and will be held until process modifications are made to the aeration system enabling the plant to process 10 MGD.

The overall performance of the treatment plant is summarized on Table 1. The performance of the process unit is discussed in following paragraphs.

1. <u>Secondary System - PACT</u>

Organic removal across the PACT system is monitored by analyzing for biological oxygen demand (BOD), total organic carbon (TOC), and chemical oxygen demand (COD). Primary effluent, first and second stage PACT effluent BODS

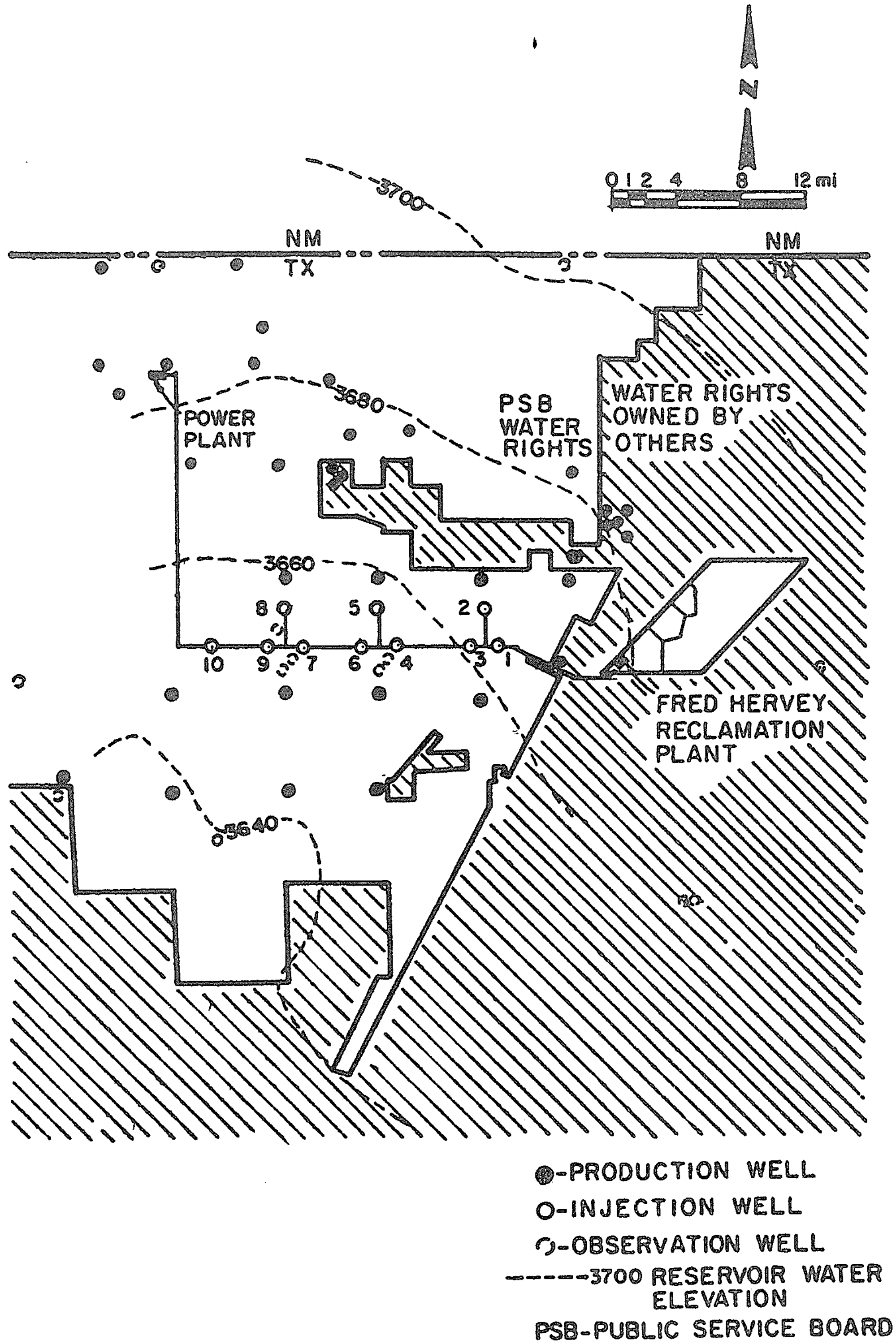

Figure 1. System Layout

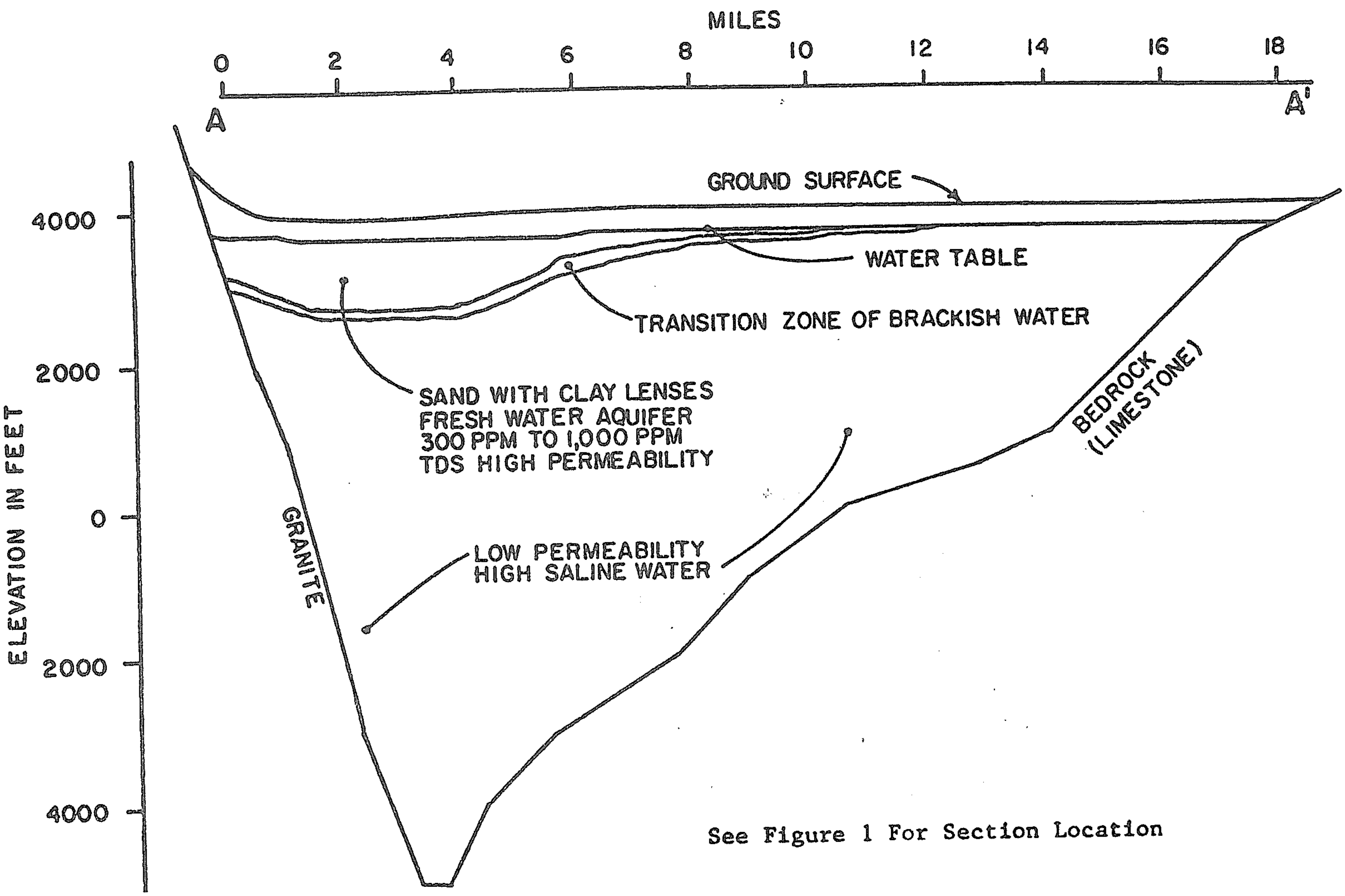

Figure 2. Ground Water Occurrence, Mesa Area of Hueco Bolson

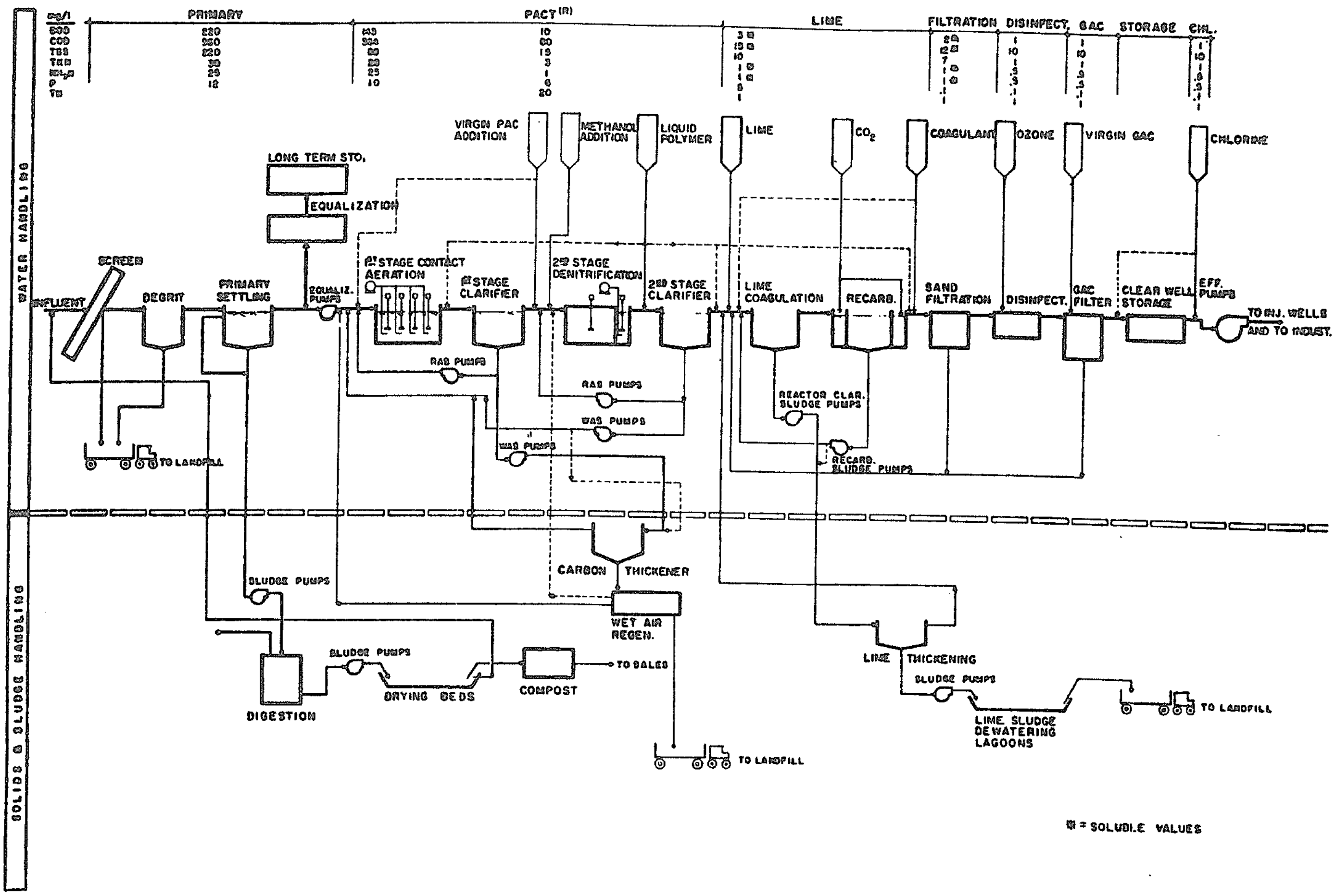

Figure 3. Process Design

Table 1

1986
AVERAGE OPERATING VALUES

Constituent	Influent Concentration	Product Water Concentration
BOD mg/l	165	
NH_3-N mg/l		0.18
NO_3-N mg/l		1.59
COD mg/l	254	24.4
TOC mg/l	27.0*	0.80
TSS mg/l	127.83	
TDS mg/l		611.83
Turbidity NTU		.21
PO_4-P mg/l		0.6
Chloride		200.67
Sulfate		88.67
Total Coliform colonies/100ml		0

*settled value

Table 2

1986 EL PASO TOTAL NITROGEN DATA ($TKN + NO_3$)

	Primary Effluent mg/l	First Stage Effluent mg/l	Second Stage Effluent mg/l	Overall % Removal
Jan.	29.6	19.7	3.5	88.2
Febr.	30.3	22.7	3.6	88.1
Mar.	31.7	16.5	1.2	96.2
April	27.8	8.8	1.0	96.4
May	27.3	5.6	0.6	97.8
June	25.2	6.3	1.0	96.0
July	22.3	7.0	1.3	94.2
Aug.	17.7	14.7	2.6	85.3
Sept.	19.4	16.2	4.3	77.8
Oct.	20.8	15.7	1.7	91.8
Nov.	24.7	11.3	3.8	84.6
	25.2	13.1	2.2	90.5

averaged 85 mg/l, 3 mg/l and 1 mg/l for 1986, respectively. Overall removal of BOD is greater than 98%. BOD removal was stable throughout the year, without exception.

Average TOC concentrations through the PACT system as above were 29 mg/l, 2.9 mg/l, and 2.4 mg/l, respectively. Overall removal was greater than 90%. Soluble COD is also monitored. Yearly average values were 155 mg/l, 36 mg/l, and 31 mg/l for the sample points mentioned above.

Nitrogen removal across the PACT system was very stable throughout the year. Total Kjeldahl Nitrogen (TKN) removal in the first stage ran 96%. The primary, first, and second stages averaged 25.4 mg/l, 1.0 mg/l and 0.6 mg/l, respectively.

Ammonia nitrogen removals mirrored this performance with primary, first and second stage concentrations of 20.4 mg\l, 0.4 mg/l, and 0.2 mg/l, respectively, for a 99% overall removal.

Nitrate removal overall was relatively stable across the process as a whole. The first stage nitrate concentration ranged from 22 mg/l to 5 mg/l. The yearly average was 11.6 mg/l. The second stage nitrate averaged 1.6 mg/l. Table 2 shows the total nitrogen removal across the PACT system.

Methanol is added to the denitrification (second) stage as a carbon source. Because of sensing control problems in the NO_3-MeOH loop, methanol is fed manually. As a result, methanol is generally overfed. Even though this occurs, based on total nitrogen removed across the PACT system, methanol consumption is 2.1 lb per pound of nitrogen removed.

The plant staff is satisfied with the performance of nitrification-denitrification aspects of the PACT system citing much greater stability than has been their experience with other nitrification processes.

2. Secondary Solids Processing - Wet Air Regeneration

Solids wasted from the PACT system to control solids residence time are processed through a wet air regeneration unit as shown in Figure 4. The unit regenerates the spent powdered carbon for reuse in the PACT process. In addition to carbon regeneration, the process destroys the spent sludges' biomass and oxidizes about 85% of all organics submitted to it. Because of conditions maintained therein, the balance of the organics exit the process in the form of low molecular weight oxygenated organics, mainly acetic acid.

Proper operation of the wet air regeneration unit requires an adequate temperature (greater than 440 °F to drive the reaction to proper completion),

WET AIR OXIDATION FLOW SCHEME

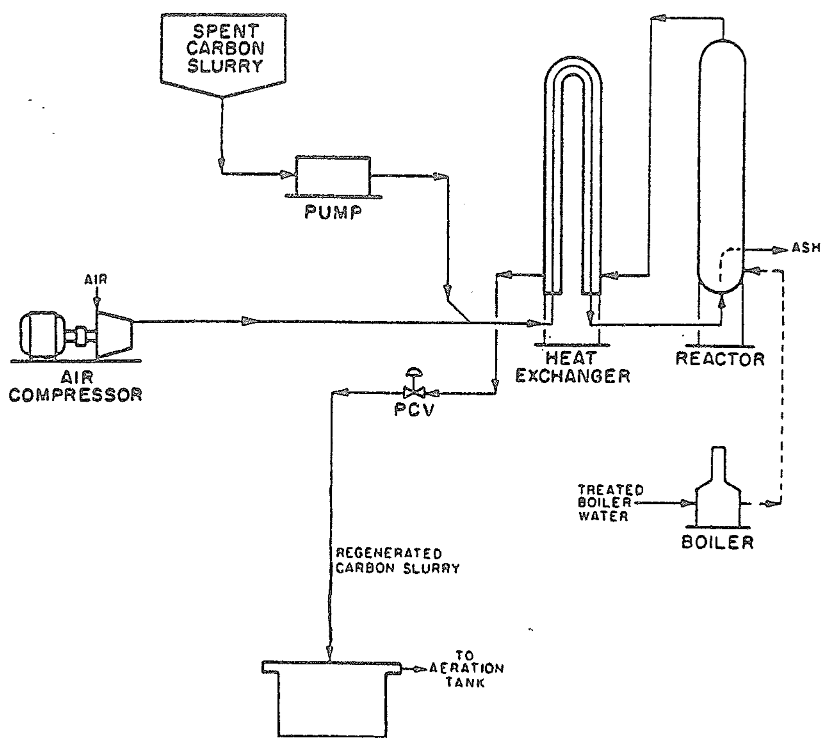

Figure 4.

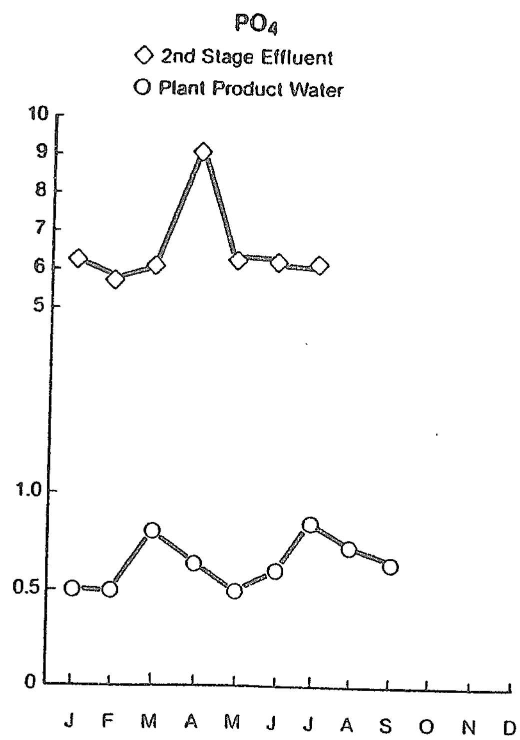

Figure 5.

adequate pressure (greater than 700 psig to control evaporation of water), and adequate residual oxygen in the off-gas (2-3% to assure a minimum recycle of COD to the PACT system).

The wet air regeneration unit allows some flexibility in the feed solids composition the unit can process. For instance, solids to regeneration have ranged from 5.7% to 12.4%. As long as the unit's residual O_2 content is sufficient, the slurry feed rate can be matched to the air compressor rate.

The percent oxidation achieved by the regeneration unit averaged 81%, within an acceptable range for the PACT/wet air regeneration systems.

There have been some problems associated with the regeneration system. Process air is supplied by one of two large reciprocating air compressors. Initially, both compressors suffered from lubrication problems which ultimately lead to the rebuilding of various stages of the machine. The supplier and manufacturer worked together to locate the cause of the problems and to resolve it.

Another problem has been heat exchanger scaling. In wet air regeneration, scales are removed by recirculating a solution of dilute nitric acid, HNO_3.

3. Lime - Recarbonation

The lime treatment step is used for removing phosphorus, heavy metals and killing virus. Lime is added for pH control to pH 11.1. Average lime dose for 1986 was 265 mg/l as CaO. Phosphorus removal is shown in Figure 5. Metals have not been a problem in the plant product water.

Virus analyses have been run on plant product water annually and no virus have been detected. Additionally, virus analyses were run on internal plant streams with no virus detected except in the primary clarifier effluent.

The lime reactor and first stage recarbonation tank require descaling about every four months. This is not considered unusual for such a process.

The recarbonation process drops the pH to 7.5 in two stages, by dissolving carbon dioxide in the water. Chemical consumption for the lime processes are about as anticipated.

4. Sand Filtration

Sand filtration is done with traveling bridge type sand filters. Effluent turbidity has averaged 1.05 NTU during 1986. During the summer, an algae film develops on the surface of the water above the sand. It poses only an appearance problem and does not affect performance. The algae film is skimmed off manually about once per week.

5. Ozone Disinfection

Disinfection is provided by one of two ozone units. Operation has been very good with no coliform detected in the effluent. Ozone dose has averaged 1.75 mg/l in 1986. Control of the dose is based upon contactor efficiency rather than ozone residual. High pH to the contactor has resulted in loss of ozone residual due to the conversion of ozone to the OH radical. Disinfection capability remains high during this situation but control on residual is not feasible.

Pitting corrosion of the cooling water jackets was experienced and was apparently due to chloride pitting of the 304 stainless steel. The problem was resolved by installing a closed loop cooling system for the ozone units.

6. Granular Carbon Filter (GAC)

The granular carbon filter was installed to provide a final polishing removal or organic compounds. The 1986 average loading to the GAC filter was 1.84 mg/l TOC with only four occasions exceeding 5 mg/l. The average loading for 1986 was 0.00023 pounds of TOC per pound of carbon. No granular activated carbon has been regenerated or replaced.

Since adsorption on activated carbon (Calgon Filtersorb 300) is an equilibrium process, the carbon bed acts very much as a peak leveler. Adsorption occurs when either high feed organic concentrations or very low levels of adsorbed materials on the carbon are encountered. When the feed organics drop off or the carbon bed becomes saturated, organics desorb according to the equilibrium of the process. Table 3 shows this phenomenon occurring where the influent Trihalomethane Formation Potential (THMFP) in nanomoles is sometimes less than the effluent value. This nanomole value can be multiplied by 20% to approximate the concentration in micrograms per liter. Initial indications demonstrate that reduced regeneration of PACT carbon caused the higher influent THMFP values in late 1985. For the dates sampled, several show negative removals, but during these periods product water remained within standards. Plant personnel are currently concerned that the procedure used to determine THMFP may not be accurately representing the influent THMFP concentrations. Other methods of analysis are being considered.

7. Injection Wells

There are ten injection wells in the project. The water bearing strata is a fine grained alluvium under water table conditions. Each well is approximately 800 feet deep and is completed about 450 feet into the water table. Normal static water

Table 3

EL PASO GAC FILTER THMFP

Month	GAC Inf. (Nanomole)	GAC Eff.	Removal Eff.
Oct.85	76	41	35
Nov.85	26	19	7
Dec.85	3	15	-12
Jan.86	1	5	-4
Mar.86	1	7	-6
Jan.87	7	12	-5
Mar.87	0	0	
May 87	3	14	-11

Table 4

1986 COST BREAKDOWN

	$/1000 gal.	%
Labor	0.49	32
Power	0.51	33
Chemicals	0.28	18
Maintenance	0.12	8
Miscellaneous	0.13	9

Table 5

CHEMICAL COST, 1986

Chemical	Cost, $/1000 gal.	%
CO_2	0.063	22
Lime	0.083	30
HNO_3	0.012	4
Methanol	0.035	13
Powdered Carbon	0.016	5
Granular Carbon	0.000	0
Polymer	0.015	5
Miscellaneous	0.055	20
TOTAL	0.280	

levels are about 350 feet below the surface. A 16" casing is used and is perforated (wire wrap screen) from the water table to total depth.

To date, all of the wells have been used for injection on a routine basis. Water is injected down a 3.5" tubing sized to dissipate the hydrostatic head and eliminate freefall into the well. It has been found that the wells will operate at an injection rate of between 500 and 800 gpm. Injection rates are held constant by a rate of flow controller. Hydrostatic buildup under injection conditions ranges from 100 feet to 150 feet initially and builds to approximately 250 feet before the well is backwashed with a pump installed in the well.

Backwashing procedures are initiated when the water table rises to within 100 feet of the surface. Each well is continuously monitored electronically with a downhole pressure transducer to indicate the water level in the well. Backwashing consists of pumping the well at a rate of 1000 gpm for several 30 minute periods so the well is surged. After the well blowndown clears up, usually after 3 or 4 cycles, the well is allowed to pump continuously for about two hours. This procedure is usually done every three months although the range is from two to four months. After backwashing, the hydrostatic buildup, after injection is resumed, will be about the same as it was initially. Figure 6 shows the buildup experience on recharge well number 1 during 1986 and shows the effect of backwashing.

There are six observation wells in use. These wells are clustered in groups of two around two of the injection wells and are located 300' and 700' downgradient from the injection well. Two more observation wells are each located 300 feet upgradient from different injection wells. These wells are monitored quarterly with fluid resistivity logs and samples are taken at points indicated by the logs.

To date, the only significant change in the water, based upon sampling results, has been an indication of trihalomethanes (THM) in the observation wells. The THMs have been detected at depths of 400 to 450 feet with the maximum value being 6.1 micrograms per liter. Dibromochloromethane and bromoform are the predominant forms detected. There have been no THMs detected in the produced water. The THMs could be formed as a result of the 0.1 milligram per liter free chlorine residual carried in the injected water and the organic material in the aquifer.

8. <u>Reliability</u>

Reliability has been high in that no "off spec" material has been injected based upon laboratory analysis of water in the holding basins. The treatment plant has the capability of "wasting" after most process units, thus an upset in one process will

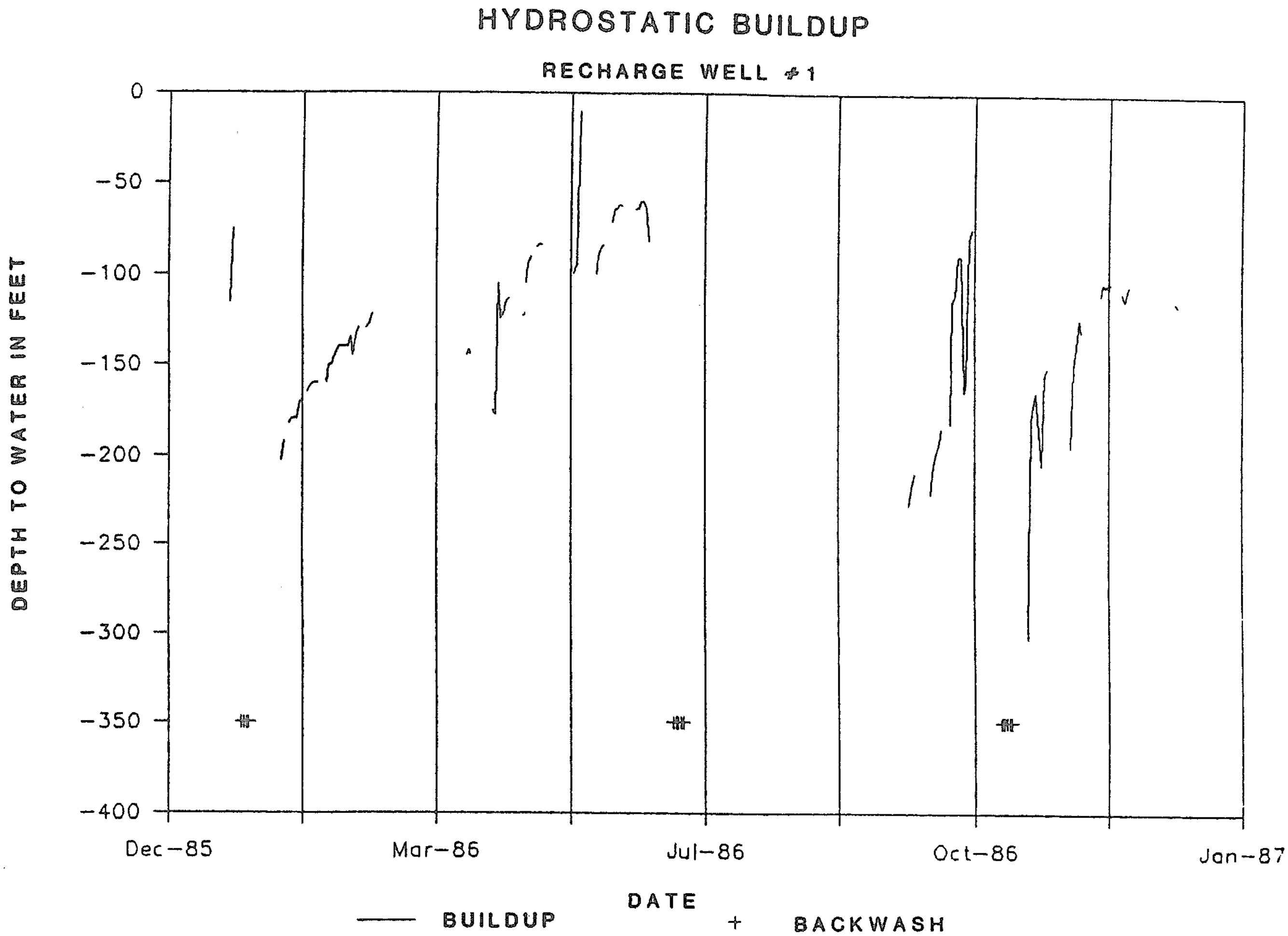

Figure 6. Hydrostatic Buildup
Recharge Well #1

not propagate through the plant. This system has been used on occasions where ammonia bleed through, loss of methanol feed or electrical problems were encountered.

9. Costs

Capital costs on the project were approximately $33 million for all costs including the plant, reclaimed water pipelines, and injection wells. The United States Environmental Protection Agency provided approximately $20 million toward the project.

In 1986, a total of 1.4 billion gallons of drinking quality water was returned to the Hueco Bolson reservoir by the Fred Hervey Water Reclamation Plant. The cost of this water was approximately $1.55/1000 gallons. Table 4 shows the breakdown of costs into major categories. Power and labor costs were nearly equal and made up a total of 65% of the overall costs. Chemical costs made up another 18%, with powdered carbon being only 5% of the chemical costs.

The chemical costs are broken down in Table 5. The major chemical costs are lime, carbon dioxide and methanol. The other major miscellaneous cost item was largely contributed by liquid oxygen fed to the force main to help reduce sulfides entering the plant.

No granular carbon was purchased in 1986. The product water never failed to meet the effluent organic requirement.

The operating costs have increased over the first two years of operation. During roughly the first five months of operation, the costs were reported to be $1.00/1000 gallons. The records show that the second half of 1985 ran at $1.17/1000 gallons and 1986 ran at $1.55/1000 gallons.

The major areas of cost increases have been power, chemicals and maintenance. Chemicals, alone, rose $ .10/1000 gallons. Another $ .045/1000 gallons is attributed to miscellaneous, with most of the remainder associated with power.

It is reasonable to expect some increase in maintenance costs. Equipment warranties will expire and the costs will shift from the supplier to the owner.

10. Conclusion

Since the Fred Hervey Water Reclamation Plant was placed in service in 1985, the facility has consistently met priority established aquifer recharge goals. The amounts of water recycled to the potable water system to date are felt to be minor based upon injected volumes and the displacement volumes involved in traveling to the production wells.

This project has many unique features and much is being learned about treatment of waters for reuse and recharge. El Paso Water Utilities has submitted a request for funding from the U.S. Bureau of Reclamation under the High Plains States Groundwater Recharge Demonstration Program to support additional study of operational data on the Hueco Bolson Recharge Project. Data from this proposed project could be helpful to other municipalities that now have or are planning advanced wastewater treatment facilities capable of producing high quality effluent which may be used to replenish diminishing local ground water supplies.

ALBUQUERQUE'S WATER RESOURCES MANAGEMENT PLAN

William H. Otto, Assistant Director
Public Works Department
City of Albuquerque

INTRODUCTION

The city of Albuquerque thanks the Water Resources Research Institute for its invitation to be on the conference agenda. The primary concern of the Water Resources Management Plan is to ensure an adequate water supply for the city of Albuquerque.

Albuquerque does not now have a Water Resources Management Plan; however, we have recently initiated a project to develop a plan. It is this project, the development of a comprehensive, long-range water resources management plan, that I will discuss with you today.

The city has over the years developed and implemented plans for its ground water supply and distribution of that supply. With a great deal of foresight, the city contracted for San Juan-Chama Diversion Project water. In accordance with a master plan, the water system has been expanded in an orderly and economical manner to meet the water supply needs of the city. The city believes it is now time to renew and expand its planning efforts to meet future water supply requirements. The source of supply is the key element in those planning efforts.

BACKGROUND

Before discussing the plan, I will provide some background information on Albuquerque's water supply system. Albuquerque's water utility has grown from its inception in 1885 to a water system that today has 121,000 service connections serving 438,000 people. One of Albuquerque's major assets is its abundant water resources. The city's supply is derived from an underground basin of water located along the Rio Grande. The water is currently withdrawn utilizing 81 wells which have a total production capacity of 240 million gallons per day. Our peak day of record was 185 million gallons which occurred this past summer. The total production for 1986 was 34 billion gallons.

We expect the water system will serve a population of 525,000 in ten years. By year 2025, we forecast that the system will serve 875,000 people, double today's service population. That growth, to year 2025 and beyond, can only occur with appropriate planning and development of the water supply source.

OBJECTIVES OF THE WATER RESOURCES MANAGEMENT PLAN

The primary objectives of the development of a long-range water resources plan are to (1) obtain a comprehensive geohydrological understanding of the ground water resource, (2) assess the potential for alternate sources of supply, (3) prepare a groundwater quality management program, (4) evaluate legal and institutional matters related to a water resources plan, (5) prepare a master plan for ground water well and surface water supply (if required), and (6) prepare a long range plan for the development and management of water resources for the city's water supply system.

These objectives are in response to Albuquerque's water supply mission, system planning, design and operational requirements, and existing problems. The city of Albuquerque has the responsibility for supplying, in perpetuity, potable water to present and future customers. The city must ensure that an adequate supply of water will always exist and that the city has a legal right to use the water. Albuquerque is obligated to deliver water meeting Safe Drinking Water Act standards and to provide an adequate, reliable and economical supply.

To fulfill this mission, the city must have the knowledge and tools to plan, design, operate, and maintain the water supply system. Implementation and enforcement of regulations to prevent degradation of its ground water source must be pursued. In addition, we need to develop policy and a plan of action to acquire and develop our water resources.

A greater understanding of aquifer characteristics is necessary to prepare a long-range well location and production plan, develop optimal well design and construction criteria, and for evaluation of well problems. We must develop ongoing monitoring and analysis programs to appraise the withdrawal of ground water and its effect on the resource, and learn the variations in factors that influence the quantity and quality of the water resource. Ground water models must be refined to predict more accurately the consequences of ground water withdrawal strategies.

Pollution of the ground water supply is a major concern. The effects of contamination have been widely reported in the local news media. Health risks and economic consequences of inaction must be assessed. The city needs to develop a ground water quality management plan for the prevention and mitigation of ground water degradation.

The need for the Water Resources Management Plan can be emphasized by the following questions.

1. What is the sustained yield of the ground water system? What share of that yield is available to the city?
2. What is the quality of the ground water areally and at depth? Will saline water intrusion or subsidence occur as a result of long-term withdrawals of the ground water?
3. What is the extent, type and location of existing contamination of the ground water system, and what effects will that contamination have on existing and future ground water withdrawal strategies?
4. Besides ground water, what alternative water resources are available for city use?

These few basic questions and lack of answers thereto, typify our current limitations in carrying out long-range water supply system planning. An abundant amount of water resources information has been produced to date, and voluminous data are available. However, that information has not been assimilated and utilized for the purpose of developing a water supply plan. It is now necessary to collect, interpret, and evaluate that data. This will provide additional information essential to formulating a comprehensive technical understanding of the resources and development of appropriate planning strategies.

WATER PLAN

The city has created a preliminary work plan for development of a comprehensive Water Resources Management Plan. The approach involves at least a dozen overlapping work elements, as follows:

1. Management objectives
2. Population and demand forecasts
3. Ground water use
4. Alternate sources of water
5. Geology
6. Hydrology
7. Pollution
8. Monitoring
9. Data management

10. Model development and calibration
11. Legal and institutional constraints
12. Applied research

Management Objectives

The project objectives previously outlined are also the principal management objectives. Upon initiation of the project, the project team will evaluate the city's established goals and objectives and will develop detailed plan objectives. Subsequently, a final work plan which includes methodology and scheduling will be formulated.

Population and Demand Forecasts

The objective is to develop reliable estimates of future service populations, their location, and water use requirements. Once water resource availability is determined, it will be necessary to develop policies related to the ultimate service population, service area, bulk sales, and region issues.

Initially, forecast horizons will be selected and demand scenarios prepared for those horizons. Those scenarios will be used to test the ground water system's yield capabilities and for comparison with overall feasible resources.

If preliminary examinations of feasible water resource availability show probable resource limitations, more detailed population and demand studies will be performed. This data will be used for precision modeling, conceptual system configuration, and other phases of work.

Ground Water Use

This element will involve various studies and evaluations to predict the longevity of the ground water resource and to establish criteria and strategies for production of ground water to ensure a sustained supply without negative impacts. The U.S. Geological Survey has developed a three-dimensional model of transient ground water flow for the Albuquerque-Belen basin. The city will use the model, with some modifications, to perform preliminary simulation studies. Also, a next-generation model will be developed for more accurate yield predictions and study of well and well field withdrawal strategies.

Alternate Sources of Water

The objective is to determine feasible sources of water supply other than local Rio Grande basin ground water. Heretofore, Albuquerque has relied entirely on the ground water beneath the city for its water supply. Pollution, water-rights issues, and the possibility that future demand may exceed the amount of water we may safely take from the ground create a need for an understanding of the location, amount, and cost of water that the city might obtain from other sources.

Alternate sources of water that may be investigated include (1) Rio Grande basin surface water, (2) other basin surface water, (3) ground water from other nearby basins, (4) other imported water, (5) storm runoff, (6) sewage effluent, and (7) conservation.

Geology

The objective is to define the water-bearing and water-yielding properties of the rocks of the Albuquerque basin and the larger Rio Grande drainage basin that impact upon Albuquerque's immediate and potential water resource. Specific objectives include:

1. Definition of the Albuquerque basin in three dimensions;
2. Preparation of a detailed geologic map of the Albuquerque basin;
3. Preparation of maps that show the physical and chemical properties of the rocks that control water behavior both on the surface and in the ground;
4. Creation of a data management program that will allow the city to update maps easily, build numerical models of water-resource systems, and predict the character of the rocks that new wells will tap, and thereby determine their design and yield; and,
5. Characterization of the features of the Rio Grande drainage basin that may have a direct effect on Albuquerque's water supply.

To carry out these activities, the city will make use of existing data as well as gather new data. Ideas concerning the stratigraphic sequence from a variety of sources will be integrated into one fixed, but flexible, conceptual model of the Albuquerque basin and its location on the Rio Grande drainage basin.

Hydrology

The objectives of this element are to (1) quantify the hydrologic cycle as it applies to the Rio Grande drainage basin and the Albuquerque basin, and (2) characterize processes that operate in the basins. Specific objectives include:

1. Quantification of the surface water resources of the major drainage basins tributary to the Rio Grande, and of the Rio Grande drainage basin above San Acacia;
2. Characterization of the movement of ground water from recharge to discharge areas under pristine conditions and present pumping conditions;
3. Identification of recharge areas and rates, and the volume of water that each contributes;
4. Definition of the interrelationships among the flow of the Rio Grande, diversions from the Rio Grande, the drains, and the ground water resources;

5. Quantification of ground water discharge to streams, evapotranspiration, and wells;

6. Quantification of ground water underflow;

7. Quantification of the amount of water that can be pumped from wells;

8. Investigation of:

   A. the shape of the water table and the distribution of head,

   B. the seasonal and annual variation of the water table and of head,

   C. the hydrologic features of each stratigraphic unit,

   D. soil-moisture distribution and variation in the vadose zone,

   E. recharge areas and rates,

   F. stream flow and diversion,

   G. ground water discharge to streams, evapotranspiration, and wells, and

   H. the chemistry of water under pristine and present conditions; and,

9. Preparation of detailed hydrologic budgets.

When the city thoroughly understands the hydrologic budget of the Rio Grande drainage basin and its tributaries, and the ground water budget of the Albuquerque basin, it will know the ground water resources with which it has to work.

Pollution

The objective is to prevent pollution from diminishing the ground water resource. Specific objectives include:

1. Determination of present and potential sources of pollution (its sources, extent, and amount);

2. Cleanup of pollution before it can reach city wells;

3. Development of standards and procedures that will minimize pollution potential; and

4. Development of cleanup procedures for anticipated pollution problems.

Monitoring

The objective is to characterize changes in the water-resources system and the factors that influence it. A specific objective of the monitoring element is the development and implementation of an ongoing routine program to measure parameters that account for changes in the water resource.

Parameters the city expects to measure include:

1. Those associated with city wells such as depth to water, pumpage, and properties of the water pumped;

2. Land-use changes;

3. Stream flow and storm runoff;
4. Ground water levels in the Albuquerque Basin;
5. Climatic features such as precipitation, evapotranspiration, and air temperature;
6. Chemical constituents of surface and ground water; and
7. Soil-moisture variations.

Data Management Element

The objective is to create a data management system that will contain all data. Specific objectives include:

1. Creation of a universally available data catalog;
2. Establishment of a procedure for adding new data as it becomes available;
3. Automatic production of basic data reports; and
4. Development of automated procedures for detecting problems.

Model Development and Calibration

The objective is to develop calibrated numerical models. Specific objectives include the development of models to:

1. Emulate pristine conditions;
2. Generate present conditions; and
3. Predict the (a) consequences of changing the ground water system, (b) optimum yield of the system and of individual wells, (c) effects of pollution and of proposed remedial efforts, and (d) short-term behavior of a single well or group of wells in a well field.

Legal and Institutional Constraints

The objective is to make the city aware of and immediately responsive to legal or institutional factors that affect or might affect its capacity to deliver water. Specific objectives include:

1. Cataloging water rights in the Rio Grande basin;
2. Summarizing relevant principles in acts, statutes, court decisions, adjudications, and State Engineer findings and orders that relate to water rights;
3. Cataloging acts and statutes, rules and regulations, case histories, court decisions, and other relevant documents that apply to water resources use and pollution, and to summarize provisions that apply to operations of the city;
4. Developing a procedure to insure that the city will stay abreast of statutory and regulatory changes;
5. Establishing guidelines and procedures for city participation in the formulation of new legislation or rules and regulations;

6. Establishing the city's authority to preserve the water resource; and

7. Determining the city's position on resource management issues such as those created by the 1986 amendments to the Safe Drinking Water Act.

Applied Research

The applied research element consists of independent studies designed to solve specific city problems. Immediate problems include:

1. The feasibility of using San Juan-Chama water for artificial ground water recharge;

2. How to optimize well development and rehabilitation;

3. What standards and criteria to use in designing new wells; and

4. Consequences of iron bacteria in wells.

CONCLUSION

In conclusion, I will describe briefly the initial steps in the plan development. The city has appropriated $2.3 million toward the effort and is in the process of retaining a consulting firm for the project. We have entered into cooperative agreements with the U.S. Geological Survey to perform certain geo-hydrological tasks, and we anticipate additional cooperative arrangements.

The consultant contract work will begin about March 1988. The first project task will be for the consultant, in conjunction with the city, to prepare detailed project methodology, schedules, cost estimates and manpower allocations. An iterative, phased work plan is most probably in order.

In Phase I, as now envisioned, preliminary work will be performed as follows:

1. Evaluate the alluvial-aquifer system underlying the Albuquerque area to determine the sustainable yield of the underground basin;

2. Identify and assess potential alternate sources of supply, including Rio Grande Basin surface water, imported water, reclaimed wastewater, conservation measures, and other resources;

3. Evaluate the feasibility of artificial ground water recharge with San Juan-Chama Diversion Project water;

4. Develop a ground water quality management program; and

5. Compile and interpret existing information on the geological and hydrological characteristics of the ground water system.

It is anticipated that the Phase I work will be performed in an 18 month time period, and that the total project will require five years. Data collection and analysis will continue indefinitely in order to maintain a dynamic water resources management system.

The project is a major undertaking and is, at the least, of a regional nature. We will be reaching out to obtain expertise, on a contractual or advisory basis, from the State's water resources professional community; that is, we will enlist experts like yourselves.

Thank you for the opportunity to describe the city of Albuquerque's Water Resources Management Plan project. We are excited about this effort and the opportunity it presents to develop and maintain a water resources management system that maximizes use of the resource while minimizing harmful actions.

Thank you.

DESIGN AND MANAGEMENT OF INFILTRATION BASINS FOR ARTIFICIAL RECHARGE OF GROUND WATER [1]

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INTRODUCTION

With artificial recharge of ground water, surface water is infiltrated into the ground for storage in aquifers and eventual recovery from wells. Infiltration and flow to aquifers can be achieved with infiltration facilities on the surface (see Figure 1). Such systems require permeable surface soils to obtain adequate infiltration rates, vadose zones without clay or other flow-restricting layers that would inhibit the flow to the aquifer, and aquifers that are unconfined. Where these conditions do not exist, or where suitable land would be too expensive, artificial recharge of ground water can be achieved with wells.

Recharge Wells

Recharge or "injection" wells are similar in construction to pumped wells, using screened section(s), gravel packs (in unconsolidated aquifers), and grouting. Before injection, the water needs to be carefully treated to remove essentially all suspended materials. Even then, injection wells in unconsolidated aquifers eventually clog up at the interface between the well and aquifer. This requires periodic pumping and/or redevelopment (surging, jetting) of the well. Because of clogging, the specific capacity of wells for injection into unconsolidated aquifers is only about half the specific capacity for pumping. Injection wells in fractured-rock aquifers or in limestone with solution channels or other well-developed secondary porosity have injection rates that are closer to pumping rates. Water for injection wells should be applied through a relatively small pipe in the well that ends below the water level. This is to avoid free fall of the water in the well and resulting entrainment of air in the water. Dissolved air in the recharge water could cause problems of "air binding" in the aquifer as air goes out of solution and forms entrapped air in the aquifer if the recharge water is colder than the ground water. The entrapped air can significantly reduce the hydraulic conductivity of the aquifer around the well and, hence, the injection rate. Ground water recharge with injection wells usually is much more expensive than recharge with spreading or infiltration basins, often by an order of

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[1] Contribution from the Agricultural Research Service, U.S. Department of Agriculture

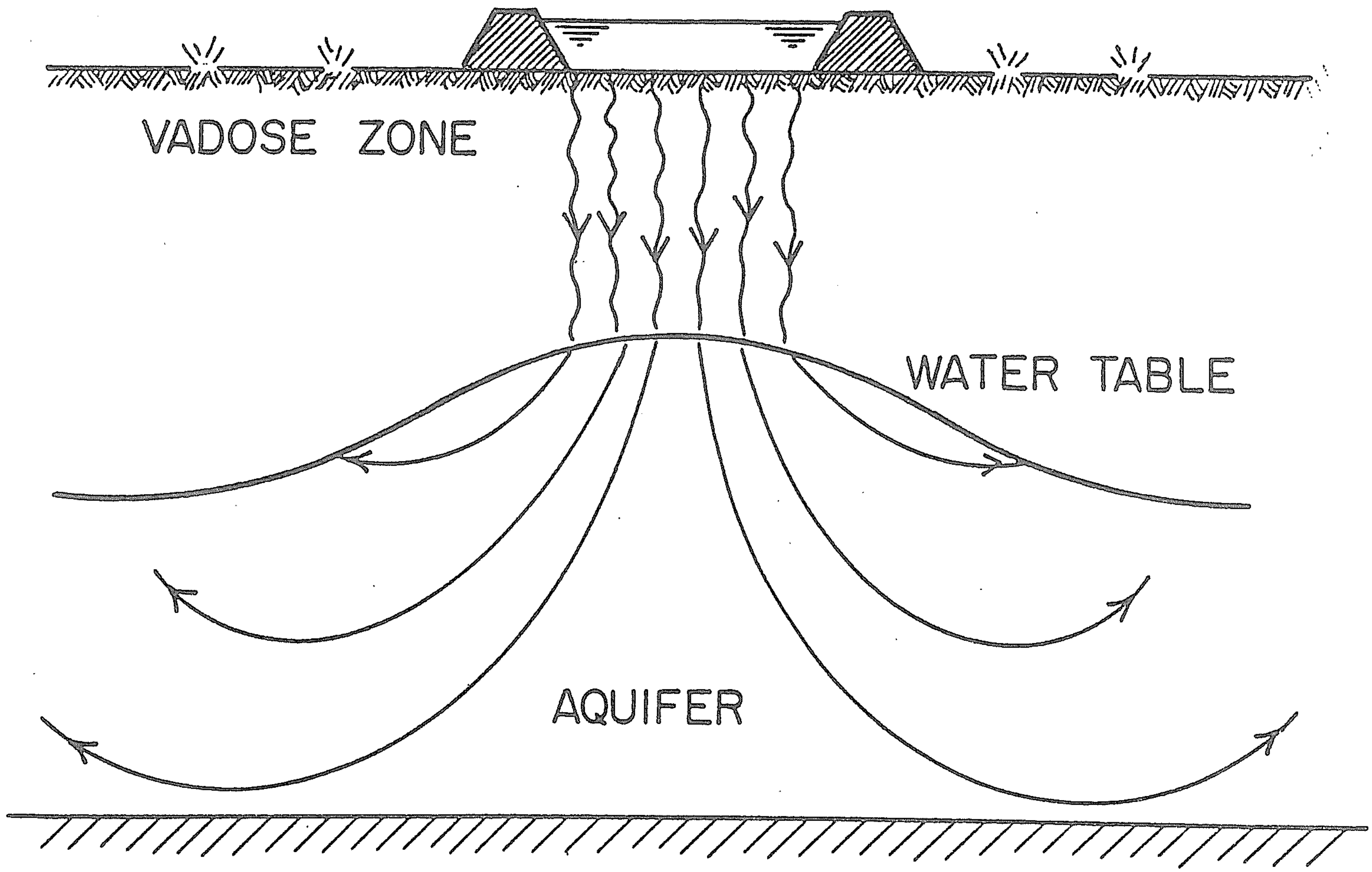

Figure 1. Schematic of ground water recharge system showing infiltration basin, vadose zone with wetted zone (wiggly lines), ground water mound, and flow lines in aquifer.

magnitude. Therefore, the rest of this paper will be devoted to design and management of infiltration systems for ground water recharge.

Infiltration Systems

Infiltration facilities for ground water recharge can be divided into in-channel and off-channel systems. In-channel systems consist of weirs, dams, and levees (T-dikes or L-dikes) to increase the wetted area and, hence, the infiltration in the stream bed or floodplain. Off-channel systems are basins in old gravel pits or specially constructed basins in areas of permeable soil. Design and management criteria to maximize the hydraulic capacity of infiltration basins depend on water quality, climate, and soil. Thus, these criteria are site-specific and they must often be evaluated by on-site experimentation. Factors to be studied are optimum schedules of flooding, drying, and cleaning of the basins; optimum pre-treatment of the water; optimum water depth; and optimum velocity of the water (basins with stagnant water versus channels with flowing water). There are also environmental factors to be considered (insects, algae, odors). Sources of water for artificial recharge of ground water include surplus water in streams and rivers (including possibly increased flow due to cloud seeding or water harvesting techniques), storm water runoff, surplus water in aqueducts or water transfer projects (California Aqueduct, Central Arizona Project), and sewage effluent or other wastewater. Some water sources are continuous and permit year-around operation of the infiltration basins. Others are seasonal or haphazard.

Basin Management

Infiltration rates in flooded basins decrease with time due to accumulation on the bottom of sediment that was suspended in the water. Biological activity in the water (growth of algal cells that form a filter cake on the bottom upon infiltration), and on the bottom (bacterial and algal activity) can also reduce infiltration through formation of clogging layers. Thus, the basins must be regularly dried and cleaned to restore infiltration rates. If the clogging material consists primarily of silt, clay, or other inorganic matter, it must be removed by scraping, raking, or other procedure that removes only the clogging material. Disking the clogging material into the subsoil gives temporary improvement, but ultimately the entire soil layer to the depth of disking may have to be removed because of accumulation of fine particles. If the clogging material is primarily organic (sludge, bacteria, algae), drying alone can give considerable recovery of infiltration rates due to the decomposition, shrinking, cracking, and curling-up of the material. Under those conditions, cleaning the basin bottoms may not be necessary for every drying period, but may be done only occasionally, like once or twice a year. The best combination of drying and cleaning schedules must be determined on-site, especially for projects in new areas where there is no local experience with management of infiltration basins.

Sometimes, flooding and drying cycles are controlled by life-cycles of insects. To avoid nuisance problems, flooding periods may have to be only a few days to prevent hatching of insect eggs and emergence of adult insects (for example, the midge flies in California).

Where the water for recharge basins contains considerable suspended material, it can be more economical to remove this material in pre-sedimentation basins with possible use of coagulants to enhance settling of the solids. However, this costs money. On the other hand, not removing suspended solids first and letting them all accumulate on the bottom of the infiltration basin costs money, too, in the form of frequent drying and cleaning of the basins. Thus, there is an optimum combination of pre-treatment and drying and cleaning of the basins. This economic optimum must be determined for each individual system where pre-sedimentation appears desirable.

Where surface water is available for artificial recharge of ground water during most of the year or the entire year, there may be an interest in using the infiltration basins also for recreational purposes. Such use places constraints on the management of the basins for maximum hydraulic loading. Regular drying and cleaning may then be more difficult. Pre-sedimentation may be desirable to minimize sediment accumulation on the bottoms of such basins.

A choice can be made between infiltration basins that have essentially stagnant water where even the finest suspended material can settle out, and infiltration channels where the water is kept moving to create enough turbulence to keep the fine material in suspension. On-site testing needs to be done to see which system is better and gives the highest infiltration rates. If the channel system with moving water is used, a few infiltration basins may have to be constructed at the end of the channels to catch any residual flow.

Effect of Water Depth

Intuitively, one would think that a large water depth in infiltration basins gives higher infiltration rates than a small water depth. This may not always be so, however. If the ground water table is above the bottom of the basin, as can happen if the basins are in old gravel pits or where ground water tables are high, then an increase in water depth could produce a significant increase in infiltration rate. If the ground water table is a considerable distance below the bottom of the basin, an increase in water depth will produce only a small increase in infiltration rate if the basin bottom and banks are clean (not covered by sediment or other clogging material). This can be demonstrated by applying Darcy's equation to the flow from the basin to the ground water. If, however, the wetted perimeter of the basin is covered by a well-developed clogging layer (organic or inorganic), the entire head due to water depth in the basin is dissipated across the clogging layer, and the infiltrated water moves as unsaturated flow to the underlying ground water. Applying Darcy's equation to the flow through the clogging layer then shows that for this case there is an almost linear relation between water depth in the basin and infiltration rates. In that case, for example, doubling the water depth would essentially double the infiltration rate. However, there are other effects that can negate this linear relation.

The first effect is compaction of the clogging layer due to an increase in the seepage force across this layer as the water depth and, consequently, the head loss across the clogging layer, are increased (see Figure 2). The compaction of the clogging layer produces a significant decrease in the hydraulic conductivity of this layer, causing a lower increase in infiltration rate than expected from the hydraulic head (water depth) increase alone, and perhaps even a decrease, depending on the type of clogging material.

The second effect is that if increasing the water depth does not produce a proportional increase in infiltration rate, the turnover rate of the water in the basin decreases, which could promote the growth of suspended, unicellular algae in the water due to longer exposure to sunlight. The algae will then be filtered out on the bottom as water infiltrates and form a filter cake on the clogging layer, which further reduces the hydraulic conductivity of this layer and, hence, the infiltration rate. This, in turn, reduces the turnover rate in the basin even more, increasing the exposure of suspended algae to sunlight which increases the growth of algae and further clogs the bottom layer with the algal filter cake, and so on.

The third effect is that at high algae concentrations, uptake of carbon dioxide from the water for photosynthesis by the algae becomes significant, causing the pH of the water in the basins to increase to values as high as 9 or 10. At these pH values, calcium carbonate will precipitate out and accumulate on the bottom, further aggravating the clogging process and reducing infiltration rates even more.

In view of these processes, shallow basins may actually produce higher infiltration rates than deep basins where the wetted perimeter of the basin is covered with a clogging layer. Since a number of factors govern the relation between water depth and infiltration rate, the water depth giving maximum infiltration rates must be evaluated by on-site experimentation. If deep basins are considered or changeovers from shallow basins to

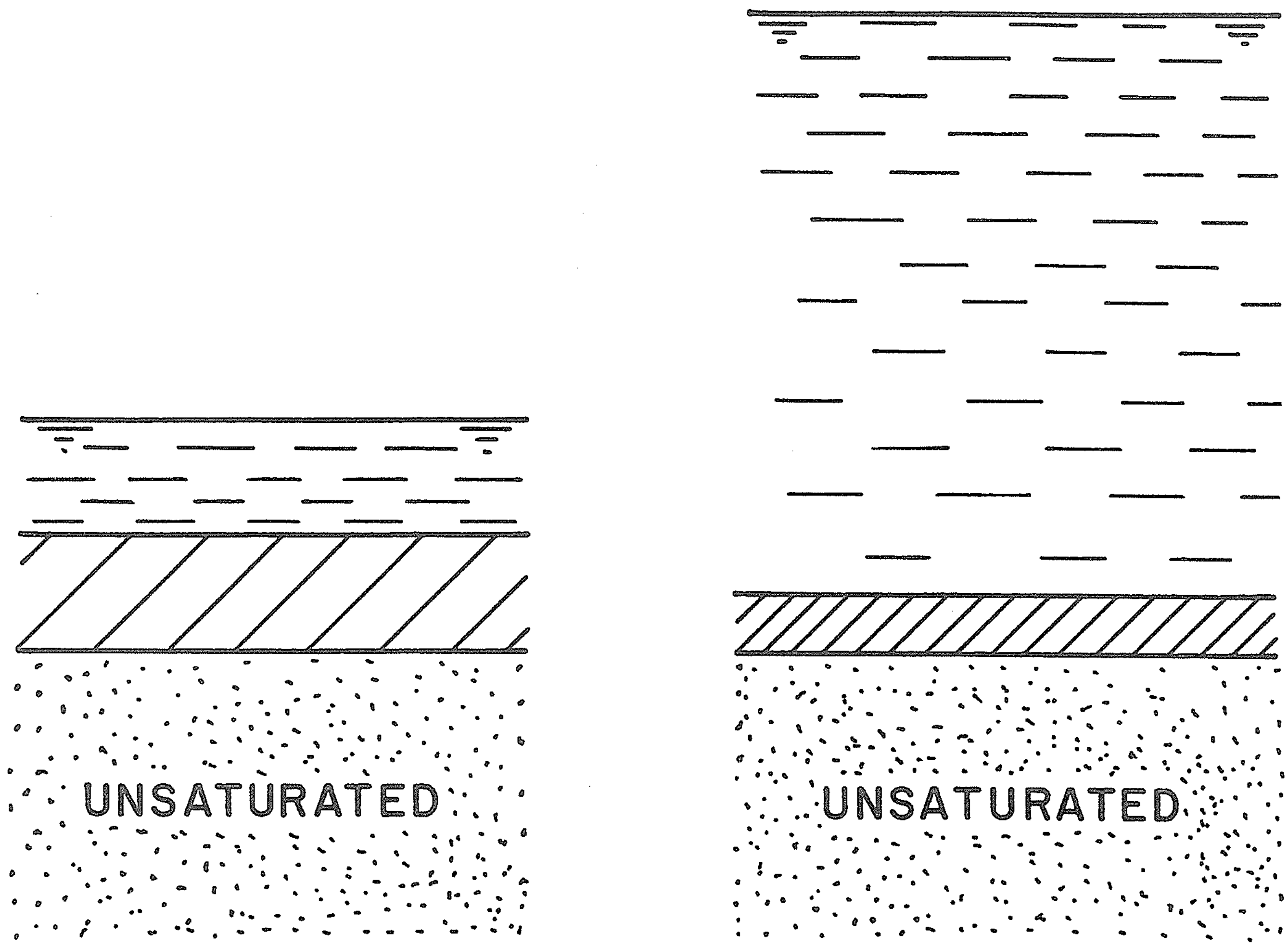

Figure 2. Compaction of clogging layer (hatched) by increasing water depth from small (left) to large (right).

deep basins are contemplated, the local conditions should be thoroughly investigated, and studies with test basins should be made to ensure that the deep basins will produce the desired results.

Site Selection and Hydraulic Loading Rates

Since infiltration basins for artificial recharge of ground water require permeable soils, identification of permeable soil profiles and site selection are extremely important. Small cylinder infiltrometers, double-ring (buffered) as well as single-ring systems, are useful for comparisons and measuring relative infiltration rates, but they overestimate the infiltration rates for larger inundations and cannot be used to predict hydraulic loading rates for infiltration basins (Bouwer, 1986). Such prediction is better achieved with larger test basins and by supplementing infiltration tests with measurements of soil hydraulic conductivity in the vadose zone. For unclogged basins and deep ground water tables, basin infiltration rates are approximately equal to the average resaturated hydraulic conductivity (harmonic mean, see Bouwer, 1978, pp. 56-60 and pp. 253-254) of the vadose zone or upper portion thereof. Thus, hydraulic conductivity measurements can give a good estimate of maximum hydraulic loading rates attainable with the basins.

Methods available for in situ measurement of resaturated hydraulic conductivity in the vadose zone include the air-entry permeameter, double-tube method, infiltration gradient technique, and reverse auger hole or well pump-in method (Bouwer, 1978, p. 123-130). Hydraulic conductivity of stony or gravelly materials can be estimated from the hydraulic conductivity of the soil between the gravel or boulders and the volume fraction of the rock or void ratios of the soil and rock matrix (Bouwer and Rice, 1984a).

Permeable soils typically have hydraulic conductivities in the range of 3 ft/day (fine loamy sands) to 30 ft/day and sometimes even higher (sands, and sand and gravel mixes). Because of clogging, infiltration rates of recharge basins tend to be less than the resaturated hydraulic conductivity of the underlying soil materials. Actual infiltration rates during flooding thus generally vary from about 1 ft/day to 10 ft/day. For year-around operations and including time for drying and cleaning the infiltration basins, hydraulic loading rates or accumulated infiltrations typically range from 100 to 1000 ft/yr.

Ground Water Mounds

When the infiltrated water joins the underlying unconfined aquifer, a ground water mound is formed (see Figure 1), and the recharge water moves mostly laterally through the aquifer to produce smaller ground water table rises further away. The rise of ground water mound during infiltration and the fall of the ground water mound during drying can be predicted with Hantush's equation (Bouwer, 1978, p. 283). This equation can also be used to calculate the effect of the infiltration system on ground water levels at various distances from the infiltration basins. If there are complicating factors in the aquifer system, such as a natural ground water table slope and other recharge or discharge mechanisms (losing streams, wells, springs, uptake of ground water by vegetation, etc.), the effect of artificial recharge on ground water levels can be estimated by modeling the aquifer system, using finite difference or finite element analysis techniques.

Aquifers should be sufficiently transmissive to keep ground water mounds below the bottom of infiltration basins if reductions in infiltration rates are to be avoided. A long, narrow infiltration basin or system of basins produces lower ground water mounds than square or round systems with the same area and hydraulic loading.

Water Quality

As the infiltrated water moves through the vadose zone and aquifer, some quality parameters may be improved, and some may be adversely affected. Constituents that are partly or almost completely removed from the water as it moves through the vadose zone and aquifer include suspended solids, bacteria, viruses, other microorganisms, biodegradable material (BOD), nitrate, and some synthetic organic compounds (particularly the non-halogenated hydrocarbons). Since the soils in ground water recharge systems normally are quite coarse and permeable, there is little or no clay, and ion exchange will be insignificant. Hence, the ionic composition of the water after it has moved through the vadose zone and aquifer generally will be about the same as that of the water entering the infiltration basins.

Adverse effects include mobilization of iron and manganese from the vadose zone and aquifer as oxygen levels are reduced, and leaching of trace elements (including selenium, arsenic, boron, cadmium, molybdenum, and mercury) from the vadose zone. Leaching of trace elements may be significant where soils are relatively fine and almost marginal for artificial recharge of ground water, and where the soils have not had a long history of infiltration. Such soils include basin and valley soils and marine deposits, i.e., the San Joaquin Valley in California where selenium is leached from the soil and appears in the drainage water from the irrigated fields. Alluvial fans, stream channels, and floodplains generally would not be expected to have problems of leaching of trace elements, but it should be checked to avoid unpleasant surprises later on.

There may also be concern for humic and fulvic acids and algal compounds and metabolites that may already be in the water before infiltration. These organics may not be completely removed in the vadose zone and aquifer. Since they react with chlorine to form trihalomethanes (THMs), special consideration may be required when the water is pumped from the aquifer and needs to be disinfected for drinking (Fam and Shenstrom, 1987). However, unpolluted, pristine ground water also contains organic carbon, mostly as fulvic or humic acids and typically at concentrations of about 0.2 to 0.7 mg/l (Thurman, 1979). Such water is commonly disinfected with chlorine when used for public water supplies, without giving much thought to the possibility of forming THMs.

From an operational standpoint, the most important quality parameters of the water going into infiltration basins are the total dissolved solids content (TDS) and the sodium adsorption ratio (SAR), calculated as $Na/[(Ca+Mg)/2]^{1/2}$ with the concentrations expressed in meq/l. TDS and SAR control whether clay in the soil is flocculated or dispersed. A flocculated state is preferred because a soil with such a clay is much more permeable than a soil with dispersed clay. A low SAR and a high TDS favor flocculation, whereas a high SAR and a low TDS favor dispersion of clay (see McNeal's graph in Bouwer, 1978, p. 44). Soils below infiltration basins generally are sandy or gravelly and contain little or no clay. The same is true for aquifers. Thus, SAR and TDS will have little or no effect on the hydraulic conductivity of vadose zones and aquifers, but they will have an effect on the hydraulic conductivity of the sediment layers on the basin bottoms. Such layers consist of fine materials and often contain clay that was suspended in the water. Clogging due to inorganic sediment accumulations on the basin wetted perimeter thus tends to be more severe where SAR and TDS cause the clay to be dispersed than where the clay is flocculated, necessitating more frequent cleaning operations for the former. Sometimes, dispersing SAR and TDS values can mobilize clay particles in the aquifer system. These particles can then migrate through the aquifer and move to wells where they increase the turbidity of the pumped water.

Recharge with Sewage Effluent

Where sewage effluent is used for ground water recharge, the quality improvement of the sewage water as it moves through the vadose zone and aquifer becomes very significant. As a matter of fact, this "treatment" aspect may be the most important part of the recharge system, and the main purpose of the recharge system could be to give "soil-aquifer treatment" (SAT) to the effluent. SAT systems typically are designed and managed as recharge-recovery systems. The product water or "renovated" sewage water from SAT systems can be used for stream flow replenishment, unrestricted irrigation (including crops consumed raw by humans), and drinking (after further treatment and/or blending with other water).

Sewage effluent typically has had primary and secondary treatment and mild chlorination before it is used for ground water recharge. Primary effluent can also be used as such, but infiltration rates tend to be less due to more suspended solids and clogging. Thus, where primary effluent is used, a larger area will be necessary for the infiltration basins. As the effluent moves through the vadose zone and aquifer, the following quality improvements can be expected, as indicated by a pilot project (Bouwer et al., 1980) and a demonstration project (Bouwer and Rice, 1984b) in the Phoenix, Arizona, area.

1. Suspended solids, biodegradable material (expressed as biochemical oxygen demand or BOD), bacteria and viruses are essentially completely removed.
2. Concentrations of phosphorus and heavy metals are greatly reduced (phosphate by about 90 percent to about 0.5 mg/l as phosphate phosphorus).
3. When the flooding and drying periods of the basins are selected to stimulate denitrification in the soil (obtained in the Phoenix area with flooding and drying periods of about 10 days each), nitrogen concentrations are reduced by about two-thirds. For the Phoenix project, this left about 6 mg/l of nitrogen in the renovated water, almost entirely in the nitrate form.
4. Total organic carbon content is reduced to about 2 mg/l. Most of this carbon probably is in the form of humic and fulvic acids, but there is also a wide spectrum of refractory synthetic organic compounds, mostly at concentrations on the ppb (micrograms/l) level. Halogenated hydrocarbons were more persistent than non-halogenated hydrocarbons in the underground environment.
5. The TDS content of the renovated water was about 2 percent higher than that of the sewage effluent, mostly due to evaporation from the basins.

The renovated water from the Phoenix project meets the public health, agronomic, and aesthetic water quality requirements for unrestricted irrigation and recreation. If the renovated water is to be used for drinking, further treatment is required. This treatment could consist of activated carbon filtration to remove TOC, disinfection, and possibly reverse osmosis. Because considerable quality improvement has been obtained by the flow through the vadose zone and aquifer, treatment of renovated water from an SAT system for drinking will be much more effective and economical than treatment to convert sewage plant effluent directly into drinking water.

The Phoenix projects are in loamy sand overlying coarse sand and gravel. Hydraulic loading rates are about 300 ft/yr. Thus, one acre of infiltration basin can handle 300 acre-feet of sewage effluent per year or 0.37 mgd. Evaporation rates are about 6 ft/yr.

Thus, the recovery efficiency is about 98 percent. The ground water table is at a depth of about 10 feet in the pilot project and 50 feet in the demonstration project.

After the recharge water has moved through the vadose zone and some distance through the aquifer, its quality often is still not as good as that of the native ground water. Thus, SAT systems should be designed and managed for complete recovery of the renovated sewage water within a given distance (a few hundred to a few thousand feet, for example) from the infiltration system. This not only assures complete recovery of the infiltrated sewage water, but it also protects native ground water resources outside the aquifer portion dedicated to SAT.

Examples of various types of SAT systems with complete recovery of renovated water are shown in Figure 3. The top system, where renovated water drains into surface water, is used to reduce pollution of surface water by wastewater. Cities or towns using this system may get credit for the return flow into the stream and be allowed to divert more water from the stream. If they discharge their sewage effluent directly into the stream, they would not get credit and would require a discharge permit. The system in Figure 3B can be used where ground water tables are high and the renovated water can be recovered by gravity with underground drains. Where the ground water is deep, the renovated water must be recovered with wells. For Figure 3C, encroachment of renovated water into the aquifer outside the SAT system is prevented by monitoring ground water levels at the outside of the system (see observation wells in Figure 3C), and managing infiltration and well pumping rates so that ground water levels at the observation wells never rise higher than the ground water table outside the SAT system. In Figure 3D, infiltration basins are clustered together and surrounded by a circle of wells for pumping the renovated water. However, these wells tend to deliver a mixture of renovated sewage water from the SAT system and native ground water that is drawn from the aquifer outside the SAT system. This could be beneficial where such blending is desired, but objectionable where there are legal restrictions on pumping native ground water. The systems in Figures 3C and 3D allow seasonal rises of the ground water table to store renovated water in the winter and pump it up in the summer. Such seasonal storage is necessary where the renovated water is to be used primarily for crop irrigation.

Pilot projects

There are hundreds of successful artificial ground water recharge projects in the U.S. alone, and many more in the rest of the world. Recharge systems are site-specific and what works well in one place may not be the best in another. Thus, when artificial recharge of ground water is considered in areas where there is no previous experience

A

B

C

D

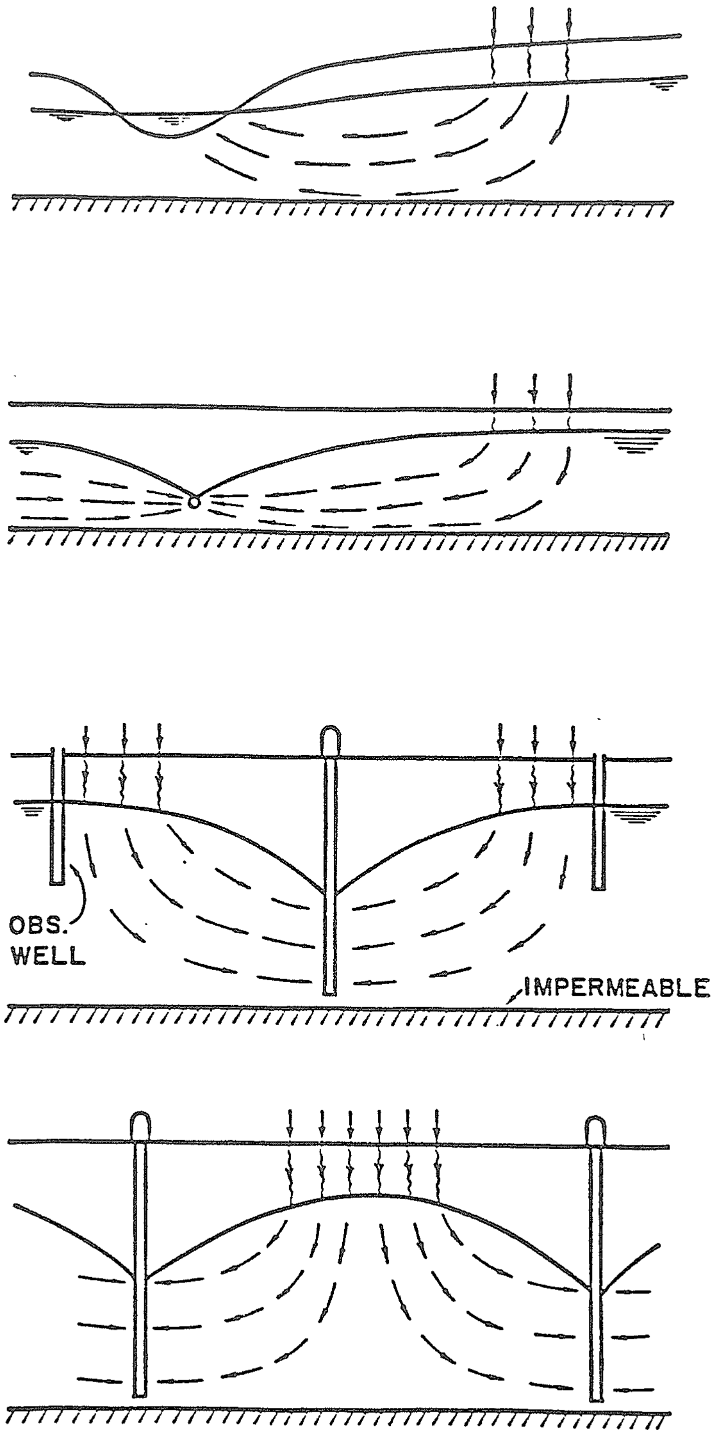

Figure 3. Schematic of soil-aquifer treatment systems with natural drainage of renovated water into stream, lake, or low area (A), collection of renovated water by subsurface drain (B), infiltration areas in two parallel rows and line of wells midway between (C), and infiltration areas in center surrounded by a circle of wells (D).

with such systems, it is always desirable to start with a small project to obtain local experience with artificial recharge of ground water and to develop design and management criteria for the full-scale project. This prevents costly mistakes and can save large amounts of money later on.

REFERENCES

Bouwer, H. 1978. Groundwater Hydrology. New York: McGraw-Hill Book Co.

Bouwer, H. 1986. Intake rate: cylinder infiltrometers. In Amer. Soc. of Agronomy Monograph on Methods of Soil Analysis, No. 9, Part 1, Physical and Mineralogical Methods, 2nd ed., pp. 825-844.

Bouwer, H. and Rice, R.C. 1984a. Hydraulic properties of stony vadose zones. Ground Water. 22(6): 696-705.

Bouwer, H. and Rice, R.C. 1984b. Renovation of wastewater at the 23rd Avenue rapid-infiltration project, Phoenix, AZ. J. Water Poll. Contr. Fed. 56(1):76-83.

Bouwer, H., Rice, R.C., Lance, J.C., and Gilbert, R.G. 1980. Rapid-infiltration research--The Flushing Meadows Project, Arizona. J. Water Poll. Contr. Fed. 52(10):2457-2470.

Fam, S. and Shenstrom, M.K. 1987. Precursors of non-volatile chlorination by-products. J. Water Poll. Contr. Fed. 59:969-978.

Thurman, E. M. 1979. Isolation, characterization, and geochemical significance of humic substances from groundwater. Ph.D. Thesis, Dept. Geol. Sci., University of Colorado, Boulder, Colorado.

IMPLICATIONS OF BOMB ^{36}CL AND BOMB TRITIUM STUDIES FOR GROUND WATER RECHARGE AND CONTAMINANT TRANSPORT THROUGH THE VADOSE ZONE

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The vadose zone (zone between the land surface and the water table) is both the interval through which most ground water recharge moves and the avenue of most movement of contaminants into ground water. Knowledge of how water and solutes move through the vadose zone is thus critical both to ground water management and to aquifer protection. The movement of water and solutes under agricultural fields and humid region soils is fairly well understood. Numerous tracer studies, in the field and in the laboratory, have demonstrated the nature of soil water transport under these conditions.

Unfortunately, the transport of water and contaminants in desert soils is understood far less well. This is in part because there is less economic incentive to investigate water in natural desert soils. It is also due to the nature of the physical processes involved. Water typically moves downward under agricultural soils at the rate of several decimeters per month. In contrast, under desert soils the flow is on the order of centimeters per year. Meaningful tracer experiments would thus take 20 to 40 years, a prohibitively long time.

This difficulty may be overcome through the application of environmental tracers. Environmental tracers are substances that are present in the environment due to natural or anthropogenic phenomena, rather than the efforts of the investigator, and that have desirable properties for tracing the movement of soil water. These properties include chemical stability, lack of sources in the soil, and lack of adsorption on the solid phase. The "classic" soil water tracers for laboratory experiments are tritium (^{3}H, incorporated in the water molecule as ^{3}HHO), a tracer for the water itself, and ^{36}Cl (as the $^{36}Cl^{-}$ anion), a tracer for conservative solutes (Biggar and Nielsen, 1962; James and Rubin, 1986). The presence of these radioisotopes as environmental tracers would greatly facilitate comparison of field studies with analogous laboratory experiments.

Fortuitously, atmospheric nuclear weapons testing in the 1950s and 1960s has provided us with pulses of atmospheric fallout of tritium and ^{36}Cl. Chlorine-36 was produced by neutron activation of chloride in seawater during the U.S. explosions at Bikini and Enewetok atolls. The fallout of ^{36}Cl and tritium as a function of time is illustrated in Figure 1. Chlorine-36 fallout is taken from Bentley et al. (1986) and tritium fallout from IAEA (1983).

During the fallout period, the radioisotopes entered the soil surface along with precipitation or as dry fallout. Since that time they have been moving downward along with the soil water. By measuring vertical profiles of the tracers, some basic questions can be answered: (1) How fast does water move down through desert soils? (2) How does the movement of solutes compare to that of the water? (3) How much do solutes spread out (disperse) during flow?

Field Studies

In order to address these questions we performed ^{36}Cl and tritium measurements on samples from vertical auger holes at three sites in central and southern New Mexico. The first site (designated SNWR 1) was in a sandy soil forming an old floodplain of the Rio Salado, on the Sevilleta National Wildlife Refuge 20 km north of Socorro. The second site (SNWR 2) was close to the first, but on a Pleistocene terrace above the river. The soil was a sandy loam at this site, in contrast to the well-sorted fine sand at the first. The third site (NMSUR) also had a sandy loam soil. It was located on the New Mexico State University Ranch north of Las Cruces. The sites are described in greater detail in Mattick et al. (1987).

Water was removed from the soil by azeotropic distillation and analyzed for tritium by direct liquid-scintillation counting. Chloride was leached from the soil with deionized water and analyzed for ^{36}Cl by means of accelerator mass spectrometry (Elmore et al., 1979). Results are shown in Figure 2.

In both cases where tritium and ^{36}Cl were measured together, the result is the opposite of what might have been expected. In spite of the fact that the ^{36}Cl fallout peaked earlier than the tritium, the tritium pulse is found deeper in the soil. This result is particularly anomalous in light of the anion exclusion phenomena which normally causes ^{36}Cl to move faster than tritium even if the two are introduced together (Krupp et al., 1972; Gvirtzman et al., 1986). We tentatively attribute this apparent retardation of the chloride to microscopic-scale vapor-phase transport of the water in the dry desert soils. The tritium moves along with the water molecules in the vapor phase, but the ^{36}Cl must follow much more tortuous paths in the liquid phase and thus moves downward more slowly. The evidence for this hypothesis is discussed in Phillips et al. (1987).

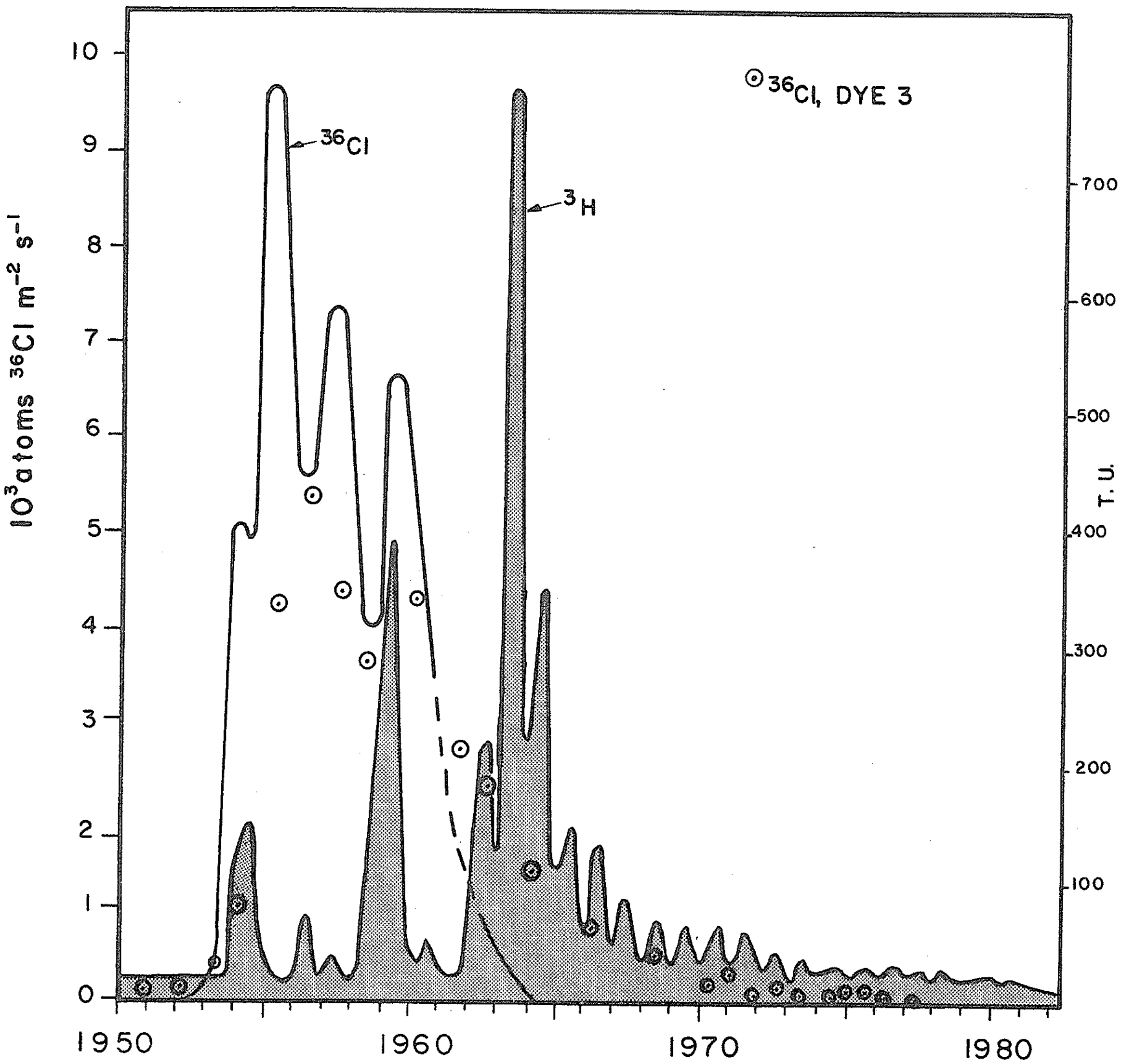

Figure 1. A comparison of average northern hemisphere bomb-^{3}H fallout (IAEA, 1983), decay corrected to 1985, with calculated mean global bomb-^{36}Cl fallout (Bentley et al., 1986).

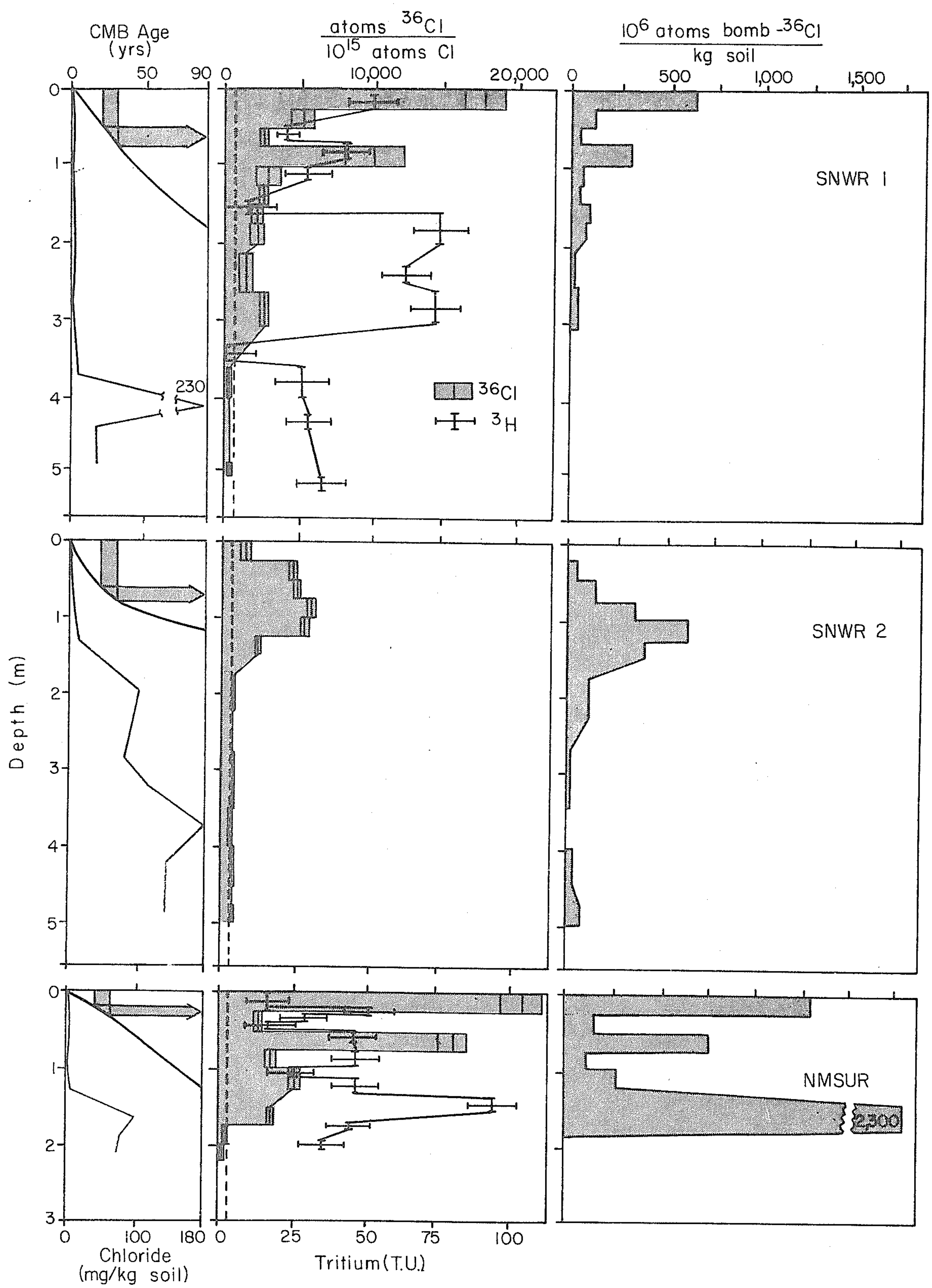

Figure 2. Chloride, chloride mass balance (CMB) age, ^{3}H, ^{36}Cl/Cl ratio, and ^{36}Cl content as a function of depth at the SNWR 1, SNWR 2, and NMSUR sites.

The transport of the tritium and ^{36}Cl were simulated using numerical modeling of the advection-dispersion equation (Mattick et al., 1986) . The ^{36}Cl profile at the SNWR 2 site could be simulated using an apparent dispersivity of 8.0 cm, and the tritium distribution at SNWR 1 using an apparent dispersivity of 5.3 cm. Much of the tritium dispersion may be due to vapor diffusion. Variable velocities in both space and time are probably another major contributor to the apparent dispersion.

Conclusions

The combination of ^{36}Cl and tritium from nuclear weapons fallout has proved to be a successful environmental tracer for long-term water and solute movement in natural desert soils. The information that they provide is equivalent to that from a 30-year-long artificial tracer experiment. Some of the results from the tritium and ^{36}Cl tracing provide unexpected insights into transport processes in desert soils.

1. The downward velocity of the soil water at SNWR 1 (computed from the penetration depth of the tritium peak) is about 15 cm/yr and at NMSUR it is about 7 cm/yr. This difference could be anticipated, given the more clay rich soil texture at NMSUR. However, the net specific flux to the depth of the tritium peak at the two sites is remarkably similar, about 0.9 cm/yr in both cases. This value is in good agreement with estimates by Stephens and Knowlton (1986) for the SNWR 1 site, based on soil-physics monitoring techniques.
2. Chloride is retarded relative to tritium at both sites, rather than moving faster as in previous laboratory and agricultural field experiments. This is probably due to water movement in the vapor phase (on a microscopic scale) as well as the liquid phase. This property of desert soils may be very beneficial from the viewpoint of retarding the movement of contaminants through the vadose zone to the water table.
3. The amount of dispersion is much larger than in laboratory experiments on the same scale. This is not unexpected, given the much more variable boundary conditions and heterogeneous materials in the natural situation. The greater dispersion of ^{36}Cl than tritium is unexpected, inasmuch as tritium can diffuse in both the vapor and liquid phases whereas ^{36}Cl can move only in the liquid. Again, this may be due to the more tortuous paths that some of the ^{36}Cl must follow in the liquid phase, but which the tritium can avoid by means of vapor transport. The absolute magnitude of the observed dispersion of either tracer is not particularly

large and does not indicate that early arrival of contaminants at the water table due to accelerated dispersive transport is likely to be a major problem.

4. The field results reported here indicate that standard laboratory experiments are of limited value in predicting the movement of water and solutes in natural desert soils. The differences are probably largely due to the much slower water velocities, longer time scales, and greater importance of vapor diffusion at low water contents. Further field investigations in desert soils should yield fundamental insights into the transport processes in this environment.

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REFERENCES

Bentley, H.W., Phillips, F.M., and Davis, S.N. 1986. Chlorine-36 in the terrestrial environment. Handbook of Environmental Isotope Geochemistry. 2B:427-480.

Biggar, J.W., and Nielson, D.R. 1962. Miscible displacement: II. Behavior of tracers. Soil Sci. Soc. Am. Proc. 26:125-128.

Elmore, D., Fulton, B.R., Clover, M.R., Marsden, J.R., Gove, H.E., Naylor, H., Purser, K.H., Kilius, L.R., Beukens, R.P., and Litherland, A.E. 1979. Analysis of ^{36}Cl in environmental water samples using an electrostatic accelerator. Nature. 277:22-25.

Gvirtzman, H., Romen, D., and Margaritz, M. 1986. Anion exclusion during transport through the unsaturated zone. J. Hydrol. 87:267-283.

IAEA (International Atomic Energy Agency) 1983. Isotope Techniques in the Hydrological Assessment of Potential Sites for the Disposal of High-level Radioactive Wastes. IAEA Tech. Rept. Series No.228. Chapter 7 "Tritium", Vienna.

James, R.V., and Rubin, J. 1986. Transport of chloride ion in a water-unsaturated soil exhibiting anion exclusion. Soil Sci. Soc. Am. J. 50: 1142-1149.

Krupp, H.K., Biggar, J.W., and Nielsen, D.R. 1972. Relative flow rates of salt and water in soil. Soil Sci. Soc. Amer. Proc. 36:412-417.

Mattick, J.L., Duval, T.A., and Phillips, F.M. 1987. Quantification of Groundwater Recharge Rates in New Mexico Using Bomb 36Cl, Bomb 3H and Chloride as Soil-Water Tracers. New Mexico Water Resources Research Institute, Technical Report No. 220, New Mexico State University, Las Cruces, New Mexico.

Phillips, F.M., Mattick, J.L., Duval, T.A., Elmore, D., and Kubik. P.W. 1987. Chlorine-36 and tritium from nuclear weapons fallout as tracers for long-term liquid and vapor movement in desert soils. Submitted to Water Resources Research.

Stephens, D.B., and Knowlton Jr., R. 1986. Soil-water movement and recharge through sand at a semi-arid site in New Mexico. Water Resour. Res. 22: 881-889.

NEW MEXICO GROUND WATER QUALITY PROTECTION STRATEGY

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New Mexico currently has one of the most advanced ground water protection programs in the country, in large part because of the state's early concern and action. The State Constitution, adopted in 1911, addresses the allocation and use of water, and a 1971 constitutional amendment requires the legislature to provide for water pollution control. In 1967, the state legislature passed the Water Quality Act establishing the Water Quality Control Commission (WQCC) and assigned the Commission the duties of adopting regulations to prevent or abate water pollution and to develop a continuing planning process. Comprehensive regulations covering ground water quality were adopted in 1977. Many other states have not yet implemented effective water pollution regulations.

BASIS FOR STRATEGY DEVELOPMENT

In 1978, President Carter's Water Policy Message directed federal agencies to expand federal and state dialogue and cooperation on ground water issues. In 1979, the U.S. Environmental Protection Agency (EPA) began development of a ground water protection strategy; in 1980, a proposed strategy was distributed for comment; and in 1984, a final Ground-Water Protection Strategy was issued. Four major EPA objectives were to:

1. strengthen state ground water programs;
2. assess ground water problems from unaddressed contamination sources;
3. issue guidelines to direct EPA ground water protection and cleanup efforts; and
4. to strengthen EPA's ground water management organization and its cooperation with other federal agencies and the states.

In pursuing the first of these objectives, the EPA encouraged states to make use of existing grant programs to develop their ground water protection programs and strategies. The New Mexico Environmental Improvement Division (EID) has for several years received funds from the EPA under Section 106 of the Clean Water Act to strengthen New Mexico's ground water protection program. Recently, this grant has been used, in part, to prepare its ground water quality protection strategy. The purpose of the formal strategy is to detail the manner in which the state will strengthen its protection program in the future.

A number of states have already submitted strategies to the EPA, while New Mexico's strategy is still in preparation. The significance of this is not that New Mexico's strategy is late in being submitted, but that the format and substance of the strategy are being developed with the deliberations of other states available as background. Additionally, there has been increasingly consistent guidance from the EPA and there have been several books published on strategy development. Within this context, New Mexico's Ground Water Quality Protection Strategy is expected to provide useful information and guidance to municipal, county and regional governments as well as state agencies which deal with ground water contamination. The public and their elected representatives will also find useful material within the strategy.

STRATEGY DEVELOPMENT

Development of a sound and useful ground water quality protection strategy requires establishment of a goal; assessment of the current protection system; development and assessment of possible additions, deletions, and alternative approaches to the current system; and development of a scheme for selecting and implementing specific improvements.

The Current System

The current ground water protection system provides protection to ground water quality through numeric and narrative standards. Numeric standards established by the WQCC include 33 health-related, nine aesthetic-related (causing problems such as disagreeable taste and odor) and five agriculture-related ground water contaminant concentration limits. An example of a narrative standard is the WQCC's prohibition of contamination by "... a water contaminant or combination of water contaminants (among the 87 listed and potentially toxic chemicals) in concentration(s) which, upon exposure, ingestion, or assimilation either directly from the environment or indirectly by ingestion through food chains will unreasonably threaten to injure human health, or the health of animals or plants ..."

The purpose of the WQCC regulations is to protect all ground water in the state which has an existing total dissolved solids concentration of 10,000 mg/l or less, for present and potential future use as domestic and agricultural water supply, and to protect those segments of surface waters which are gaining because of ground water inflow.

There are over 400 facilities operating with discharge permits issued under these regulations. Only one percent of these facilities have caused ground water contamination in excess of standards. Yet the EID is aware of almost 900 incidents of ground water contamination which occurred between 1927 and 1986 and which were caused by unpermitted discharges. Only 54 of these cases have received or soon will receive some degree of remediation.

The state's Hazardous Waste Management Regulations require owners or operators of hazardous waste management facilities to monitor for indications of the presence of hazardous constituents in ground water above background concentrations. Where contamination is detected, cleanup is required to background concentrations or to Alternate Concentration Limits. The New Mexico Environmental Improvement Board, which promulgates these regulations, is required by the state's Hazardous Waste Act to adopt regulations equivalent to EPA's regulations. EPA's regulations are adopted pursuant to the Resource Conservation and Recovery Act. There are more than 750 facilities in the state which handle hazardous waste. The number of these which has caused ground water contamination is unknown. There are only 23 facilities which are subject to current hazardous waste permitting requirements. Contamination at seven of these sites has been documented, and corrective action has been or is being taken at all seven sites.

New Mexico's Liquid Waste Disposal Regulations cover residential septic tank discharges. Ground water is protected through lot size (density) and water table clearance requirements. There are approximatelY 135,000 septic systems in the state, about 50,000 of which have state permits. Most of the remaining systems have been "grandfathered". There have been approximately 450 cases of ground water contamination from septic systems, most of which are reported as excessive nitrate concentrations in areas of dense residential development. No remediation of contaminated ground water has occurred.

<u>Ground Water Classification</u>

In assessing the current system, there are a number of questions which should be asked. One of the first is, "Is all ground water in the state which needs protection adequately protected by statute and regulation?" In other words, if present statutory requirements and regulations were enforced in all circumstances where they apply, would all significant present and future ground water quality problems be eliminated? This question naturally leads to additional questions: Is there ground water in the state that doesn't need protection? What is adequate protection? For what is the ground water protection being provided? Most states begin to answer these questions by categorizing ground waters according to a classification system. Ground water standards are then set for classes of use.

For example, Wyoming's regulations have identified seven categories of ground water use and protection, including domestic (<500 mg/l TDS); agricultural (<2000 mg/l TDS); livestock (<5000 mg/l TDS); industrial (<5000 mg/l TDS); mineral, hydrocarbon and geothermal (no TDS limit); fish and aquatic life (<500mg/l for egg hatching, <1000 mg/l for fish rearing, and <2000 mg/l for sustaining aquatic life); and unfit for any use (no TDS limit). Dischargers impacting water with existing uses cannot make the affected water unsuitable for its intended use at any place of withdrawal. Discharges to unappropriated waters cannot cause the affected waters to exceed established numeric use standards.

Another approach has been taken by Connecticut. That state has four categories of ground water within its classification system: uncontaminated public drinking water supplies; uncontaminated private drinking water supplies; contaminated but treatable ground water; and contaminated and untreatable ground water. There are no associated numerical standards. Discharges of increasing ground water impact are allowed over aquifers with increasing degrees of contamination. Completed aquifer classification maps provide guidance for siting permitted dischargers (in general, none but innocuous discharges are allowed into the first two categories of aquifer), and serve as planning tools for water supplies and waste disposal and influence remedial additions.

In New Mexico, the Hazardous Waste Management Regulations protect all ground water in the state to drinking water standards or better. The WQCC regulations protect ground water of 10,000 mg/l TDS to standards of highest use. Should ground waters of the state with TDS concentrations greater than 10,000 mg/l receive protection by the WQCC regulations for highest use, for example, for use in secondary recovery of hydrocarbons by the oil and gas industry? Should New Mexico expand its classification system, for example, based on aquifer vulnerability, and develop aquifer vulnerability maps to aid in focusing state ground water protection and remediation efforts? Should there be areas of special protection, for example, no discharge zones around municipal wellheads?

<u>Governmental Authorities</u>

Another general question that should be asked is, "How should authorities and responsibilities for ground water quality protection be distributed?" Ancillary questions include: Which governmental entities are most appropriate to deal with which ground water contamination problems? What are the appropriate sources of technical and financial support for these entities and what authorities are necessary to meet concomitant responsibilities?

It is Florida's policy to ensure that all local government plans include provisions for the control of development which protect existing and future ground water supplies from degradation. Dade County, Florida protects its wellfields by purchasing and decommissioning high-risk facilities such as gasoline stations which are located within wellhead protection areas.

Massachusetts has a program which provides financial assistance to communities to purchase land or easements to protect the recharge areas of water supply wells from future development. Since 1982, almost $15 million has been provided to cities and towns which have developed plans for ground water protection. Land owners can also be compensated through reduced taxes in proportion to the decrease in appraised value. The Cape Cod Planning Commission sponsors educational programs on waste reduction for individuals and industries. Also, a local regulatory program for underground storage tanks is in effect.

The city of Austin, Texas enacted ordinances to protect watersheds in the Edwards Aquifer recharge area. Three zones were established within each watershed: critical water quality zones which are to be free from development; buffer zones where urban development is severely restricted; and upland zones which are the least restrictive on development. Underground Water Conservation Districts may soon establish ground water protection rules in various Texas localities.

In New Mexico, the state is prohibited from directly dictating land use in its pursuit of public and environmental protection. But local governments have both the responsibility to protect public health, safety and welfare as well as the unique authority to manage land use practices. At present, eight counties have enacted zoning ordinances, three of which address ground water quality problems through subdivision requirements. Should the state require that all local planning processes include provisions for ground water quality protection? Should the state provide incentives to local governments to consider ground water quality in their planning processes, for example, through tax breaks or grants? Should the state be required to provide technical and financial assistance to local governments, for example, in the form of consultation and/or vulnerability maps of local water supply aquifers?

<u>Contamination Prevention and Cleanup</u>

The EID estimates that about six percent of the known ground water contamination cases are being cleaned up. What damage is being caused by the remainder? What are the health effects of people presently drinking contaminated ground water unbeknown to the EID and themselves? Is it regulations, resources or both which limit the state's cleanup efforts?

The Regional Water Quality Control Board, California's water pollution abatement agency, cannot effectuate abatement as rapidly as is technically feasible because of its immense caseload and severe understaffing. As a result, contamination migration presents unnecessary threats to water supply wells and the abatement costs are increased geometrically. It is estimated that staffing levels should be increased 400 to 600 percent, an action that is generally regarded as politically impossible. In response to this situation, local governments have proposed that they be given authority to step into the abatement process if the state cannot move rapidly on any particular case. Nevertheless, California has about $100 million available in a state "superfund" and about $9 million in a leaking underground storage tank fund.

Arizona, suffering from significant ground water quality problems, approved a landmark Environmental Quality Act in May, 1986. That act established the Water Quality Assurance Revolving Fund, made up of legislative appropriations, monies from penalties and monies recovered from responsible parties for cleanup costs. The fund is to receive $6 million per year and can accumulate up to $25 million. Its purpose is to provide for monitoring of pollution and ground water cleanup. Staffing for the ground water protection program was more than doubled with the addition of approximately 130 positions.

The recently enacted Iowa Clean Water Act raises approximately $12 million per year for the next five years for control of ground water contamination. The law is unusual in that it stresses education and research. For example, centers are created at three public universities to study contaminant health effects, proper waste disposal and reduction of agricultural chemical use. Approximately three-quarter of the $64.5 million cost will be paid for by chemical manufacturers and dealers.

Should New Mexico significantly increase its staffing and funding levels, and if so, should the funding come from increased taxes, ground water user fees, fees on dischargers, fines and penalties or some other source or combination of sources? Should local governments be given a role in contamination cleanup, and if so, how will those efforts be funded?

Implementing Improvements

There is a long list of general and specific questions which should be asked in the process of developing a state ground water protection strategy. For example, should the monitoring and protection afforded private wells be expanded? What are the effects of agricultural practices on the state's ground water quality, and are those practices in need of additional regulation? Should there be an approved hazardous waste disposal site in the state in order to minimize illegal disposal? Should contamination standards be developed for water-borne pathogens? Are present minimum lot size requirements for the installation of septic systems inadequate? Should septic systems continue to be allowed to be installed on small lots platted prior to applicable regulations?

In developing the New Mexico Ground Water Quality Protection Strategy, the EID is attempting to set out these and additional issues for appraisal. It anticipates the formation of a committee made up of representatives of state, regional, county and municipal governments, environmental groups, industry, Indian tribes, academics and the public-at-large to deliberate these questions and develop recommendations. The document providing background on the state's ground water resources, its ground water quality problems, current ground water protection programs and possible approaches to ground water quality problems, will be available from the EID in a couple of months. The committee will be expected to characterize New Mexico's interest in protecting ground water quality, to make known the views of particular constituent groups where applicable, to provide feedback to the state on existing ground water quality protection policy, to recommend ground water quality protection policy, and to recommend constructive changes. This process should take one to two years.

OIL CONSERVATION DIVISION PROGRAM FOR GROUND WATER PROTECTION

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INTRODUCTION

The Oil Conservation Division (OCD) is unique among New Mexico state regulatory agencies in that it is the only agency other than the Environmental Improvement Division (EID) that administers several wide-ranging water quality protection programs. Some of these programs have been developed and remain separate from the umbrella state Water Quality Act which, until the advent of various federal programs, controlled other discharges to ground water. Among the types of discharges regulated by the OCD are surface and underground disposal of water produced concurrently with oil, natural gas, and carbon dioxide; waste drilling fluids and muds; and waste fluids at crude oil recovery facilities, service companies, natural gas plants and refineries.

Most of these activities are regulated under the New Mexico Oil and Gas Act, which also authorized the OCD to set requirements for proper drilling, completion, plugging and abandonment of wells. Additional authority is granted OCD under the Geothermal Resources Act, and through administrative delegation by the Water Quality Control Commission under the Water Quality Act.

This paper will briefly discuss the differing statutory authorities and activities conducted by OCD through rules and regulations adopted pursuant to those statutes. The division of fresh water protection responsibilities between OCD district and Santa Fe staff will be explained. Finally, staff and other resource needs required to implement effectively water quality programs will be presented.

OIL AND GAS ACT

When the New Mexico Oil and Gas Act (70-2-1 through 70-2-38, NMSA 1978) created the Oil Conservation Commission[1] in 1935, it authorized rulemaking for prevention of waste and to protect correlative rights, but did not specifically address fresh water protection. However, the original act did require that dry or abandoned wells be plugged in a way to confine fluids to their existing zones.

Under these and other provisions of the statute, the OCD adopted rules regarding drilling, casing, cementing, and abandonment of wells. These activities, by themselves, provide some fresh water protection.

In 1961, the act was amended to allow the OCD to make rules providing for fresh water protection from improper disposal of drilling or production waters. Under the 1961 amendments, the state engineer designates which water is to be protected. Currently, protection is to be afforded to all surface water streams, all surface and ground water having 10,000 mg/l or less total dissolved solids (TDS), and all surface water over 10,000 mg/l TDS that impacts protectable ground water.

When the volume (see Table 1) and composition (see Table 2) of the produced water are examined, the need to require proper disposal for water protection can be immediately seen. In addition to inorganic salts, dissolved and floating hydrocarbons also provide contamination threats (see Table 3). In the past several years, numerous contamination reports, mostly in Southeast New Mexico, have been received by the OCD and the EID. Most incidents are the result of past practices that may have occurred up to several decades ago.

Under the Oil and Gas Act, statewide regulations can be adopted after notice and hearing, or rules specific to a particular practice, operator, or geographic area may be issued as OCD "orders." When an order is approved for a specific operator, it serves as a permit. Using one or the other of these methods, the OCD administers requirements for underground injection of produced waters and non-"hazardous" production fluids, for surface disposal of such fluids, and for disposal of non-recoverable waste oils and sludges from production and oil treating plants. A summary of major rules and orders is provided in Table 4.

Although the requirement to protect fresh water is statewide, two orders (R-3221 and R-7940) control the actual surface disposal of water in southeast and northwest New Mexico. R-3221 prohibited surface disposal in Lea, Eddy, Chaves and Roosevelt counties of southeast New Mexico beginning in January, 1969. Later amendments excepted certain

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[1] By law the Oil Conservation Commission has concurrent jurisdiction with the OCD over all matters relating to oil and gas. The Commission generally hears proposed rules of a statewide impact and acts as an appeal body from OCD actions.

TABLE 1. 1985 NEW MEXICO PRODUCED WATER CUMULATIVE SUMMARIES

WATER PRODUCTION SUMMARY

	Southeast N.M.	Northwest N.M.	Statewide
Water Produced with Oil			
Barrels Produced	304,546,026	57,805,557	362,351,583
No. of Wells	22,488	2,582	25,070
Water Produced with Gas			
Barrels Produced	4,981,425	916,366	5,897,791
No. of Wells	3,655	13,602	17,257
Total No. Oil & Gas Wells (1985)			42,327
Total New Mexico Produced Water			368,249,374 Bbls. 15.466 Bil. Gal.

PRODUCED WATER DISPOSAL SUMMARY

	Southeast N.M.	Northwest N.M.	Statewide
Secondary Recovery Injection			
Bbls. Water Reinjected	141,522,471	41,063,330	182,585,801
No. of Wells	2,684	196	2,880
Salt Water Disposal Injection			
Bbls. Water Disposed	135,775,609	10,680,471	146,456,080
No. of Wells	277	19	296
Total Injection Wells (1985)			3,176
Total Injection Water Disposal	277,298,080	51,743,801	329,041,881 Bbls. 13.820 Bil. Gal.
Difference* Between Total Produced Water and Total Injected Water:			39,207,493 Bbls. 1.647 Bil. Gal.

*Water disposed of in permitted ponds, make up for secondary recovery, unlined pits.

TABLE 2. MAJOR CONTAMINANT CONCENTRATIONS (mg/l) IN OIL FIELDS PRODUCED WATER INJECTED INTO DISPOSAL WELLS IN SOUTHEAST NEW MEXICO

Parameter[1]	Range	Arithmetic Mean	Standard Deviation	Geometric Mean[2]	Median	Samples
Chloride	498-198,000	71,227	46,882	49,754	56,750	123
Sulfate	0-5,500	1,533	1,124	1,083	1,300	119
TDS[3]	2,060-320,495	110,086	69,921	81,212	92,924	98
pH[4]	4.2 - 8.7	6.4	0.7	6.4	6.5	110
Iron	0 - 1,396	122.3	315.1	9.2	11.1	68

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[1]Analyses from salt water disposal applications on file with N.M. Oil Conservation Division, Santa Fe. All values milligrams per liter except pH. All values total values; not field filtered. State ground water standards: chloride, 250 mg/l; sulfate, 600 mg/l; TDS, 1,000 mg/l; pH, 6 to 9; iron, 1.0 mg/l.

[2]Log geometric mean $=\sum \log x_i/N$.

[3]Total Dissolved Solids.

[4]Values are pH units as reported on laboratory analysis form.

TABLE 3. HYDROCARBON CONCENTRATIONS (mg/l) IN SAMPLES OF OIL FIELD PRODUCED WATER, SAN JUAN BASIN, NEW MEXICO

Parameter[1]	Range	Arithmetic Mean[2]	Geometric Mean[2,3]	Median	No. Samples	STANDARDS: U.S. EPA Primary Drinking Water	STANDARDS: State Ground Water
Benzene[4] (0.001)	0.001-65	16.88	6.46	12.35	19	0.005	0.010
Ethylbenzene[4] (0.001)	0.001-1.95	0.50	0.24	0.50	19		0.75
Toluene[4] (0.001)	0.001-53.4	15.3	5.6	12.2	19		0.75
Xylenes[4] (Total) (0.001)	0.001-25.1	5.3	2.2	4.0	19		0.62

[1]Sampled by N.M. Oil Conservation Division April, 1984 through June, 1986. Analyses by N.M. Scientific Laboratory Division. All samples from oil-water separators at leases; all values milligrams per liter. Values represent total concentration, samples not field filtered. Values in parameter column are detection limits. Intervals and maximum number of samples: Pennsylvanian 1, Dakota Sandstone 8, Gallup Sandstone 3, Mesaverde 5, Chacra 1, Fruitland 1. Pictured Cliffs wells visited did not produce water.

[2]Detection limit values included in calculation of means.

[3]Log geometric mean = $\sum \log x_i/N$.

[4]One sample (Fruitland Basal Coal) had no aromatic hydrocarbons detected.

Table 4 - Major OCD Fresh Water Protection Rules

Major OCD Statewide Regulations

#	TITLE	PURPOSE
0.1	Fresh Water	Defines "Fresh Water" to be protected.
1.	Scope of Rules and Regulations	Rules 1, 2 and 3 state in general terms that fresh water is to be protected and that OCD staff has authority and duty to enforce such rules.
2.	Enforcement of Laws, Rules and Regulations	
3.	General Operations/Waste Prohibited	
8.	Lined Pits/Below Grade Tanks	Requires OCD approval of design and leak detection system.
105.	Pit for Clay, Shale, Drill Fluid, and Drill Cuttings	Requires on-site disposal in a manner to prevent fresh water contamination.
106.	Sealing Off Strata	Requires wells to be drilled and abandoned in a manner to prevent water or contaminant migration.
107.	Casing and Tubing Requirements	Requires necessary surface and intermediate casing strings and cement to protect fresh water.
116.	Notification of Fire, Breaks, Spills, and Blowouts	Notification and action requirements.
202.	Plugging and Abandonment	Requirements for plugging and abandonment of drill holes and wells.
308.	Salt or Sulphur Water	Monthly reporting of water volumes.
310.	Tanks, Oil Tanks, Fire Walls and Tank Identification	Prohibits oil storage in earthern reservoirs, and requires fire walls.
312.	Treating Plants	Specifies requirements for facilities performing oil recovery from production wastes.
313.	Emulsion, Basic Sediments, and Tank Bottoms	Prohibits pollution of fresh waters or surface damage from these wastes.

Table 4 (Con't)

#	TITLE	PURPOSE
701-708	Rules for Injection of Fluids	Underground Injection Control (UIC) regulations for salt water disposal, water floods and pressure maintenance.
709.	Removal of Produced Water From Leases and Field Facilities	Requires tranporter authorization to move fluids off-site.
710.	Disposition of Transported Produced Water	Prohibits disposal in water courses, pits, or in any other place or manner which will constitute a hazard to fresh water supplies.

Major OCD Area-Wide Orders

#	DATE	AREA	PURPOSE
R-1224-A	1958	Hobbs, Monument and other community areas within Lea County Underground Water Basin.	Prohibits disposal of produced water in unlined pits.
R-2526	1963	Oil pools of Pennsylvanian and Wolfcamp geologic age, Lea County.	Prohibits disposal of produced water in unlined pits.
R-2788	1964	An area 12 miles in length within 2 miles of the Pecos River in Chaves County.	Prohibits disposal of produced water in unlined pits.
R-3164	1966	Vacuum Oil Field (NW of Hobbs) Lea County.	Prohibits disposal of produced water in unlined pits.
R-3221 (as amended)	1967	All of Lea, Eddy, Chaves and Roosevelt Counties (effective 1969).	Prohibits disposal of produced water in unlined pits. Areas have been and can be specifically excepted from the general order after demonstration through formal OCD hearing of no protectable fresh water.

Table 4 (Con't)

#	DATE	AREA	PURPOSE
R-7940	1985	Defined "vulnerable" ground water areas in the San Juan Basin, mainly along the San Juan, Animas and La Plata River valleys.	Prohibits disposal of produced water in unlined pits, with small volume exceptions dependent on salt concentration and depth to ground water.
R-7940-A	1986	All of San Juan Basin (San Juan, McKinley, Sandoval and Rio Arriba Counties).	Requires permits for commercial surface disposal facilities and registration and approval of centralized surface disposal operations.

geographic areas from the order if the area contained no ground water, or the existing water was greater than 10,000 mg/l TDS. Large areas of Eddy County east of the Pecos River, and west of the Caprock in Lea County have been excepted from the order by the commission. Companies can request that additional areas be added, but at a public hearing they must make a proper hydrologic showing of no protectable water.

In northwest New Mexico, Order R-7940, adopted in 1985, specified the most important areas of vulnerable ground water to be protected. These areas of shallow ground water are located mostly along the San Juan, Animas and La Plata River valleys. Aquifers in these valleys are not protected by fine-grained consolidated sediments as they are in other areas of the San Juan Basin. However, even in these shallow ground water areas of the Basin, continued small volume discharges up to 210 gallons (5 barrels) per day of produced water were authorized except where the ground water was less than ten feet (all discharges banned), or where the produced water was greater than 10,000 mg/l TDS (discharges limited to 0.5 barrels per day). These discharges were allowed to continue pending the results from a study (nearing completion) of the effect of small volume discharges on ground water. Preliminary results of the study have shown floating and dissolved hydrocarbon contamination at a number of the sites investigated. A complete discussion of the regulatory history of the San Juan Basin can be found in an earlier paper (Boyer, 1986).

WATER QUALITY ACT

The New Mexico Water Quality Act (74-6-1 through 74-6-13, NMSA 1978) provides the statutory authority for OCD environmental regulation of refineries, natural gas plants, and oil field service companies. Discharges to ground water at these facilities are controlled under the Water Quality Control Commission (WQCC) Regulations. As a constituent agency of the WQCC, OCD has been delegated authority to administer the regulations at these facilities and at geothermal operations (See Appendix). State water quality regulations at most other facilities are administered by the EID. That agency also administers WQCC regulations at in-situ brine extraction facilities. These were previously under OCD control and transferred to the EID prior to establishment of the OCD Environmental Bureau in 1984.

Discharge plans are being reviewed by the OCD staff for those refineries and natural gas plants not yet permitted. Most permitting remaining for these facilities is in northwest New Mexico. Renewal of discharge plans is required every five years and the earliest southeast gas plant approvals are coming due for review. Only several service companies in the Hobbs area have received discharge plan approval and other existing facilities there have received a lower priority in OCD's discharge plan schedule.

The relationship between the regulatory authorities and administrating agencies in implementation of the regulations at refineries and gas plants is shown in Figures 1 and 2. It must be emphasized that language in the Water Quality Act specifically prohibits WQCC concurrent jurisdiction over oil and gas production activities that may cause water pollution and are regulated by the OCD through the Oil and Gas Act. The delegation to the OCD of WQCC authority effectively eliminates this conflict because the same staff persons administer both sets of regulations, and apply whichever is applicable to the regulated facility.

Although the WQCC Ground Water Quality Standards can not be applied directly to permitted operations regulated under the Oil and Gas Act, OCD staff use them as guidelines since they have been developed for New Mexico's ground water quality and are both more comprehensive and realistic than some federally promulgated standards. In instances where the Oil and Gas Act is silent, such as requirements for cleanup and remedial action in the event of a spill or contamination, they are applied in reclamation actions. Under the WQCC delegation agreement, OCD staff are responsible for proper enforcement of the Water Quality Act in these instances.

GEOTHERMAL RESOURCES ACT

Regulations adopted under the Geothermal Resources Act (71-5-1 through 71-5-24, NMSA 1978) are structured similar to those of the Oil and Gas Act. Its provisions control drilling, casing and cementing of geothermal wells; and production volume of the geothermal fluids so that the geothermal reservoirs will not be depleted, or unfairly appropriated by a particular user. The act and regulations adopted thereunder specify that activities be conducted in a manner such that human health and the environment are afforded maximum reasonable protection, and that disposal of produced waters be in a manner so as not to constitute a hazard to surface or underground usable waters.

Unlike the Oil and Gas Act, the Geothermal Resource Act has a clause allowing concurrent jurisdiction with other state agencies having regulatory jurisdiction. This means that WQCC Regulations are also applicable. Again, these responsibilities have been delegated to the OCD, and in practice only storage and disposal of geothermal fluids are currently being regulated via discharge plans. Other aspects of the operation (drilling and

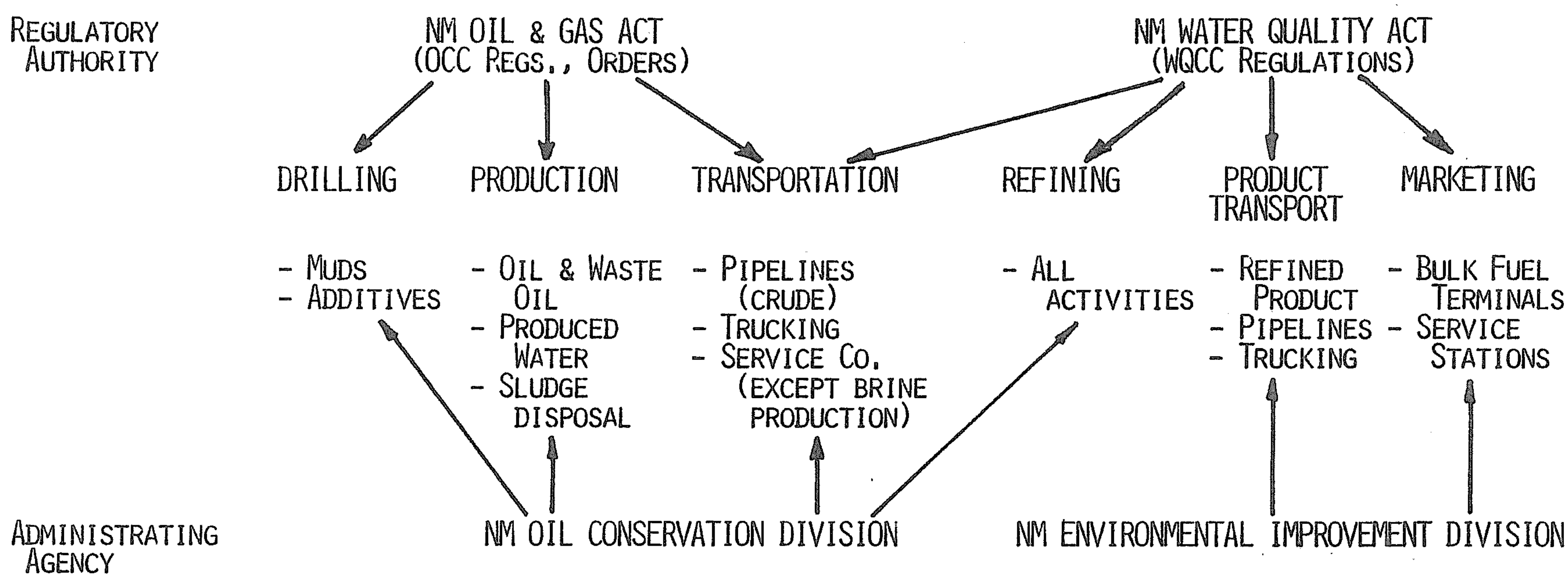


Figure 1. State Fresh Water Protection Programs - Oil

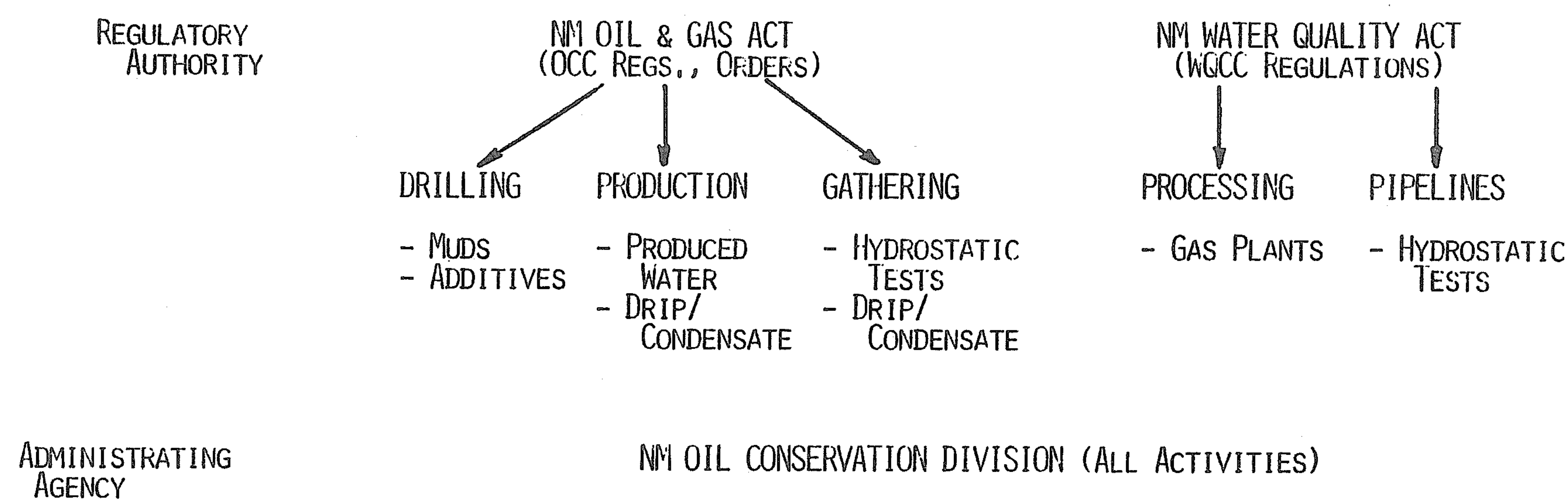


Figure 2. State Fresh Water Protection Programs - Natural Gas and Carbon Dioxide

production) are covered through permits issued under the Geothermal Resources Act. These relationships are diagrammed in Figure 3.

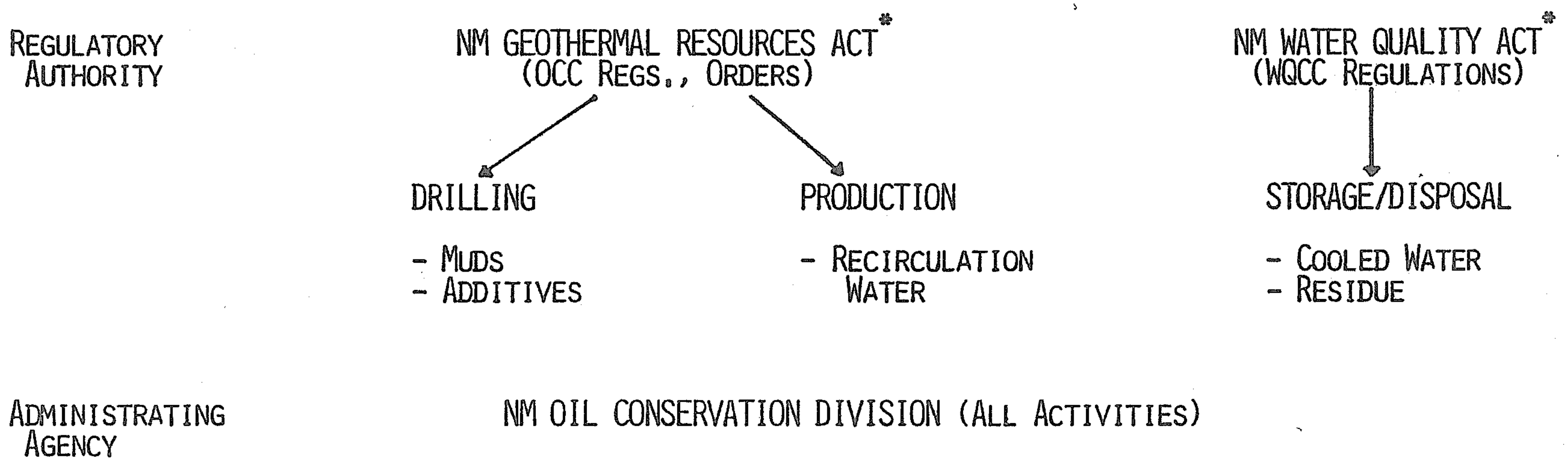
IMPLEMENTATION

Environmental activities conducted by the OCD are implemented by OCD's Santa Fe office and four district offices (see Figure 4). In addition to matters related to oil and gas production, Santa Fe staff process, approve or set for hearing, applications for surface disposal or underground injection of salt water, for water flooding used in secondary oil recovery or pressure maintenance, and for waste oil recovery/treating plants. With the exception of some surface disposal applications reviewed by the Environmental Bureau, all of the above activities are performed by OCD's petroleum engineers. However, Environmental Bureau staff provide valuable input and guidance in the application process, especially for possible impacts to ground water from proposed surface disposal or waste oil treating plants.

The Environmental Bureau, formed in 1984, performs water protection activities not carried out in other OCD programs. These include permitting of oil refineries, natural gas plants, oil field service companies, and other regulated discharges to ground water. Bureau staff perform inspections and sampling at these facilities, ground water contamination investigations, sampling of ground water at domestic wells and other locations suspected of having contamination, and supervise ground water cleanup and remedial actions. The bureau coordinates OCD environmental programs and responds to information requests by industry, federal and state agencies, and other members of the public. Additional regulations for fresh water protection are researched, written and proposed to the Oil Conservation Commission, and guidelines to assist industry in complying with regulatory requirements are prepared and updated.

Activities performed by the Environmental Bureau are carried out by a staff of three including a hydrogeologist, chemical/environmental engineer and a petroleum geologist. A fourth temporary staff person, a ground water hydrologist funded by an EPA grant, is assigned through January 1988 to assist in the San Juan Basin Investigation. This project is studying ground water contamination and the necessity of additional regulation of production discharges in that area.

Daily activities performed by OCD district staff provide protection for fresh water. All permits to drill, complete, work-over, and plug oil, gas and injection wells are reviewed and approved by district staff which includes a district geologist. The review



* ALTHOUGH BOTH STATUTES ARE APPLICABLE TO ALL ACTIVITIES, IN PRACTICE THE WATER QUALITY ACT IS MORE LIKELY TO BE APPLIED ONLY TO DISPOSAL ACTIVITIES WITH THE GEOTHERMAL RESOURCES ACT PROTECTING FRESH WATER FROM DRILLING AND PRODUCTION ACTIVITIES.

Figure 3. State Fresh Water Protection Programs - Geothermal

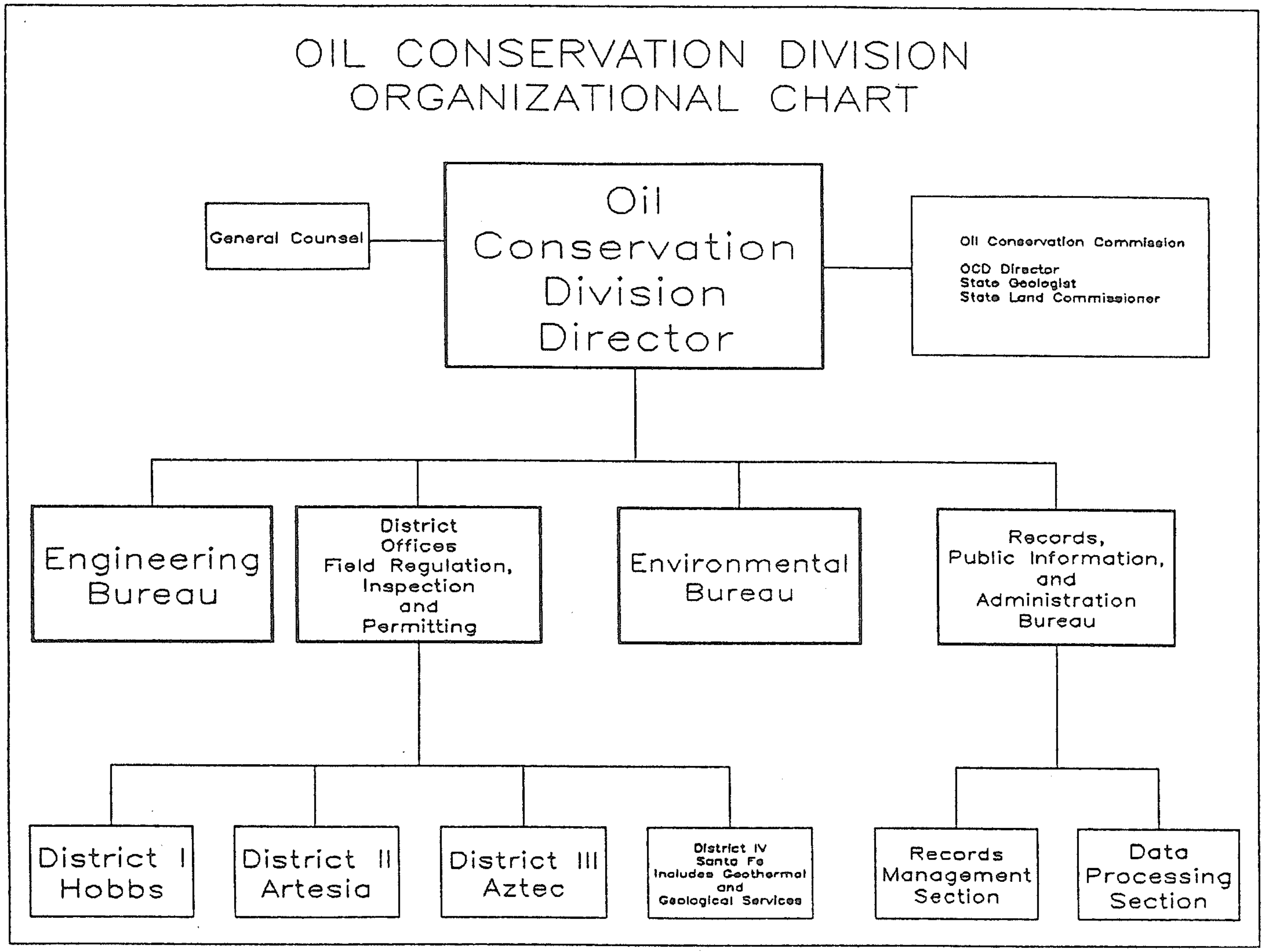


Figure 4. Oil Conservation Division Organizational Chart

ensures proper casing and cementing programs to protect fresh water. Field inspectors witness required cementing and testing of production and injection wells, and respond to complaints of possible rule violations. They collect water samples, supervise cleanup of minor spills and leaks, and provide first response to oil and gas related environmental problems.

EFFECTIVENESS AND RESOURCE NEEDS

Since 1984, the OCD Environmental Bureau has concentrated its resources on prevention of additional contamination of fresh water by oil and gas production and refinery activities. The major efforts in this area have been discharge plan review of gas plants and refineries, and review and revisions, if necessary, of OCD rules related to surface disposal of produced water and other oil field waste. Most gas plants, except several in the San Juan Basin, have approved discharge plans.

Refinery permitting has been more difficult due to the age of several, and pre-existing documented contamination at all operating and abandoned sites except one that has not received extensive ground water study. Permitting has been facilitated by separating issues of past contamination and remedial action from the discharge plan, unless continued discharges will cause changes in contaminant migration and concentration.

Prior to 1985, no restrictions on direct discharge of oil field produced water, or related wastes existed in the San Juan Basin. The OCD has now adopted rules to prohibit discharges to very shallow ground water and restrict larger discharges in areas of vulnerable ground water. An investigation to determine if additional restrictions are necessary is nearing completion. The OCD also has required that commercial and centralized surface disposal facilities in the San Juan Basin receive approval to operate. Permitting requirements for commercial surface disposal are expected to be extended statewide in 1988 and will supplement fresh water protection Order R-3221 in southeast New Mexico.

These priorities, plus the inevitable "brushfires," have meant that other issues such as cleanup of lesser spills and leaks, ground water contamination investigations, and discharge plans for service companies have received less attention. Although the loss of the hydrologist in January 1988, will further exacerbate these workload problems, realistically, no additional state funding for this fresh water protection position can be expected until the economics of the industry and the state improve. An alternative strategy based on partial funding from two different EPA programs is being pursued, but with no guarantee of success at this time.

An additional fresh water related problem that has recently received attention is the large number of production wells that have been shut-in or temporarily abandoned. The reason for this increase is that the lower price of oil and natural gas since 1985 has led to the shut down of marginal producing wells. However, these wells can not be left indefinitely in this condition because natural processes cause casing deterioration that can lead to interstrata communication and possible fresh water contamination. Over 7500 wells are now shut-in or temporarily abandoned, and OCD staff desire rule changes to require proper temporary plugging for wells shut-in for over six months. Such plugging would be allowed for a maximum of five years without reapproval. Several additional staff, mostly clerical, would be needed to administer the rule change, but the seriousness of the problem may require emergency consideration of the positions. If position savings are identified in other departmental programs, the possibility of transferring some of the positions targeted for elimination should be vigorously pursued.

SUMMARY

The OCD has an ongoing fresh water protection program staffed by persons knowledgeable in several engineering and scientific specialties needed for proper implementation of the program. The OCD is cognizant of potential contamination due to oil and gas activities, and enforces and revises state rules as necessary to protect this resource. Proper staffing is always crucial to every successful program, and OCD, like other agencies, has found that the demands for services by industry and the public is in conflict with budgetary constraints due to the general economic situation of the oil and gas industry and the state. Since the OCD administers mostly state regulatory programs, it is able to tailor and implement these in a manner to provide maximum effectiveness with available staff, and with a minimum of bureaucratic requirements. To continue to provide maximum frontline services, the OCD is pursuing alternative staffing strategies using existing state or federal funding sources.

REFERENCE

Boyer, D.G. 1986. Differences in Produced Water Contaminants From Oil and Gas Operations in New Mexico - Implications for Regulatory Action. In Proceedings of the Conference of Southwestern Ground Water Issues, Tempe, Arizona, October 1986. National Water Well Association. pp. 291-316.

APPENDIX

WATER QUALITY CONTROL COMMISSION

DELEGATION OF RESPONSIBILITIES TO ENVIRONMENTAL IMPROVEMENT DIVISION AND OIL CONSERVATION DIVISION

In an effort to prevent duplication of effort and to clarify the division of responsibilities pursuant to the provisions of the Water Quality Act, NMSA §§ 74-6-1 et seq. (1978), as administered and enforced by the Water Quality Control Commission, the Commission hereby approves the following list of delegated duties and responsibilities for two of the agencies that are constituent agencies to which authority can be delegated, the Environmental Improvement Division ("EID") and the Oil Conservation Division ("OCD"). The Commission is specifically authorized to take this action by NMSA § 74-6-4E (1978) and by other general provisions of the Water Quality Act. The Commission notes that pursuant to NMSA § 74-6-9C (1978), constituent agencies may "report to the Commission and to other constituent agencies water pollution conditions that are believed to require action where the circumstances are such that the responsibility appears to be outside the responsibility assigned to the agency making the report." The Commission encourages OCD and EID to continue close communication and cooperation where responsibility is unclear, to ensure that water pollution is prevented or abated quickly, efficiently and consistently. In situations involving discharges or facilities under the jurisdiction of both agencies, the agencies shall mutually agree which shall be the lead agency and shall determine the method by which the discharge plan shall be evaluated and approved. In preparing this delegation statement, the Commission is cognizant of the limitations imposed on its authority by the Water Quality Act, especially NMSA § 74-6-12G (1978) which prohibits it from taking any action which would "interfere with the exclusive authority of the oil conservation commission over all persons and things necessary to prevent water pollution as a result of oil or gas operations...."

This delegation shall supersede all previous delegations to EID and OCD; reference to the dates and minutes of Commission meetings in which previous delegations were made are in parentheses and the minutes are attached. The specific grants of authority are not intended to be comprehensive. When a question of authority and jurisdiction arises, which is not specifically delegated, the general provisions below shall control.

1. General Provisions

As a general rule, OCD will administer and enforce applicable Commission regulations pertaining to surface and ground water discharges at oil and natural gas production sites, oil refineries, natural gas processing plants, geothermal installations, carbon dioxide facilities, natural gas transmission lines, and discharges associated with activities of the oil field service industry. The Commission recognizes that OCD also administers regulations under both the Oil and Gas Act and the Geothermal Resources Act, and that OCD shall have discretion as to which regulations to enforce in any given situation. OCD shall have jurisdiction over all activities associated with exploration for or development, production, transportation before refinement, refinement, storage or treatment of unrefined oil and natural gas, or oil or gas products on refinery premises.

EID will administer and enforce Commission regulations regarding discharges from transmission, transportation and storage facilities for oil or oil by-products after refinement (including but not limited to gasoline stations), except those within refinery premises. EID will administer and enforce all Commission regulations pertaining to all other discharges to surface and ground water which are not specifically delegated to other departments and agencies. (Source: 1/13/69 and 5/8/84 Commission minutes)

2. Specific Grants of Authority

A. EID shall certify §404 dredge and fill material permits under the Clean Water Act ("CWA"). (Source: 1/13/76 and 6/14/83 Commission minutes)

B. EID shall administer the Wastewater Construction Grants program pursuant to §205 of the CWA. (Source: 6/14/83 Commission minutes)

C. EID shall certify NPDES permits pursuant to Title IV of the Federal Water Pollution Control Act Amendments of 1972 and §402 of the CWA. (Source: 10/1/74 and 8/14/84 Commission minutes)

D. EID shall certify hydropower licenses issued by the Federal Energy Regulatory Commission. (Source: 8/14/84 Commission minutes)

E. EID shall administer and enforce Commission regulations pertaining to the disposal of human excrement and bath water at oil and natural gas production sites, oil refineries, natural gas processing plants, geothermal installations, carbon dioxide facilities and natural gas transmission lines when the treatment facilities for the sewage are a separate and isolated discharge unmixed with any produced water, oil field waste or oil field service waste. (Such an isolated discharge would include: a small sewage treatment plant, package plant, or septic tank and drainfield.) If, on the other hand, sewage is in a discharge combined or mixed with produced water, oil field waste or oil field service waste, OCD shall have jurisdiction. (Source: 5/8/84 Commission minutes)

F. EID shall administer and enforce Commission regulations at brine manufacturing operations and concerning discharges to ground or surface water at brine manufacturing operations, including all brine production wells, holding ponds and tanks. OCD shall have jurisdiction over all manufactured brine once it is transported, used or disposed of off brine plant premises for use in or directly related to oil and gas operations regulated by OCD. OCD shall regulate brine injection through its Class II Underground Injection Control (UIC) Program if the brine is used in the drilling for or production of oil and gas. EID shall regulate brine injection through its UIC Program if the brine is used for other purposes. (Source: 5/8/84 Commission minutes)

G. EID shall administer and enforce all programs implemented by the state under PL 92-500 (The Federal Water Pollution Control Act) and its Amendments, unless directed otherwise by the Commission. (Source: 7/8/75 Commission minutes)

H. OCD shall have general jurisdiction over the oil field service industry. Many activities that would ordinarily be regulated by EID are regulated by OCD when those activities occur in the oil field service industry. The following list, which is not intended to be inclusive, serves to help clarify this delegation:

OCD	EID
waste oil handled or processed by oil field service companies or treating plants	used motor oil handlers
all underground and above-ground tanks on refinery premises, unless the tanks contain unmixed sewage; all underground and above-ground tanks not on refinery premises which contain crude petroleum, produced water or oil field service chemicals	all underground and above-ground tanks not on refinery premises, unless the tanks contain crude petroleum, produced water or oil field service chemicals
tanker trucks hauling, spilling or disposing of well-service chemicals, kill water, produced water, crude oil, tank bottom sludge and other oil field wastes and oil field service materials	tanker trucks spilling or disposing of non-oil and gas production wastes, non-oil and gas service materials, or refined petroleum products
washings from trucks and other equipment used in the transport, production or refining of oil and gas crude products, production wastes or service materials	washings from trucks and other equipment not used for oil and gas production related purposes

Both EID and OCD are authorized to continue to take appropriate legal action in their respective areas of delegation (including initiating proceedings in court) on behalf of the Commission on a finding of good cause to believe any person is violating or is threatening to violate a Commission regulation or the Water Quality Act. The agencies shall send a copy of each Complaint, Settlement Agreement and Judgment to the Commission Secretary for distribution to Commission members. (Source: NMSA § 74-1-8.2(B) (1978), 2/8/71 and 1/11/83 Commission minutes)

WATER QUALITY CONTROL COMMISSION

Richard Holland

By: Denise Fort, Chairperson (Acting)

January 15, 1986

Date

STATE WATER STRATEGIES FOR THE FUTURE

Tom Bahr, Secretary
Energy, Minerals and Natural Resources Department
Santa Fe, New Mexico 87503

The New Mexico water strategy can be capsulized in seven points: (1) keep New Mexico water in New Mexico for use by New Mexicans; (2) if we have to let some of it out, sell it by the gallon, not by the acre-foot; (3) keep our water from becoming contaminated; (4) let the market be the primary allocator of water rights; and (5), (6), and (7) plan, plan, plan.

Let me re-cap our water situation here in the state. Our supplies are finite. Our surface water supplies of 1.3 million acre-feet are fully appropriated; we're not going to get anymore. There are strict limitations, and our demands are increasing. Projected water demands to the year 2020 indicate we are going to be in a deficit situation of over several hundred thousand acre-feet per year. The supply and demand curves are going to cross somewhere about the turn of the century, and that's only thirteen years away.

Our options are limited on water importation. No matter which scenario you look at in terms of significant water augmentation to the state of New Mexico, we are at the bottom of the pipe. Economics and politics would have to change significantly for importation to be a reality in my lifetime.

Desalting is another option. We have 15 billion acre-feet of brackish ground water in the state. You could cover up the state 200 feet deep with it. You can desalt water right now, but it is expensive. Costs exceed $500 an acre-foot. There are very few ways to exploit saline water given that it is very, very expensive to utilize. You're not, for example, going to make the deserts bloom with desalted water unless there are major breakthroughs in reducing energy costs.

Weather modification (cloud seeding, and snow augmentation) have been tried without apparent success. Even the experts can't agree on this technology and even if they could, the lawyers would argue for the next 50 years as to who owns that extra water.

I have to conclude, and have concluded for a number of years, that we must learn to live with what we've got; there's no way around it. We have to use water more efficiently. We need to conserve water more. Conservation has taken on a whole new meaning to me since 1980, and when I think of conservation, I think of new dimensions. Within the law, we need to be able to conserve what water we have in New Mexico for use in New Mexico. We're in a whole new ball game right now. We now have an interstate market in water because of recent court decisions. We do have a certain amount of unappropriated ground water left in New Mexico. If we don't have a plan for its use, it will be up for grabs. Keep that thought in mind while I review two pieces of legislation passed in the last session that are significant to this particular issue.

The first is House Bill 337 which directed the Interstate Stream Commission (ISC) to do a number of things. First, it authorizes the ISC to appropriate ground water or purchase ground water rights on behalf of any of the various regions of the state. It also provides the authorization to make grants or loans for the purpose of regional water planning, and it gives a certain amount of funding to the ISC to do this. The activity that led up to this legislation was primarily the result of a massive undertaking led by Chuck DuMars at the University of New Mexico Law School. The study, which culminated in this legislation, can perhaps be characterized as the most exhaustive analysis of policy options related to a particular water issue that has ever been conducted in the state of New Mexico.

A second piece of legislation (really three pieces of legislation: (1) a house memorial, (2) a senate memorial, and because it received attention too late in the session to become a regular law, (3) a capital outlay appropriation) involves the Energy, Minerals and Natural Resources Department. Essentially it directs our department to get involved with the inventorying and cataloging of existing water plans and planning activities in the state of New Mexico and begin the process of developing what is termed a comprehensive state water plan. The legislation also instructs the department to serve as a repository for this information.

These two pieces of legislation are a direct outgrowth of issues that were stimulated and spawned by the El Paso water litigation, with which I am sure you are familiar. A United States Supreme Court decision has essentially said, aside from the fact that ground water is an article of commerce, that state ownership of water is legal fiction. The study team lead by Professor DuMars explored that concept and came to the conclusion that if a state were to participate in the market rather than just regulate the market, then you could, in fact, have bona fide state ownership of ground water. We could probably spend the next five hours talking about that concept. Suffice it to say this legislation was a result of that concept.

The second element of that court decision had to do with the concept that a state has a limited preference to its internal waters. There are various schools of thought among attorneys who have been examining this concept. Basically, the argument is that if a state can document and demonstrate on a statewide basis that it is going to have water shortages in the future, and if a plan to alleviate that deficiency in the future has been developed, there is a certain amount of water that is reserved to the state to alleviate that projected shortage. The documentation must come from local, regional, and state levels in some detail. This concept has not been tested in the courts. It is a theory that has yet to be upheld, but I think it has a lot of merit. It is essentially the basis of many of the arguments that are currently being made in the dispute between the city of El Paso and the state of New Mexico, in which El Paso is trying to acquire ground water from New Mexico.

When I talk about planning, I'm talking about a process whereby the theory and facts of a plan must survive strict judicial scrutiny. You've got to have your act together. Your figures have to be accurate and your analysis must be sound. A significant amount of planning has been conducted in the state of New Mexico, but most of it has dealt with surface water. We have about $1.5 billion worth of planning and development for surface water supplies in the state of New Mexico. By and large, our surface water supplies are fully developed.

Ground water is another story. Ground water planning has been left primarily to local and county government. It's been a very localized type of activity with little state financing.

The last overall water plan for New Mexico was completed back in 1976. The plan was called the "Water Resources Assessment for Planning Purposes." It was a $2.5 million undertaking, and for 11 years served as the primary document used by the planning community.

The approach that we're going to take goes something like this. The appropriation we have is not large: we have $150,000 to start this thing called the comprehensive water plan. The first step is to get a handle on what a plan is all about, and I picture it in three phases: (1) You must have a data collection phase; you need mapping and analysis of the situation as it currently exists. (2) You need to have projections on where you're going to be down the road. These projections must be evaluated very carefully and appropriate goals formulated. (3) You have to develop a program to implement policy. Policy options are going to emerge from the planning process at some point. Options must be selected and translated into actual policy.

As far as data collection is concerned, I don't see a need at this time to do a whole lot more collecting of new data. There's a lot of information already available. The U.S. Geological Survey, the Corps of Engineers, the Bureau of Reclamation, the State Engineer Office, county and local governments, and a host of agencies are sitting on a ton of data.

The information needs to be pulled together in a compatible format and automated. Also, we need to take a very careful look at projections. There are many different projections that have been made at the local and county level. Projections need to be made again at the state level.

Ultimately, we're going to need to come up with a host of options. For example, to solve the water problem in Otero County, one option might be to take a pipe from Dona Ana County over to Otero County. You might have some folks in Las Cruces not real keen on that idea. Implementing water conservation is another option. Should conservation be mandatory or voluntary? How about having the Interstate Stream Commission appropriate ground water in the Lordsburg area and pipe it over to Silver City, given Silver City's shortage? That is one option and again, some folks might not support this proposal. Another option is to let the problems be solved in the market place. This is the kind of exercise I'm contemplating.

The last careful look at an assessment was done 11 years ago. We need to update it and determine from what base we're starting. The previous assessment took planning up through the projection phase and presented the conclusion that we must live with what we've got, since it's clear we're not going to get anymore.

New uses are being accommodated in the market place, with water being reallocated from the irrigated, agricultural sector into the municipal and industrial sectors of the economy. Currently, some consider this to be the most appropriate option, but additional analysis needs to be done because of the existence of an interstate water market.

When I talk about planning, I'm not talking about a plan coming down from the city of Santa Fe prescribing what needs to be done, who gets the water, and how much they get. That will not work. It'll never work, and I hope it isn't even thought about. What I'm talking about is a bottom-up type of approach. After options for solving problems are identified, the plan must be turned over to the legislature and the political process.

Where are we right now in the process? We're getting tooled up. We are trying to determine where we might obtain additional funding, as $150,000 will not get you very far in an undertaking of this magnitude. The Corp of Engineers has expressed some interest in participating in the process through some of their cooperative programs.

The two seemingly innocuous pieces of legislation described above have received little public attention. There was some debate in the legislature, but I would guess not many people know much about it. But think about the implications of the state of New Mexico being authorized to appropriate water to itself, and actually getting involved in a comprehensive water planning process. These are very significant changes to the state of

New Mexico, and I would simply caution that we need to proceed very, very carefully. We have, I think, some of the best water laws in the western United States. They have worked extremely well as long as we have had a high degree of control over our internal waters.

The courts have now thrown us into a whole new arena, and planning is the name of the game. We can't ignore conflicts when they arise; they must be identified and analyzed. Once evaluated, the public and their representatives are going to have to get involved in the process. As I said before, the democratic, political process has to take over. The big concern I have is that when the political process takes over, it better go into the process with its eyes open. In other words, informed decisions must be made.

The New Mexico Water Resources Research Institute's annual conference is perhaps the single most important educational forum on water issues in the state of New Mexico. These conferences have been going on for 32 years and, knowing of the intensity of water resources issues, I'm sure these conferences will be going on year after year after year. Thank you.

EFFECTS OF THE CLEAN WATER ACT ON INDIAN LANDS

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The purpose of this talk is to acquaint you with the National Pollutant Discharge Elimination System (NPDES) permit program as regulated by the Clean Water Act and a significant amendment to it adopted by the Congress this year. I shall address the NPDES permit system and the Congressional amendment. Mr. Domenici shall address the interrelationship of water quantity rights and water quality controls.

The federal Clean Water Act is the mechanism whereby Congress has provided a comprehensive program for controlling and abating water pollution. The Clean Water Act expresses congressional intent on eliminating water pollution through the use of effluent limitations imposed on entities which discharge into the navigable waters of the United States. These limitations are imposed by means of NPDES or "National Pollutant Discharge Elimination System" permits which are issued by the EPA or the states. The act was designed to regulate to the fullest extent possible those sources emitting pollution into rivers, streams, and lakes. The cornerstone of the regulatory scheme is that those entities needing to use waters for waste distribution must seek and obtain a permit to discharge that waste, with the quality and quantity of the discharge regulated.

There are two types of permits. Section 402 NPDES permits cover waste type discharges of pollutants. They contain effluent limitations on certain chemical parameters which are derived from EPA promulgated effluent guidelines or the water quality stream standards promulgated by the states. Section 404 permits cover non-waste discharges of dredged or fill material. The state role in the issuance of NPDES permits is set forth by the Clean Water Act in Section 401. The states must certify that construction and operation of any facility or activity which requires a federal license or permit does not violate any state water quality standard. In New Mexico, water quality standards are promulgated pursuant to the authority of The New Mexico Water Quality Act at Section 74-6-1 et. seq. The water quality stream standards designate the uses for which the surface waters of the State of New Mexico shall be protected and prescribe the water quality standards necessary to sustain the designated uses. The standards are consistent with Section 101(a)(2) of the Clean Water Act which declares that it is a national goal of water quality to provide for the protection and propagation of fish, shellfish and wildlife.

In New Mexico, there are other essential uses of water. They include agricultural, municipal, domestic, and industrial uses.

The protection of designated uses by Indian tribes has proved to be a fruitful battlefield for litigation. The state recently concluded a major case in which the Water Quality Control Commission was sued for failing to protect designated uses of the Acoma and Laguna Pueblos in the setting of stream standards on the Rio San Jose. In that case the Pueblos charged that the Treaty of Guadalupe Hidalgo secured to the tribes the right to have their historical uses of water protected and preserved from effluent discharges by the Grants Sewage Treatment Plant upstream. The plant was discharging effluent into the Rio San Jose pursuant to a properly issued NPDES permit. The tribes claimed that neither the permit nor the state streams standards protected their designated use of Rio San Jose water. At issue in the case was the conflict between Indian desires to maintain an ecologically pure environment and state and NPDES standards allowing for discharge of pollutants, under permit, into the Rio San Jose.

This year the Congress enacted a significant amendment to the Clean Water Act. It provides in Section 518 that the Indian Tribes are to be treated as states for the purposes and objectives of the Act. The most significant aspect of this is that it would allow the Indian tribes to establish water quality stream standards for waters running through their borders. The EPA has 18 months from the date of the amendment to promulgate final regulations which specify how Indian tribes shall be treated as states. That process is currently underway.

The major issue, however, is the promulgation of stream standards by the various Indian tribes for the water running through their borders. By setting stream standards higher than or at variance with established state stream standards, the tribes could impact the holders of NPDES permits upstream from their reservations. The problem is potentially significant for New Mexico as 9.4% of New Mexico's land is under Indian ownership on more than 20 Indian reservations. The chief concern centers on the Rio Grande and its tributaries. The state and nine Indian tribes could establish water quality standards on portions of the 465-mile main stream of the river. Although six of these nine tribes would have less than ten river miles, many are strategically located adjacent to municipalities with wastewater treatment plants. These include Albuquerque, Santa Fe, and Los Alamos. When tributaries are included, an additional ten Indian tribes and two Navajo chapters could affect the Rio Grande system. This phenomenon is not limited to the Rio Grande. The San Juan River, the Rio San Jose, the Jemez and the Pojaque all have Indian tribes which could set stream standards on portions of their reaches.

If tribes along these rivers were to set stream standards higher than or at variance with state stream standards, NPDES permit holders currently discharging into these rivers in accordance with state stream standards could find that Indian stream standards make it impossible for them to meet the conditions of their permits. Moreover, the potential exists for the Indian tribes to object to the issuance of NPDES permits upstream. In New Mexico the impact would chiefly be felt on the wastewater treatment facilities operated by municipalities including those at Taos, Albuquerque, Grants, Farmington, Santa Fe, and Los Alamos.

Let me give a practical example of how the conflict might arise. The amendment to the Clean Water Act, Section 518, specifically incorporates the provisions of Section 401(a)(2). That provision is addressed to the states. It provides that when a discharge may affect the quality of the waters of any other state, the Administrator of the EPA shall notify the affected state within 30 days of application for the discharge permit. If within 60 days after receipt of such notification the state determines that such discharge will affect the quality of its waters so as to violate a water quality requirement, the state may notify the administrator of the EPA of its objections to the permit and request a hearing. In the situation created by Section 518, the amendment, the tribes must be treated like the states. They would have the right to object to any upstream discharge which they determine would affect the quality of waters in tribal lands which did not comport with tribally adopted stream standards.

The picture is not entirely bleak, however. The amendment makes some provision to deal with potential conflicts. It provides that the administrator, in promulgating regulations to determine how the Indian tribes shall be treated as states, shall consult affected states sharing common water bodies with Indian tribes and provide a mechanism for the resolution of any unreasonable consequences that may arise as a result of differing water quality standards set by the state and the tribes on common bodies of water. That process is under way. At present an informal dispute resolving mechanism is under consideration. It would involve the resolution of disputes by the regional administrator. In the event of an impasse, resolution of disputes would be made by the EPA Administrator in Washington.

SURVEY OF NEW MEXICO LAW REGARDING INTERRELATIONSHIP OF WATER QUANTITY RIGHTS AND WATER QUALITY CONTROLS

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INTRODUCTION

Recent amendments to the Clean Water Act delegate an expanded role to Indian tribes located on streams in determining surface water quality standards. This expanded tribal role may be the watershed for an increasing interrelationship between traditional water rights and water quality regulation in New Mexico through statute, judicial decision, and administrative authority. The interrelationship between water quantity and water quality will dictate that water allocation and distribution will be subject to a water quality regime as well as the prior appropriation doctrine.

New Mexico clearly has not been on the forefront of the growing movement for establishing a public interest in existing water rights. Nonetheless, New Mexico has recognized that water quality degradation may be a basis for denying water right permits under the existing impairment standard. In addition, the as yet undefined "public welfare" standards in the permit process provide another basis for involving water quality concerns within the existing New Mexico permit process.

An as yet untapped source for interrelating water quality with water quantity rights is interpretation of the nature and extent of water quality rights under the Treaty of Guadalupe Hidalgo. Other potential areas include the public trust, the federal reserved general forest water right, and the more specific federal reserved wild and scenic, or wilderness water right.

This paper will outline the status of these various doctrines within the New Mexico water right regime and their impact on the role of technicians, administrators, property holders and water users. One result of these trends may be an increasing reliance upon ground water to satisfy rights as a means to avoid complicated flow rate, dilution and non-point impacts involved in surface water.

As has been discussed, the impact of the recent amendments to the Clean Water Act may potentially have great consequences for New Mexico. Because the amendments implement water quality standards from other permitting and administrative processes, they may authorize actions that infringe on existing water rights. While recent amendments to the Clean Water Act occupy just a portion of the potential water quality initiative, they may have a disproportionate impact in New Mexico. The concerns for water quality, in particular the instream flows, dilution and temperature impacts, dissolved oxygen rates, cumulative effect of non-point discharge and return flow, and the effect of diversions on flow rates required to dilute existing or planned water usages, all signal an increasing complexity in the water quality and water quantity realm.

RECENT AMENDMENTS TO CWA

The recent amendments to the Clean Water Act establish Indians as sovereign bodies, identical to states, for purposes of establishing stream standards for waters passing through their territories. (Water Quality Act of 1987, Pub. L. 100-4, §506(e) 101 Stat. 77, 1987.) Under the amendments, Indian water standards for waters entering their boundaries may impact upon upstream discharges. See, e.g., Lake Erie, Etc. v. U.S. Army Corps of Engineers, 526 F. Supp. 1063 (1981) (CWA provisions requiring notice of potential discharge to downstream states for downstream determination of whether "such discharge will affect the quality of its waters so as to violate any water quality requirement in such states"). Currently, where a stream crosses state boundaries, the National Pollutant Discharge Elimination System (NPDES) permit is issued by the state where the discharge occurs. However, the permit includes requirements that the discharge meet the downstream state's water quality standards. (See attached portion of an NPDES permit which requires discharges into the San Juan Basin to comply with Colorado River salinity standards.) Thus, the downstream state, in addition to establishing its own standards, may establish guidelines that will set policies for discharge levels which may be allowed for upstream states.

The provisions of the amendments requiring that Indian tribes be treated as states envision a procedural mechanism for establishing mutual understanding between tribal and non-tribal standards. Hopefully, the procedural mechanism to be established pursuant to the amendments will assist in solving disputes where a permitted upstream discharge would not meet downstream standards. However, the potential that existing, renewal, and new NPDES discharge permits will have to be altered to meet downstream standards, is very real. In order to determine whether an upstream discharge will meet a downstream standard, it is necessary to incorporate scenarios of flow rates which will dilute the upstream discharge before it reaches the downstream measuring point. This dilution factor threatens to commit existing water to provide regulated diversions and planned return flow. It may also limit the types of non-point return flow of current or future uses of already appropriated water. Although the Clean Water Act itself does not control non-point discharge, or existing water rights, the types of diversions and return flows of existing rights may be controlled by the downstream quality standards. This scenario would approximate the impact of public trust instream flow, and federal reserved right instream flow doctrines. New Mexico has not been forced to deal with this type of water quality/quantity interrelationship yet.

NEW MEXICO SUBSTANTIVE LAW REGARDING THE INTERRELATIONSHIP BETWEEN QUANTITY AND QUALITY

1. The Permit Procedure for New Appropriations, Change of Location and Transfer.

   A. "Impairment."

   In New Mexico, the permit procedure for change of location has acknowledged that under the impairment standard, change of location which may harm the quality of existing water rights without impairing the quantity may be denied. City of Roswell v. Reynolds, 86 N.M. 249 (1974); City of Roswell v. Berry, 86 N.M. 110 (1969); Stokes v. Morgan, 101 N.M. 195 (1984).

   In the City of Roswell v. Reynolds, the court stated,

   > We are also concerned with impairment by reason of increase and salinity of the water by reason of a lowering of the water table.

   86 N.M. at 253, City of Roswell.

   The court found that allowing the change of location for permitted city rights would increase the salinity level at the new location. The impact of allowing ground water diversion at the proposed location would result in:

   > The upward movement toward the wells in that vicinity of waters of greater salinity found in the lower portions of the artesian aquifer and in a lateral movement from the north and east toward wells of waters of greater salinity.

   The court also looked at the result of increased salinity on crop yields in the moved to area. Thus, the New Mexico Supreme Court has clearly held that degradation of water quality caused by increased salinity of wells in the region of the new location constitutes impairment.

The impairment standard in the permit process for change of location, transfer, and new appropriation is identical. The burden is on the applicant to prove that no impairment will occur if the permit is granted. The decision in City of Roswell v. Berry applies across the board for all of the permits that incorporate an impairment standard. There has not been a decision regarding extracted water from a surface flow (decreasing available dilution and increasing salinity) that has been denied on impairment grounds. Nonetheless, City of Roswell v. Berry implies that if an appropriation from either a surface or a ground water source did in fact diminish existing water quality levels, the infringement could constitute impairment and thus provide a basis for denying an application.

B. The "public welfare."

The "public welfare" standard is incorporated in each of the permitting procedures involving appropriations, transfer, and change of location for ground and surface waters. The standard may also provide a basis for denying applications that would have an adverse impact upon not only existing water rights users, but upon other parties who have standing to challenge the proposed permit. Sections 72-5-6, 72-5-24, 72-12-3, 72-12-7, NMSA 1978 (1985 Repl. Pamp.). The standing provisions under the new "public welfare" guidelines are very broad.

> Any person, firm, or corporation or other entity objecting that the granting of the application will be contrary to the conver-sation of water within the state or detrimental to the public welfare of the state and showing that the objector will be substantially and specifically affected by the granting of the application shall have standing to file objections or protest.

Section 72-12-3 N.M.S.A. 1978 (ground water); } 72-5-5 N.M.S.A. 1978 (surface water). Certainly there is ample precedent from other states, impairment decisions, and the broad public interest statement[1] that would allow protesters to argue that a change of location, a transfer, or a new appropriation would be against the public interest. Those changes which substantially impact existing flow rates required to dilute NPDES discharge or accumulated non-point discharge would fall in this category. The New

Mexico permit procedure allows parties to oppose permits based on water quality concerns.

2. Do Water Rights Under the Treaty of Guadalupe Hidalgo Contain a Water Quality Protection Element?

There are potential lines of argument for supporting the proposition that water rights based upon the Treaty of Guadalupe Hidalgo, (including Pueblo Indian rights)[1] and other rights predating the treaty (such as water rights to a land grant or community) may have an inherent water quality element. It may also be demonstrated that the uses for which the water has historically been put to use, may themselves contain an implicit water quality element. Neither of these arguments has been explicitly tested by a New Mexico court. However, the decisions in State of New Mexico, ex. rel. Reynolds v. Aamodt, 618 F. Supp. 993 (D.N.M. 1985), and State of New Mexico v. Aamodt, 537 F.2d 1102 (lOth Cir. 1976) cites, as well as U.S. v. Abeyta, 632 F. Supp. 1301 (D.N.M. 1986) give some support for proponents of both lines of argument.

A. Treaty-Based Water Rights Under Spanish-Mexican Water Rights Law Contain a Water Quality Element.

The decisions in Aamodt clearly indicate that a court defining the rights to water from a distribution and delivery system under Spanish-Mexican law, prior to the 1848 Treaty of Guadalupe Hidalgo, must be examined in light of the Repartiamento system which allocated and distributed water. Whether or not this system recognized and protected rights to a given quality of water has not been addressed. The findings of fact and conclusions of law set forth in the Aamodt decisions contain language very similar to the impairment language under the New Mexico statutes, which generally protect water allocation rights from "injury."

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[1] A trial court, in the decision of In re Howard Sleeper, et al., No. RA 84-53C (April 16, 1985, Court of Appeals Docket No.) denied a water transfer based upon the public interest standard after considering cultural impact. Environmental, water quality impacts seem to be equally part of the public interest as cultural dislocation. Thus, under both the impairment and the public welfare provisions of the New Mexico permit procedures involved in appropriations, transfers, and change of location, seem to indicate that future appropriations, transfers and change of location will be considered in terms of the water quality both in terms of impact upon the uses in the existing area, as well as the proposed transfer or change of use location.

The historical roots of the term, "harm" may or may not include a right to a quality of water. See Conclusion of Law #10, Aamodt (1985).

> "... All other persons received an allocation of water for irrigation based upon the relative needs of all users and the application of the principle of non-injury, that is, that no one's use of water should result in injury to another person."[2] 618 F. Supp. at 998.

Under the rationale of the Aamodt decisions, the meaning of "injury" may need to be determined on a case-by-case basis. Perhaps at some point, a general understanding will be reached as to whether water allocations protected under the Repartiamento system included a water quality element. Until clear guidance from an appellate court is given, the issue will remain open.

B. A Treaty-Based Right Includes Quality Implicit in the Particular Usage.

Other rights protected by the treaty, including protection of religious rights, and, perhaps, fishing, hunting, and environmental rights, may dictate a sufficient water quality to meet these treaty-protected uses. The Treaty of Guadalupe Hidalgo guaranteed the protection of liberty and property rights of Mexican citizens residing in the conquered territory, as well as "the free exercise of their religion without restriction." The few cases that have interpreted this language have determined that traditional water rights will be respected. Aamodt, supra. A 1986 New Mexico Federal District Court decision, U.S. v. Abeyta, 632 F. Supp. 1301 (D.N.M. 1986) held that the religious protections guaranteed by the treaty allow Pueblo Indians to violate federal statutes regarding the killing of bald eagles, unless Congress specifically states that the religious protection does not apply. The implication from this decision may be that religious rights, which rely upon a quality of water, such as baptismal ceremonies or the like, may be protected under the treaty. In U.S. v. Abeyta, the court looked to traditional, religious uses of bald eagle feathers and found these uses were protected by the treaty. Under treaty interpretation rules, Congress must specifically abrogate these rights through federal statute in order to override the treaty provisions.

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[2] *perjuicio* is the Spanish term used to denote injury in several early documents. See, Water Ordinances For Salamanca, March 24, 1610, approved by the Viceroy January 22, 1611; Petition of the Fiscal of Mexico, June 26, 1643.

The court in Abeyta alluded to hunting and fishing rights, stating, "the Court need not and does not decide what hunting rights might attach to the New Mexico pueblos by virtue of the 1848 accords between the United States and Mexico." It has been and will continue to be argued that hunting rights and fishing rights may have been considered property rights under Spanish-Mexican law. These rights cannot be infringed upon by activities that interfere with the quality of water; activities that may eventually impact upon either the fishing or hunting habitat or species. Since there is no appellate decision on these particular issues, especially none which address the New Mexico pueblos' rights to water quality for particular uses under Spanish-Mexican law, this area remains at issue and may provide another avenue for protection of water quality by tribes.

C. Are Treaty-Based Rights Immune from the Public Trust?

An added consideration of the relationship between treaty-based property rights and water quality, may be that such rights are not equally susceptible to governmental exercise of doctrine like the public trust. In Summa Corporation v. Calif. ex rel Lands Commis., 466 U.S. 198, 80 L.Ed. 2d 237 (1984), the U.S. Supreme Court decided that title based on rights ensured by the Treaty of Guadalupe Hidalgo was immune from the California easement asserted under the public trust doctrine. The court stated "'sovereign' claims such as those raised by the state of California in the present case must, like other claims, be asserted in the patent proceedings or be barred." In California, all title based on the treaty was determined in federally mandated patent proceedings (Act of March 31, 1851). The court held that these proceedings established title and could not at a later date be subjected to the public trust. This case provides an interesting parallel to rights determined in New Mexico stream system adjudications. Must public trust interests be raised during the adjudication or be barred under Summa Corp.?

Avenues for protection of water rights derived from Spanish-Mexican law, as incorporated by the Treaty of Guadalupe Hidalgo, may be available. Whether these rights would override an existing or proposed upstream or ground water diversion, eventually impacting upon the protected uses, is an open question. Nonetheless, it must be considered that these potential uses could further circumscribe diversions, return flows, or cumulative non-point discharge because water flows reaching the tribal boundaries may be affected and negatively impact the water relied upon for tribal uses. Further, are tribal rights, if quantified in an adjudication, immune from public trust?

3. Public Trust Doctrine.

New Mexico, along with a handful of other Western states, has not recognized the public trust doctrine as embodied in the California decisions of National Audubon Society v. Superior Court of Alpine County, 189 Cal. Rptr. 346, 658 P.2d 709 (1983) and U.S. v. State Water Resources Control Board, 227 Cal. Rptr. 161 (Cal. Appeals, First District 1986). These cases have held that water rights are granted, subject to a public trust which may allow a governmental agency, at a date subsequent to the permit and after long-standing application of given quantities of water has been maintained, to invoke the public trust and diminish or otherwise alter the existing usage in order to provide water flow and quality levels to protect public interest. These cases obviously walk the cutting edge between the taking of private property by a governmental entity and legitimate government regulation and control of public resources. New Mexico has not adopted nor rejected these specific public trust arguments. However, the public welfare provisions in the appropriation, transfer, and change of location permit procedure discussed supra, closely resemble the public trust language. A governmental entity could easily promote public trust-like values within the existing New Mexico statutory framework on permit applications.

The critical question is whether an existing use may actually be curtailed or otherwise circumscribed when the existing user does not apply for a permit but merely desires to maintain a continuing use. The California decisions indicate that the state administrative body may infringe upon and curtail existing usages outside of the permit process. There is no New Mexico authority which would allow governmental bodies to accomplish this type of public trust curtailment. Nonetheless, amendments such as the recent amendments to the federal Clean Water Act, come very close to allowing, or forcing, state regulatory bodies to accomplish what is the equivalent of a public trust doctrine: that is, imposing restrictions upon existing usages in terms of diversion, cumulative non-point source discharge and return of flow. Thus, it is critical that federal and state statutes which require administrators to provide or meet water quality standards be recognized as potential actions which may curtail or limit existing usages in order that flow and discharge rates may be controlled to meet downstream standards.

4. Federal Reserved Water Rights and the So-called Secondary Federal Reserved Water Rights.

The landmark case of U.S. v. New Mexico, 57 L. Ed. 2nd 1052, 438 U.S. 698 (1978) firmly concluded that federal acts establishing federal reserves must clearly indicate the desire to reserve water for given usages. Otherwise, such water rights will not be implied nor granted to the federal government. This decision affirmed the New Mexico Supreme Court decision of Mimbres Valley Irr. Company v. Salopek, 90 N.M. 410 (1977). The Mimbres decision held that the original purposes for the Gila National Forest did not include recreational purposes and minimum instream flows.

The U.S. v. New Mexico decision has been followed in numerous cases to limit federal reserve water rights. However, the strength of U.S. v. New Mexico has been called into question by the decision in Sierra Club v. Block, 622 F. Supp. 842 (D.C. Colo. 1985) which found that where wilderness area is designated by the Wilderness Act, unappropriated water rights are reserved by the Federal Act. This decision threatens to enlarge greatly the scope of federal reserved rights for, at least, the lands reserved by the Wilderness Act.

In the one New Mexico decision since Sierra Club v. Block, the Special Master in State of New Mexico v. Molycorp of America, C79780C (Red River) (March 27, 1987) firmly rejected the rationale of Sierra Club v. Block. The U.S. claimed rights reserved under the Wild River and Wilderness Act for waters being adjudicated in the Red River Adjudication. The court relied upon the language of the federal acts to deny the claims.

> "Nothing in this chapter shall constitute an express or implied claim or denial on the part of the Federal government as to exemptions from state water laws." The Wilderness Act in 16 U.S.C. 1133 has identical language. This disclaimer negates any intent by Congress to make a reservation of water rights in derogation of state water laws.

The court noted that authorities have held that Congressional intent is not to be implied to declare reserve rights even where there is no express disclaimer, as is in the Rivers and Wilderness Acts. The court relied upon these authorities to "give(s) support to the wisdom of ignoring the implications of Sierra v. Ling (Block)." Thus, the Special Master in the Red River Adjudication squarely rejected the Sierra v. Block rationale and decision. As such, New Mexico is, for the time being, without a strong decision implying a reservation of water rights for federal reservations. The implications of a decision like Sierra Club v. Block on existing water rights threaten not only the quantity of existing uses if a priority date of the time of the reservation is given to the federal reserved right; but, in addition, the federal reserve right, particularly if it includes an instream flow, may curtail and circumscribe existing uses so that the instream flow, perhaps of a required quality, may be maintained to satisfy the prior federal reserve right. While this problem has not arisen to a great degree yet in New Mexico, it may, particularly with the pending review of Sierra v. Block.

5. State Legislation.

The New Mexico Legislature has adopted an El Rio Chama Scenic and Pastoral River Statute. The state legislature has not established instream flow of protections under the El Rio Chama Scenic and Pastoral River. This statute requires that certain sections of the Chama River and its tributaries be managed in a cooperative effort with federal agencies to "protect the River's natural values." The statute specifically states that, "nothing in the El Rio Chama Scenic and Pastoral Act shall be construed as being incompatible with existing state property laws. Nothing shall be construed to be incompatible with regulation of river flow for flood control or beneficial uses of water." Thus, the statute clearly attempts to safeguard existing beneficial uses. The potential for state legislation to infringe upon existing uses has been demonstrated in other Western states where minimum instream flow statutes or state versions of Wilderness and Wild and Scenic River designations have been enacted. These include reservation of unappropriated water rights, and, perhaps, a circumscription of existing water rights, to provide instream flow to satisfy the uses of the river systems. New Mexico has not gone this far yet, but it should be noted that if it does, or if water quality protection for water flowing in New Mexico Scenic Rivers is adopted, existing beneficial uses may be impaired.

6. What Does the Growing Interrelationship Between Quality and Quantity Mean to Persons and Entities Involved with Water Distributors and Allocation?

A. Technical support.

Technical support includes hydrologists, environmental, civil, and waste water treatment engineers, and other water technicians. Sound knowledge and expertise of the interrelationship between water quality and quantity is absolutely required when preparing to advise parties on the impacts of water projects, changing water uses, and new appropriations. In addition, technological understanding is required in the evaluation of the impact of permit applications, legislation, and of case decisions.

B. Water administrators and policy makers.

Quality concerns within water quantity distribution and allocation will become increasingly sensitive. Balancing the constitutional protections against taking of private property with the traditional lack of concern of water users with meeting water quality concerns will prove challenging for water managers. As with water technicians, an understanding of the technical interrelationship between water quality and quantity will be critical. Also, understanding the various rights, responsibilities, and interests of private water users, as well as environmental, recreational, and aesthetic concerns, will be required. Mandated state, federal, and local guidelines may prove to be extremely difficult and complicated to follow.

Understanding water rights in terms of the consideration of all various parties' claims to the resource as opposed to the traditional, narrower view of water rights as a right to a quantity from a distribution system may prove to be the wave of the future. It should be noted that one of the new case books that previously may have been called a water rights case book or the like, is now entitled "Legal Control of the Water Resources." Sax, Legal Control of Water Resources: Cases and Materials, 1986.

C. Private water owners.

Private water owners should be increasingly concerned with the impact on their traditional private property rights, of state, federal, and local regulations, as well as statutory changes that allow other parties to become involved in the permit procedure. Some of this regulation is clearly allowable, but there may come a point where this regulation constitutes the taking of a given, existing property right. For example, in California, persons are required by the public trust to change their existing water uses and, in effect, to buy more water rights to cover existing water uses. This may constitute the taking of an existing property right. Two recent U.S. Supreme Court decisions have narrowed the allowable impact of government regulation which will survive a takings test. The decisions may provide guidelines which will further delineate the proper parameters for government regulation that concern infringement of private water rights. First Evangelical Lutheran Church of Glendale v. County of Los Angeles, California, 482 U.S. ___, 96 L. Ed. 2d 250 (June 9, 1987); Nollan v. California Coastal Commission, 438 U.S. ___, 97 L. Ed. 2d 677 (June 26, 1987). On the other side of the issue, private water owners may want to start considering ways in which they can protect their rights to a quantity of water given certain quality standards. The New Mexico stream system adjudication procedures allow for rights to be defined "by any other means which are necessary to properly identify the right." Section 72-4-19 N.M.S.A. 1978.

Perhaps, as water users go through costly, lengthy adjudications to protect and quantify their existing water rights, they might want to consider providing a water quality element. This will require other users on the system not to interfere with their right to receive a given quality of water, satisfactory to their traditional water use. For example, growers involved in sensitive agricultural operations may want to have a guarantee of a water free of high salt content. This is particularly true if they have been receiving water free of salt and have relied upon and invested in operations which depend upon salt-free water. This scenario may provide an example where the private water user may actually want to use some of the doctrines pointed out in this paper in attempting to protect a given quality of water for an existing use.

CONCLUSION

The interaction between water quality and water quantity means that water allocation and distribution will be subject to water quality controls. This will impact upon traditional water rights. The increased and well-defined role given to Indian tribes under the recent amendments to the Clean Water Act to set downstream NPDES water quality standards is one example of quality controls which could impact upon traditional water rights.

Permit No.

AUTHORIZATION TO DISCHARGE UNDER THE
NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

In compliance with the provisions of the Federal Water Pollution Control Act, as amended, (33 U.S.C... 1251 et. seq; the "Act"),

is authorized to discharge from a facility located near Farmington, San Juan County, New Mexico

to receiving waters named the Animas River; then to the San Juan River in Segment No. 2-403 of the San Juan River Basin

in accordance with effluent limitations, monitoring requirements and other conditions set forth in Parts I (5 pages), II (14 pages), and III (1 page) hereof.

This permit shall become effective on October 13, 1986

This permit and the authorization to discharge shall expire at midnight, October 12, 1991.

Signed this 12thday of September 1986

for Oscar Cabra Jr.
Myron O. Knudson, P.E.
Director, Water Management Division (6W)

PART III
OTHER CONDITIONS

A. Salinity (TDS) is determined by the "calculation method" (sum of constituents) as described in the latest edition of "Techniques of Water Resources Investigations of the United States Geological Survey - Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases."

B. This permit shall be reopened and modified to comply with the Colorado River Salinity Standards if the TDS monitoring indicates that these standards are being violated.

SOUTHWESTERN INDIAN WATER RESOURCES MANAGEMENT: ISSUES AND STRATEGIES FOR ASSURING CLEAN WATER

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INTRODUCTION

Southwestern Indian water quality management is a complex subject encompassing many ideas. It includes: (1) identification of ground and surface water resources; (2) measurement and recording of water quality information; (3) development of water laws or codes for the establishment of water quality standards; (4) issuance of permits to control water use, quality, and quantity; (5) eventual creation of an Indian water management body to administer codes and participate in their enforcement; and (6) identification and utilization of federal, state, and local assistance and funding sources along with the creation of Indian funding sources.

In 1970, the federal government announced a national policy of self-determination for Indian tribes and in 1975, the commitment was signed into law as the Indian Self-determination and Education Assistance Act. Indian self-determination applies to tribal self-government and to the actions or states of a tribe as determined by that tribe without interference from the U.S. government. To ensure a clean and safe water resource, the tribes must begin to understand their water quality information, problems, needs and goals, and then begin to develop a water management body. The U.S. Bureau of Indian Affairs (BIA) and Indian Health Service (IHS) will provide water quality data, water resources inventories, and cooperative studies to assist the tribes in self-management. The Environmental Protection Agency (EPA) will also provide assistance as directed in the Safe Drinking Water Act and Clean Water Act. The EPA assistance includes programs in cooperation with state, local, tribal and other agencies to promote research, training, investigations, funding, and regulatory guidance to understand causes, effects, extent, prevention, reduction, or abatement of water pollution in protection of tribal water quality. Additional assistance is provided from other federal, state, tribal and local sources.

The U.S. Congress recently passed two amendments, one to the Safe Drinking Water Act (SDWA) in 1986, and one to the Clean Water Act (CWA) in 1987. These amendments include provisions to allow recognized U.S. Indian tribes to participate as states in the acts and obtain assistance and funding from the EPA for the management of their water resources. A tribe applying for state status must be recognized by the federal government; the tribe must have a federally recognized governing body carrying out substantial governmental duties and powers over federally reserved lands.

The BIA is directed by statute to protect the water resources on Indian trust lands. However, Congress did not require the BIA to protect Indian water resources in either the Clean Water Act or the Safe Drinking Water Act. Therefore, the BIA has recognized its unique role in the management of tribal water resources to protect Indian water in the following ways: (1) assist tribes in attaining management capabilities in accordance with the federal trust responsibility to protect Indian water resources from loss; (2) utilize limited budget for tribal water resources management planning; (3) encourage tribes to work with the federal agencies charged with the responsibility of addressing the water quality management and protection issues; (4) encourage and aid tribes in forming cooperative agreements among tribes, EPA, BIA, IHS and other agencies; (5) where cooperative agreements obligate tribes to co-manage water resources under special water codes, the BIA will consider approval of such codes on a reservation-by-reservation basis; (6) with respect to a tribe's primary enforcement responsibilities, the BIA will support tribal efforts to establish apolitical forums for resolution of violations of the CWA and SDWA and for other primary enforcement responsibilities which the tribe seeks to achieve with EPA guidance; and (7) support tribal participation in all technical operations required by the EPA in its enforcement of the CWA and SDWA. The BIA supports the goal of Indian self-determination of the management of tribal water resources and will not attempt to speak for tribes or assume their role as managers of their water resources, if the tribes have established the capability to act on their own behalf.

Southwestern Indian water management also means identifying the role players who will aid the establishment and development of a comprehensive tribal water quality (and quantity) management plan. These role players include talented tribal personnel, technical and legal consultants, state and local water agencies, regional water groups who may share the same aquifer or ground water basin, and the federal agencies whose trust responsibility to the Indian tribes includes the protection of their water resources until full Indian self-determination of the water quality protection scheme is achieved.

Federal Trust Responsibility

The federal government views its trust responsibility to Indian tribes as the management, protection, and development of the tribe's natural resources until tribal participation and administration of programs is achieved. The BIA Albuquerque Area Office (one of 12 BIA regional offices with an administrative area which includes New

Mexico, parts of Arizona, Colorado and Texas) and other federal agencies have developed a basic understanding of major southwestern tribal water quality management issues because they have assumed their trust responsibilities and have assisted the tribes in solving many water quality problems. The water problems dealt with in this area office usually involve contamination of a ground water resource used for irrigation, livestock or domestic use.

<u>Tribal Water Quality Management Issues</u>

Due to the recent amendments to the Clean Water Act and Safe Drinking Water Act, the BIA believes tribal development of water management programs will require federal assistance from agencies including BIA, IHS, EPA and U.S. Geological Survey (USGS). In some cases, the complex regulatory programs must be developed and operational within a few years. The BIA Albuquerque Area Office has identified several Indian water quality management concerns including: (1) the small populations of the New Mexican Pueblos and other Indian bands and communities; (2) the sometimes very small tribal economic base; and (3) the lack of hydrologists, geologists, and engineers within some of the Indian nations.

However, by necessity, the pueblos and reservations are training water managers and technicians as water pollution problems threaten their water supplies. Many of the New Mexican Pueblos situated along the Rio Grande are dependent upon the Rio Grande as an irrigation resource and upon ground water as their major domestic source. An exception to this demographical and geographical set includes the Navajo Nation which has a comprehensive water code, a substantial annual income, dependency primarily on ground water, and use of their own native engineers, water managers and scientists. The Jicarilla and Mescalero Apache tribes of New Mexico are also distant from the Great River (Rio Grande), but utilize some surface water sources as well as their primary source of ground water. These tribes also have somewhat larger populations than the Rio Grande Pueblos, and depend heavily on natural resources development and/or tourism for economic stability. Other tribes not dependent on the Rio Grande include the Pueblos of Acoma, Laguna, Zuni, Jemez, Zia, Tesuque, Nambe, Pojoaque and Picuris. These Pueblos depend primarily on ground water for domestic and other uses. In contrast, the Southern Ute and Ute Mountain Ute Tribes in northwestern New Mexico and southwestern Colorado depend primarily on surface water sources for domestic and other uses.

Another important issue is that nearly all Indian lands administered through the BIA Albuquerque Area Office are experiencing some water quality problems. Federal standards for obtaining and ensuring the quality of surface and ground water are just now being implemented. A complex addition to the water quality problem is the water quantity problem; New Mexico's ground and surface water rights are being quantified through adjudication. The Albuquerque Area Office is preparing at least six adjudications involving New Mexico's designated basins defined by surface water sources.

Indian Water Codes

When a southwestern Indian tribe wishes to develop a water code it must (1) have knowledge of its tribal water rights including amount of water quantified, if available; (2) determine present and projected water needs; and (3) identify and understand its local economic base, and the base of competing water users. A tribe also must gather ground and surface water quality data, determine areas that need to be sampled, and develop a sampling program. The water code must be developed on the basis of current legal requirements including (1) determination of tribal water rights; (2) development of the code through the tribal legislative process; (3) identification of relevant CWA and SDWA conflict-of-interest issues; and (4) development of an independent water agency to enforce programs if conflict-of-interest is determined. The creation of an independent tribal water agency is encouraged as it would enable tribes to master management skills, avoid certain conflict-of-interest situations related to tribal enforcement of programs, and administer programs without being affected by tribal elections.

Some tribes may not have the structure or population to form a non-political water agency or may wish to administer programs but not enforce them. The BIA suggests that these tribes may work under a memorandum of understanding with the EPA for EPA enforcement or serve on federal boards which could be charged with civil violation enforcement responsibilities.

Costs associated with administrative, regulatory, and enforcement duties should be considered when developing a water code. It must be realized that very little income, except for permit and license fees, will be received to support the water program. The tribal water agency should identify and apply to federal clean water programs that provide funding. Furthermore, the agency should utilize services provided by the IHS and BIA. The IHS develops, operates and maintains the tribal public water supplies and waste treatment systems. The BIA is a source of historical water data, including quantity, quality, and water use data, and data concerning current water development systems.

The Clean Water Act and Safe Drinking Water Act, Issues and Strategies

The aforementioned has provided information on southwestern Indian water management issues stemming from the basic tribal need to manage their own valuable water resources. Programs within the CWA and SDWA provide national water quality management goals and the steps to achieve them. For example, the acts provide for cooperative agreements among various groups that play a role in helping tribes maintain clean water.

The goal of the Clean Water Act is to restore and maintain the chemical, physical and biological integrity of the nation's surface and ground waters. The act provides water management schemes in the form of surface water and effluent standards as part of the protection of surface water quality. The goal of the Safe Drinking Water Act is to develop and enforce monitoring and reporting requirements to restore and maintain safe drinking water, and to protect surface water and ground water that are or potentially may be used as drinking water supplies.

A general description of the Clean Water Act sections which apply to recognized Indian tribes is given in section 518 of the 1987 CWA amendments. The Clean Water Act programs that include tribal participation are water quality management planning (Title I), construction of wastewater treatment works (Title II), adoption and enforcement of water quality standards and protection of water from point and non-point source pollution (Title III), and the National Pollutant Discharge Elimination System (NPDES) permit program (Title IV). This new policy for involvement of Indian tribes firmly establishes the congressional and federal agencies' intent to assume their trust responsibilities and assist Indian tribes in the prevention, reduction, and elimination of water pollution. The United States goal for Indian water management is to promote Indian self-determination by gradually withdrawing from each water quality management program as the tribe acquires the expertise to manage its water resources and implement protection schemes.

Specific sections of the CWA allowing involvement of recognized tribes include the following: Section 104 and 106 of Title I define the CWA goals and policy, all of Title II explains the grant process for construction of water treatment works, Sections 303, 305, 308, 309, 314 and 319 of Title III describe stream standards and other water quality standards and methods of enforcement, and Sections 401, 402 (NPDES permits), and 404 describe different permits and licenses for actions that may alter the natural environment but which should be utilized to protect affected water quality.

<u>Clean Water Act Programs</u>

Section 518 of the new amendments emphasizes several important ideas described in more detail within Titles I, II, III, and IV. These concepts include a discussion of the EPA and IHS programs for the assessment of waste treatment management programs, the reservation of specific funds for Indian programs, cooperative agreements, and the definition of the "treatment as states" concept. Section 518 defines an Indian tribe as any tribe, band, group or community recognized by the Secretary of the Interior, and which also exercises governmental authority over federally reserved Indian lands.

The EPA and IHS are assessing tribal needs and obstacles concerning sewage treatment works. Also being reviewed is the possibility of funding under Section 205 and/or for inclusion on priority lists under Title II, Section 216. The EPA must submit an assessment by February, 1988, to Congress with recommendations regarding (1) EPA assistance to develop waste treatment management plans to construct treatment works, and (2) methods to involve the Indian tribes in the administration of Title II programs.

The EPA will be reserving funds specifically for Indian water quality management programs. Half of one percent of the sums appropriated under Section 207 and described in Section 205 (funds development and implementation of waste treatment management programs) is authorized for Indian tribes. This section reserves funds for grants only for the development of waste treatment management plans and for the construction of sewage treatment works for use by the Indian tribes.

Another important concept in CWA Section 518 is the discussion of cooperative agreements between the state(s) and tribe(s) for purposes of the CWA programs which regulate surface water quality. The EPA encourages cooperative management programs and will intervene when disagreements occur over such matters as different methods of determining stream standards, and different stream standards for shared water bodies.

The "treatment as states" concept discussed in Section 518 states that Indian tribes may be treated as states under the noted CWA sections if they meet the following requirements: (1) the Indian tribe must be recognized by the Secretary of the Interior and exercise governmental authority over the federal Indian reservation or pueblo, (2) the structure of the tribal governing body or the governing body itself has substantial duties and powers, (3) the Indian tribe exercises its functions within the borders of its lands, and (4) EPA judges the tribe to be reasonably capable of carrying out the duties set out in the CWA. The BIA has most of the documentation to aid the EPA in its determination of the tribes' capabilities for participation in the CWA programs.

Funding Under the Clean Water Act

Funds will be allotted for use by recognized Indian tribes for treatment as states under Sections 106, 205, and 319 of the CWA. Section 106 provides tribal requirements including the development of water quality management programs allowing the EPA to make allotments based on tribal pollution control programs. The tribes must meet other requirements, including the reporting of (1) a water quality inventory, (2) pollution sources, (3) a summary of their pollution control program and (4) information on tribal water treatment works for determining priority funding. The EPA is discouraging tribes from contracting out management services under any of the CWA or SDWA programs. Therefore, the BIA has commented to the EPA several times regarding the scarcity of tribal technical staff including engineers, hydrologists, geologists, and chemists. Although smaller pueblos often have experienced water managers, technical experts may need to be hired.

The BIA has assisted tribes in the northwestern United States and Great Lakes area in their development of cooperative tribal fisheries commissions for management of fisheries resources within a shared watershed. These commissions have facilitated the concentration of technical expertise and allowed the represented tribes to share interests and views in program planning and implementation. These successes in fisheries management may be translated to water quality management and become models for water quality management planning in the southwest.

The BIA has presented another strategy for developing increased funding by citing draft SDWA regulations which allow for an increase in the federal share, and a decrease in the tribal share for funding certain SDWA programs. An eligible tribe must demonstrate that it does not have adequate funds before it can apply for and receive the increased federal share. The BIA is encouraging the EPA to provide similar funding flexibility to CWA regulations.

Section 106

Section 106 states that tribes must develop a water pollution control program within a two-year period. However, this two-year period may be too short considering the small population, economic base, and potentially large point and non-point pollution problems facing some of the pueblos. To meet the deadline, the BIA and the IHS may assist in the identification, characterization, and inventorying of water resources data, as well as point and non-point sources of pollution. Additional EPA assistance is described in the EPA Indian Policy Statement of 1984 which details EPA intent to aid the tribes in achieving the federal goal of Indian self-determination (and in this case the development and management of a water pollution control program). Assistance may also come from other pueblos or reservations that share a common watershed or an aquifer. These tribes may wish to join together and develop a cooperative water pollution control program.

Section 205

The EPA and IHS program for assessment of the need for sewage treatment works on Indian lands is discussed in Sections 518 and 205 of the CWA. The BIA Albuquerque Area Office is encouraging Indian tribes in the area to submit comments to BIA, IHS, and EPA on their sewage treatment needs. The BIA, IHS, and EPA assistance is vital in determining cost-effective measures, since these agencies have been responsible for some of the assistance for protection of water quality, and may have determined alternate measures for successfully maintaining good water quality.

Section 319

Section 319 is a new section to the CWA, and describes non-point source management programs. Indians submit a management program to the EPA for approval. The program must include a comprehensive non-point source assessment, targeting of specific waters with non-point source contamination, and development of a management plan. Part of the management plan should include identification of management practices for various types of non-point source pollution control.

For the purpose of assisting the tribe in implementing a management program, the EPA awards grants to a tribe after approving the tribe's assessment report and management program. Grants may also be authorized to tribes to carry out ground water quality protection activities as a part of the non-point source management programs.

Some Indian tribes may not have access to non-point source information required for Section 319 funding. These tribes may be able to obtain existing information from the BIA and IHS. The BIA has helped to complete Environmental Impact Statements (EISs), which define best management practices (BMPs) for restoring surface and ground water quality which had been polluted by point or non-point sources. To identify BMPs, the BIA utilizes procedures described in the National Environmental Policy Act (NEPA), Department of Interior (DOI) departmental manual on environmental quality, and BIA supplements to the DOI manual, as well as procedures defined in other environmental acts.

Due to their small size and lack of native technical personnel, some of the smaller pueblos may obtain technical research and reporting assistance as required in Section 319 by hiring consultants, cooperating with other tribes or states, and utilizing BIA, IHS, EPA and other agencies' technical assistance. The tribes' abilities to conduct research, demonstration programs, and training programs as outlined in Section 319 are generally limited without some initial direction and training from government or private agencies.

Safe Drinking Water Act Programs

The goal of the Safe Drinking Water Act is to develop and enforce monitoring and reporting requirements to restore and maintain safe drinking water. The basic Indian program under the SDWA is outlined in Section 1451 and includes reference to EPA's policy and treatment of the Indian tribes as states. The EPA policy considers two programs, the Underground Injection Control program (UIC), and the Public Water Systems program (PWS), for which recognized tribes may request and be delegated primary enforcement responsibility. Tribes must meet the criteria for recognition as states, in the same manner as for CWA programs. The EPA and the IHS are currently conducting a survey of drinking water on Indian lands, identifying problems, and the need for alternate drinking water sources. Other SDWA programs in which tribes may participate include the Sole Source Aquifer Protection program, and the Wellhead Protection Program.

Proposed rules have been published regarding Indian participation in the UIC and PWS programs. Due to the complexity of the SDWA and requests by some of the southwestern tribes for explanations, the BIA suggests that cooperative work groups could be created to decipher regulations and use past experiences to produce a realistic approach to the Indian regulatory structure. Tribes also emphasized that the EPA work groups should include representation from southwestern tribes, as well as from the BIA, IHS, and EPA. Management and identification of PWS or UIC problems have justified Memorandums of Understanding (MOUs) between tribes and federal agencies. The MOUs are an important link in creating water management bodies on tribal lands, providing data, and leading to the tribal formulation of a water code. MOUs may also be important for allowing the EPA to retain primary enforcement on Indian lands for programs which may result in conflict-of-interest situations including tribal criminal enforcement responsibilities. Under the PWS or UIC program, a tribe that obtained primary enforcement responsibility would be directed to enforce water quality standards for public water systems. The conflict-of-interest situation results when the tribe owns the municipal systems and would be policing itself. The EPA needs to consider that application for the PWS or UIC programs often indicates that the tribe itself is the owner or operator of a PWS or UIC well or system of wells.

The EPA suggests (in its draft regulations) that interested tribes establish an independent tribal commission or agency to manage the programs and thus avoid conflict-of-interest situations. Some of the New Mexico pueblos may not have the governmental structure, population, or economic status to form a non-political commission, and may wish to be involved only in administering programs and not enforcing them. Within the new SDWA proposed regulations, the EPA has developed some strategies to administer the SDWA programs in an efficient manner by not requiring the tribes to create and run their own certified labs, but, instead, to allow state or EPA certified laboratories to perform water analyses. A small tribal population or economic base could preclude the tribe from establishing such a program.

Role Players in the Tribal Involvement in the Clean and Safe Drinking Water Acts

Tribes often are the first to identify potential water pollution and may choose to take the responsibility, as set out in the CWA and SDWA amendments, for attaining or maintaining water quality within EPA standards for their uses, including domestic, religious, fishery, agricultural, industrial and other uses. If the tribe has primary enforcement responsibility, it must be able to monitor and understand water quality standards and the effects and control of discharges. The tribes may create a tribal water agency composed of nonpolitical or appointed staff that could overcome potential conflict-of-interest situations arising from tribal enforcement of some of the CWA or SDWA programs, and would provide continuity to the water management system.

A secondary role may be played by the federal government as trust officers for the protection of the Indians' natural resources. Federal agencies other than the EPA, IHS and BIA also may supply water quality data, provide training, or participate in tribal water management programs. For example, the U.S. Fish and Wildlife Service (FWS) has entered into a Memorandum of Understanding with some of the Rio Grande Pueblos and the BIA to share fish, sediment and water sampling work and analyses at stations along the Rio Grande.

The federal government may provide assistance at some point in the water management program for (1) identification and classification of aquifers by quality, quantity, use and source; (2) control of contamination sources including non-point and point discharges; (3) development and enforcement of numeric and narrative ground water or surface water standards; (4) control of land use (facility citing), with emphasis on the protection of recharge areas; and (5) a legal definition of tribal water resources. Due to possible pollution problems and by tribal request, the BIA has begun intensive ground and surface water quality sampling programs at some of the New Mexico Pueblos. The EPA, through federal regulations, encourages participation by state, federal and local agencies in order to save money, develop a common understanding of water quality goals, and provide expert information for the tribes.

The southwestern state governments may play a tertiary role in the development of CWA and SDWA programs on Indian lands. State responsibilities as outlined in the CWA and SDWA, are similar to those the tribes are striving to meet. The states' programs with the EPA include assessment of surface water quality based on stream uses, and those assessments of upstream and downstream reaches of rivers which may cross tribal land. State ground water protection may be achieved by monitoring and prescribing discharge plans, underground injection controls, and limiting land use which may contaminate or otherwise impair another existing water supply. Tribal and state water quality programs may include an exchange of data to help provide assessments necessary to maintain both the state and tribal water quality standards. Knowledge of the programs utilized by adjacent states or tribes, and general agreement on water quality criteria is essential. The EPA assumes the role of arbitrator if disagreements between the state(s) and tribe(s) occur. Local governments may have a role in Indian water quality management that is similar to the state role.

Consulting scientists, engineers, and attorneys will probably play a vital role in southwestern Indian water management. Though the EPA discourages contracting out for water quality management services, the tribes may not have the technical or legal staff necessary to operate a successful program. Experts may be utilized efficiently if tribes with common water quality interests form intertribal water commissions as part of their management planning.

Summary

The concepts of Indian water quality management include the identification of ground and surface water sources; the measurement and recording of water quality information; establishment of water quality standards; issuance of permits to control water uses, quantity and quality; development of water codes; creation of an Indian water management agency to administer codes and participate in their enforcement; and identification of funding and assistance from tribal, federal, state, and local sources. The CWA and SDWA amendments have created an avenue whereby recognized Indian tribes can participate in their own water management, thus achieving some self-determination. But the acts do not recognize the variety of Indian nations and unique governmental structures that are different from most state governments. The EPA is recognizing these tribal issues now and developing regulations which provide some flexibility. Strategies have been developed by the EPA and are recognized as the CWA and SDWA regulations are published. Strategies have also been developed by the IHS and BIA, whose trust responsibilities have included data gathering and data management for a wide variety of water quality issues, and by other government agencies in their willingness to share data and technical expertise. The new regulations, federal funding and assistance, state and local assistance, and the tribes' developed water management programs (perhaps with an Indian water management agency) will result in the eventual tribal self-determination of their water management programs.

URBAN PURCHASES OF WATER FROM FARMS: IS THE MARKET THE ANSWER TO WESTERN WATER SCARCITY?

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Traditionally western agriculture has joined other regional interests to obtain federal support for water supply projects. California's Imperial Irrigation District and the city of Los Angeles formed the coalition that pushed through the Hoover Dam, and similar coalitions have backed every large western water development project. We can see that this coalition was successful because virtually all of the high-potential sites for water and power development in the west have their dams and reservoirs in place. New water for the fast-growing sector of western municipal and industrial water users will have to come from some other source. The attention of western cities has turned to their former partners, the farms, as a source of new water supplies.

URBAN ACQUISITION OF IRRIGATION WATER RIGHTS

The first purchase of agricultural water by a western city was probably the acquisition of Owens Valley by Los Angeles, which began in 1904. Thirteen percent of the water supply for the Metropolitan Water District of Southern California (MWD) still comes down the Los Angeles Aqueduct from the Valley.[1] In the intervening 85 years, Los Angeles has been forced to purchase virtually the entire valley, sever the water rights, and sell or lease the property back. The transfer of water out of Owens Valley has given rise to many lawsuits, several still pending, to dynamitings and threats of violence, and to a local resentment of Los Angeles that is still strong.

The most recent acquisition of agricultural water for urban use may be the purchase of large tracts of land in La Paz County, Arizona by Phoenix, Scottsdale, and other central Arizona cities. The cities expect to pump La Paz County ground water and transport it through the Central Arizona Project to their service areas. Scottsdale bought the Planet Ranch on the Bill Williams River in 1985, Phoenix bought 14,000 acres including two towns in the McMullen Valley at the end of 1986, and there are daily rumors of new purchases in La Paz County by developers or by municipalities. A rash of community meetings, legislative hearings and the formation of rural water-defense groups reveals a deep concern on the part of La Paz citizens for the consequences of these purchases.[2]

New Mexico itself has three interesting agricultural water transfer cases: El Paso's application to appropriate large amounts of ground water from the Hueco and Mesilla Bolson in the Lower Rio Grande Basin;[3] Albuquerque's standing offer of $1000/acre foot for upstream surface water rights in the Rio Grande;[4] and the unique Sleeper case, in which the sale of an acequia right to a resort for snowmaking was found to be a threat to a unique and precious state resource, the cultural heritage of northern New Mexico.[5]

The impacts of these purchases on the source communities are complex and tied to water-use practices in western agriculture and the ways in which irrigated agriculture has affected the social and economic structure of western communities. A review of the origins and development of irrigation in the West will be useful before we turn to the question of community impacts.

WATER USE ON WESTERN FARMS

Both Bureau of Reclamation (BuRec) policies and the appropriations doctrine have contributed to an illusion that irrigation water is low cost. The federal government came into the western water picture at the turn of the century when private farmers, local districts and state irrigation projects had failed to extend irrigated acreage in the West beyond the 3.6 million acres or so of relatively easily irrigated land that had come under the ditch by 1889.[6] The Reclamation Act of 1902 was to be funded initially by revenues from sales of federal lands and later through sales of water to farmers.[7] Reclamation was enormously successful on the engineering front; its economic successes were less impressive. Water payments were originally to cover the project costs over a repayment period of ten years, without interest. In 1910, the Reclamation Fund received a $20 million loan to keep it from bankrupting;[8] in 1914, the repayment period was extended from ten to 20 years;[9] in 1921, Congress passed a resolution to allow farmers in arrears to receive water deliveries,[10] and by 1922, 60% of the irrigators with contracts with the Bureau were defaulting on their payments;[11] in 1924, repayment was extended to 40 years;[12] and in 1939, repayment was extended again, to 50 years, and water prices were adjusted according to "ability to pay," with the difference to be made up with revenues from hydroelectric projects.[13]

Repayment, as a percentage of the costs of BuRec projects that are allocated to irrigation, averaged between 20-31% in the period 1949-1977, depending on whether inflation is accounted for or not.[14] If there are other water users who would pay more than cost for the BuRec irrigation water, the percentage of *opportunity cost* paid by farmers is even lower. In 1970, one third of the irrigated acres in the 17 western states were supplied with low-cost water under BuRec contracts.[15]

Nonfederal western water allocation institutions also demonstrate a commitment to making water available to agriculture on easy terms. In order to legitimize investment in diversion and distribution works for irrigators and mines, appropriation doctrine based the right to water on beneficial use, rather than on location by a stream.[16] In many western states, beneficial use does not imply "conservative" use, so that irrigators with appropriative water rights have no incentive to conserve their water. Irrigators may even lose the right to water recovered by investment in ditch lining, better distribution systems, improved grading, etc., on the grounds that it is no longer applied to the beneficial use on which the right is based.[17] Ground water rights which arise from the rule of capture similarly reduce the apparent cost of water by eliminating the opportunity cost of future uses of water from the irrigator's accounts.[18]

IRRIGATED AGRICULTURE AND THE RURAL ECONOMY

The subsidy of irrigation water in the West has not had the envisioned effect of creating a region of yeoman farmers. Where agriculture is most productive, in California, Arizona, and Texas, the high fixed costs of irrigation are spread out over much larger farms; more pesticides, fertilizer and energy are used to guarantee the high crop yields that will cover the fixed costs, with the result that large amounts of agricultural capital leak out of the rural areas into the hands of agrichemical producers in other regions. In a recent Office of Technology Assessment (OTA) report, Dean MacCannell asserts that this drain is so severe that improvements in the agricultural economy are actually associated with deterioration in the rural community. He says:

> In our own studies, we have found depressed median family incomes, high levels of poverty, low education levels, social and economic inequality between ethnic groups, etc., associated with land and capital concentration in agriculture. ... The absence of a middle class at the community level has a serious negative effect on both the quality and quantity of social and commercial services, public education, local governments, etc. ... large-scale farm operators tend to bypass local public and commercial services and establishments, preferring to shop in distant cities and to purchase education, police protection and recreation, etc. from the private sector for their own exclusive use...

> If this evolution is permitted to proceed unchecked, the United States will soon have a high technology, heavily capitalized agricultural production system embedded in a rural society which is structurally similar to the Third World. Moreover, this arrangement will increasingly appear to be an intentional product of national policy.[19]

The status of the typical "common man" in the more successful agricultural regions of the West has become one of farm laborer rather than small farmer. In 1944, Walter Goldschmidt, a California sociologist, warned that when the size of a farm exceeds a family's ability to provide the main source of labor and management, agricultural income becomes disassociated from the rural community and generates social inequality and poverty. Recent studies such as the OTA report seem to confirm the Goldschmidt hypothesis. The huge seasonal labor pool required to harvest the crops on the large farms has created a migrant rural proletariat whose wages are kept below poverty levels by the availability of legal and illegal Mexican labor at low wages.

In those regions where large-scale agribusiness predominates, local communities lack the public and private infrastructure associated with self-government. Ironically, these already weak communities will be hardest-hit by changes in the local economy arising from sales of agricultural water.

In areas of the West where agriculture has been less profitable, particularly New Mexico, the concentration of farm sales on very large farms has been less severe. While New Mexico was not included in the MacCannell study, comparisons can be made between New Mexico and Arizona farms, for example, that indicate a difference. Average annual value of sales per farm in 1982 was $63,079 in New Mexico; $208,197 in Arizona. Distribution of sales is also more even across New Mexico farms than across Arizona farms. The dollar value of average sales per farm, for instance, on farms with annual sales below $15,000 was $3,538 in 1982 in New Mexico, higher than in Arizona, where it was $3,221. The situation is reversed for farms with annual sales above $100,000, where the average in New Mexico is $352,903; in Arizona it is $727,469.[20] The conflict of interest reported by MacCannell and others between agricultural producers and rural citizens dependent on agriculture-related incomes is probably less serious in New Mexico than it is in Arizona.

However, in any rural community where transferable water rights are owned by irrigators, a potential conflict of interest exists. If farmers, often in dire straits financially, stand to gain by selling water rights to nonlocal municipalities, the effect on the rural community of the export of local water is not likely to be fully incorporated into the farmer's decision to sell. An Arizona farmer who sold her land in the McMullen Valley to Phoenix put the farmer's position succinctly: "It just isn't good business to raise cotton that nobody wants with water that everybody wants. If it's not good business, it's not good farming."[21] At the same time, the sale of 14,000 acres of irrigated land in McMullen Valley to Phoenix took 10% of the taxable property in La Paz County off the tax rolls and raised a wide spectrum of concerns for the local community.

CONCENTRATION OF URBAN DEMAND

The attractiveness of agricultural water to municipal water managers depends on (1) the legal security of the water right that the city acquires and the legal liabilities that the city may incur; (2) the physical security of expected water deliveries to satisfy that right; (3) the cost of transporting the water from the rural area-of-origin to the city; (4) quality of the water; (5) the cost of ownership of the water right; and (6) the likelihood of political opposition of the water transfer. The first three conditions particularly tend to concentrate urban purchases in a localized rural area.

1. Legal Security of the Water Right: The procedure for acquiring and maintaining a legal right to water varies across the western states, but most states impose conditions on water rights that differ from those on other types of real property.

- Most prior-appropriations rights are forfeit if they are not used over a statutorily-defined period, so a water right must be exercised to be maintained, encouraging use of water which is not needed.[22]

- In Arizona, both surface and ground water rights are appurtenant to the land, though the location at which they are used may be changed. In order to maintain a water right, the rightholder must own the land to which the right is appurtenant. This means that any entity that wishes to acquire water rights must also become a landowner.[23]

- In Colorado, Arizona, Nevada, and Utah, the rights to water which is saved through conservation measures may not be sold, limiting the transferability of water.[24]

- Virtually everywhere, transfers of water rights are possible only if protected third party interests, such as those in return flows or ground water levels, are shown not to be injured. Since actual effects on third party interests are not known with certainty, the security of transferred rights is always threatened by possibly affected interests.

All of these legal qualities operate to maximize the impact of the transfer of agricultural water -- the purchased right must be used, whether it is needed or not; the purchaser may be forced to acquire land as well as water; it will be much easier to purchase water by extinguishing an existing use than by agreement to a conservation and exchange plan; and it is often easier and safer to buy out affected third-parties than to show noninjury.

2. Availability of Secure Water Supplies: Security of water deliveries where seasonal and annual flows are highly variable comes from three major sources: stored water, with security increasing with the size of the storage project; appropriative rights with early dates, particularly in major streams; and ground water. Much of the stored water in the West is under contract with the Bureau of Reclamation; while this water may become transferrable in the future, it is not at present.[25] Early priority water is much sought after -- the earliest priorities in the West are associated with Indian reserved rights which has an uncertain status as to transferability.[26] This leaves ground water. The ground water resource is not subject to seasonal variations as surface waters are; this security makes ground water supplies an attractive water source for municipalities.

3. Cost of Transport Concentrates Urban Demand: Urban purchases tend to concentrate in rural areas located near existing transport facilities, either natural stream beds like the Rio Grande, or public canals like the Central Arizona Project (CAP). Even where water rights are to be moved through exchanges instead of physical transport, purchases concentrate in areas where such exchanges may be made (along the Rio Grande or the Colorado River, for example).

While the total amount of agricultural water that can be absorbed by cities is small relative to total agricultural water use, these three factors will tend to concentrate urban demand in areas small enough to be heavily impacted by sales of water rights to cities.

Impacts of Water Reallocation on Rural Communities

These impacts take a number of forms, and may include erosion of the tax base, environmental effects, loss of income and weakening of local institutions, loss of political authority, and decay of community trust in due process and fairness of the water allocation system.[27]

Tax Base Impacts: Often the first loss felt by the exporting region is loss in tax base. This loss has two sources. First, many water importers are municipalities so that the lands or real property rights they hold are not taxable. If water rights purchases or purchases of land for the purpose of acquiring water rights are concentrated in a particular county or political subdivision, a significant share of the local tax base can be wiped out in a single transaction. Phoenix's purchase of the McMullen Valley area of La Paz County in December of 1986 took 10% of the County's taxable land off the tax rolls; up to 32% of the private land in La Paz County could be purchased for its water rights.[28] In 1945, the city of Los Angeles owned 98.84% of the private farmland in Owens Valley and 88% of the town property,[29] creating obvious problems for local government revenues. This situation eventually led to the passage of a constitutional amendment making municipal water-supply property in California taxable.[30]

Second, the reduction in agricultural and associated sales in the exporting area reduces assessed values, sales, and income, and further depresses tax revenues. Assessment rates are often limited by law, so that loss of tax base cannot be made up by raising taxes. For rural areas that are not yet incorporated, the loss of potential tax base can foreclose the opportunity for self-government. Without taxable property, townspeople can't incorporate, hire administrators, make collective decisions on matters that affect their lives.

Environmental Impacts: Purchases of either surface or ground water raise environmental issues. For surface water, instream flow conditions downstream of the urban diversion will be impacted. The results may include environmental degradation, loss of wildlife habitat, loss of recreational opportunity, economic and environmental losses due to degradation of water quality, and increased flood hazard. A sale of ground water rights from a farmer to a city may increase the level of long-term depletion of the aquifer and reduce the residual stocks left for future water uses in the area-of-origin, since the city can afford to pump at much greater depths than are justified by returns to irrigation water.

The retirement of agriculture on the land is another source of environmental impact. Cultivated lands in an arid climate do not revert to their natural state when they are abandoned. Dust, Russian Thistle (tumbleweed) and other nuisance weeds typically invade the once-cultivated land, imposing costs on neighboring farms and business and giving the area a look of poverty and neglect that may discourage transition of the land into nonagricultural uses.[31]

Income and social effects: The exporting region loses not only the incomes of the producers who sell their water, but also the incomes which depend on the producers--sales in the agricultural supply sector and production in agricultural processing industries as well as the local expenditures of farmers and employees of farm-related businesses. On the other hand, importing regions gain production in municipal service sectors and urban industry. The transfer represents a regional redistribution of direct and indirect incomes from rural to urban areas. Market theory tells us that the incomes lost to the rural areas will be less than those gained by the urban importers so long as importers are required to pay the purchase price; however, the loss of secondary incomes may still be a severe blow to the exporting region that should be addressed in the transfer decision.

The loss of secondary incomes in Owens Valley as a result of the purchase of water in that area by Los Angeles which began in 1904 amounted to a localized depression. The area of Laws, Round Valley and Bishop, California, within the valley, suffered a 20% decrease in population between 1920 and 1930; six elementary schools were closed and six others were consolidated; sales volumes for Bishop merchants fell by more than 50%. The reparation claims against Los Angeles included claims for damages due to loss of income from merchants, laborers, barbers, Indian farm laborers, medical personnel, etc. These claims were eventually settled by Los Angeles purchasing most of the town properties as well as the agricultural lands to which the water rights were attached.[32]

Weakening of Local Institutions: The viability of water-related institutions in the exporting region may be threatened by transfers, with a significant impact on quality of rural life. The Middle Rio Grande Conservancy District in central New Mexico and the Elephant Butte Irrigation District have contested the right of their members to sell their water rights as individuals. Such sales threaten the political viability of the district in an era of high demand for water rights.[33] Culture itself may be seen as a water-related institution. A recent decision in the New Mexico Court of Appeals barred a transfer of agricultural water rights to a ski resort on the basis that the transfer was contrary to the public interest. Judge Encinias said, in that decision:

> This region of northern New Mexico and its living culture are recognized at the state and federal levels as possessing significant cultural value, not measurable in dollars and cents. The deep-felt and tradition-bound ties of northern New Mexico families to the land and water are central to the maintenance of that culture....I am persuaded that to transfer water rights, devoted for more than a century to agricultural purposes, in order to construct a playground for those who can pay is a poor trade, indeed.[34]

The redistribution of political authority over resource use: Local government's ability to implement rational water-use policy and planning may be seriously impaired by export of resources outside of the political jurisdiction. In New Mexico, for example, the state takes an active facilitating role in water management through the state engineer, who issues permits and allows transfers in accordance with his powers under state law. The state engineer may require that such rights be exercised in a manner which promotes the public welfare and conserves the state's natural resources. In 1980, El Paso sought to appropriate unappropriated ground water from the Mesilla-Bolson basin in southern New Mexico, and the federal District Court in El Paso v. Reynolds[35] found New Mexico's statutory prohibition of out-of-state exports unconstitutional on the basis of violation of the Commerce Clause. The decision placed New Mexico in a situation where an appropriator whose water uses are not under the jurisdiction of the state engineer sought water rights under state law. The ability of the state engineer to implement water planning and policy with respect to the water appropriated by El Paso is severely limited relative to instate water users. The decision has given rise to changes in the New Mexico law and to an ongoing reconsideration of state water policy to determine how to protect New Mexico's interests under the new situation.

Fairness and Due Process: Finally, important social effects depend on whether the transfer is perceived as following due process. Where the transfer is seen as unfair or underhanded, exporting communities are often torn by internal conflict and a pervasive feeling of helplessness and victimization. In Owens Valley, this phenomenon reached its apogee. A 1928 report observed:

> ... the Valley is, even today, a hotbed of suspicions, prejudices and hatred. Suspicions are mutual and widespread. The Valley people are suspicious of each other, suspicious of newcomers, suspicious of city men, suspicious, in short, of almost everybody and every thing.... Owens Valley is full of whisperings, mutterings, recrimination and suggestion of threat of one kind or another.[36]

Tucson's purchase of agricultural land for water in Avra Valley has given rise to similar distrust and resentment, though not nearly so violent. Avra Valley farmers feel that the city's presence has contributed to the declining profitability of agriculture in the area, and businesspeople in the community of Marana, which serves the valley, have closed up shop due to declining sales, for which they hold the city's purchases accountable. At a recent conference on rural/urban water transfers, the mayor of Marana expressed the town's feeling of powerlessness:

> Tucson started buying up all the land to the west of us and to the south of us for water rights. ... they kept on buying and kept on buying till it looked like we were going to be surrounded and we started to wonder well what's going to happen to our water table when this town starts growing, which it is now, so we are in a dilemma there. Tucson [even] has control of our effluent. ... and we don't feel that's right. I don't know what we can do about that either ...[37]

Many of these impacts cannot be quantified. The loss of community trust that results from a perception that due process has been violated, the loss of political authority or deterioration of social infrastructure as a result of removal of water decisions from the local area, cannot be captured as dollar values. Other consequences, secondary income effects and lost tax revenues, for example, can be quantified. These values may be small relative to the benefits accruing to the importing municipality. The magnitude of these costs speaks to the efficiency of the new allocation. However, in equity terms, these costs should be given weight if they are important in the context of the small rural economy, regardless of whether they are counterbalanced by benefits elsewhere.

CONCLUSIONS

The question -- is the market the answer to Western water scarcity? -- seems to have contradictory answers:

Rural western communities have become water-dependent as a result of public provision of cheap agricultural water to farms; cities are increasingly in need of the water that is being applied to low-valued uses on farms because it is so cheap. Taken together, these statements indicate that facilitating the purchase of rural water by cities is a good thing.

On the other hand, the movement of water out of the countryside will have strong impacts in rural areas that will not fall on the farmers who are selling water (whose price will be met), but on the public sector, the business sector, local institutions and the environment. Ironically, the rural public sectors, business sectors, local institutions and even rural environments have been weakened in many areas by the dynamic of irrigation agribusiness, which does not return profits to the local community and creates a class division in the countryside.

The resolution of the contradiction lies in a policy that facilitates transfers of water, but which does so in a way that provides for a rural voice in the transfer decision.

Because rural communities will be impacted, perhaps severely, by retirement of agriculture and the export of their most basic natural resource, state water transfer policies should require that those communities be involved in the decision as to the terms, conditions and timing of transfer as well as the management of land, canals, and infrastructure owned by the importing municipality. Transfers of conserved water, leasebacks and contingency transfers which retain some water use and authority in the rural region of origin should be exploited as much as possible. And finally, we should take our time. Barring the case of prolonged drought in the immediate future, the water needs that most western cities seek to satisfy with rural supplies are needs for the future. The impacts of water sales on rural communities are still largely speculative, and the remedies for these impacts virtually unexplored. A gradual approach to facilitating rural/urban transfers is, at this time, low cost, and offers a high payoff on the learning curve.

On the rural side, it is imperative that local communities have a clear idea of how they are affected by local water use, of what their future local water needs are; what the water quality impacts of changes in water use are, what development they expect to see and what the water and other infrastructural needs of that development are, and how their fiscal situation will be affected by the water transfer, if they are to take advantage of having a role in the water-transfer decision.

This means that rural communities need to do a totally unfamiliar thing -- long-range water planning. This is not a small order. Farm communities lack the planning experience, the technical staff, the data base and the public education and issue-definition that urban water planners have built up over the years. Irrigation communities may be poorer in these areas than other rural areas due to the effects of concentrated land ownership. Nevertheless, rural citizens are the only experts on the effects of water, irrigation and water-related institutions on their own lives and environment. In order to minimize the negative effects of movement of agricultural water out of the rural sector and take advantage of the urban demand for water to create some positive effects, rural communities have to define their own options in terms of the future as seen through local eyes. This is a participatory, bottoms-up planning process by necessity, since information on impacts and mitigation can only be uncovered from the bottom. The bad news is that participatory planning is slow, demanding and difficult to structure. The good news is that a plan based on open airing of the objectives and options of those who will be affected by the plan is likely to be implemented because it is compatible with the reality of the local community.

The answer, then, is yes, markets may be a powerful strategy in coping with western water scarcity. When we choose to employ the market to achieve public objectives, it is important to realize that the market is an allocation tool, it does not itself embody any objective. Introduction of market changes when market forces have been stifled may result in sudden changes in land and water ownership that destabilize the region and stress already weak communities. The objectives of regional water allocation policy must be politically defined -- they will not be produced from market transactions by an invisible hand. Political support for rural community involvement in the transfer decision and technical support for rural water planning are critical to defining the objectives of western water policy.

ENDNOTES

1. Wahl and Davis, 1986, p. 160.
2. Transcripts, 1987.
3. Gross, 1984.
4. Water Market Update, January, 1987, p. 4.
5. Water Market Update, January, 1987, p. 9.
6. Reisner, 1986, p. 116.
7. Act of June 17, 1902, 32 Stat. 388.
8. Reisner, 1986, p. 120.
9. Act of August 13, 1914, ch. 247, 38 Stat. 686.
10. Pub. Res. of May 17, 1921, ch. 7, 42 Stat. 4.
11. Reisner, 1986, p. 121.
12. Act of May 25, 1926, ch. 383, 44 Stat. 636.
13. Act of August 14, 1939, ch. 418. 53 Stat. 1187. For a history of Reclamation policy and an analysis of ability to pay provisions, see Burness et al., 1980.
14. Burness et al., 1980, p. 821.
15. U.S. Department of Commerce, Bureau of Census, 1969 Census of Agriculture, vol. 4, Irrigation, Washington, D.C.: GPO, 1973, p. 82.
16. Drake v. Earhart, 2 Idaho 750, 23 P. 541 (1890).
17. Salt River Users' Association v. Kovocovich 411 P.2d 201 (1966); Southeastern Colorado Conservancy District v. Shelton Farms, Inc. 529 P.2d 1321 (1974).
18. Hirschleifer, 1960, p. 59-66.
19. MacCannell, 1983, p. 7-9.
20. U.S. Census of Agriculture, 1982, Table 11.
21. Personal communication, March 20, 1987.
22. Saliba and Bush, p. 60-62.
23. Saliba and Bush, p. 63-64.
24. Saliba and Bush, p. 64-65.
25. Ellis and DuMars, 1978.
26. Stoltzfus, 1987.
27. See Nunn and Ingram, in Water Resources Research, forthcoming.

28. Nunn and Checchio, 1987.

29. Ostrom, 1953, p. 127.

30. Ostrom, 1953, p. 135.

31. Meitl, Hathaway and Gregg, 1983 and Karpiscak, 1980.

32. Ostrom, 1953.

33. Gisser and Johnson, 1983.

34. In the Matter of Howard Sleeper, et al., Rio Arriba County Cause No. RA 84-53(C).

35. El Paso v. S.E. Reynolds, No. 80-270, (DNM Sept. 5, 1980).

36. Quoted in Ostrom, 1953, p. 130.

37. Billy Schlissler, In Transcripts, 1987, p. 19.

REFERENCES

Burness, H.S., Cummings, R.G., Gorman, W.D., and Lansford, R.R. 1980. United States Reclamation Policy and Indian Water Rights. Natural Resources Journal 20:807.

Ellis, W.H. and DuMars. C.T. 1978. The Two-Tiered Market in Western Water. Nebraska Law Review 57:333-367.

Gisser, M. and Johnson, R.N. 1983. Institutional Restrictions on the Transfer of Water Rights and the Survival of an Agency. In Water Rights: Scarce Resource Allocation, Bureaucracy, and the Environment, ed. T.L. Anderson, p. 137-161. Cambridge: Ballinger Publishing.

Goldschmidt, W.F. 1978. As You Sow. New Jersey: Allenheld, Osmun and Co., 1944.

Gross, S.P. 1985. Commerce Clause Curbs State Control of Interstate Use of Groundwater: City of El Paso v. Reynolds. Natural Resources Journal. 24(1): 213-20.

Hirshleifer, J., DeHaven, J. and Milliman, J. 1960. Water Supply: Economics, Technology, and Policy. Chicago: University of Chicago Press.

Karpisak, N.M. 1980. Secondary Succession of Abandoned Field Vegetation in Southern Arizona. Doctoral Dissertation, Department of General Biology, University of Arizona, Tucson, Arizona.

MacCannell, D., 1986. Agribusiness and the Small Community, Technology, Public Policy and the Changing Structure of American Agriculture. Volume II, Part D, Paper 1, Washington, D.C.: Office of Technology Assessment.

Meitl, J.M., Hathaway, P.L., and Gregg, F. 1983. Alternative Uses of Arizona Lands Retired from Irrigated Agriculture. Cooperative Extension Service, College of Agriculture, University of Arizona, Tucson, Arizona.

Nunn, S.C., and Checchio, E. 1987. Water Ranches, Community Impacts, and Innovative Ideas in Arizona. Water Market Update. 1:7:10.

Nunn, S.C., and Ingram, H.M. 1988. Information, the Decision Forum, and Third-Party Effects in Water Transfers. Water Resources Research (forthcoming).

Ostrom, V. 1953. Water and Politics: A Study of Water Policies and Administration in the Development of Los Angeles. Los Angeles: The Haynes Foundation.

Reisner, M. 1986. Cadillac Desert: The American West and its Disappearing Water, New York: Viking Penguin.

Saliba, B.C., and Bush, D.B. 1987. Water Markets in Theory and Practice: Market Transfers, Water Values and Public Policy. Studies in Water Policy and Management, No. 12, Boulder: Westview Press.

Stoltzfus, D.M. 1987. Issues and the Role of Innovation in the Allocation and Transferability of Indian Water Rights. Water Transfers in the Southwest: Explorations, ed. S.C. Nunn, pp. 31-50. Tucson: W.K. Kellogg Foundation and University of Arizona.

Transcripts, The Fourth Annual Public Policy Forum. April 8, 1987. Water Transfers and the Quality of Rural Life, Division of Economic and Business Research, University of Arizona, Tucson, Arizona.

Wahl, R.W. and Davis, R.K. 1986. Satisfying Southern California's Thirst for Water: Efficient Alternatives. Scarce Water and Institutional Change, ed. K. Fredericks, pp. 102-133. Washington D.C.: Resources for the Future.

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