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Robert S. Kerr Environmental Research
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Research and Development

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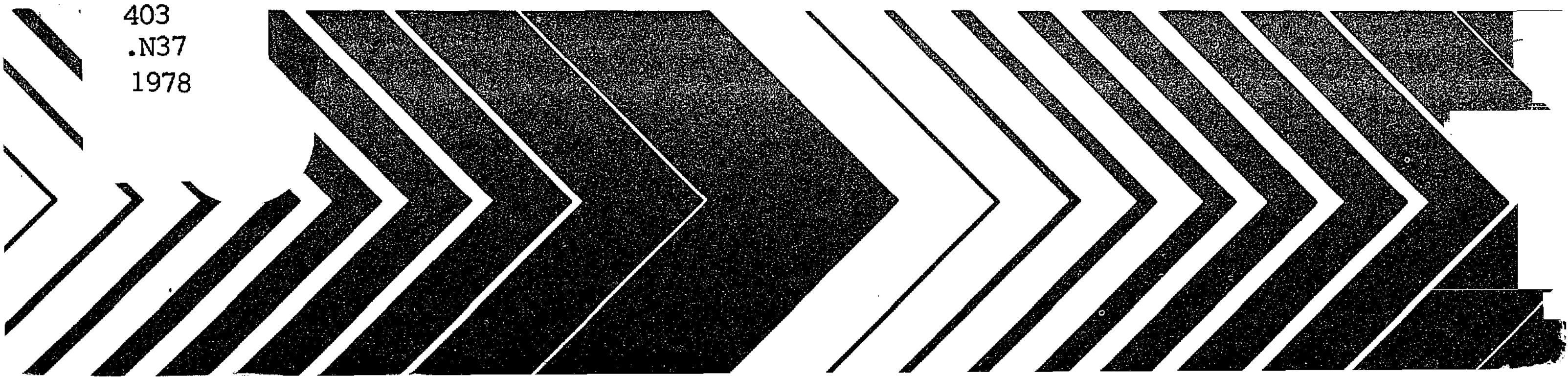
Proceedings of the Fourth National Ground Water Quality Symposium



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EPA-600/9-79-029
August 1979

PROCEEDINGS OF

THE FOURTH NATIONAL GROUND WATER QUALITY SYMPOSIUM

Cosponsored by the
U.S. Environmental Protection Agency
and the
National Water Well Association

September 20-22, 1978

Minneapolis, Minnesota

Grant No. R805747

Project Officer

Jack W. Keeley
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ROBERT S. KERR ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
ADA, OKLAHOMA 74820

DISCLAIMER

FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques, and new technologies through which optimum use of the Nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate, and management of pollutants in ground water; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries; and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report contributes to that knowledge which is essential in order for EPA to establish and enforce pollution control standards which are reasonable, cost effective, and provide adequate environmental protection for the American public.

William C Galegar

William C. Galegar
Director

ABSTRACT

The Fourth National Ground Water Quality Symposium was held in Minneapolis, Minnesota, September 20-22, 1978, in conjunction with the annual convention of the National Water Well Association.

The Symposium was dedicated to the late George Burke Maxey and the keynote address was given by Courtney Riordan, Associate Deputy Assistant Administrator, Office of Air, Land & Water Use, Office of Research and Development, U.S. Environmental Protection Agency.

A debate format on "The Issues of Our Time" featured national authorities presenting neutral, pro, and con views followed by audience reaction, and addressed nine topics:

- GROUND WATER POLLUTION--AN IMMINENT DISASTER OR LIMITED PROBLEM
- GROUND WATER QUALITY STANDARDS--NECESSARY OR IRRELEVANT
- LAND APPLICATION OF WASTE--AN IMPORTANT FUTURE ALTERNATIVE OR AN ACCIDENT WAITING TO HAPPEN
- THE FEDERAL GROUND WATER PROTECTION PROGRAM--TODAY'S HOPE OR TOMORROW'S UNDOING
- STATE GROUND WATER PROTECTION PROGRAMS--ADEQUATE OR INADEQUATE
- THE 208 PLANNING APPROACH TO GROUND WATER PROTECTION--A TERRIBLE JOKE OR A FOOT IN THE DOOR
- CONTROLLED DEGRADATION AND/OR PROTECTION ZONES--SENSE OR NONSENSE
- GROUND WATER MODELS--PRACTICAL TOOLS OR INTELLECTUAL TOYS
- WATER BORNE DISEASE--A CURRENT THREAT OR A THING OF THE PAST

The Transactions of this Symposium are submitted in fulfillment of Grant No. R-805747 by the National Water Well Association under the sponsorship of the U.S. Environmental Protection Agency.

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PROCEEDINGS OF THE FOURTH NATIONAL
GROUND WATER QUALITY SYMPOSIUM

September 20-22, 1978

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EPA'S NEW EMPHASIS ON GROUND-WATER RESEARCH[a]

by Courtney Riordan[b]

It's a pleasure to be in Minneapolis with the country's leading ground-water authorities as you meet to discuss the pressing issues which we are likely to face during the coming decade. The timing for this Symposium is auspicious. It comes at a time when EPA is accelerating its efforts to protect the quality of the country's ground-water resources under both the Safe Drinking Water Act and the Resources Conservation and Recovery Act.

For those of you who have spent professional careers in the ground-water development and protection field, this must be an exciting time. Over the years you have persisted in telling the world of this valuable resource and of the need for protecting its quality. You have tried to place our underground water in proper perspective as a valuable renewable resource. Your efforts and words sowed the seeds that are now bearing fruit.

The 1977 Report to Congress on Waste Disposal Practices and Their Effect on Ground Water pointed out that there are at least 17 million waste disposal facilities placing over 1.7 trillion gallons of contaminated liquid into the ground each year. While the expansive nature of ground water makes it available in various quantities at almost any location, it is also subject to contamination from a wide variety of sources distributed widely throughout the country. Moreover, restoration of underground-water quality is difficult, time consuming, and expensive. In almost every situation, the cost of restoring the integrity of ground water once contaminated exceeds its marginal value in use. It follows that our goals must focus primarily on the protection of ground-water quality rather than its restoration. This is in fact the mandate that has been given to EPA by the Safe Drinking Water Act enacted in December 1974 and the Resources Conservation and Recovery Act of 1976.

As we have gone about implementing these Acts, we have discovered how little we actually know about our vast underground-water reservoirs, particularly in light of the potential stresses posed

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

[b] Associate Deputy Assistant Administrator, RD-682, Office of Air, Land and Water Use, Office of Research and Development, U.S. Environmental Protection Agency, 401 M Street SW, Washington, D.C. 20460.

by the millions of waste sources which threaten their quality. It is appropriate therefore that our initial efforts be directed toward the collection of information to form a foundation for future action, particularly in the development of rules and regulations called for in the Acts. In this way, we hope that the intent of these Acts can be carried out giving adequate consideration to the full range of social, economic, and technical implications involved.

The 1977 Report to Congress was an example of these efforts. It was an attempt to collect all of the available information on the impact of waste disposal practices on ground water in order to place the problems in proper perspective. Nothing raises the quality of the level of discussion about a problem more than hard data. My experience is that in technical discussions we have something like the reverse of Gresham's law, i.e., good data chases out bad opinion. Another study is just now getting under way which is aimed at describing the nature of the drinking water of the Nation's rural population. Still another study has recently been completed which describes the effects of the abandonment of wells—oil, gas, water, and others on ground-water quality.

A major project has begun to evaluate the effects of pits, ponds, and lagoons on our Nation's ground water. It is a five million dollar effort being carried out by EPA's Office of Drinking Water in cooperation with our Regional Offices and the States. An inventory of these impoundments will be determined for a great many using a method developed by one of your distinguished associates, Harry LeGrand.

Although the Office of Research and Development has had a role in each of these projects, our efforts have been hampered by limited resources in the ground-water research area. About two years ago we became convinced that ORD must expand these efforts as a primary means of improving our technical capability to deal with ground-water quality problems. We decided to accomplish this by adding to our existing program at the Robert S. Kerr Environmental Research Laboratory at Ada, Oklahoma. I think many of you are familiar with this group, particularly since they have worked with the National Water Well Association in presenting this series of ground-water quality symposia.

Our plans for developing this Center have been thoroughly prepared and we expect will be carefully executed. Plan preparation began two years ago by asking a selected group of your peers to advise us on the goals of this new initiative so that they would fill the needs of EPA's Operating Programs and the non-federal user community, yet not duplicate or compete with the research of other Federal agencies.

We developed a research strategy based on the suggestions and recommendations by broad user groups and professional participation. This strategy was adjusted after considerable consultations within the Agency, our Science Advisory Board, the Drinking Water Advisory Council, and the Subcommittee on the Environmental and Atmosphere of the House Committee on Science and Technology. Our actions have followed a deliberate step-by-step progression to assure that this important initiative will, to the greatest extent possible, be directed toward the needs of the user while maintaining scientific integrity and quality.

Our research efforts will address the development of monitoring and measurement methods and transport and transformation characteristics of contaminants in the subsurface environment. This will allow us to prepare guidance documents for use by other parts of the Agency in developing sensible waste source control criteria. Of course, a considerable part of our activities will continue to be in the form of technical assistance to the Agency and others.

This year we have supported the establishment of a center for ground-water information at the offices of NWWA in Columbus. We are confident that this center will provide computer literature search services on specific topics to all of you in the ground-water industry. We have also worked with the U.S. Geological Survey to establish a clearinghouse for ground-water models at the Holcomb Research Institute in Indianapolis. This effort is aimed at assisting water resource managers and others in selecting the proper models for their particular needs while sponsoring worldwide workshops to bring the managers and modelers closer together.

This Fourth National Ground Water Quality Symposium is another example of our efforts to assure that information, ideas, and opinions are made available to you in public forum. Each of the symposia has been constituted with a different format geared to the needs of the time. I find this year's format particularly timely and exciting. The time could not be better suited in light of the growing nationwide interest in our valuable ground-water resources. The issues for debate have been wisely selected. They will undoubtedly serve as our constant companions for at least the next decade.

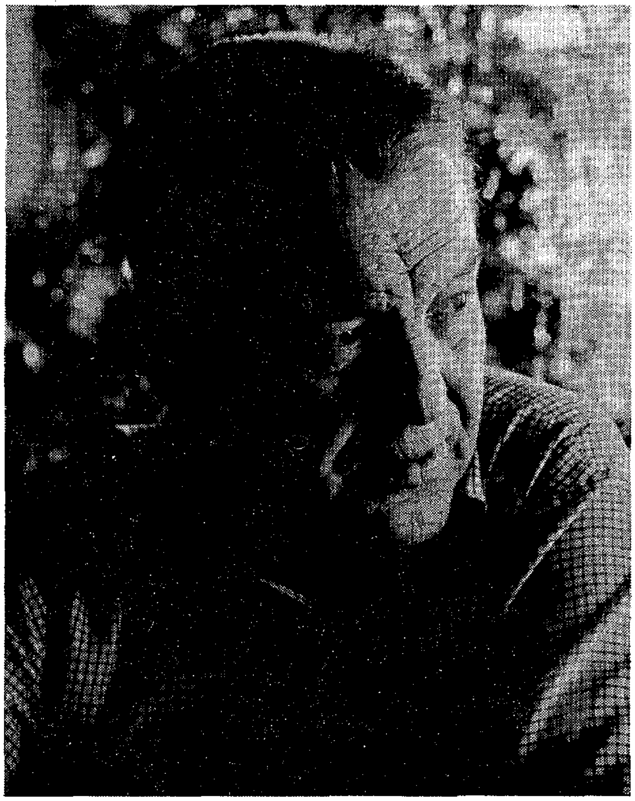
I am confident that, by working together and sharing our knowledge, we can do a creditable job in providing the best technical and scientific advice that is available.

George Burke Maxey: A Lasting Influence on the Course of Modern Hydrology[a]

by Gilbert F. Cochran[b]

It is difficult to summarize in these few pages a life of nearly 3 score years that began April 3, 1917 in Bozeman, Montana and ended so suddenly and unexpectedly on February 6, 1977, in Reno, Nevada, a life that encompassed a professional career spanning nearly 35 years. All I can hope to do is portray a little of what George Burke Maxey did and maybe something of who he was, because the latter is what remains for so many of us in hydrology.

Each of us as we go through life will leave some mark upon the world, however small. Some will be remembered for what they did, others for what and who they were. Few, I think, will have a greater or more lasting impact on a field of science than did George Burke Maxey on hydrology and water resources. He touched a great many lives and was many different things to so many different people. To some of us he was Burke, to many more he was George and to even more, Dr. Maxey. Born in Bozeman, Burke grew up and attended school in nearby Livingston, a picturesque little town in a stimulating, vigorous and beautiful environment. He always remained in love with that country and throughout his life returned often, drawn back by



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[a] Memorial address presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20, 1978.

[b] Research Professor, Water Resources Center, Desert Research Institute, Reno; and Nevada State Science Advisor, Governor's Office of Planning Coordination, Carson City, Nevada.

family, friends, the people and the country itself.

Burke began his academic career at the University of Montana at Missoula where in 1939 he received a B.A. in Geology. It was there also that he met Jane Clow who later in 1941 became Jane Maxey, his lifelong companion and supporter. He continued his education at Utah State Agricultural College in Logan, receiving an M.S. in Geology in 1941.

Like so many prominent hydrologists, Burke began his professional career with the U.S. Geological Survey. He started out in 1941 as a Student Aide in the Water Resources Division in Salt Lake City and in 1942 became Junior Geologist working in Utah's Pavant Range and Flowell areas. From Utah he was assigned for a brief period to Louisville, Kentucky before being promoted to Assistant Geologist and reassigned in 1944 to Las Vegas, Nevada. This assignment was the start of a long and intimate relationship in that beautiful and arid State. Burke remained in Las Vegas from 1944 to 1946, and during that time conducted a hydrologic evaluation of the Las Vegas Valley that was to lay the foundation for Nevada's eventual development of its Colorado River allotment through the Southern Nevada Water Project.

During the 1940's the entire population of Nevada was less than 150,000 people and it was known that the State's 160-odd valleys were dry but no one knew how dry or how much water there really was. While in Las Vegas, Burke became fast friends with the Assistant State Engineer of Nevada who was then on his way to becoming "Mr. Water" in the State, Hugh A. Shamberger. Burke worked with Hugh and promoted the concept of a State-USGS cooperative ground-water reconnaissance program to determine a first estimate of the State's water resource—a massive undertaking. Burke's study of the Las Vegas Valley formed the basis and the starting point of that program through his formulation of a methodology to deal with the tremendous paucity of hard data and to squeeze the last possible drop of information from general hydrologic principles and relationships.

In 1946 Burke was promoted to Associate Geologist and transferred to Ely, Nevada where he worked with Tom Eakin and others on a series of reconnaissance studies of 13 valleys in eastern Nevada. In these studies he and Tom refined Burke's Las Vegas approach to estimating natural ground-water recharge and formulated a set of relationships that are used yet today (and virtually unchanged) to determine the limit of appropriable ground water under Nevada water law. This early work in Nevada also laid the foundation for a paper Burke was to write nearly a quarter of a century later and for which he was presented the O. E. Meinzer award in 1971. The title of that paper was "Hydrogeology of Desert Basins" (*Ground Water,* V. 6, No. 5, 1968).

In 1948 Burke took leave of the Geological Survey to complete his academic training at Princeton University where in 1950 he received an A.M. in Geology and in 1951 his Ph.D.

The Princeton decision was a turning point in Burke's career, for from that time on except for some brief interludes, he became a member of the academic community. In 1949 he joined the faculty of the University of Connecticut at Storrs as an Instructor of Geology advancing to Associate Professor before leaving in 1955. Burke was always a builder and collector of things. He built programs and organizations. He collected everything—stamps, books, coins, friends and students, to name only a few. And it was at Connecticut that Burke began collecting and building from rough stock one of the things he most dearly loved—graduate students with ability and an interest in water. It was also while at Connecticut that Burke became involved with water resources and hydrogeology at the international level.

From 1952 to 1954 Burke took leave from the University to accept foreign assignments with the U.S. Geological Survey and what is now the U.S. Agency for International Development in Tripoli, Libya. He served as Geologist and then as Acting Chief of the Natural Resources Division of the Point 4 program.

In 1955 Burke left the University of Connecticut to join the Illinois Geological Survey as Geologist and Head of the Division of Ground-Water Geology and Geophysical Exploration and to also become Professor of Geology at the University of Illinois. Several of Burke's students followed him to Illinois, and while there he found and attracted additional talent to add to his growing collection of students.

Burke remained at Illinois until 1962 when he was sought out to head up the Hydrology Department of the newly created Desert Research Institute at the University of Nevada, and to assume the position of Professor of Geology. At that time Burke returned to Nevada and Reno to begin creating a successful and innovative hydrologic research program. And again, as when he left Connecticut, several of Burke's students followed him to both study and work in Nevada.

Though Burke did not return to live in Nevada until 1962, he had never lost contact with the State, its problems or its people. Through his good friend, Hugh Shamberger, and those many others he had befriended in the '40's, Burke had been retained since 1951 as a consultant to the Nevada Department of Conservation and Natural Resources. In this capacity he had helped to shape and direct the reconnaissance program he had promoted while with the Geological Survey.

One of his first activities at the University of Nevada was to begin building an interdisciplinary graduate program in hydrology and hydrogeology. His activities resulted in this land grant school's first Ph.D. program and its first Ph.D. degree recipient, Roger Morrison. Since that time there has been a steady outpouring of M.S. and Ph.D. recipients well schooled and trained in the hydrological sciences—not geologists, not engineers, not economists, but hydrologists with varying undergraduate academic training.

At the Desert Research Institute, Burke simultaneously built a water research program that first focused on his love—ground water—but that broadened to one encompassing surface water, water chemistry, water resources engineering and water resources planning—a true center for study and research in hydrological sciences.

Burke came back to Nevada at a time when this nation was awakening to the fact that a more vigorous and far reaching program was needed in water research and training. This was the period of time that saw the creation of Universities Council on Water Resources (UCOWR), the Federal Interagency Committee on Water Resources Research (COWRR), the passage of the Water Resources Research Act of 1964 and the Water Resources Planning Act of 1965. In each of these Burke played a significant role as an active proponent and instigator.

Burke's professional career was full and active. He was a member of, and in several instances helped to establish, over 16 professional organizations and societies, and in each he vigorously worked to promote advances in hydrology and enlightenment in water resources management. He also served as chairman or member of over a dozen important national or regional committees including those of the American Geophysical Union, International Union for Geodesy and Geophysics, Geological Society of America, National Academy of Sciences, and the International Hydrological Decade. Burke was Distinguished Lecturer for the American Association of Petroleum Geologists, Visiting Geoscientist for the American Geological Institute, Visiting Professor of Hydrogeology at Indiana University, and Visiting Scientist in Geophysics (Hydrology) for AGU.

Burke was a U.S. Delegate to many international symposia, Vice President and President of the Commission on Groundwater of the IUGG, consultant on ground-water problems to the U.S. Atomic Energy Commission, and American Editor of the *Journal of Hydrology.* And in his spare time, Burke was author or coauthor of over 60 published articles, papers and reports dealing with hydrogeology, hydrology and water resources planning. His individual accomplishments and activities are too extensive to enumerate here. Suffice it to say he was busy and productive.

One activity that Burke especially enjoyed was that of being a water resource planner. This was a job he did well, not only in the U.S. but worldwide. This role took him from Montana and Nevada to Poland, Kenya, Mexico, the Sudan and Egypt. Burke's foreign assignments left behind a spirit of goodwill and international cooperation in each of these countries and resulted in the coming of many foreign students to study in the United States.

These are only some of the things Burke Maxey did; they are not who he was. To have known him was an experience, and to each who did I am certain that experience was different. Burke was a man of great compassion, who had undying faith in the ability of young people to produce. His true lasting legacy and contribution to hydrology grew from that compassion and faith in the form of the large number of students, undergraduate and graduate, that he trained.

Burke liked to refer to his graduate student academic progeny as his "sons," and when some of them began teaching he was blessed with "grandsons" and even eventually "great-grandsons." This reference was not empty but rather reflected the true feeling of kinship that Burke developed with his students, a feeling that was mutual. Burke was an excellent teacher who continually challenged his students and through this and his own knowledge, opened doors to knowledge. But equally important was the fact that Burke forced his students to think and act for themselves.

However, not only did Burke produce excellent scientific minds, he helped to develop men of compassion and understanding through his own example. Burke was always ready to share what he had, to give a student money to get home on, to provide a place to eat and sleep. His home was always open. These students that Burke inspired, cajoled and pushed to succeed are now spread throughout this country and the world in prominent positions and as leaders in the hydrological sciences.

I do not know the full number of students Burke trained, let alone the number of "grandsons" and "great-grandsons," but at the risk of offending many, I mention some few whom I know and who are proud to have known Burke: Bob Farvolden, Pat Domenico, John Bredehoeft, Martin Mifflin, Bill Back, Dave Stephenson, Richard Parizek, Richard Cooley, Jerold Behnke, Art Ziezel, Bill Dudley, Bill Greenslade, Jim Hackett . . . and the list goes on and on. In fact it is difficult to go to any meeting where there are hydrologists, and not find a significant number of them who have been directly influenced by Burke or one of his students. Burke left a lasting and indelible imprint on his adopted State of Nevada and through his many students, has left his mark on the course of modern hydrology, a mark that will last, I think, for a very long time.

Burke made people think, whether it was in a classroom, in the field, or in a meeting such as this. He was always perceptive and offered up difficult questions—not infrequently of one word—why? Often Burke would team up with friends such as Ray Kazmann and Jim Warman to let a speaker know when he was off-base. Those were exciting meetings for everybody—except the speaker. It seems that many meetings are quieter now. There is a need for someone to step forward to help fill that role to ensure that we keep trying to answer the question of "why."

Ground-Water Pollution — A Status Report[a]

by David E. Lindorff[b]

ABSTRACT

Recent research has expanded our understanding of the suitability of waste disposal in various hydrogeologic settings. Although more research is needed, our knowledge can provide a basis for preparing guidelines for action that will protect ground water from waste disposal practices. It is impossible, however, to prevent accidental spills, unlawful dumping, and ground-water contamination or pollution resulting from some old, unregulated waste disposal practices. Therefore, more than 170 case histories of subsurface contamination or pollution were studied to evaluate the effectiveness of remedial action in different geologic environments. The case studies indicate that the severity and extent of ground-water contamination is determined by (1) the hydrogeologic setting, (2) the nature of the contaminant, and (3) the effectiveness of regulatory action.

Industrial wastes are the most common sources of ground-water contamination. The most serious incidents are those that pollute or threaten water supplies and those that cause a fire or explosion. Once ground water is contaminated, remedial action is time consuming and expensive. Each incident must be handled as a separate problem. Although prompt action is essential to limit contamination and minimize remedial action, no strategies have been established for rapid response to contamination or pollution problems.

Ground-water contamination will continue, but its impact can be reduced. The role of hydrogeologists in regulatory agencies should be strengthened to provide proper evaluation of potential sources of contamination and to aid in remedial action when ground water is contaminated. Cooperative efforts to develop strategies will ensure proper handling of future emergencies.

INTRODUCTION

More than 170 documented case histories of ground-water contamination or pollution were studied to develop an understanding of the status of ground-water pollution. The case histories indicate that once ground water is contaminated, remedial action is time consuming and expensive. Therefore, protection of ground water from contamination is essential. For this reason, extensive research in recent years has focused on the movement and attenuation of contaminants in various hydrogeologic settings. We have come a long way in understanding the behavior of contaminants in the subsurface and in understanding the suitability of waste disposal in various geologic environments. Although more research is needed, we now have a basis for preparing guidelines that will protect ground water from waste disposal practices. Ground-water contamination or pollution can be reduced, but cannot be totally eliminated. Accidental spills and unlawful dumping will continue to occur.

This paper will examine the status of ground-water pollution through examples of ground-water contamination and pollution and by summarizing some of the research in recent years. Finally, some options are considered for limiting future ground-water contamination problems.

Before proceeding further, the terms contamination and pollution require definition. Contamination of water is defined as the alteration of water quality in an undesirable manner and pollution as the contamination of water to the point where it is unfit for a particular use.

LESSONS FROM CASE HISTORIES

Contaminants may reach ground water from a variety of sources (see Table 1). Some wastes are by design discharged to the subsurface; examples

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

[b] Illinois State Geological Survey, Urbana, IL 61801.

Table 1. Classification of Sources of Ground-Water Contamination (after USEPA, 1977)

Wastes		*Non-Wastes*
Sources designed to discharge waste to the land and ground water	*Sources that may discharge waste to the land and ground water unintentionally*	*Sources that may discharge a contaminant (not a waste) to the land and ground water*
Spray irrigation	Surface impoundments	Buried product storage tanks and pipelines
Septic systems, cesspools, etc.	Landfills	Accidental spills
Land disposal of sludge	Animal feedlots	Highway deicing salt stockpiles
Infiltration or percolation basins	Acid mine drainage	Ore stockpiles
Waste disposal wells	Mine spoil piles and tailings	Application of highway salt
Brine injection wells		Product storage ponds
		Agricultural activities

include septic systems, spray irrigation, and land disposal of sludge. Other wastes may reach ground water unintentionally. Wastes may, and often do, migrate to ground water from impoundments, landfills, animal feedlots, leaky sewer lines, and other sources.

Not only wastes may adversely affect ground water, however. Petroleum products may enter the ground-water flow system from a leak in a pipeline or storage tank. Ground water also may be contaminated from the storage or application of highway salt.

Increased regulation may reduce but not totally eliminate the potential for ground-water contamination. To identify the most critical factors for protection of ground water, examples or case histories of ground-water contamination must be evaluated. Over the past three years, 173 case histories of subsurface contamination or pollution were studied (Lindorff and Cartwright, 1977). A few cases came from environmental agencies and personal experience.

The information presented in the case studies found in the literature varied considerably, partly because the articles were written for a variety of purposes. Many contained little or no documentation of geologic and ground-water conditions. Some incidents were well documented, however, and they provide a useful base of information.

The case studies indicate that the severity and extent of ground-water contamination is determined by: (1) the hydrogeologic setting, (2) the nature of the contaminant, and (3) the effectiveness of regulatory action.

The ground-water setting determines the potential extent of contamination or pollution. As shown in Figure 1, contaminants introduced into the subsurface on an upland recharge site potentially may move a great distance and may affect a major portion of an aquifer. This is especially true in areas underlain by coarse-grained sediments or fractured rocks, where contaminants may move rapidly through the subsurface with little or no attenuation.

In Nassau County on Long Island, pollution of a well in the 1940s was traced to disposal of

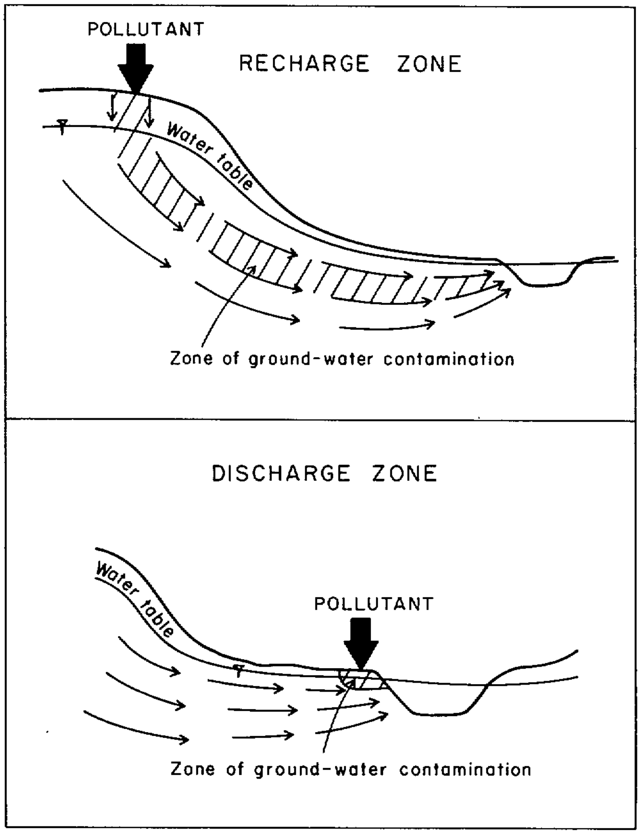

Fig. 1. Extent of ground-water contamination from pollutant entering recharge and discharge zones (Bergstrom, 1968; Lindorff and Cartwright, 1977).

plating wastes in three unlined lagoons overlying a sand and gravel aquifer. As of 1970, the plume of contaminants was 4,000 feet long, 1,000 feet wide, and up to 70 feet thick (Perlmutter and Lieber, 1970).

If the source of contamination is in or near a discharge zone (Figure 1), the potential extent of ground-water contamination is much more limited. This was noted in northeastern Illinois (Hughes, Landon, and Farvolden, 1971) and later in Iowa (Palmquist and Sendlein, 1975) in studies of the migration of leachate from landfills located in or near discharge zones. Leachate discharged to an adjacent river in each case. If a stream or river is unable to assimilate the leachate by dilution, the quality of surface water may be adversely affected.

In fine-grained environments adsorption and filtration and low hydraulic conductivity limit the extent of contamination. In southeastern Illinois, a train derailed in 1969 and spilled 15,000 gallons of cyanide. The fine-grained surficial material limited the penetration of the cyanide to a depth of 3 to 4 feet [Illinois Environmental Protection Agency (IEPA) files]. The contaminated soil was excavated; this may be the most effective option in similar environments. Fine-grained environments reduce the spread of contaminants, but also limit the options for recovery of contaminants if this action becomes necessary.

The extent of ground-water contamination or pollution is likely to be more extensive in areas underlain by coarse-grained materials or fractured bedrock. Contaminants may move a great distance in fractured bedrock with no attenuation. Earlier this year in southern Missouri, the collapse of a sinkhole beneath a sewage lagoon permitted thousands of gallons of sewage to enter the dolomite aquifer and to migrate some 20 miles before discharging to the surface (James Williams, Missouri Geological Survey, personal communication). The hydrogeologic setting, therefore, determines the potential extent of contamination.

The severity of a pollution incident also is dependent on the volume and nature of the contaminant. Table 2 lists the contaminants for each of the case studies and the environmental impact. Of the 173 case histories, 116 were studied in an initial investigation (Lindorff and Cartwright, 1977), and the remaining 57 were studied later. The first column indicates the total number of cases involving each contaminant. The number and percentage of incidents affecting or threatening ground-water supplies are tabulated in the second column. The third column lists the number and percentage of cases that threatened or produced fires or explosions.

Table 2. Summary of Ground-Water Contamination Incidents — Contaminants and Impacts

Contaminant	*No. of incidents*	*Water supplies (%)*	*Fire or explosion (%)*
Industrial wastes	50	31 (62)	2 (4)
Landfill leachate	46	7 (15)	0
Petroleum products	27	18 (67)	10 (37)
Organic wastes	21	15 (71)	0
Chlorides	16	13 (81)	0
Radioactive wastes	7	2 (29)	0
Pesticides	4	2 (50)	0
Fertilizer	3	3 (100)	0
Mine drainage	3	1 (33)	0
	173	91 (53)	12 (7)

The most common category of contaminant was industrial wastes. This category includes a wide spectrum of wastes from all types of industries, such as acids, various solvents, plating wastes, and others, including some unidentified wastes. Most but not all of the contaminants were waste products. Various chemicals were discharged to the subsurface from accidental spills. Industrial wastes reached ground water from impoundments or lagoons, spills, pipeline breaks, land disposal of wastes, and improper disposal. Impoundments were the most common sources of contamination. In the past, industrial lagoons and impoundments typically have been monitored poorly if at all.

Landfill leachate was the second most common contaminant. Only about 15 percent of the landfills that were studied produced well pollution, however; this suggests that landfills are a less serious hazard than other sources of contamination. Many of the case studies were research investigations concerned with the migration of leachate from landfills. In most cases the extent of ground-water contamination was limited to the site itself or to a small area adjacent to the landfill. The geologic materials have generally been able to attenuate the contaminants or to reduce leachate concentrations by dilution.

An exception is a landfill in northern Delaware that has contaminated a major regional aquifer and has threatened municipal and industrial supplies. The refuse was placed in an abandoned sand quarry separated from the regional alluvial aquifer by a thin clay layer. Excavation of the clay for cover material permitted leachate movement to the underlying aquifer with little or no attenuation (Apgar and Satterthwaite, 1975).

Of 27 cases involving petroleum products, 18 polluted or threatened water supplies and 10 produced a fire and/or explosion. Although the contaminant in only a few cases, petroleum products potentially are a more serious environmental threat than landfill leachate or most industrial wastes. Early in 1978, a number of explosions and fires resulted from extensive gasoline pollution of an alluvial aquifer along the Mississippi River near East St. Louis. Although three refineries are present in the area, the source of pollution has never been identified. The gasoline apparently has been in the ground for many years. Heavy rainfall this spring and reduced pumpage of the sand and gravel aquifer raised ground-water levels and forced explosive concentrations of gasoline into several basements and sewers in the area (IEPA files).

Petroleum products may enter the subsurface as a result of pipeline breaks, storage tank leaks, spills, and from unknown sources. In nine cases, the source of contamination was never identified positively. In 1968 a large volume of gasoline was discovered on a relatively flat portion of a water table between two pumping cones for municipal ground-water supplies in the Los Angeles-Glendale area. Preliminary estimates suggested as much as 250,000 gallons of gasoline were present in the subsurface. Again the exact source was never identified positively (American Petroleum Institute, 1972; Williams and Wilder, 1971).

Organic wastes were the fourth most common contaminant (Table 2). Of the 21 cases involving various organic wastes, 15 resulted in ground-water supplies being affected or threatened. Sources of contamination included sewage impoundments, septic tanks, feed lots, and improper waste disposal. Some problems develop over a long period of time. For example, the use of septic tanks and cesspools since 1910 in Nassau County, Long Island, has resulted in the widespread deterioration of ground-water quality and the subsequent abandonment of the upper glacial aquifer as a source of water supply (Sulam and Ku, 1977).

Chlorides are a potential threat to ground water because they generally are not attenuated in the subsurface. Of the 16 cases involving chlorides, 13 contaminated or threatened water supplies. Chloride entered ground water from salt storage areas, oil-field brine ponds, brine injection wells, and improper land disposal. In West Virginia, chloride concentrations rose steadily in several shallow wells when road salt was stored in an area nearby. The affected wells were all finished in a highly permeable carbonate aquifer within a zone located 1,500 feet downgradient of the salt pile (Wilmoth, 1972).

The other four contaminants in Table 2 were involved in significantly fewer incidents. Radioactive wastes, pesticides, fertilizers, and mine leachate were detected collectively in 17 cases, 8 of which affected or threatened water supplies.

Some contaminants pose a potentially serious hazard just because of their character. The most dangerous contaminants are petroleum products and toxic and/or explosive chemicals and industrial wastes that can threaten or produce fires or explosions.

The case histories indicate two categories of ground-water contamination incidents. Some problems such as accidental spills are detected within a short period of time. In such situations, quick response is necessary to limit ground-water contamination and to minimize the remedial action. Only six of the case histories were detected as a spill, however, and less than 10 percent were discovered within the first 24 hours (Lindorff and Cartwright, 1977).

Most contaminants are detected some time after entering the subsurface. Weeks, months, or years may pass before a problem is noted. The contaminant may travel a great distance and may affect a large portion of an aquifer before pollution is recognized. In Colorado, industrial wastes were discharged to unlined lagoons for about 11 years before ground-water pollution was detected. Several square miles of a shallow aquifer were affected (Walton, 1961; Walker, 1961).

Even if the source is identified and removed, and no further contaminants enter the ground-water flow system, contaminants can continue to adversely affect ground water for a long time. With no remedial action, tens, hundreds, or thousands of years may be necessary to flush the contaminants out of the ground-water flow system. In Arkansas, chloride contamination of a sand and gravel aquifer was traced to a brine disposal pit in an oil field. About one square mile of the aquifer was affected. An evaluation of possible renovation techniques concluded that an estimated 250 years would be needed for natural flushing to remove the chlorides from the aquifer (Fryberger, 1975).

When contamination is detected immediately after the incident, prompt response is important. When contaminants have been in the subsurface a long time, however, quick action may not be warranted. Conditions will not change dramatically, so more effort can be devoted to an evaluation of the extent of contamination and determination of the proper remedial action. Alternatives may include ground-water renovation, identification and elimination of the source of contamination, efforts to alleviate the problem for those affected, or perhaps no action at all. Time is available to gather the necessary expertise to fully consider all the options.

Responding too hastily may create more serious problems. In Rockford, Illinois, contamination was initially detected in an industrial well near a landfill. Use of the well was ordered discontinued; this permitted the contaminants to migrate to other wells in the area, including a municipal supply well and several private wells. These ground-water supplies then had to be abandoned (Illinois State Geological Survey files). Perhaps an early technical evaluation in response to the initial contamination would have resulted in successful remedial action and minimal ground-water degradation.

Regulatory agencies, therefore, should be equipped to respond promptly in those instances where contamination is detected at an early stage. The agency must also be able to draw together all necessary expertise to evaluate long-term pollution problems. Environmental agencies in the United States and Canada were surveyed in 1975 to discover what procedures had been developed for dealing with ground-water pollution emergencies (Lindorff and Cartwright, 1977). The responses indicated that no established strategies had been developed for rapid response to ground-water contamination or pollution problems. The survey also suggested that not all States have available the technical expertise to offer advice and assistance for incidents of ground-water contamination. Only about one-third of the States responding indicated that they possessed the expertise, geological and otherwise, to respond effectively to ground-water contamination problems.

Illinois is perhaps typical of most States. Currently, the Illinois Environmental Protection Agency (IEPA) responds to air and water emergencies through an Emergency Response Program, which maintains a hotline 24 hours a day. Upon notification of an emergency, an IEPA representative visits the site and offers assistance. However, no specific strategy has been developed for handling ground-water emergencies.

The staff of the IEPA includes geologists, chemists, soil scientists, and others who can provide expertise in the event of a ground-water contamination incident. Assistance is also available from a variety of other State agencies, such as the Illinois State Geological and Water Surveys, the State Fire Marshal, the Illinois Department of Public Health, and the Illinois Emergency Services and Disaster Agency. Although Illinois does have many pertinent resources, they are not organized to respond to ground-water contamination problems. This is probably true of most States.

RECENT RESEARCH

The best way to minimize ground-water contamination is to prevent it. Therefore, the regulation of waste disposal to protect ground water is especially important. To effectively regulate potential sources of contamination, we must understand the behavior of contaminants in the subsurface. Then we can predict the environmental impact. Recent research can now provide much of the needed information.

The following discussion of research is not meant to be complete but to highlight some of the information regarding the movement and attenuation of contaminants in the subsurface.

Much of the research has concentrated on landfills in various geologic environments. California has researched landfills since the early 1950s. Several studies investigated the generation and movement of leachate and gases (California State Water Pollution Control Board, 1952, 1954, 1961). The research suggested that, in a dry climate, landfilling above the water table would not impair ground-water quality but that subsurface contamination is very likely when refuse is in continuous or intermittent contact with ground water. We know now that leachate forms even in landfills above the water table; however, because evaporation exceeds precipitation under arid conditions, leachate formation is a slow process.

Research in Pennsylvania (Apgar and Langmuir, 1971), in Illinois (Hughes, Landon, and Farvolden, 1971), and elsewhere has shown that the rate of leachate production in a humid environment is almost unaffected by refuse disposal above or below the water table. The leachate enters the ground-water system in all cases. In northeastern Illinois, approximately one-half of the annual precipitation infiltrates into the refuse to produce leachate (Hughes, Landon, and Farvolden, 1971).

Where refuse is placed in fine-grained materials, a ground-water mound is likely to form within the refuse, because infiltration and leachate formation are more rapid than is migration into the surrounding less permeable, fine-grained sediments (Figure 2). Ground water may discharge as seeps along the

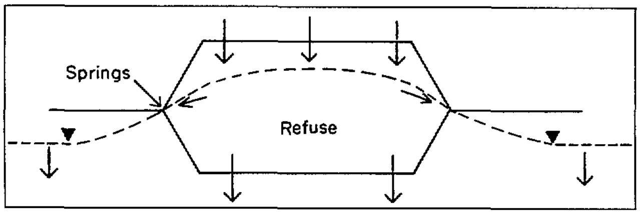

Fig. 2. Ground-water mound developed in landfill refuse (after Hughes, 1972).

edge of the landfill where the ground-water mound intersects the land surface. Because of the mound, ground water flows away from the landfill in all directions.

Fine-grained environments appear to be the most suitable for landfill siting. Clay minerals limit the rate of leachate migration and remove chemical constituents by cation exchange, thereby providing a natural renovation of the leachate. Cations in solution replace calcium and magnesium on the clay structure and increase their concentration in the leachate; this is the "hardness halo" that has been noted at several landfills (Griffin *et al.*, 1976).

Sites underlain by coarse-grained sediments are usually considered poor choices for landfills. Recent investigations of six landfills in sandy environments in Wisconsin and Illinois, however, indicated that little leachate migrated beyond the perimeters of the landfills themselves (Gerhardt, 1977; Johnson and Cartwright, 1978). Even though leachate is quite undesirable, leachate concentrations may be reduced within a relatively short distance, even in less desirable environments, by attenuation and/or dilution.

The importance of understanding the hydrogeologic conditions to permit evaluation of potential environmental impact has been stressed in research to date. Knowledge of the position of the landfill in the ground-water flow system and of the nature of the surrounding earth materials provides a basis for determining the degree of natural renovation offered by the site. To be aware of the ground-water resources and the existing or potential uses of local aquifers is also essential.

Although there is no substitute for site evaluation, geologic mapping can provide a guide for the planning and siting of disposal sites (Kempton, Bogner, and Cartwright, 1977). As we gain knowledge of the surficial geology and the hydrogeologic properties of the materials, maps can be prepared to show, in general, the suitability of an area for solid waste disposal (Figure 3). In Illinois, 9 to 15 meters (30-50 feet) of relatively impermeable material provides a mappable base for sanitary landfill suitability (Cartwright and Sherman, 1969). In De Witt County (Figure 3), only the upland areas covered by clayey glacial till meet this requirement consistently. The upland portion of De Witt County (area 1) is generally considered suitable for solid waste disposal. Portions of area 2a may be suitable, but it locally includes sand and gravel or silt zones within 6 meters (20 feet) of land surface. Only a few suitable areas may be found in area 2b because of the proximity to streams and sand and gravel deposits. Areas where loess overlies shallow sands and gravels are included in area 3a; area 3b includes land in the stream valleys. Both areas are unfavorable for waste disposal. This map provides a general guide to landfill suitability, but more information would be necessary for a specific site.

Where geologic factors are inadequate to provide for natural renovation of leachate, the site can be engineered to protect the subsurface environment. Site design may include a liner or a well to collect leachate, a treatment or recycling system, an impermeable cover to minimize infiltration, wells for venting of gases, or some combination of techniques (Hughes, 1972). An understanding of the hydrogeologic conditions is necessary to determine which approach might be most effective.

The behavior of other potential contaminants in the subsurface also has been investigated. Researchers at Pennsylvania State University have been studying the environmental aspects of spray irrigation of sewage effluent for more than ten years (Parizek *et al.*, 1967; Sopper and Kardos, 1973). Work in Illinois (Hinesly, Braids, and Molina, 1971) and elsewhere has focused on the impact of land disposal of sludge. The U.S. Geological Survey is currently studying the impact of sludge disposal on reclaimed strip mine land in western Illinois (Gary Patterson, U.S. Geological Survey, personal communication). Because nitrates are weakly adsorbed by soils, the nitrogen loading rate is an important factor in protecting ground water. Heavy metals may be of concern in sewage sludge; excessive loading rates may permit metal uptake by crops or migration of heavy metals into the subsurface.

Workers in Canada have been studying the migration of radioactive wastes since the early 1960s (Parsons, 1960, 1961, 1962; Cherry, 1973). The research to date improves our understanding of low-level waste migration. Although detailed information for each site is needed concerning

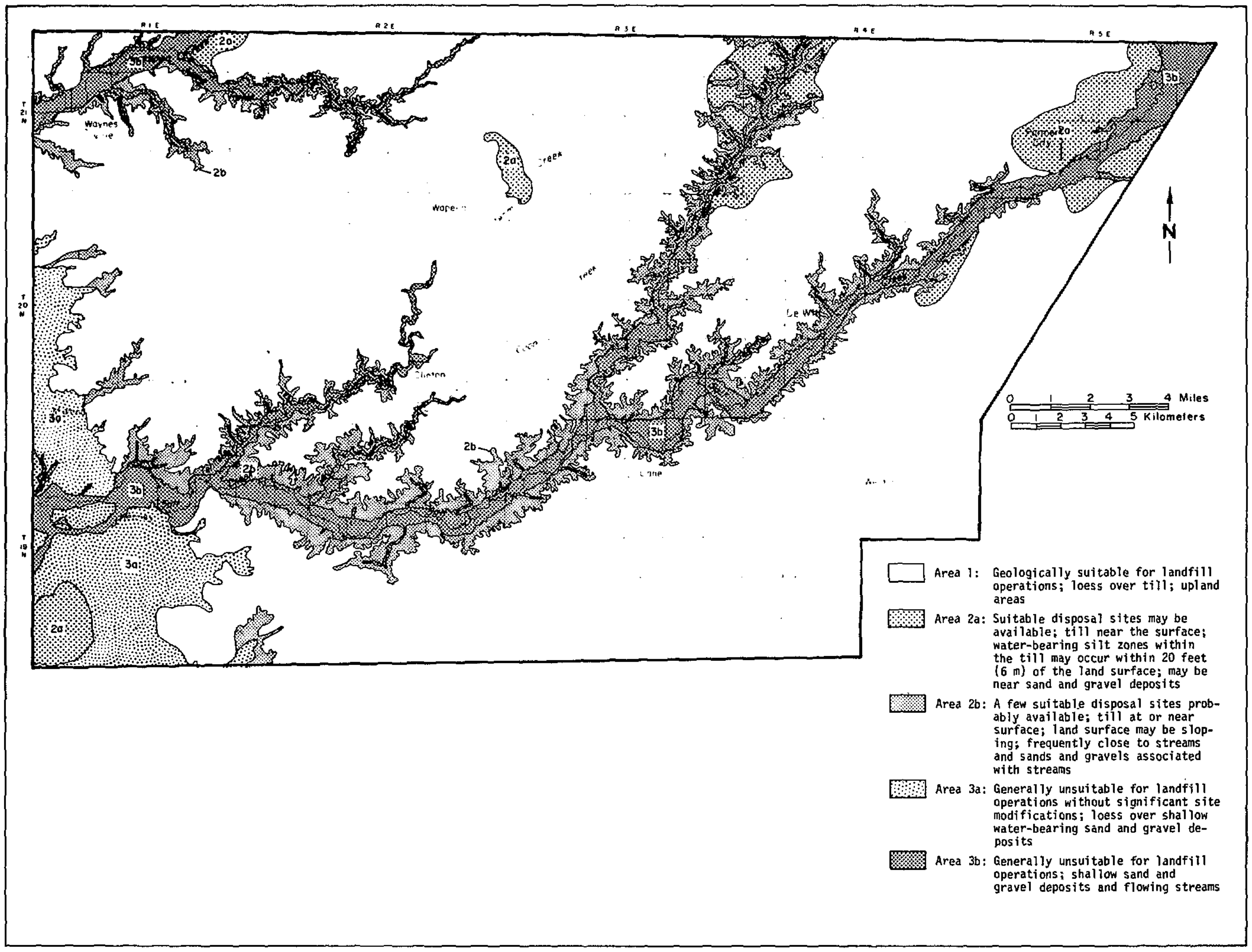

Fig. 3. Geologic conditions for solid waste disposal, De Witt County, Illinois (Hunt and Kempton, 1977).

predicted flow paths and rates of nuclide transport, public acceptance of such sites may be a more serious problem than site selection. There is still uncertainty as to the most suitable geologic settings for high-level radioactive waste disposal; more research is needed.

Time does not permit a complete review of all research investigating the migration of contaminants in the subsurface. Although research must continue, much valuable information has been generated in recent years that can provide a logical and reasonable scientific basis for the regulation of waste disposal to protect ground water.

FUTURE TRENDS

Regulations can reduce but not totally eliminate ground-water contamination. Accidental spills and unlawful dumping will continue. Because of the impossibility of monitoring all pipelines and storage facilities of the oil industry, petroleum products will continue to be a significant source of ground-water contamination. We are also likely to continue to face contamination problems from old, abandoned, unregulated waste disposal sites.

Increased land disposal of wastes will require effective regulation to minimize environmental degradation. Recent environmental regulations limiting disposal of industrial wastes into the air and surface water will increase use of land disposal because it is a cheaper disposal alternative. Spray irrigation and land disposal of sewage sludge will also increase because federal guidelines require consideration of all alternatives for sewage treatment and disposal. The increasing volume of radioactive wastes will necessitate action to locate favorable sites for disposal—especially for high-level wastes.

RECOMMENDATIONS

We can reduce ground-water contamination by thoroughly evaluating and monitoring waste disposal facilities and by responding quickly and effectively when a contamination problem is detected. The case histories and research suggest several steps that can be taken to minimize the incidence of ground-water contamination and limit the extent of contamination once discovered:

1. An inventory, and subsequent evaluation, in a State or a particular area of existing and potential sources of contamination would determine the relative significance or contamination potential of the various sources. Such an inventory might include septic systems, spray irrigation systems, land disposal of sludge, municipal and industrial impoundments or lagoons, landfills, feedlots, acid mine drainage, salt stockpiles, and perhaps others. Some potential sources may be poorly regulated if at all. Such information would provide a basis for developing guidelines or regulations to evaluate potential sources.

2. Equally important is the delineation of those areas geologically most sensitive to environmental degradation. This would include areas in which geological materials are naturally unsuitable for waste disposal and those in which existing or potential aquifer use might be jeopardized if contaminants reach ground water.

3. In addition to ground-water protection, plans or strategies must be developed to limit contamination once it is discovered. Cooperative efforts are needed to develop a plan for an early evaluation of each incident and an appropriate response based on the hydrogeologic setting, the nature of the contaminant, and the extent of contamination. A regulatory agency may have the expertise to respond to emergency situations, but may seek consultation with outside resources to properly evaluate remedial action for a long-term pollution problem. Each incident must be handled as a separate problem.

4. The role of hydrogeologists in regulatory agencies should be strengthened to provide proper evaluation of potential sources of contamination and to aid in remedial actions when ground water is contaminated.

5. Several lines of needed research are suggested by the evaluation of the case histories:

a. The movement of contaminants in the unsaturated zone.

b. Ground-water monitoring and sampling techniques.

c. Techniques for removal of contaminants, especially of hydrocarbons, from the subsurface.

d. The migration of radioactive nuclides in various hydrogeologic environments.

e. Documentation of ground-water contamination cases for possible application to future problems.

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Ground-Water Pollution — An Imminent Disaster[a]

by Wayne A. Pettyjohn[b]

ABSTRACT

The significance of ground-water pollution depends on our perspective. To those individuals who are directly affected, it is an imminent disaster. Once contaminated, ground water may remain in an unusable or even hazardous condition for decades or even centuries as illustrated by situations in central Ohio, New York, London and many others. All polluted water can be treated to make it potable, but the expense may far exceed the resources of the individual homeowner.

For millennia, man has disposed of his waste products in a variety of ways. The disposal method might reflect convenience, expedience, expense, or best available technology, but nevertheless in many instances, leachate from these wastes have come back to haunt later generations. This is largely because we have not thought out the consequences of our actions. Several short circuits commonly exist in our planning procedures. In particular these boil down to four major unknowns that someone eventually may have to deal with: (1) the composition and volume of the waste, (2) the exact location of its disposal, (3) estimates of the potential detrimental effect of the leachate on the environment and (4) the hydrogeology of the system.

The volume of waste produced annually is increasing at an exceedingly rapid pace and, since land disposal is becoming more popular, there is an even greater potential for ground-water pollution. Many wastes are long-lived and chemically complex and when mixed may form new compounds of unknown characteristics whose potential effects on health are largely unknown. It is imperative that we realistically examine methods of waste disposal and possible aftereffects. Further we cannot depend solely on federal, State or local controls.

In most instances no well-established strategies have been developed for rapid response to alleviate ground-water pollution problems and in many cases, agencies do not even have technical expertise available to them for advice and assistance. Furthermore, how can anyone accurately predict what might happen at some future date at a ground-water contamination site since installation of other wells, variable discharge rates and changes in land use all may influence overlapping cones of depression and drastically change the configuration of the water-level surface?

Individual polluted ground-water sites generally do not include extremely large areas. The problem cannot be compared to a modern day example of *On the Beach.* On the other hand, ground-water pollution is certainly a disaster to those individuals who depend on ground water as their source of supply and who awake some morning to find it contaminated. Moreover, regulatory agencies, industries and the courts have paid but little attention to the problems of individual homeowners who usually must bare the sole burden of cost and inconvenience, perhaps for years.

Ground-water pollution may lead to problems

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of inconvenience, such as taste, odor, color, hardness, or foaming but some cases are far more serious when pathogenic organisms, flammable or explosive substances or toxic chemicals or their by-products are concerned, particularly when long-term health effects are unknown.

The purposes of this report are to point out that (1) ground-water pollution is an imminent disaster to those individuals who are directly affected, and that (2) once polluted, ground water may remain in an unusable or even hazardous condition for decades or even centuries. Granted, any water supply can be treated to make it potable, but can the individual homeowner pay the cost and should he be required to do it? The examples briefly described herein are few in number only because of space constraints. The illustrations are highly generalized, but nearly all are adequately described in the literature.

1968 – CENTRAL OHIO

An oil-field brine holding pond was constructed adjacent to a producing well in central Ohio in 1968. Two years later when the well was plugged, the holding pond was filled, graded and seeded. The chloride concentration in the ground water in the vicinity of the former pond still exceeds 36,000 mg/l some 10 years after the operation began and 8 years after reclamation.

1964 – CENTRAL OHIO

Scores of brine holding ponds were constructed in central Ohio during an oil boom in 1964; many are still in use. Recently a number of test holes were constructed within 200 feet of one such pond. Within its vicinity shallow ground water contains as much as 50,000 mg/l of chloride and reflects a problem that began more than 14 years ago. Moreover, brine-contaminated ground water provides part of the flow of many streams and this has caused degradation of surface-water quality (Pettyjohn, 1971, 1973, 1975).

1954 – BAVARIA, GERMANY

Documentation of the migration of leachate plumes originating at garbage dumps and landfills is becoming increasingly abundant. Data show that under certain hydrologic conditions leachate plumes can move considerable distances and degrade ground water throughout wide areas. Furthermore, the problem is worldwide. Exler (1974) described a situation in southern Bavaria, Germany where a landfill has been in operation since 1954. The wastes are dumped into a dry gravel pit. Data collected from 1967 to 1970 showed the narrow lense-shaped plume had migrated nearly 2 miles (Figure 1). The ground water in the vicinity of this site has been degraded for nearly 25 years.

BAVARIA, GERMANY
1955

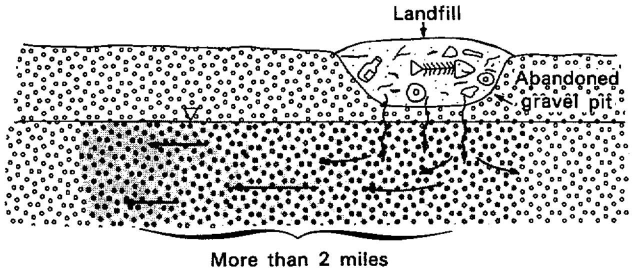

Fig. 1. Leachate from a landfill in Bavaria has migrated more than 2 miles and the ground water has been degraded for nearly 25 years.

1945 – KEIZER, OREGON

Incompletely processed aluminum ore was dumped into a borrow pit in Keizer, Oregon from August 1945 to July 1946 (Price, 1967). The ore and mill tailings had been treated with sulfuric acid and ammonium hydroxide. First recognized by local residents in 1946, the contaminated ground water locally contained more than 1,000 mg/l of sulfate; many shallow domestic wells tapping the Recent alluvium were contaminated (Figure 2).

In the Spring of 1948 the waste was removed from the borrow pit. Two wells, reportedly capable of producing more than 700 gpm (gallons per minute) were installed near the pit and for several months pumped to waste the contaminated ground water. By 1964 the contaminants had migrated more than a mile. No doubt some of the waste is still in the ground water at Keizer, and although

KEIZER, OREGON
1945

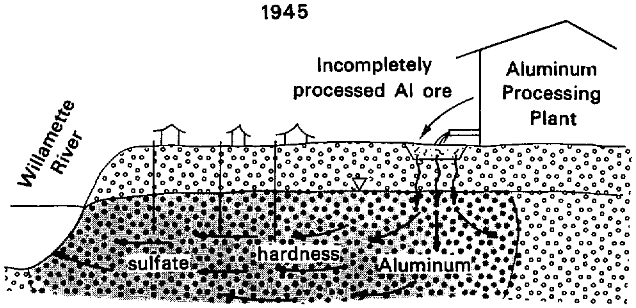

Fig. 2. Thirty-three years after disposal began the leachate from aluminum ore and mill tailings is still a problem in Keizer, Oregon.

considerably diluted, its effects remain noticeable some 33 years after disposal began.

1942 – NIAGARA FALLS, NEW YORK

Hooker Chemicals & Plastics Corp. began to bury chemical-filled drums in and along the margin of Love Canal in Niagara Falls 36 years ago. In 1953 the 16-acre site was sold for $1.00 to the Niagara Falls Board of Education (Anon., 1978). The area was soon developed. By 1976 an abnormally high water table caused some of the chemicals to seep to the surface and form pools; fumes seeped into basements.

So far more than 80 chemicals have been identified and at least 7 are carcinogenic. There are at least 30 sites like Love Canal in New York alone. Nationally, according to the U.S. Environmental Protection Agency, there are more than a thousand.

Are examples of ground-water pollution by industrial wastes a rarity? Not likely, if the situation in Michigan is typical.

> "Declared bankrupt in August, the Story Chemical Company left a disarray of improperly stored chemicals on its site in Muskegon. Lakeway Chemical's contamination results from 13 years of discharges to seepage lagoons. In April, Systech Waste Treatment Center reported that 500,000 gallons of sodium formate wastes were missing from their underground storage facility and presumed to be in the ground. Contamination at the Hooker Chemical site consists of hexachlorobenzene, C-56, carbon tetrachloride, and tetrachloroethylene. Ground waters at the Central Sanitary Landfill near Pierson in Montcalm County were contaminated when Approved Industrial Removal, a licensed liquid industrial waste hauler, illegally buried a truck tank plus a 10,000-gallon tank in the ground and filled them with 8,000 gallons of C-56 wastes from Hooker Chemical. Later removal of the tanks disclosed damage and leakage. Production Plated Plastics, Inc., a company that metal plates plastic automotive components such as hubcaps and headlamp housings, doubled their production without increasing their waste-water treatment capacity. As a result, residential wells in the area are contaminated with high levels of chromium. At the Gratiot County Landfill, Michigan Chemical disposed of 270,000 pounds of waste containing 70 percent PBBs. Preliminary studies show traces of PBBs in the ground water." – (*Water Well Journal*, 1978, p. 15.)

1942 – LONG ISLAND, NEW YORK

A well-documented study by Perlmutter and others (1963) showed that disposal of chromium and cadmium-rich plating wastes from an aircraft plant on Long Island during a 20-year period contaminated a shallow aquifer (Figure 3). The contamination was first discovered in 1942, and by 1962 the degraded ground-water zone was about 4,200 feet long and 1,000 feet wide. The 1962 study demonstrated that the chromium-cadmium enriched cigar-shaped plume "had not only reached Massapequa Creek but was present in the stream as well as in the beds beneath it" (Perlmutter and others, 1963, p. C183).

Now, more than 36 years after disposal began, these plating wastes are still slowly migrating with the ground water.

1936 – WESTERN MINNESOTA

During the middle and late 1930's grasshopper infestations were stripping the vegetation throughout wide areas in the Northern Great Plains. In western Minnesota partial control was obtained by a grasshopper bait consisting of arsenic, bran and sawdust. Eventually the leftover bait was buried. In May 1972, a contractor drilled a well near his office and warehouse on the outskirts of a small town. During the next two and a half months 11 of the 13 individuals employed at the site became ill; two were hospitalized. They were suffering from arsenic poisoning. One sample of water from the well contained 21 mg/l of arsenic. Analysis of soil from the site revealed arsenic concentrations ranging from 3,000 to 12,000 mg/l. Apparently the well was drilled in the near vicinity of the grasshopper bait disposal site, the location of which had long been forgotten by the local residents who had been bothered by grasshoppers some 40 or so years earlier (AWWA, 1975).

1914-1918 – LONDON, ENGLAND

Wastes from munitions works include picric acid, a toxic, intensely bitter, pale yellow substance. Picric acid is not readily removed by traditional water treatment methods and its migration through the unsaturated or saturated zone does not appear to neutralize it.

During the critical World War I years of 1914-1918, wastes from the manufacture of explosives at a plant near the Thames River just

LONG ISLAND, NEW YORK 1942

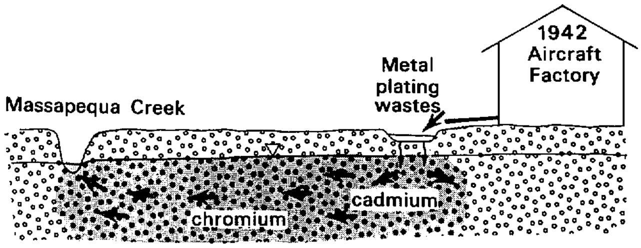

Fig. 3. More than 36 years after disposal of plating wastes began, the ground water remains polluted in South Farmingdale.

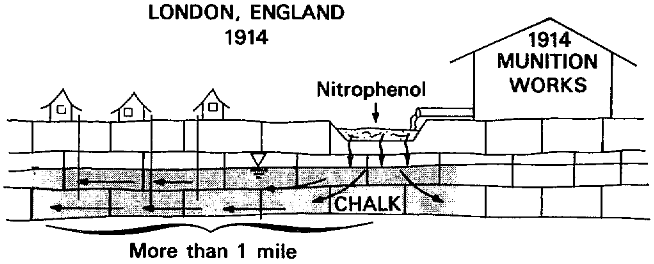

Fig. 4. The picric acid, which has been found in the ground water near London for decades, originated at a World War I munitions plant.

northeast of London, England were placed in abandoned chalk pits (Figure 4). In the early 1920's water from a nearby well was first reported to have a yellow tint (Essex Water Co., 1974). Additional water samples collected between 1939 and 1955 also contained a characteristic yellow picric acid tint. Sampling ceased in 1955 when the pump was removed.

By 1942 the pollutants had migrated at least a mile as indicated by another contaminated well. There is no reason to believe that the picric acid has been flushed from the aquifer within the past 23 years. The ground water has certainly been polluted for 40, quite probably for more than 60, and very likely for many more years to come.

1910 – BARSTOW, CALIFORNIA

Because of high evaporation and low recharge, waste disposal in arid regions can lead to long-lived ground-water quality problems. In the first place, salts are concentrated by evaporation to form highly mineralized fluids. Secondly, water supplies may not be readily available and, therefore, every effort must be made to protect existing supplies.

Ground-water contamination in the desert environment near Barstow, California was described by Hughes (1975). Beginning around 1910, waste fuel oil and solvents from a railroad system were discharged to the dry floor of the Mojave River near Barstow. The first municipal sewage treatment plant was constructed in 1938; the effluent was discharged to the riverbed. Sewage treatment facilities were enlarged in 1953 and 1968. Effluent disposal was dependent on evaporation and direct percolation into the alluvial deposits.

At the U.S. Marine Corps base near Barstow, industrial and domestic waste treatment facilities first became operational in 1942; effluent disposal relied on direct percolation and evaporation. Some of the effluent was used to irrigate a golf course. Other sources of ground-water contamination were two nearby mining and milling operations.

Analysis of well waters collected during the Spring of 1972 indicated the existence of two zones of contaminated ground water in the alluvial deposits of the Mojave River (Figure 5). The deeper zone, originating from the 1910 disposal area, exceeded 1,800 feet in width and extended nearly 4½ miles in a downgradient direction. Its upper surface lies 60 or more feet below land surface. The second or shallow zone originates at the sewage treatment lagoon installed in 1968 and at the Marine Corps golf course. This zone consists of two apparently separate plumes. The upgradient plume extends nearly 2 miles downstream, while the plume originating at the golf course is nearly a mile long. They are about 700 feet wide. Hughes estimated that the pollution fronts are moving at a rate of 1 to 1.5 feet per day. The Marine Corps well field lies in the path of these plumes; several domestic wells have already been contaminated. In this instance poor waste disposal practices, beginning nearly 70 years ago and coupled with subsequent inadequate methods, may cause water-supply problems at the Marine Corps base unless expensive corrective measures are undertaken.

1905 – LONDON, ENGLAND

From 1905 to 1967 wastes from a gasworks plant were deposited in abandoned gravel pits along the Lee River near Waltham Cross, a few miles northwest of London, England (Toft, 1974). The tar acids, oils, and sulfate sludge infiltrated to contaminate the ground water over a wide area (Figure 6). Apparently the pollution was first detected in 1935, some 30 years after disposal began. At this time oil, floating on the ground water, emerged at land surface. Continual but slow accumulation of oil on the land led to hazardous conditions and, in 1943, the oil was ignited.

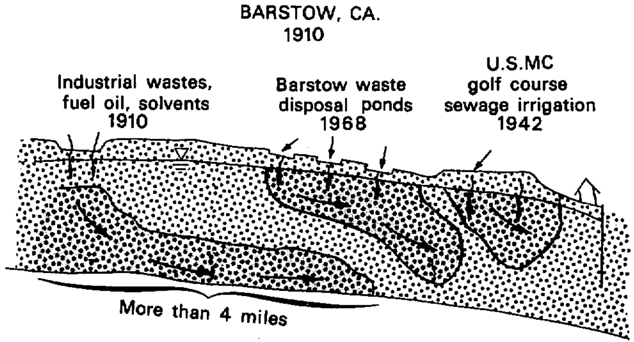

Fig. 5. Waste disposal beginning nearly 70 years ago at Barstow, California is now threatening an important well field at the nearby Marine base.

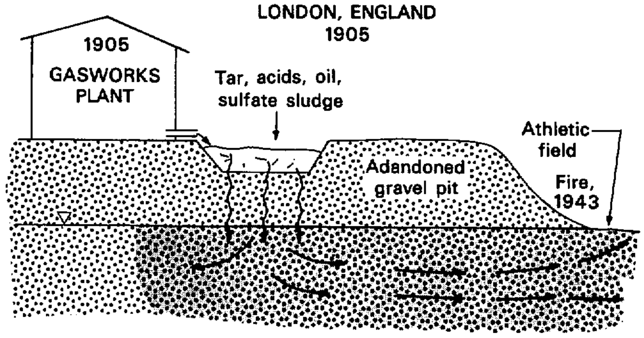

Fig. 6. Ground-water pollution by wastes from a gasworks plant near London has even created a fire hazard.

Contaminated ground water was also encountered in new excavations where it appeared as high concentrations of sulfate in 1958 and as oily waters in 1961. Oily liquids also seeped into Pymmes Brook and the River Lee Navigation channel in 1965 following a substantial rise in the water table after heavy rains. In 1966 additional surface-water degradation occurred because of the discharge of oil from streamside seepage zones.

Ground water in the surficial sand and gravel deposit was contaminated over a wide area. Fortunately, most water supplies in this area are pumped from an underlying chalk, which throughout much of the region is separated from the gravel by the London Clay. It is evident from this example that waste disposal, which began more than 70 years ago, continues to be troublesome and that ground-water contamination can indeed become a fire hazard.

1904 – CROSBY, NORTH DAKOTA

All ground-water pollution is not necessarily bad. Inhabitants of Crosby, a small village in northwestern North Dakota, believed they produced the best coffee in the State because the water from which it was made contained "body." The rather highly mineralized water (dissolved solids = 2,176, sulfate = 846, chloride = 164, and nitrate = 150 mg/l) used for brewing the coffee was obtained exclusively from an old dug well. The well, however, was constructed, probably near the turn of the century, at the site of the local livery stable. Apparently it was livestock wastes that provided the peculiar flavor so characteristic of the coffee made in Crosby (Pettyjohn, 1972).

1899 – BARBERTON, OHIO

The manufacture of soda ash, caustic soda, chlorine and allied chemicals began at Barberton, Ohio shortly before the turn of the century. The plant discharged a mixture of calcium and sodium chlorides directly to the Tuscarawas River and to retention ponds. The discharge of chloride in 1966 averaged 1,500 tons per day (Rau, 1975). These wastes have led to serious ground-water pollution problems in eastern Ohio and have necessitated abandonment of streamside well fields at Barberton in 1926 and at Massillon and Coshocton in 1953.

Municipal wells at Zanesville, more than 135 river miles downstream from Barberton, have also been adversely affected by the chloride induced into the watercourse aquifer from the contaminated Muskingum River. Due to high treatment costs Zanesville officials considered abandoning their well field in 1963. At the confluence of the Muskingum and the Ohio Rivers, about 220 river miles below Barberton, is the city of Marietta. Almost 20 years ago, Marietta officials were concerned over the marked increase in chloride in municipal wells during the preceding 10 years (Parker, 1955). The cause, of course, was induced infiltration of the chloride-rich Muskingum River water (Pettyjohn, 1971).

It is evident that decades of poor waste-disposal practices at Barberton have grossly contaminated or seriously impaired streamside aquifers and well fields for a distance of over 200 river miles. The soda ash plant at Barberton was closed in 1973 and waste discharges substantially reduced. Presumably, these water-quality problems will decrease in severity over the next several years, after a history of nearly 80 years.

1887 – COEUR d'ALENE, IDAHO

According to Mink and others (1972), mining operations in the Coeur d'Alene district of northern Idaho have been continuous for more than 90 years. Unfortunately, leaching of the ancient mining and milling wastes is now affecting the chemical quality of ground water in several areas, including Canyon Creek basin near Wallace. Here high concentrations of zinc, lead, copper and cadmium occur in both ground water and soil samples.

1884 – NEW STRAITSVILLE, OHIO

Ninety-four years ago, striking miners set fire to several deep mines in the vicinity of New Straitsville, Ohio. Still burning uncontrollably, the fires were started by disgruntled workers who rolled burning wood-filled coal cars into the shafts that honeycomb the ground under the town. In the years since, many wells have become contaminated, dried up or produce water hot enough to make instant coffee.

1872 – BELLEVUE, OHIO

Disposal of domestic, industrial and municipal wastes, which probably began around 1872 through wells and sinkholes tapping a permeable limestone aquifer, was the birth of a contaminated area that now encloses some 75 square miles. By 1919 the practice of disposing of sewage at the northern Ohio town of Bellevue was well established and many wells had been contaminated. In the early 1960's some wells were reported to yield easily recognizable raw sewage, including toilet tissue and a variety of unmentionables (Ohio Division of Water, 1961). This problem began more than a hundred years ago and remains to this day.

1815 – NORWICH, ENGLAND

A gasworks plant was built at Norwich in 1815 and abandoned in 1830. Phenolic compounds, originating from whale oil, infiltrated and remained in the underlying chalk for at least 135 years when it contaminated a newly drilled well in 1950 (Wood, 1962; Pettyjohn, 1972). These organic compounds, no doubt, are still there more than 160 years later.

17th CENTURY – SOUTHERN ENGLAND

A well drilled into the chalk at a gasworks plant in southern England produced hydrogen sulfide. Although questionable, officials claimed that the hydrogen sulfide was derived from drainage from a 17th Century Black Plague burial pit.

For centuries man has tolerated inadequate waste disposal and even when the resulting contamination leads to great expense and inconvenience, generally no one is greatly concerned except, perhaps, those immediately affected. This is not always the case, however, and sometimes the reaction is swift and effective. My colleague Stig Bergström has provided an example. The popularity of many European health spas is closely interwoven with the spa's reputation, a slight blemish on which, either real or implied, can be disastrous. A few years after World War I, a small town in central Sweden became well known for the mineralized waters at their extremely popular spa. The water, pumped from a well, was distributed to specific-use sites, including an open basin or fountain used exclusively for drinking water.

Following a formal ball and a good deal of eating and drinking, officers from a nearby military installation gathered in the vicinity of the drinking fountain. The next morning a rumor quickly spread that one of the drunken officers had urinated in the fountain. Within hours of this unsubstantiated event, spa guests began a mass exodus and reservations were cancelled. The spa never regained its popularity and shortly thereafter it was forced to go out of business.

The Swedish reaction, however, is certainly not universal. Bill Back of the U.S. Geological Survey described an interesting example of complacency. Near the center of a village in the Yucatan is a large-diameter dug well that apparently is used for more than just a water supply. One public spirited individual painted in large bold letters the following request: NO ORINAR EN ESTE POZO. Neither the sign nor what it implies has had much effect on the population or the use of the well.

SUMMARY

Our concept of the seriousness of ground-water pollution is related to our perspective. Generally we overreact, underreact, or simply don't react at all. On the other hand, ground-water pollution is indeed an imminent disaster for those who are directly affected or those who will be affected some time in the future. The problem is further compounded by a general lack of adequately trained regulatory personnel, ineffective legal controls and primitive but expensive cleanup procedures. The few cases cited above conclusively show that, once polluted, an aquifer may remain in an unusable or even hazardous condition for decades or even centuries.

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Ground-Water Pollution — A Limited Problem[a]

by D. Theodore Clark[b]

ABSTRACT

Few would argue that ground-water pollution is a problem and that serious ground-water pollution problems do exist. As serious as some isolated ground-water pollution problems are, regionally and nationally, it is only a limited problem. An industrial landfill may result in a leachate plume contaminating ground water over an area of up to several square miles downgradient from the disposal site. Municipal landfills or chemical/petroleum spills can result in polluted ground water over areas measured in square miles. Surrounding these areas of ground-water pollution, however, are tens and hundreds of square miles of area where the ground water moving through the aquifers maintains its natural good quality. The ratio of good quality to contaminated water is such that ground-water pollution can really only be considered as a limited problem.

The problem will most likely remain limited as existing and future regulations continue to restrict the poor disposal practices that have been responsible for much of the past and existing pollution problems. Technology has advanced to the point that with proper management and sound governmental regulations, control, isolation and cleanup of contamination sources and areas of polluted ground water can be so effective that migration of the pollution front can be stopped and actually reversed with time.

The same technology that provided us with the new chemicals and the wastes that show up in water analyses, has also provided us with the means of detecting many more contaminants at much lower levels of concentration in a water sample than was possible 50, 25 or even 10 years ago. One must thus ask, has ground-water pollution really become a national crisis, or do we just know more about an old problem made apparently more complicated by our own technological advances?

I am here for two reasons: first, I find the NWWA Technical Sessions worth my time because they are very well done and informative. And, secondly, I am here because of the initial announcement of this Symposium I picked up at last year's Technical meetings in Boston. A quick review of the announcement started me thinking, how can "ground-water pollution—a limited problem" be considered the negative side of the issue? Can "ground-water pollution—an imminent disaster" really be the positive side of the issue? So, in a way, I'm here to defend the issue that ground-water pollution is a limited problem and, in some respects, it can be considered the positive side of the discussion.

In support of the limited problem of ground-water pollution, I will concentrate my discussion on two basic concepts: first, the ratio of nonpolluted to polluted ground water; and, second, the role of technology in ground-water quality.

Dr. Pettyjohn has given us some examples of serious ground-water pollution and the problems that can result. Most of us have either seen or heard

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[a] Presented at the Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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about serious ground-water pollution problems—they do exist. There are thousands of municipal, industrial, and private landfills across the country. Many of these landfills have the potential for pollution, and, in some cases, they in fact do pollute the ground water below and adjacent to the disposal areas. Hundreds of additional pollution problems have resulted from storage tank and pipeline leaks of petroleum products. Many of these leaks and spills are serious because of the volume of product involved and the effort that must be expended to correct the problem.

Not many of these problems, as serious as they are, however, affect large areas. Most of the serious ground-water pollution problems that I am aware of affect areas measured in the tens to hundreds of acres with a few involving several square miles. Let's put the ratio of polluted ground water to natural, nonpolluted ground water into perspective. I will use the State of Ohio to illustrate my point. The land area of Ohio is 41,000 square miles. Ground water is produced from high yielding sand and gravel deposits, carbonate and sandstone aquifers, and poor yielding shale aquifers. Ohio ranks high as an industrial State and has a high population that is spread fairly uniformly across the State. For one percent of the State to have a serious ground-water pollution problem, it would require 410 individual sites creating ground-water contamination each averaging a square mile, or 2,600 individual sites, if we use a more realistic size of 100-acre sites.

Here's another way to look at it. In northwestern Ohio, individual wells will yield 100 to 1,000 gpm from the carbonate aquifer. It is possible that the water may be high in hardness or contain some H_2S or iron, making it poor quality water, a natural problem, but the water is generally of good quality. The point is, wells yielding adequate amounts of good quality, natural ground water can be drilled almost anywhere in northwestern Ohio. If local landfills, chemical plants, or petroleum terminals cause a local ground-water pollution problem, some adjacent area residents may have to have new wells drilled or have to relocate to obtain a satisfactory water supply. But, these steps can be done and have been done. Sure it's a serious problem, but I would not consider it a disaster.

Technological advances over the past 10 to 20 years have provided us with many new products, chemicals, synthetics, and ever increasing quantities of waste. Environmental concerns raised during the past decade have made us all aware of the problems resulting from unchecked discharge and disposal of our waste products. The same technology that developed the new products has also provided the capability of detecting an increasing number of chemicals, metals and minerals in smaller and smaller concentrations. A water sample 10 years ago that was tested and reported as "pure, natural ground water," today could be considered as polluted because of our ability to measure traces of a metal or chemical now known to be harmful if consumed in large quantities. The point is that ground-water pollution is not new; what is new is how and what is causing the pollution and the fact that sources of past and present pollution can be detected more readily.

There will be a tendency in the future for ground-water pollution to be abated for several reasons. Federal, State and local regulations covering the handling, storage, use, and disposal of chemicals and wastes have initiated increasing control over the rising rate of ground-water pollution. Improved regulations and disposal methods should decrease the potential for future ground-water pollution. As we become more aware of the cost of improper disposal practices and the resulting wasting of our natural resources, there will be a more conscious effort toward improved waste disposal and pollution prevention.

A second reason why serious ground-water pollution will be decreased is the improved understanding and capability of controlling and containing sources of ground-water pollution. Many of the serious ground-water pollution problems that exist today are the result of past waste disposal practices or a leak that went undetected for a long period of time. Some of the problems are being controlled to limit the migration of contaminated water. In some cases, efforts are underway to totally confine or even remove the source of the problem. And, of course, many of the causes for such pollution are being controlled now that the nature of the results is better known.

The control and the restoration of ground-water pollution are the keys to solving the most serious problems without the situation becoming a disaster. The disaster may result from the cost and effort involved in the control and restoration of the problem. A case in point is the Love Canal problem in Niagara Falls, New York.

Several additional examples may better illustrate how applied technology has been used to limit or solve the problem of ground-water pollution. In the first situation, an abandoned sand and gravel pit was used initially as a dump until regulations prohibited such operations. To become an "approved landfill," burning of trash stopped and waste was covered with sand located on the site. Several truck loads of sewerage treatment plant sludge and an industrial liquor are also disposed of at the site each day. About 6,000 feet downgradient, but east of the normally expected ground-water flow paths, are two municipal water-supply wells drawing water from the same glacial aquifer complex in which the landfill is located. The position of the two wells altered the ground-water flow path by drawing landfill leachate-contaminated ground water into the wells. Chlorides and nitrates reached a high level resulting in a total shutdown of the two wells. Evaluation of the ground-water flow paths indicated that with time, the water quality adjacent to the wells should improve and that the wells could be pumped for short intervals to help meet peak demands. Consideration is being given to diversion pumping as a means of offsetting the effect of the pumping wells. In this case, alternate actions are taking place to deal with a pollution problem created by poor waste disposal activities of the past.

The second example involves past disposal activities of industrial chemical waste. The disposal site had not been used for several years and, in fact, had been reclaimed to the extent that part of the area is the site of a modern chemical waste treatment facility. A preliminary ground-water monitoring program of the site indicated contaminated ground water, the source most likely being the abandoned disposal area. A more detailed study confirmed the source and the extent of the problem. Due to the chemical nature of the source and the fact that the problem would not go away in a short period of time, it was concluded that the source area should be contained to stop the migration of contaminated ground water beyond the property. A containment system was installed and followup monitoring has demonstrated its effectiveness. The source has been isolated and ongoing work outside the containment area is in the process of achieving almost complete ground-water quality restoration. In this example, a ground-water pollution problem has been brought under control and the potential of it becoming a more serious problem averted.

The objective of this Symposium and the three points of view presented are to generate interest resulting in an exchange of ideas and comments. It has been my pleasure to be a part of this program. Thank you.

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D. Theodore Clark has been employed by the consulting firm of Dunn Geoscience Corporation, Latham, New York, as Senior Hydrogeologist since 1973. His responsibilities include ground-water exploration and development, aquifer tests and analysis, hydrologic water budget analyses, and ground-water pollution studies. During the past two years, Mr. Clark has worked extensively on ground-water pollution monitoring and evaluation of industrial and chemical landfills.

Audience Response to Session I — Ground-Water Pollution

Wayne Jackman, Ontario Ministry of the Environment, Stoney Creek, Ontario, Canada L8E 3H2: I'd like to give an example of what confronts our government. It shows the frustration we have in regard to environmental impact assessments.

Locations of a landfill site must have proper hydrogeologic evaluation done by consulting firms. When it involves an environmental hearing board, the opponents are given a say. In many cases the regional governments, as well as individual public groups, hire hydrogeologists to oppose the landfill sites, resulting in hydrogeologists arguing against hydrogeologists. In many cases, you end up with a committee trying to decide what is right and wrong, becoming so confused that they submit to political pressures, and landfill sites go down the tubes, although it may have been a very good site to begin with. Then the cycle starts all over again.

In the meantime, old and out-of-date landfill sites are being over-taxed, built too high, industrial wastes are being put into them, in many cases illegally; but, because a number of areas where deep well disposal has been cut off or alternative types of treatment have not gone in because of the local opposition from citizens' groups, we end up with a situation where industrial wastes aren't allowed to be disposed of anywhere, but it has to be disposed of somewhere, so illegal operations result.

Ray Kazmann, Professor, Department of Civil Engineering, Louisiana State University, Baton Rouge, Louisiana 70808: This session is going to set the tone for this Symposium. What we say here will influence legislation and will influence attitudes.

I'd like to take the negative side of this argument that the ground-water pollution problem is a relatively limited problem. Anytime someone points to a major pollution problem and has to bring in illustrations 130 years old—that's stretching to make a case. None of the problems that have been brought forth are insolvable from an engineering standpoint. It's a question of money. Who pays how much? That's important, but there are also costs involved in writing legislation based on hard cases, because that means that you're involving the entire country in unnecessary costs for things that may not ever happen.

There's also a necessity to place a priority system on contamination cases. Biodegradable compounds—sure they're important, but they're relatively easy to treat. Once you get the leachate out of the ground, you can treat it with almost normal municipal sewage practices—either lagoons or some other relatively cheap method. Poisons, like these PCB's, are another problem and they need to be monitored and collected. Exactly what to do with it I don't know because nobody seems to come forth with a chemical solution. But I can collect it for you at least.

Metals, heavy metals, chromium and hexachromium, primarily are difficult but they might be considered as oil bodies. Pump the water out, treat it, and get the cadmium or other metal out. So I don't consider hard cases to be a good basis for passing legislation. I think the problem is more local, and if you can associate future mistreatment of wastes, make the perpetrator pay; that's really the purpose of legislation. We need more education; we need more maps showing areas favorable for waste disposal and unfavorable for waste disposal. It's education and a matter of priority.

Keith G. Kirk, Partner/Hydrogeologist, Environmental Exploration, Inc., Box 795, Morgantown, WV 26505: I put forth to you that there is no imminent disaster of ground-water pollution, but in fact an ongoing catastrophe. In the coal mining areas of the Appalachians and eastern coal measures, ground water has already been irreversibly contaminated and depleted by fossil fuel extraction, i.e. coal mining, oil and gas production. In the three-county area surrounding Pittsburgh, the major aquifer, other than alluvial deposits adjacent to the rivers, is the Pittsburgh sandstone. This aquifer has been polluted by acid mine drainage or dewatered entirely from the mining of the valuable Pittsburgh coal seam.

In the highly acid-producing coal measures of central Pennsylvania, near Brookville, Pennsylvania, over 500 square miles of land are all but devoid of potable ground water because of over half a century of mineral extraction that has again either polluted or depleted the ground water in that area. Example after example of such contamination could be cited. This contaminated ground water adversely affects rural Appalachia and helps to compound its problems of unemployment and rural poverty.

Now, in the name of energy independence, much of the ground water in the western States will soon fall victim to the shovels of the energy extractors, just as much of the ground-water resources in the Appalachians has. Action must be taken by hydrogeologists and contractors immediately to insure that the ground-water protection section of the recently passed Federal Surface Mine Reclamation Act is enforced. The Office of Surface Mine Reclamation, the agency in charge of enforcing this act, is already backstepping because of pressure from the coal industry. Citizens of the western coal measures, you have been put on notice!

Jim Waltz, Associate Professor of Hydrogeology, Colorado State University, Fort Collins: I'd like to talk about number four on the scoreboard of contaminant incidents; the organic contaminants. I think it was at the First Ground Water Quality Symposium in Denver that I addressed the topic of contamination from sewage disposal through septic tank systems. Contamination from septic tank systems, particularly in areas of igneous and metamorphic crystalline rocks, constitutes a type of contamination that is geologically sensitive.

Because it has to do with individuals, it is seldom monitored adequately. I think this problem is more intense than would be indicated by the fourth ranking ahead of industrial landfills, petroleum, and organics which was the order in which the wastes were listed according to incidents. I feel that there are many more incidents of organic waste contamination from septic tank systems that are never discovered because it has to do only with private individuals. The conventional septic tank sewage system, the leach field system, is designed to be used for soils that are about 6 feet thick. In the mountainous terrain, the igneous and metamorphic terrain, where I've had most of experience, soils are rarely over a foot thick. The weathered rock can be altered and dug, and it's considered by county sanitarians to be soil. It has the percolation characteristics of a good soil, but not a filtering characteristic, and I think that is the critical point in the errors that are made permitting absorption fields to go in where they should not.

The aspect of this problem which makes me think that it is not an imminent disaster is that in some of the mountain communities in Colorado, where I've done my studies, where perhaps 50 percent of the wells are contaminated by this source of contamination, the residents are uninformed about having X number of bacteria in their well. They say, "I've been drinking it for 20 years. I feel great." Perhaps that clearly underlines the fact that there is no disaster in this type of contamination, but there are also cases where contamination has occurred, and where serious illness results. If a person is drinking his own sewage, perhaps that's not a serious problem, but I do think it deserves more attention than it's getting.

Brad Caswell, Maine Geological Survey, Augusta, Maine: I represent Maine. We don't have too many ground-water regulations at this time. In fact, we don't have much ground water but I'd like to speak about the bureaucracy doing the regulating, as being part of what I see as the ground-water pollution disaster. We're all looking up to these institutions to protect our ground water. We give them a little science, they give us back the bureaucracy to do it, and it has begun to scare me. I had something to do with setting up or suggesting ways of disposing of solid waste in Maine about 7 years ago. We have all kinds of forms, all kinds of people hired, and there's a definite procedure of waste regulation going on in Maine. It's come to me now that some of our procedures are wrong. We need to change them. I go back to that bureaucracy and I'm having a heck of a time getting people to listen, getting them to change their style. Maine is just now starting to talk about more regulations because we're becoming more interested in ground water. We recently had our biggest pollution disaster in Maine's history.

I'm quite frightened that we may now regulate ground water to a point where the bureaucracy gets so intransigent that it is not going to be able to change with the times. I'd like to relinquish the rest of the time to the panel members to make comments.

Ted Clark, Dunn Geoscience Corp., Latham, New York: I indicated that I thought one of the reasons ground-water pollution would be a limited problem, or remain a limited problem, was that some State, Federal and local regulations, put somewhat of a damper on what I feel was an increasing rate of ground-water pollution. I think some of the proper steps, some of the work we've been doing implementing regulations, evaluations and monitoring programs are helping and some precautions are now being taken.

Properly managed and operated landfills today certainly don't cause the same sort of problems that the old dumps in abandoned gravel pits did. They certainly did contribute to ground-water pollution.

I feel that some of the regulations, controls and requirements that are being implemented definitely do have some real benefit. We are seeing it already, and in the future, we will not be running across as many examples that we know about today that Wayne described.

Wayne Pettyjohn, The Ohio State University, Columbus: If you think that the laws are going to stop ground-water contamination, you're out of your mind. Let me give you an example. In Ohio, which is a good place to be from we have a fair amount of oil production. When these wells were drilled, they used oil brine holding ponds. Now they used to call these evaporation pits, because they put this brine in there, maybe an inch or so with a layer of oil on the top and all the water would evaporate. Now we know that because the water level in those things continued to drop. Those things were contaminating streams, so they passed the law. They said that we will no longer use oil field brine holding ponds for evaporation pits. They are now called temporary storage structures, but they work the same way.

We have drilled over 200,000 oil wells in Ohio, and nearly every one of them has had a pit. Now maybe the contamination route would cover half an acre. Well, about half an acre times 200,000, that's a good many acres where the chloride content, as I showed you, might well exceed 30, 40, 50,000 mg/l many years later.

The passing of laws isn't necessarily going to solve any of our problems.

David Farlow, Water Resources Engineering, Stanley Consultants, Muscatine, Iowa: I'd like to ask a question that is based on a trend that I've observed to be taking place. This is that any change in ground-water quality seems to be defined as pollution.

Now, what about the case of a landfill where the natural ground-water quality has a pH of 8, and due to the acid for example, the pH drops to 7. Is that pollution? We see, perhaps, a situation where the TDS level of ground water naturally might be 300 mg/l, and it goes to 400. Is that pollution? So, the question I want to ask here is, if a change does occur in ground-water quality, but the ground-water quality still meets drinking water standards, is it polluted?

Wayne Pettyjohn: My immediate reaction to that would be no. Somewhere recently I read the definition that contamination occurs when the water quality has been changed from one quality standard to another generally considered less desirable. Pollution is where it becomes such quality that it's really not fit for the normal use, such as drinking or some processing or something that involves the use by mankind. I think, in this case, where maybe the quality or the chemistry is changed to some extent with solids or something increased by a couple hundred parts or something like this, it still may not be altering the natural ground-water quality enough to be considered pollution.

Ground-Water Quality Standards — A Neutral View[a]

by Donald K. Keech[b]

ABSTRACT

An objective view of the need for ground-water quality standards requires that an individual recognize the value that ground water contributes to the water supply needs of our nation. A vast number of people living in rural areas and a large number of communities are dependent upon ground water as their sole source of water for domestic, industrial, commercial, and agricultural needs.

This large use and dependency upon ground water dictates that these resources are valuable and must be protected for both present day and future uses. There are many examples where present methods of disposal of wastes generated in America have not been satisfactory from an environmental standpoint, with an exception of projects where disposal sites have been properly designed, operated, and managed for protection of the ground water.

One possible solution for ground-water protection is the establishment of ground-water quality standards. The purpose of such standards is to protect the public health and welfare and maintain the quality of ground waters in all usable aquifers for individual, public, industrial, and agricultural water supplies. A legal basis must exist and the prescribed steps must be followed as dictated by the rule making process. The primary aim of such standards is to prevent the degradation of ground waters such as they will not become a public health hazard or harm the users of the ground water.

The backbone of such a standard rests on the completion of a hydrogeological study which is necessary to determine background water quality information, set up the monitoring program and outline sampling to determine when water quality changes are taking place and what is a significant change.

Ground water provides the only usable source for a potable water supply for many parts of the nation. In Michigan over 2.3 million people depend upon ground water as their source of water for drinking and other domestic needs plus meeting the need of a vast number of second homes, commercial and industrial developments, and a growing agricultural need. Nationally, 35% of all water used by municipalities comes from underground aquifers and ground water furnishes 80% of water used in rural areas for domestic needs and livestock watering. Thus it is evident that every person in the United States with any background in the many uses of ground water is concerned about protecting the ground water as a valuable natural resource.

The question is then how to protect these valuable underground-water resources. Even a cursory review of ground-water literature indicates that many aquifers across the United States have

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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been rendered unusable for production of a safe, wholesome water supply due to one type of pollution or another. It is evident that existing policies and disposal methods have not been successful in protecting the ground water.

The complex society in which we live generates all types of waste: chemical, liquid and solid, sanitary, industrial, hazardous, toxic, and undoubtedly many others. How can we dispose of these wastes safely? It is obvious that some of the practices in the past cannot be permitted and new methods of disposal are being looked at. At the present time there is an emphasis to use the ground surface as a disposal medium for liquid wastes, sludges, and solid wastes. It is obvious that materials leak from these disposal sites and end up in the ground waters. On the other side of the coin, there are examples where disposal sites are properly designed, constructed, operated, and monitored to protect the ground waters from the leachate.

One solution to consider is ground-water quality standards. If ground-water criteria is the answer, then consideration must be given to a large number of factors. It is evident that every drop of ground water will not be maintained in pristine quality, but ground-water rules would be established to protect the ground water as a valuable resource. A decision must be made as to exactly what is to be accomplished with a clear definition of purpose. One statement of purpose for ground-water quality standards follows: "to protect the public health and welfare and maintain the quality of ground waters in all usable aquifers for individual, public, industrial, and agricultural water supplies." After the purpose is agreed upon then a decision must be reached as to how to accomplish these goals. The intent is to provide a mechanism to provide for nondegradation of ground-water quality in all usable aquifers. These are aquifers that are currently being used or have a potential for production of water for drinking purposes, and various industrial or agricultural applications. Such rules would not generally apply to the highly mineralized brine or oil and gas producing aquifers. To assure that aquifers are not degraded or that they will not be degraded it is necessary to require a hydrogeological study procedure and establish ground-water monitoring requirements. From a practical standpoint it is undoubtedly desirable to provide for variances or exceptions to specific rules due to any one of a number of circumstances.

I would like to make a few comments regarding the above noted principles. First, it is absolutely necessary that a legal basis exist for adoption of a rule or standard of this nature and that the required steps be followed as dictated by the rule making procedures. This normally includes a process where public hearings are held that are open to all segments of the population to speak either pro or con regarding the proposed criteria and procedures. Written comments should also be received and justification must be provided for those that feel the rules may be too strict and for others who feel they do not satisfactorily protect the ground-water resources.

I am confident that all public health professionals in the ground-water field believe that ground water should be protected from nondegradation since any degradation may be a public health hazard or at least harm a user of that resource. It is obvious that any degradation must be measured from some background level. This presents at least two problems: (1) how is the background water quality determined, and (2) when does a change become significant. The sophisticated technology available to water chemists today permits measuring substances down into the parts per billion range. This opens the door to valid questions regarding how an agency will determine a measurable change from background levels to indicate degradation is taking place. It is nearly impossible to ascribe finite values to determine significant changes, such as a certain percent increase or an increase of some precise value. Toxic chemical levels are mandated by the Federal EPA Safe Drinking Water Regulations. However, from a realistic point of view, these decisions must be made on professional judgment based on the facts at hand, public health hazards, and experience in ground-water chemistry.

It is obvious to obtain a nondegradation condition, that proper engineering based on correct hydrogeological studies must be done prior to permitting a discharge of any type of waste. There are several avenues to accomplish this—through proper treatment, site selection, provision of barriers to control percolation and seepage, use of underdrain systems, or complete containment of a discharge within the disposal site. Public health workers recognize that the aquifers directly underlaying the disposal site are no longer usable as potable water supplies and thus are relegated to waste disposal.

To regulate discharges of waste materials for the protection of ground water, in addition to legal basis for such regulation, it is necessary to know who legally owns the ground water. Some people believe that not all ground water is necessarily water of the State, but a property owner has an inherent right to utilize ground water in a way that does not threaten or impair the public interest. The regulating agency must be prepared to answer questions regarding the right to regulate ground water if it cannot be demonstrated that a substantial public interest, public use or necessity for ground-water standards exist. If not, then the argument is advanced that the regulations constitute unnecessary and unconstitutional expropriation of a property owner's rights to utilize his property and the ground waters underlying such property. This issue may present an interesting legal discussion in some States.

Probably the most important tool in making any determination in the area of ground-water quality standards is the completeness and thoroughness of the hydrogeological study and report. This study will form a basis for any discharge permit and perhaps even renewal of an existing permit when the potential exists for contamination of ground water. The hydrogeological study forms a basis for all decisions in matters relating to protection of the ground-water quality. Problems are encountered in determining the degree or sophistication of a study, which would vary depending on the volume and potential hazardous nature of the waste. Representatives from the fields to be regulated, both the private and public sector, are concerned about the economic impact of the cost of these studies and question who is capable or qualified to conduct such a study. It has been pointed out that the small number of firms generally available for conducting hydrogeological studies minimizes choice of contractors and could affect meeting required timetables. A lack of an adequate number of qualified firms could present problems in obtaining the required study in an acceptable economic and time framework.

The purpose of the hydrogeological study is to obtain all known information in the hydrogeological field, define the engineering modifications that may be necessary, design a ground-water monitoring program, delineate the usable aquifers, and establish the impact a discharge may have on ground water contained in any usable aquifer. This type of report must contain sufficient data presented in a logical and understandable manner to support the conclusions and recommendations.

Another major aspect of ground-water quality control relates to monitoring ground water to observe for changes or any degradation that may be taking place or to assure that no contaminants are entering a useful aquifer. Both water quality and water level data should be collected in a monitoring system which must be specifically designed to adequately assess the impact of any discharge on ground water. It cannot be over-emphasized that the design of a monitoring system must be based on the geology of the area and the type of waste discharge. This means that exact details of the design and construction of monitoring wells must be specified. Criteria to be considered would be drilling methods to assure that water samples will be obtained from the precise depth anticipated where the leachate might occur and that the wells are constructed to assure prevention of vertical leakage between aquifers or leakage of surface water into the well. Another area of concern is that the monitoring wells be designed so that practical methods can be used for collection of water samples and measurement of water levels. In other words, the monitoring system must be able to accomplish what it was intended to do.

Monitoring is another area where those to be regulated can express concern since various aspects of monitoring are extremely difficult to define. This relates to the specific chemicals or other tests to be made, the number of samples to be collected, the frequency of collection, and the time period to be covered by the monitoring program.

Another concern will be expressed in this whole area regarding activities that perhaps should be excluded from the hydrogeological study and monitoring requirements. Obviously, if a specific activity may pose a threat or be injurious to the protected uses of the aquifer, such studies will be required. On the other hand, it is not practical to require an indepth study for a home sewage disposal system, application of dust suppressant or deicing chemicals which are used within normally accepted or regulated practices, controlled application of chemicals for domestic or agricultural uses when used in normally accepted or regulated practices, disposal of untreated noncontact cooling water, and undoubtedly other activities may be excluded from these requirements.

The nondegradation principle is certainly a lofty idea and desirable for protection of ground-water resources. On the other hand, there will be instances when a variance will be requested to allow a reasonable degradation in a usable aquifer. Obviously when variances are granted, the degradation cannot preclude the use of the aquifer for its protected uses and will not become injurious to the public health, safety or welfare. Such variances would only be granted in exceptional circumstances where it is determined that strict conformity is not economically or technically feasible and no prudent alternative exists. Granting variances must be consistent with promotion of the public health, safety, and welfare in light of the State's paramount concern for the protection of its natural resources. This is an area that must be handled technically correct and the criteria, limitations, or conditions spelled out completely to protect the users of ground water.

I believe that it is pertinent to discuss both positive results and problem areas when the question of ground-water standards is viewed from an objective standpoint. The Muskegon County area of Michigan, which is located on the shore of Lake Michigan, makes a good study area. The geology is fairly simple with sandy materials generally overlying deep clays extending to a depth where mineralized water is then encountered. This means the upper sands are used both as a source for drinking water and for disposal of all types of wastes. Muskegon County is an industrial area serving as a home for several large chemical plants with the resultant need for disposal of numerous by-products from the chemical production which are oftentimes hazardous. Muskegon County also operates one of the largest lagoon-irrigation systems presently being operated for disposal of waste waters. I think it is interesting to note that this facility provides treatment by three separate eight-acre area cells, with a treatment capacity of 42 million gallons per day and is presently handling an average daily flow of 27 million gallons. The treated waste water is disinfected and irrigated over 5400 acres with much of the land being planted to corn. Fifty-four center pivot irrigation rigs are being operated for disposal purposes. This site was developed on an area of marginal farm land, basically sandy in nature and generally with an extremely high water table. Concern was expressed for protection of the usable aquifers outside of the specific disposal site and accordingly the design was developed to dewater and underdrain the disposal area. An elaborate monitoring system was developed and is being actively administered to assure that containment of the waste is being obtained. It should be noted, however, that this entire disposal site has been relegated to disposal of waste water and the aquifers underlying this site are not considered a source for drinking-water supplies. Additionally it is recognized that many universities across the nation have water resource research projects whereby waste water is being treated and the soils are being used for renovation and disposal of the waste water. The disposal of the waste water is generally through an irrigation type system to provide usable irrigation water and for nutrient use through renovation of the waste water through the upper soils.

Muskegon County has other disposal sites where the highly toxic and hazardous industrial wastes are being disposed of. The unknown nature of these wastes present several problems and sometimes it is practically impossible for the laboratory to analyze for specific components. In the past, disposal of such wastes was virtually uncontrolled and sometimes it appeared to be willful waste disposal into the ground without consideration of their effect upon ground water.

An example of this type of problem relates to a chemical plant that went bankrupt a few years ago but their disposal practices had already contaminated the ground water. Wells that had been installed to purge the aquifer were then disconnected. This resulted in the contaminated ground water moving from the industrial site and contaminating many drinking water wells in the area. At the present time Muskegon County is actually hauling water for drinking and domestic purposes to 50 homes in the affected area. The Michigan legislature passed legislation allocating 1.2 million dollars (a portion of the money came from a settlement with new owners of the chemical plant) to be used for cleaning up this ground-water contamination, for disposal of the chemicals left in storage, and sludge buried on the site. Eighty seven hundred 55-gallon drums plus over 2000 smaller containers containing toxic chemicals and chemical wastes remained on the site when abandoned by the defunct chemical company. In addition it is estimated that 8000 cubic yards of sludge stored in lagoons must also be removed and properly disposed of. A total of 10 pages were required to simply list the various chemicals used by this manufacturing plant.

A portion of the money is being provided to Muskegon County for their problems in dealing with the pollution and for extension of a central water system into the affected area. It is evident from this incident that the general public has to pay part of the cost of the damages caused by uncontrolled disposal into the ground water. In addition the ground waters have been contaminated to a point where they are no longer usable for potable water purposes.

A cursory review of the literature indicates that most if not all industrialized States have recorded incidents where improper disposal practices for toxic chemicals have polluted underground aquifers to a point where they are no longer usable for production of potable water. Some of these aquifers are fairly small in extent and simply are written off and forgotten as a source of ground water. Others are much larger and affect a larger number of people. I know of instances where the only usable productive water-bearing aquifer in the area has been contaminated necessitating a small rural community to extend a pipeline a distance of over 20 miles. These types of incidents result in economic hardship to individual persons on private wells or even communities depending upon ground water for their municipal supply. In some cases industries can no longer depend upon the use of ground water for their industrial processes.

Another interesting area to review relates to irrigation of crops in the farm belt areas. Michigan farmers have found that is economically feasible to install large irrigation systems (which I believe were developed in the arid West) in an area where the average rainfall is approximately 35 inches per year. Production of corn through proper irrigation and fertilization in Michigan can rival the production from the rich corn belt areas in Indiana and Illinois. A record corn production for one irrigated acre approached 400 bushels. It is recognized that this is not a practical yield, but is not unusual for corn production to be increased from 75 bushels per acre to 150 and perhaps even exceeding 190 bushels per acre through irrigation. These excellent crop yields not only in corn, but soybeans, potatoes, and even alfalfa also require larger quantities of fertilizer which is oftentimes mixed with the irrigation water. To obtain these high yields excess nitrogen fertilizers are applied and sometimes through what appears questionable procedures for the most beneficial use of the fertilizer. There is evidence that the nitrogen is leached below the recovery zone of the root systems and thus eventually ends up in the ground water. Many areas in Michigan have evidenced an increase in the nitrate level in ground water to a point where they far exceed the EPA maximum contaminant levels for public drinking water supplies. A recent ground-water publication stated that a research project is being conducted by the University of Nebraska at Lincoln to study a means of controlling water pollution resulting from irrigation practices in the central plains States. The report goes on to state that 13 States will be studied for nonpoint pollution resulting from irrigation. It is recognized that irrigation is necessary for the abundant crop production which we expect from our farmlands but the question must be answered, what can be done to safeguard the ground waters?

There is another problem that has recently come to light in Michigan. Ground water has become contaminated from disposal of laundry wastes that contained perchloroethylene. Perchloroethylene is used as a dry cleaning fluid and many of the small laundromats provide a coin operated dry cleaning facility in conjunction with their coin operated laundromats. A nagging ground-water quality problem has been under investigation for the last 3 or 4 years and it wasn't until last year that perchloroethylene was discovered as the contaminant. This chemical has contaminated many private wells along with a few noncommunity public water supplies, including a food service establishment and an elementary school. At the present time the solution for providing a safe, potable drinking water has not been resolved. However, many homeowners, as well as the commercial establishments, have been harmed by having their source of ground-water supply contaminated by the perchloroethylene. It is recognized that the individual ownership and operation of small laundromat-dry cleaning establishments is desirable and a needed commercial venture in our communities. However, the problems we have encountered in Michigan indicates that operation and disposal of waste generated from these facilities must be regulated.

The question today is are ground-water quality standards necessary, and if necessary, how can they be effective to assure that the ground water is not being degraded? It is necessary to protect ground water for users of today and tomorrow from economic harm and to assure protection of their public health and welfare.

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Ground-Water Quality Standards — Relevant[a]

by James H. McDermott[b]

ABSTRACT

The opportunity to begin formulating a national ground-water quality protection program is at hand. In building the new program we should use the host of lessons learned in the experience of related environmental programs. This is necessary so that the new program will be realistic at the outset and congruent with the integrated planning and management of the ground- and surface-water resources of the nation.

The keystone of program development, implementation, and evaluation is and will continue to be water quality standards. To the extent that the goal "Safe Drinking Water for Americans" has already been established, the point-of-use regulations (IPDW Regs and the RPDW Regs), should serve as water quality objectives thus facilitating ground-water program formulation and evaluation. The major regulatory thrust of the program, the water quality standards, must be technology-based site selection, construction and operational standards, with only limited monitoring in a conventional water supply and water pollution control context.

INTRODUCTION

Ground-water regulations are necessary to provide a framework within which this nation can move towards integrated management of surface- and ground-water resources for both quantity and quality. The need for an integrated approach has been learned in selected instances at the local level. It has not yet been accepted on a national basis, but we must prepare the way.

President Carter's recent water resource policy review served to demonstrate that ground water is a neglected resource from a forward-looking management point of view. Ground water continues to be out-of-sight and out-of-mind. This is likely to continue until three problems are addressed:

1. The extent of quality degradation and quantity depletion must be better defined and the causes articulated.

2. The potential threat and consequences of degradation and depletion must be delineated.

3. A national policy and program must be advanced and gain widespread support acknowledging existing ownership and institutional patterns.

Few will argue with falling ground-water levels as a prima facie case demonstrating depletion. Most people can recognize and accept surface-water analogies including falling lake levels as a rational explanation of what is occurring at least insofar as quantity is concerned.

Ground-water quality is, however, another issue. Many people have difficulty visualizing the significance of water quality. For instance, it has taken the public 30 or more years to support water pollution control efforts. The need to protect, conserve, and manage ground-water quality, by comparison with surface-water quality, will be a very large step for the public at large until such time as the above three problems are addressed on a consistent basis.

The process must begin with a goal which can be readily understood by the public and a set of common national standards which acknowledge critical uses and are accepted and supported by the

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[a] Presented at the Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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technical and professional community. Common bench marks, water quality standards, are needed *today* to facilitate the technical debates which are now gaining momentum, as evidenced by this Symposium, leading towards eventual problem definition and program development.

And in a larger sense, ground-water regulations will be essential to the conjunctive management of the nation's ground- and surface-water resources in the future.

LESSONS FROM THE PAST

From the recent water resource policy review we have learned that past categorical water resource planning and development not only neglected ground water but that the categorical priority given to surface-water development also frequently led to adverse environmental consequences and economic excess. Similarly, the last twenty years of ever increasing national priority for water pollution control, ostensibly a comprehensive cleanup of the nation's water resources in the name of current and future generations, has neglected ground-water quality. Indeed past surface-water cleanup priorities have been responsible for, and recent land treatment initiatives (Session III) threaten in the minds of many, yet additional endangerment to ground-water quality.

Thankfully these imbalances in categorical approaches and loopholes in legal authorities have been identified and articulated in professional journals and Congressional hearings during this decade. Assisted by scientists, engineers, and environmentalists, the Congress has moved to provide an array of statutes which provide at least a starting point to articulate the problems (Session I) and begin managing the quality of the nation's ground-water resource (Session IV).

The fact that awareness and opportunity occur in an era of budget deficits, the inflationary spiral, the energy crunch and the regulatory backlash should not dissuade us. There has never been a "good" time to increase the regulatory burden or the Federal, State, and local financial burden in the last twenty years. Only now that the program is well advanced are the real benefits of surface-water cleanup becoming apparent. And, only now that the adequacy of surface-water resource is being questioned is the concern for ground-water resources growing. So those among us who are concerned with the environment and public health and see the future need for conjunctive management, should learn from the lessons of the past and move to formulate a ground-water strategy which goes beyond water resource planning and development, beyond ground-water quality protection, to fully integrated water resource management.

WHERE TO START

To begin to manage ground-water quality we must (1) first set an achievable goal, (2) move to define the problem, (3) examine and select control options, (4) set objectives, (5) augment or establish institutions when and where needed, (6) provide for evaluation and feedback, and (7) communicate the problem and solution to the public.

Acceptance of these basic principles, which must be accounted for at the birth of all new programs, highlights the importance of "standards."

The goal must make sense, both common sense and economic sense. For my part the goal is clear—safe drinking water for all Americans. What is less clear with respect to ground water is whether or not there is a threat. And, if there is a threat, who should pay for remedial action and regulatory monitoring?

The common view in the past was that ground waters are safe if drinkable. Today, largely because of the public notice provisions of the Interim Primary Drinking Water Regulations and public awareness associated with EPA's proposed synthetic organic contaminant regulations, the American public is beginning to recognize that our senses of taste and smell are no longer adequate.

If ground-water quality is questionable, there will emerge a recognition that someone is going to have to pay for cleanup or for quality control. It is also clear that those who are dependent upon ground water will conclude that they should not have to pay for treatment because of someone else's current or potential "abuse" of ground-water quality.

If we are to legitimately capitalize on the emerging recognition of ground-water pollution and the safety of drinking water issue we must be prepared to define "abuse" and to identify, select from, and communicate control options that make sense—common sense and economic sense. P.L. 93-523 provides a mechanism to define safety through point-of-use regulations. The abuse-safety test at the consumers' tap is thus established by maximum contaminant levels (MCL's) and potential treatment requirements specified in the IPDW regulations. At this point in the program evolution we must address several questions.

- Should the burden of proof of pollution be on the user, or the Federal, State, or local government?
- Should the cost of monitoring be shared among users and waste disposer, or be the sole responsibility of the waste discharger?
- Can we or must we depend on technology-based regulations to control potential ground-water pollution?
- Is monitoring even necessary?

The user, in a community, commercial, agricultural and industrial sense must continue to bear the responsibility and cost of routine monitoring of his source of supply be it surface or ground water. This is the only way that he can assure the quality of the product, modify or install additional treatment, or spot the signals identifying the occurrence of unexpected changes in water quality. These costs are now being borne by users, but have led many people to jump to the erroneous conclusion that the nation's ground-water-dependent systems should also serve as a National Ground-Water Pollution Network. After all, goes the argument, why increase the monitoring cost by requiring additional observation wells or by adding to the burden of potential ground-water polluters?

Unfortunately, the establishment of a national program to manage and enforce ground-water protection based on monitoring at the point of use is doomed to fail. Lessons from the history of the surface-water pollution control program support this reality.

REALITY ONE

One reality which has been mentioned this morning, and will be mentioned time and time again during this Symposium, is that once polluted, an aquifer is extremely difficult and costly to clean up. Neither dilution nor natural purification can be counted on. Once ground waters are polluted (i.e., exceed one or more MCL's in the IPDW Regs) the nation's self-supplied homesteads, public drinking water systems, and other users will incur:

1. Additional monitoring costs in attempts to isolate the cause and examine alternative control measures;

2. Treatment costs to meet quality requirements; or

3. The cost of using alternative sources of supply; while

4. Continuing to pay off the cost of existing wells and pumping facilities, with interest, which are being financed and installed at a $3 billion annual rate.

Such likely consequences did not make sense to the Congress when it established the initial scope of the Underground Injection Control Program in the Safe Drinking Water Act of 1974. And the prospects will not appeal to the nation's citizens who pay the bills, either the local water bill or through price increases in food, fiber and service upon which the country is so dependent.

But there is yet another more subtle reason for not burdening the water user with responsibility for monitoring pollution which can be prevented. Economics argues against burdening the ground-water user with searching for the emergence of one or more of thousands of potential pollutants. Moreover, the provision for treatment requirements in lieu of MCL's was created in recognition of the fact that many exotic pollutants can only be measured in research laboratories. Thus, total dependence upon point-of-use measurement would be both economically unreasonable and technologically dangerous.

REALITY TWO

A second reality is that pollution prevention must begin and end at the source. A generation of experience with concepts like "enforceable" stream quality standards highlighted economic and legal realities that cannot be dismissed. Control at the source is the only viable basis upon which to proceed in the United States.

But even this principle, forged on the anvil of surface-water quality control efforts, creates dilemmas when efforts are made to translate this lesson from surface water to ground water. For instance, how do we translate the "zero discharge" principle to the prevention of ground-water pollution? And how can we avoid making someone responsible for monitoring, to signal the early violations of technology standards, when we know that once polluted by pits, ponds, fills, dumps or injection practices, the aquifer could stay polluted for generations?

REALITY THREE

To those who cry for control and prevention at any price, a third reality must be communicated. No activity conceived and implemented by man can be certified as 100 percent perfect or risk free. There will always be risks in design and in the construction of physical facilities. Moreover, many design and construction issues are in fact created by the nature of the earth itself. The earth and its aquifers are seldom homogeneous or continuous. Further, the often heralded natural attenuation phenomena (applicable to certain pollutants), while effective in degree, provide no lifetime guarantee.

Accepting these realities means that the only reasonable approach is to move to a technology-based standard calling for "virtual zero discharge" for pollutants. This, in my view, will require evaluation of a series of tradeoffs which are clearly beyond the scope of this paper. For instance, the cost of the construction-modification-operation of a facility must be brought into balance with site-monitoring cost, the quality of the aquifers potentially impacted, the number of current or potential users at risk, and the economic impacts which users might sustain.

Again, in my view, site monitoring will require keen professional judgement. There are activities where, because of clear knowledge and experience with the waste in question, the method of disposal *and* the geology involved, no monitoring will be needed. There will be other circumstances where simple surrogates such as pH, temperature, pressure or color tests will be judged necessary at the site. In other situations involving dangerous wastes those responsible for disposal should be required to install and monitor observation wells for specific contaminants. Finally, selected waste disposal operations involving dangerous materials should bear the cost of monitoring for specific supplemental analysis, including those contaminants designated under the Safe Drinking Water Act.

THE FINAL REALITY

The questions and issues I have been addressing (and indeed, concepts like "virtual zero discharge" and "professional judgement") were purposefully chosen to stimulate this debate. Yet great care must be exercised to avoid the misunderstanding and divisions which these terms may inadvertently create. Thus, we must recognize a final reality: the problem of communication.

Many of the concerned and involved parties enter the debate from different poles. Some people tend to deal in stereotypes or are trained in absolutes. Others function in a physical, chemical and economic world where absolutes cannot be predicted, designed, or constructed. If new ground-water quality standards are to be developed and ultimately integrated into a comprehensive water resource management program, mutually agreeable standards which are feasible and economically viable must be negotiated. Thus all parties must be prepared to listen and to compromise so that a start can be made. Parties at each pole must move to forge a workable consensus so that a credible program can be presented to the public at large.

For our part, we at EPA are moving to identify for consideration and to integrate for implementation numerous available pollution control authorities. Vic Kimm's presentation during Session IV articulates the substantial progress being made within EPA toward issuing a revised version of the Underground Injection Control Regulations as part of a comprehensive, agency-wide strategy to control ground-water quality.

CONCLUSION

The opportunity to begin formulating a national ground-water quality protection program is at hand. In building the new program we should use the host of lessons learned in the experience of related environmental programs. This is necessary so that the new program will be realistic at the outset and congruent with the integrated planning and management of the ground and surface-water resources of the nation.

The keystone of program development, implementation, and evaluation is and will continue to be water quality standards. To the extent that the goal "Safe Drinking Water for Americans" has already been established, the point-of-use regulations (IPDW Regs and the RPDW Regs) should serve as water quality objectives thus facilitating ground-water program formulation and evaluation. The major regulatory thrust of the program, the water quality standards, must be technology-based site selection, construction, and operational standards, with only limited monitoring in a conventional water supply and water pollution control context.

Let's not repeat the errors of the past. Let's do it right. Let's start now.

* * * *

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Ground-Water Quality Standards — Irrelevant[a]

by Frank A. Rayner[b]

ABSTRACT

Proposals to establish national ground-water quality standards appear to be premature, and redundant because of the geohydrologic and geochemical factors governing the occurrence and development of ground water. Although it can be reasoned that there is no "good time" to establish additional governmental standards (and the resultant additional governmental regulations), it can also be strongly argued that now is a "bad time" to consider establishment of the proposed standards.

First, a present mood of the general public is away from more governmental involvement in the business and private sectors, and a rebellion against the increasing cost of government. Second, the applicability and workability of present Federal (and some State) laws that could be used to adequately protect ground-water quality, have yet to be implemented or otherwise sufficiently tested.

The full force and effect of the Water Pollution Control Act (PL 92-500 with amendments) has yet to be implemented, and Congress is still considering its "oversights" in their drafting of same.

The Safe Drinking Water Act (PL 93-523), particularly those sections designed or usable to protect ground-water quality, have yet to be tested by the EPA. Like PL 92-500, the deadline for implementation of parts of PL 93-523 has long since passed.

And the far-reaching effects on ground-water quality protection that three other federal laws—the Resource Conservation Recovery Act (PL 94-580); the Toxic Substances Control Act (PL 94-469); and Surface Mining Control and Reclamation Act (PL 95-87)—are totally unknown, since the procedures for full implementation of these acts have yet to be developed.

Therefore, it appears that establishing a new ground-water quality control act prior to testing existing law and thereby learning from their flaws or shortcomings, could result in unnecessary proliferation of law without its reasonable testing.

This appears to be a good time to interrupt the geometric progression that tends to spawn additional laws when laws are developed ahead of their established need.

Equitable and workable ground-water quality protection could be fostered through the enactment of the long overdue requirements for the integration of surface- and ground-water development and management programs, without widening the existing gap between present ground-water and surface-water management structures. This integration would decrease inefficiency of use of these water resources—which are actually inseparable in identity to their users, the American taxpayers.

Several years ago I proposed that there was no such thing as naturally pure water, particularly in the Texas water community, and that the formula for water should be changed from H_2O to H_2O_2—that is, two parts hydrogen, one part oxygen, and *one part opinion.*

At about the same time I suggested to my Texas colleagues that we could advance the causes of water conservation, protection and development 10 years by simply establishing a one-year moratorium on water meetings. I reasoned that such a moratorium would enable those that attend the water meetings—which are usually the same people, all employed by water agencies—to work

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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uninterruptedly for at least one year, which would be equivalent to 10 years of normal water-meeting-interrupted work. The first proposal met with blank stares, and the latter with hostile ones.

But, today, with this presentation, I will probably prove the first contention, and possibly hasten the institution of the latter.

My circumstance of habitat makes it very difficult for me to take the position I find myself in today—opposing the creation of new laws and rules that may offer the potential to fully protect one of the nation's most useful and essential resources—ground water.

Assaulted by the bleatings of the rabid, so-called, conservationists, I tend to turn a deaf ear to their cause; but I am forced to recall my youth in the hills of West Virginia. Born and raised through high school on a small hillside farm (here I have used the term "farm" generously, because the size of that West Virginia farm would be about that of a Texas family's vegetable garden plot) on the Monongahela River, Morgantown, West Virginia, I lived through the era of the rape of that beautiful land's abundant bituminous coal.

Hillside and strip mines belched blood-red mine acid waste into all of the area's many streams. Strip (now called surface) mining was practiced *without any land reclamation requirements.* The giant earth movers skirted the contours of the hills leaving ugly yellow scars, devoid of any ground-protecting vegetative cover; uprooting and covering millions of tall, stately hardwood trees, when the coal-bed overburden of yellow clay and rock was simply pushed over the side of the hill. The area's over-abundant rainfall did the rest, carrying the loose yellow earth into the nearest stream.

Mine acid drainage kept most of the streams' water, and their rocky beds, colored a brilliant orange, and the larger (navigable) Monongahela River a light pink. Sewage outfalls were always elevated to protect them from rising water, and totally untreated sewage, comprised of an enormous amount of solids, formed waterfalls of changing hues and varicolored large objects splashed into the Monongahela's waters.

Living between the confluence of Sulphur Creek (a local name given to Dunkards Run, because of its brilliant orange, or at low flow, blood red, color) and the Monongahela River, if we chose to go swimming, it was best to be in the River. A dip in the Sulphur Creek made our skin look like the Red Man. But, swimming in the Monongahela was not without risk, and it was always with a tightly closed mouth; if you swam therein, you were the only living thing so doing; the Monongahela was completely devoid of fish and other aquatic life.

Large slate dumps smoldered during my entire 18 years at home, and their sulphur gases and ash particulate matter combined with that of whole hillsides full of black smoke-producing coke ovens, kept the entire area covered with raindrop-size black, oily soot gobs. White snow only existed below its top layer, and sulphur gases ate the metal off cars and other objects with considerably more efficiency than does salty ocean spray. To an outsider, rust would appear to be the residents' mania for choice of color.

From mountain momma I moved (in military service) to the arid West, where the economy is almost totally dependent upon the development of ground water and petroleum resources; and the exploitation of these resources was like no change at all in habitat from my native West Virginia; the only difference between the two habitats being two-thirds less rainfall, and 100 percent fewer trees.

Brine produced with oil and natural gas was being discharged onto the very permeable soils at the land surface, to simply migrate downwards from the so-called (unlined) evaporation pits (some conveniently fitted with wells at their bottom) to enter and contaminate beyond use, the near-surface aquifers which in most cases, were the *only* fresh-water supply available.

Since stream flow, in most of the area, only occurred after storms, they were undependable as a fresh-water supply—ground water being the only dependable supply—so such streams were used as waste disposal dumps. The Trinity River between Fort Worth and Dallas was visible for miles on the darkest night—by smell. The Houston Ship Channel was claimed to contain the most buoyant water in Texas, suspended and dissolved solids adding greatly to its waters' density.

These are only a few examples, but conditions were similar throughout our Nation—the rape of the environment was accepted as a way of life.

But today, my former habitats have changed. It is no longer considered foolish to wish to live on the banks of the Monongahela River; pleasure boating, swimming and fishing have returned thereto. The slate dumps have disappeared and coke ovens are fast disappearing also. White snow, several days old, attests to the new atmosphere. Surface mining *must* be followed by land reclamation and removed overburden is not allowed to despoil the hillsides or enter the streams. Some of the choice, and usually the only *flat,* lands in the

Appalachians are now reclaimed surface mined areas.

Although improper waste disposal is still practiced in some areas, most aquifers are protected from surface disposal of brines, and other contaminants, and even the Trinity River and the Houston Ship Channel are not easily located by the nose.

Who, or what, is responsible for this remarkable reversal in our respect for our environment? Of course, it is not one person, or one thing or one entity, but a change in public attitude; *but* what helped change public attitude? If I were to choose the major motivating force, I would have to honestly pick the Environmental Protection Agency, and its predecessor, the Federal Water Quality Administration; and further laud the Agencies' dedicated and conscientious scientists, administrators, and other staff personnel.

This choice does not ignore the contribution of the numerous State and local agencies that have also been in this fight for a better environment, but even they must admit that the major catalyst has been the EPA; its relative immunity from political pressure, its conscientiousness, its laws, its rules, *and its money.*

This realization, this admittance, of having, thankfully, lived through a *forced* change of attitude to that of a respect for our environment, and protection for that which we will leave to our successors, makes it most difficult to oppose proposals for increased quality protection of ground-water supplies; protection I realize is, in some cases and areas, needed and overdue.

Specifically, however, my presentation here and my negative stand regarding proposals for the establishment of ground-water standards stems from Dr. Lehr's request that I take this position on this program, as a replacement speaker, and, perhaps, influenced from my reading of the present mood of the public regarding increased government spending and taxation.

The suggestion for establishing ground-water quality standards is not fully understood by this author. There are already water quality standards that apply to ground water (and all other water) at the point of use of such water.

My interpretation of the suggested standards is that they would apply to in situ ground water. If such is the case, no one group of standards could be made applicable. The quality of in situ ground water is the quality of the in situ ground water; therefore, standards would have to be adapted to existing conditions, and since there are greatly varying ranges of individual dissolved constituents in each aquifer, and within segments of the same aquifer, the magnitude of the number of different standards that would have to be formulated is staggering. No one list, or possibly even hundreds of lists, of standards could be developed to satisfy all ground-water quality conditions.

Only one type of standard could be developed to cover all aquifers. That standard would simply state that *"the present chemical character of the existing ground water shall not be altered."* Although such a standard would be easy to develop, its application and usefulness are impossible and worthless. Some will argue that standards could be developed that would set the maximum amount of degradation (change) permitted, but how (or by whom) could such in situ changes be monitored effectively and economically enough to provide a means to control or limit degradation then in progress?

If ground-water standards are to be based upon potable-water considerations, (human consumption standards) the implementation of such standards would wreak havoc on the ground-water economy of many regions of the Nation.

As examples, the major segment of the agricultural economy of the western United States is based upon irrigation, primarily from ground water. Most of this ground-water development is depleting the aquifers so developed, and any means of aquifer augmentation (artificial recharge) is assumed beneficial—including recirculated irrigation water and *sewage effluent.*

Everyone is familiar with the Old West saga of a gunfight at the water hole; where some rancher dammed up the stream or fenced off the spring and maintained his acquisition (his water right) with a gun. In the West, the streams have long been over-appropriated and the springs fully claimed, and gunlaw has given way to some of the most lengthy and costly water-rights litigation known to civilized man. But, there is a new water hole spurring renewed legal ramblings in the West; that is, the rights to city sewage effluent. In the eastern U.S., how to get rid of sewage may be a problem, but in the West how to acquire and keep the rights to it—the new fight at the water hole—is the main problem. Irrigation with sewage effluent is a major enterprise, and now the irrigators sometimes find themselves in conflict with other would-be users, such as thermoelectric power plants, who want to divert the irrigators' rights to sewage effluent to their own uses.

In nearly every case the irrigator who has a right to sewage effluent also has an obligation to dispose of same when he cannot utilize it all—primarily during the winter months. Such surplus effluent, since its disposal into streams is now prohibited by the Water Pollution Control Act (PL 92-500), is usually accomplished through over-irrigation of crops, or onto fallow farmland, or into surface ponds. All such methods of "disposal" provide for significant downward percolation, and recharge to any water-table aquifer underlying such areas—and such areas usually have underlying aquifers.

A classic example of this type of case is the Frank Gray operation using the City of Lubbock, Texas, sewage effluent. Irrigation on the Frank Gray farm has recharged the formerly limited (in thickness) aquifer until the water table is now near the land surface, in some areas, and some playas are now water-table lakes. This type of recharge has made possible the perpetuation of large capacity irrigation wells on the Frank Gray, and surrounding farms, and the development of numerous wells on the recharged land to supply a new power plant, and to maintain a series of recreational lakes in the City of Lubbock. *But* the aquifer now contains water much higher in dissolved solids, and probably unpotably high in nitrates. *If* the original quality of the water in the aquifer had been maintained, the obvious benefits of sewage effluent recharge would have been foregone, and untold millions in economic benefits unrealized.

The Frank Gray case is typical of thousands of similar situations throughout the western United States.

Similarly, strictly adhering to existing ground-water quality would also prevent most other artificial recharge and subsurface water storage programs, particularly if such standards are based upon potability parameters, and it would deal a death blow to effective conjunctive management of surface and ground-water resources—which, in most cases, must be based upon exchange of storage between the two regimens.

Another classic example of increasing ground-water storage at the sacrifice of ground-water quality is the Orange County (California) Water District recharge program. The Orange County district, faced with depleting ground-water supplies and sea- (salt-) water encroachment (due to ground-water pumpage), recharged the aquifer with the much lower quality water from the Colorado River. The result was the reversal of the movement of the salt-water/fresh-water interface, and a replenished aquifer with water storage larger than that of historical record; *but,* with notable degradation in water quality.

These are only two examples of the numerous ongoing recharge projects that utilize poorer (but useful) quality water to recharge aquifers containing better quality water, or water with different ratios of specific dissolved solids.

Standards that would prevent the recharging of a near-depleted or depleting aquifer with poorer quality water (but usable for most all of the present uses of the native aquifer water) would be ill conceived and natural resource wasteful, and to further limit recharge water to a quality to meet strict potability requirements would be even more restrictive, and counter-productive to water conservation efforts.

It is appropriate to note here that the NWWA's successful efforts to generate interest in the use of ground water and aquifers as a heat or cooling sump could be jeopardized by ground-water standards that would consider heat (or cold) as contaminants, such as does PL92-500 in respect to surface water. And the use of aquifers for such purposes would be suspect due to the possibility of ground-water quality changes due to the increased mineral solubility of warm injected water, and the presence of oxygen or algacides and bacteriacides or other disinfectants, and solvents that may be added to injection water.

Mr. McDermott has correctly noted that there is no good time to initiate new government programs. Continuing the reasoning along this line would lead to a further conclusion, that there is a "bad time" to initiate new government programs; and with the new wave of anti-taxation sweeping the country, now does appear to be the worst of the "bad times" to initiate new governmental spending.

The deep feelings (hidden like an iceberg) of the general public's discontent with the magnitude of governmental taxation (local, State and National) is exemplified by the type of leader they have rallied behind. To me the creator of the latest "ism"—Jarvism—is repugnant. He does not appear to me to exercise any reasoning, compassion, or understanding for the need for some (even if reduced) taxation, and his lack of finesse in his treatment of opponents is appalling. Yet he is the chosen leader of the formerly silent masses opposed to taxation. My reasoning is that if a man exercising the tact exhibited by Mr. Jarvis is emerging as an antitax leader, then the antitax feeling is a major force to be reckoned with, hence a reason to not initiate new government regulation, and increased—tax supported—regulatory activities. In other words, it appears to be a good time to "cool it."

However, in support of Mr. Jarvis' aims I note my record of recent public service to show that taxes can be reduced while governmental services are expanded. In 1976 and 1977, as the manager of a Texas ground-water district, I initiated a 40 percent reduction in the district's taxes while expanding the district's services. This was attained by expecting district employees to perform their jobs commensurate with their pay, and to require those individuals violating district rules, and those demanding special services not provided by law, to pay for the cost for rectifying the violations, and for such special services.

In lieu of initiating new water quality laws, it appears to be a good time to concentrate on the application and evaluation of the workability of those parts of existing laws that treat ground-water quality considerations, and there are a lot of existing Federal laws still left untested.

The applicability and workability of present Federal (and some State and local) laws that could be used to adequately protect ground-water quality have yet to be implemented, or otherwise adequately tested.

The full force and effect of the Water Pollution Control Act (PL 92-500, with amendment, the Clean Water Act—PL 95-12) has yet to be implemented, and Congress is still considering its "oversights" in the drafting of same.

The Safe Drinking Water Act, (PL 93-523) and the 1977 amendment (PL 95-190), particularly those sections of same that were designed or are usable to protect ground-water quality, have yet to be tested by their implementation by the EPA. Like PL 92-500, the deadlines for implementation of parts of PL 93-523 have long since passed.

And, the far-reaching effects on ground-water quality protection that three other Federal Laws: the Resources Conservation and Recovery Act (PL 94-580); the Toxic Substances Control Act (PL 94-469); and Surface Mining Control and Reclamation Act (PL 95-87) are totally unknown, since the procedures for the implementation of most of these acts have yet to be developed.

I would particularly note that the title of PL 94-469 is misleading. This act includes all chemical substances in any form, including pure water, and possibly H_2O_2, and is not limited to substances of the toxicity classification. The potential powers of the EPA provided by this act—including ground-water quality protection—are awesome. Therefore, it appears that establishing a new ground-water quality control act prior to testing existing law, and thereby learning from their flaws or shortcomings, if any, could result in unnecessary proliferation of law.

This appears to be a good time to interrupt the geometric progression that tends to spawn additional laws when laws are developed in haste of their established need.

The results of Federal (and State and local) agency hearings, Congressional hearings, studies by commissions, and public and private interests, have shown that the full implementation of PL 92-500—particularly the no-discharge provision of same—constitutes a major threat to both the quantity and quality of ground-water supplies. Since Congress is aware of the shortcomings of this law, and since it has been successfully amended in the past, it appears likely that Congress would be more apt to amend PL 92-500 to provide for more ground-water quality protection, in lieu of establishing new and separate ground-water laws. This would be one of my recommendations to proponents for new laws establishing ground-water quality standards.

The rigidity of interpretation and application of Federal rules, by some agencies, is of particular concern to me, should they be so applied to new ground-water law. Also, in my opinion, the flimsy and/or irrational reason for invoking rigid implementation of some rules are very disturbing.

The numerous excesses within the powers granted by the Endangered Species Act are particularly noteworthy. Tales of the impropriety of the rules enforcement activities of OSHA abound. The posting of warning signs at the entrance of grocery stores wherein products containing saccharin are sold is absurd. I get the impression that saccharin may be a mad dog, and a dietetic soft drink may jump off the shelf and attack me!

In regard to ground-water quality standards—at the time of the Congressional debate on HR 13002 (now PL 93-523), the hysteria about the existence of carcinogens (which *may* cause cancer) in the New Orleans water supply hit the headlines. These carcinogens were detected in quantities of parts per billion and parts per trillion. In a letter to Congressman George Mahon, of Texas, I noted that for a person to ingest one pint of a substance in the quantity of one part per billion, by drinking the New Orleans water, such a person would have to live a total of 456,621 years to do so! (If we are to be concerned with parts per billion and parts per trillion, we might as well consider the last year of a theoretical lifetime of nearly one-half million years).

Dr. Doris Thompson (then the Director of the New Orleans Health Department) noted that drinking from the New Orleans public water supply is one of the safest things you could do in New Orleans. Having been to New Orleans many times, and nearly always visiting Bourbon Street, I heartily agree with Dr. Thompson. I have not had any extensive experience with drinking New Orleans water, but I am sure it does not implant the headaches other liquids there do.

New ground-water laws will only widen the existing chasm between the development, conservation, and protection regimes adhered to by the existing ground-water and surface-water management entities; a condition that needs to be eliminated, not fostered. Amendment of PL 92-500 would help in this regard.

If new laws must be proposed, I would suggest that they embody conjunctive management, conservation and development, and quality protection of both water sources—ground and surface. Equitable and workable ground-water and surface-water quality protection could be fostered through the enactment of long overdue laws requiring the integration of ground- and surface-water development and management.

Both the surface-water and ground-water interests are firmly entrenched, and apparently determined to maintain the status quo in regard to their specific interests; therefore, any proposed law requiring conjunctive management of these two regimes is going to receive concerted opposition from both interests. However, neither self-protecting interest can argue the obvious merits for the conservation, environmental protection, quality of water protection, safety, dependability, convenience, and economics of conjunctive management of ground and surface water—which, in the eyes of the consumer and taxpayer, are indistinguishable from each other, and they are indeed one resource, both being only water.

In conclusion, I believe that the time has not yet come for the establishment of quality standards specifically for in situ ground water, and to those carrying the ball for this proposal I say, you are faced with a first-down problem—punt!

* * * *

Frank A. Rayner received a B.S. degree in Geological Engineering from Texas A & M University in 1958. He has also completed graduate level courses in Geology and Hydrology at Texas A & M and Texas Tech University. After graduating from Texas A & M he was employed as a Geologist by the then Texas Board of Water Engineers, Austin, Texas. Prior to joining the staff of the High Plains Underground Water Conservation District No. 1 (District), Lubbock, Texas, as its Chief Engineer, he was the Assistant Director of the Groundwater Division of the Texas Water Development Board. In 1969 he was appointed the General Manager of the District and served in that capacity until September 1977, when he established a private practice as a consulting engineer and geologist, specializing in ground-water development, quantity and quality evaluation, management and research. He is the author of more than 100 books, bulletins, handbooks, rulebooks, papers, articles and brochures.

Audience Response to Session II — Ground-Water Quality Standards

Bruce S. Yare, Senior Hydrologist, Peabody Coal Company, 301 N. Memorial Drive, St. Louis, MO 63102: Establishing federal or State ground-water quality standards will have a severe impact on current methods of coal recovery, especially if a nondegradation standard is adopted. Surface mining for coal creates a large volume of disturbed overburden which often has a greater porosity and permeability than the original rock materials. As ground-water levels recover in this spoil material, the water becomes highly mineralized, containing at the very least objectionable amounts of sulfate, hardness and total dissolved solids. This degradation of local ground-water quality is unavoidable, since infiltrating water is bound to react to some degree with freshly exposed rock surfaces in the spoil material, producing mineralized ground water. To give some idea as to the amount of degradation, sulfate, hardness and total dissolved solids concentrations are reported to increase as much as 621, 1366, and 3286 mg/l, respectively, over background levels after surface mining operations in Muhlenberg County, Kentucky (Herring, W. C., 1977, Ground-water re-establishment in cast overburden: NCA/BCR 7th Symposium on Coal Mine Drainage Research, Louisville, KY, pp. 71-87).

In 1977, a total of 689 million tons of coal were mined in the United States and nearly 61 percent of this tonnage was produced by surface mining methods. The potential for a great deal of localized ground-water degradation is apparent. If a nondegradation ground-water quality standard is adopted on either a State or federal level without allowance for a variance from the standard, surface mining for coal will not be possible. Given the amount of coal produced by this mining method, approximately 417 million tons in 1977, the impact of a nondegradation standard on energy production in the country is enormous.

Mark P. Zatezalo, D'Appolonia Consulting Engineers, Inc., 10 Duff Road, Pittsburgh, PA 15235: I appreciate the opportunity to respond to this question and present two statements in support of ground-water quality standards that were not brought out in the presentation.

First, I believe ground-water quality standards are obviously a necessity now and will be even more necessary in the future due to overpopulation and subsequent exhaustion of ground-water resources. Due to increased demand on ground-water reserves, what a person does with or to his or her privately-owned ground-water resource will, with increasing frequency, directly impact the availability of some other person's source of potable water. To me, there is no question that ground-water quality standards are necessary to help insure potable ground-water supplies in the years to come.

Second, and less obvious, is the effect that such standards could have in the area of waste recycling. Individuals that are forced to find ways of using materials once discarded as waste are finding that it actually can be more economical to reuse the resources contained in the waste rather than disposing of them (the recovery of mercury at Minimata Bay, Japan is a most striking example).

In my opinion, ground-water quality standards will "aid" (i.e., force) industry to find new ways to recycle waste and thus utilize our natural resources more efficiently, since as a professor once told me, "There is no such thing as pollution—only wasted resources."

Ginia Wickersham, Assistant Ground Water Division Chief, Oklahoma Water Resources Board, Oklahoma City: I disagree with Mr. Rayner's statements that ground-water quality standards are unnecessary because the "public does not want more governmental involvement in their private affairs." The public does not always know what is necessary or best, especially in the protection of natural resources. Oftentimes people forget or overlook the importance of underground-water supplies. A responsibility of the ground-water professional and regulatory agencies is to foresee potential pollution problems for the public, and prevent further degradation of water quality. A way this can be done is through the development of ground-water quality standards.

Only by developing standards for ground water can the natural chemical quality of aquifers be maintained. In Oklahoma, we have received and investigated numerous complaints of ground-water pollution. These include pollution by landfill operations, herbicides, salt water, oil and gas drilling activities, and even one case where cottonseed hulls were pumped into the fresh-water zone of a major aquifer in western Oklahoma to restore pressure in the drilling of a gas well. Our major ground-water basins are being constantly threatened and we cannot afford to let this situation continue.

Without ground-water quality standards it is very difficult to prevent or abate pollution. In Oklahoma over 60% of the population depends upon ground water for water supply, and 80% of the irrigation needs are met by ground-water resources. However, when a water well is polluted it is almost impossible to prove in court that pollution has taken place. Without a standard to compare with, how can you prove to a judge or jury that ground water has been degraded? With ground-water standards we can classify the ground waters of a State and establish baseline water quality conditions.

The States must take the lead in establishing ground-water quality standards; not the Federal government. Only with the States in charge can we have the flexibility needed in developing standards for ground water. States already have the mechanism for establishing standards, since it is the State's responsibility to protect the water quality of the State's waters. Only the States can develop standards which maintain water quality, prevent pollution, and permit management of the ground-water resources for beneficial use by all citizens. The Federal government can assist, by making Federal funds available and establishing minimum guidelines in the establishment of ground-water quality standards. It is essential, however, that the first step be taken toward protecting our ground-water resources through the development of water quality standards, as soon as possible.

Daniel P. Waltz, Hydrogeologist, Layne-Western Company, Inc., 6909 Johnson Drive, P.O. Box 1322, Mission, KS 66222: My comment is in response to the use of sewage sludge on farmland which is used to grow cash crops or animal fodder. I would not be very interested in eating food grown on such a farm, whether I was consuming it directly or through meat which was raised on feed from such a farm. I am familiar with studies of how trace metals such as zinc, cadmium, mercury, lead and others become concentrated in sewage sludge and can be passed up the food chain. I am also familiar with studies on organics such as fertilizers and insecticides, i.e. D.D.T., Paraquat and others, which also may be passed up the food chain in a similar manner. Also many human diseases caused by viruses such as hepatitis can go through a water treatment plant without being removed. It just seems to me that there has not been enough research completed in the field of sewage sludge application to fertile soil and that the unsuspecting consumer public may already be consuming products with dubious background.

Ted Clark, Dunn Geoscience Corp., Latham, NY: Sitting here I developed a couple of concepts. First, I agree that we do need to hold together our basic concept in the understanding of hydrology and geology in the movement of ground water. We must try to develop sound standards, so that we aren't faced with a kind of minimum standard or requirement, like zero discharge. This concept of zero discharge may tend to concentrate contamination at the source area. Ground-water pollution problems that we are faced with today have often developed from concentrated point source areas. We need to look at how we can better regulate with standards, how we might eliminate some of these concentrated sources that are causing so many problems.

Richard Dalton, Principal Geologist, Division of Water Resources, Trenton, NJ: I think New Jersey is getting involved in some of these problems we're discussing today in an area known as the Pine Barons. Many of you have probably heard the pros and cons on this area. There is a major aquifer there which has been delineated and regulations were set up for septic discharge. Unfortunately the people who drew up the regulations were not geologists, geochemists, or anyone involved with ground-water movement, and now we in the State must live with the procedures they set. These standards are mainly with regard to nitrate nitrogen—two ppm of nitrate nitrogen and if anyone here has looked at septic tanks, it's almost impossible to meet these standards. Ground-water quality standards should be drawn up by geologists and geohydrologists, rather than by lawmakers. We have to know what is happening underground. We're finding we have two public supplies already threatened by organic chemicals, even more so than nitrate. Here, you're talking ppm which is detrimental. One supply involves a community of several hundred thousand people. These are the things we have to address.

Land Application of Waste — State of the Art[a]

by Kenneth R. Wright[b] and Catherine Kraeger Rovey[c]

ABSTRACT

Land application of treated waste water can provide unique opportunities, not only for a final high level of waste-water treatment but for reuse of nutrients as well. Recent laws passed by Congress have made it necessary to consider land treatment when planning and designing new waste-water treatment facilities. The three types of land treatment commonly used are (1) irrigation, (2) overland flow, and (3) rapid infiltration. Selection of the most appropriate type of land treatment for a specific site is based on several considerations, including soil conditions, geology, topography, proximity to surface and subsurface water, and climate.

Ensuring the protection of ground water is essential when siting or designing a land treatment system. Ground water is an important natural resource, having considerable impact on human life and well-being as well as high economic value. Safeguarding this important resource from contamination includes careful site selection, appropriate pretreatment of waste water prior to its application, and a program of regularly scheduled monitoring to ensure that the waste water is being properly renovated for safe release to the environment.

Utilization of municipal sludge on land for agricultural production is encouraged by federal law, as is land treatment of waste water. Sludge contains concentrated wastes, and there are practical limitations on the levels of heavy metals, salts, and toxic substances in sludges applied to agricultural lands. Sludge is generally stabilized before being applied, to destroy pathogens, and reduce weight, volume and odor.

Several case studies of successful land treatment systems presently in operation are presented to demonstrate the viability of the land treatment concept.

INTRODUCTION

The application of treated waste water to land can provide a final high level of pollutant removal. It also provides the opportunity for recycling of nutrients. Land treatment is not ad hoc dumping of waste water hoping that it somehow will purify itself. Land treatment systems must be well planned and designed and carefully managed and monitored to ensure that problems do not develop.

The land application of waste water entails the use of growing plants, the soil surface and the soil matrix for removal of certain waste-water constituents. Sunlight and air make it possible for the plants to grow, the soil to remain aerobic, as well as assisting in disinfection and decomposition of organic solids and organisms.

The subject of land treatment cannot be considered in an abstract, academic or theoretical basis such as professionals did only a few short years ago. During the last 12 months, the U.S. Congress has passed a law, which the President has signed, and the Environmental Protection Agency (EPA) has promulgated rules and regulations which make land treatment a fact of life. The EPA is pressing public waste-water agencies to use land treatment, and if they do not, their construction grant applications must provide complete

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justification for rejection of land treatment. Further, these agencies cannot require overly strict pre-application treatment for the effluent to obtain EPA funding. (1)

It was in late 1977 that Congress passed PL 95-217, the Clean Water Act, with incentives for increasing the use of less costly, less energy-intensive technology. Specifically, the federal government has identified innovative and alternative technology sewage treatment works as being necessary and desirable. To encourage selection of such technology, EPA will provide an additional 10 percent bonus to its usual 75 percent grant for innovative or alternative technology, i.e., a total of 85 percent would be forthcoming from the federal government, leaving a local share of only 15 percent. While only 350 out of the 2,700 sewage treatment projects funded during the past decade have used land treatment, the percentage during the next decade is expected to rise markedly, if for no other reason than that local agencies will want to receive 85 percent federal grants.(1) Land treatment, according to EPA, qualifies under both innovative and alternative technology.(2)

Arguments, often bitter, have taken place within the engineering profession during the last decade over land treatment in general and over its components and impacts specifically. On one side have been public interest groups, advocates of conservation, sporting associations and advocates of clean streams. On the other side have been municipal and public works engineers and various sewerage associations and waste-water agencies. One good question to ask is "Why has this controversy existed, and why has it lasted so long?" Furthermore, one might ask why the decision was made by politicians in Washington rather than waste-water professionals. A third question which should be discussed today between the pro and con speakers is whether or not Congress made the right decision on land treatment in the 1977 Clean Water Act.

A wide range of design possibilities is available in land treatment to suit specific site characteristics. There are different types of land treatment, as described following.

TYPES OF LAND TREATMENT

The three types of land application in common usage are: (1) irrigation, (2) overland flow, and (3) rapid infiltration, as schematically represented in Figure 1. Each can be adapted to different site conditions, can satisfy different objectives, and can produce renovated water of varying quality, depending on design parameters and operation. There are numerous variations and combinations which can be used to optimize the system.(3)

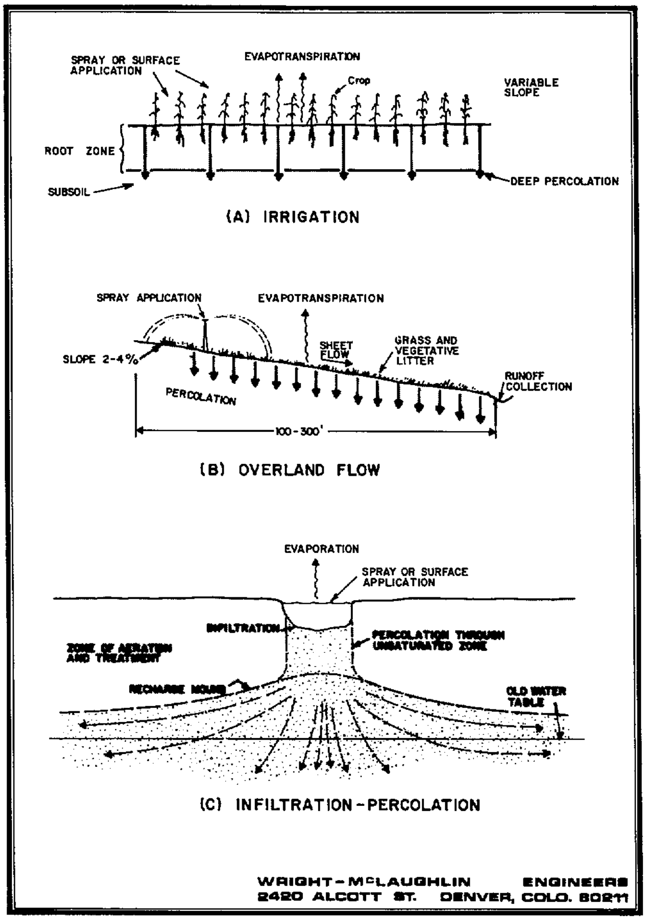

Fig. 1. Types of land application in common usage.

Irrigation Method

The irrigation method is the application of waste water to agricultural lands where a crop is grown. This method can produce an economic return on the crop as well as renovating the waste water. The minimum application is normally enough to satisfy the evapotranspiration of the crops with a 30 percent excess for deep percolation. However, some installations operate at 8 to 10 feet of application per year, which provides for deep percolation of 80 to 90 percent of the total amount applied.

The water is subjected to several processes including physical filtering, adsorption, biological activity and natural uptake, as it percolates down through the soil. A natural disinfection caused by air and sunshine may also occur.

The soil matrix filters out suspended particles in the waste water, and soil bacteria break down the soluble organics and nitrify nitrogen in the waste water. Some of this nitrogen is taken up by the plants, some is stored in the soil, and the remainder is either denitrified (N_2 gas) or percolates downward with the renovated waste water. Soil particles also absorb phosphorus and heavy metals while filtration and adsorption remove bacteria and viruses. Macro-nutrients, nitrogen, phosphorus and potassium, are subjected to uptake by the growing vegetation along with micro-nutrients such as copper, zinc, cadmium and nickel. By reading the fine print on a package of household plant fertilizer, one will note that the same constituents are sometimes colored and then packaged to sell for the equivalent of several thousand dollars per ton.

This method of land treatment is most widely used. The managers of the Bortnichy State Farm in the Ukrainian Republic of the U.S.S.R. have found irrigation land treatment very satisfactory. This Farm which serves Kiev is 16 years old, and has been extensively studied by the Ukrainian government. The Farm is described later in this text.(4)

Overland Flow

Overland flow is the application of waste water to a vegetated slope where the waste water travels along the soil-vegetation interface. The bacteria growing at the interface and on the vegetation treat the waste water in a manner similar to a trickling filter plant. While the treatment mechanism is primarily biological, there is also physical treatment caused by the filtering action of the grass. Waste water also penetrates the top few inches of soil and flows longitudinally through it, and metals, phosphorus and other nutrients are adsorbed on soil particles. The growing plants also uptake nitrogen, phosphorus and potassium.(1)

With overland flow, application rates often range between 10 and 25 feet per year and, therefore, as much as 90 to 95 percent of the applied waste water can be recaptured for recycling and reuse or discharged to the stream in a near pollutant-free condition.

Overland flow was "invented" in Ohio by a food processing company. It is generally used on very tight soils where there is essentially no downward percolation capacity. Figure 2 demonstrates how overland flow is related to the other two types of land treatment in terms of soil type.

Rapid Infiltration

Rapid infiltration requires very little land area and high permeability. The renovated water can be recovered by underdrains or adjacent wells. The main goal of rapid infiltration is treatment of the waste water.

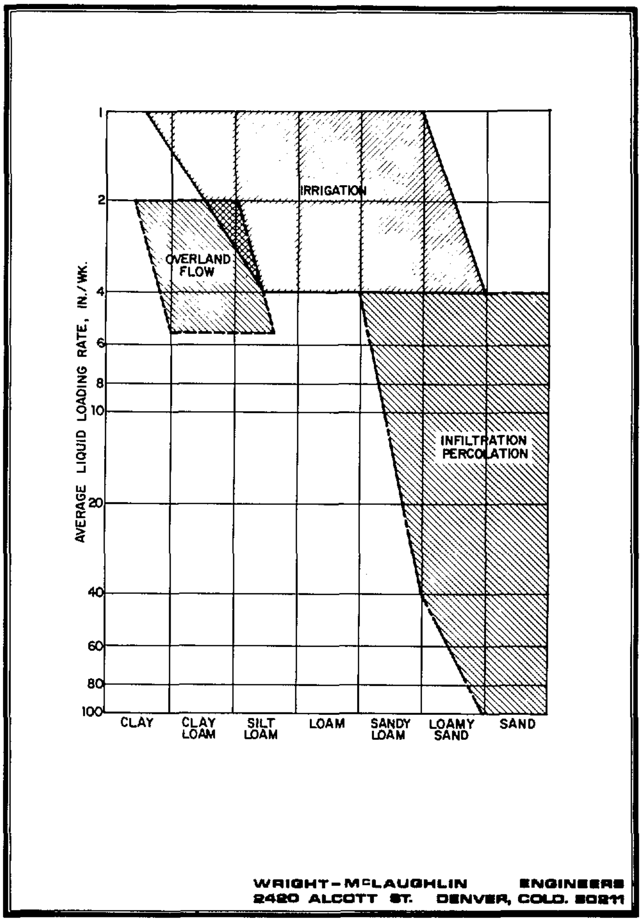

Fig. 2. Compatibility of land application types with different soils.

This method operates by merely flooding the grassed surfaces of shallow basins and allowing the waste water to seep into the ground. Application rates range from 100 to 400 feet per year.(5)

An ad hoc rapid infiltration system has been used satisfactorily on the Widefield Aquifer near Colorado Springs for some 15 years. Municipal water wells are located adjacent to the infiltration ponds. Monitoring of the municipal water supplies has been careful. The water tap foaming problems encountered were from detergent in the days prior to the introduction of biodegradable detergents. Occasional nitrogen problems have been reported. There have been no reported cases of illness related to virus or bacteria transmitted through the aquifer.(6)

IMPORTANCE OF GROUND WATER

Ground water throughout the world is an important natural resource with high economic value and sociological impact. It is important not only to protect ground-water aquifers from being polluted beyond maximum levels, but also to enhance the quality of ground water whenever feasible through proper management.

Alluvial aquifers along streams and rivers have frequently been allowed to degrade as a result of recharge with polluted surface stream water. Degradation of deep ground water has occurred as a result of human activities in aquifer recharge areas.

At Thornton, Colorado, old gravel pits and alluvial wells are used as the main water source for two cities during the winter and as a supplemental source during the summer.

The Thornton well field area lies several miles downstream from the direct surface discharge point for the Denver Metro Sewage Treatment Plant. Late in 1977, an emergency arose as a result of nitrite (NO_2) contamination of the potable water supply being delivered through the distribution system.(7) The problem was noted when a local aquarium owner reported that his fish were dying. Analyses showed that the alluvial aquifer was being recharged with effluent containing 16 mg/l of ammonia nitrogen. The treatment plant was suspected of converting ammonia to toxic nitrite between the well pumping and the delivery to the distribution system. To alleviate the problem, the water wells located immediately adjacent to the surface stream were shut down and a monitoring program was instituted.

It is important to note that no effort was made to decrease the ammonia concentrations in the effluent discharged to the South Platte River. The City of Brighton, further downstream, derives its municipal supply from the same alluvial aquifer. High concentrations of nitrate (NO_3) have been reported there for at least 20 years.

Wells, infiltration galleries, and floodplain gravel pits are used for withdrawing ground water. An evaluation of the aquifer and its characteristics is of special importance when planning and designing a land application system so that potential problems can be identified and preventive actions taken.

On any land application project, a monitoring program is essential so that trends in ground-water quality and possible escape of pollutants can be identified early.

PRETREATMENT

Prior to land application, waste water usually undergoes secondary treatment. Such treatment is recommended, but with relaxed criteria for suspended solids.(8)

The quality of waste water applied to the land varies significantly. For example, in Melbourne, Australia, the waste water receives only primary treatment prior to either irrigation or overland flow. In the Ukraine, the waste water is given full secondary treatment.(9) It is important that waste water not be overtreated prior to land application, not only because of the extra cost involved, but also because too much treatment can remove valuable nutrients. The quality of renovated water is not significantly affected by the organic quality of the water applied, that is, by BOD and suspended solids. The renovated water can generally be expected to fall within the ranges of water quality as shown in Table 1.

Table 1. Expected Quality of Renovated Water from Land Treatment Systems (10)

	Value, mg/l		
Constituent	*Irrigation*	*Infiltration-Percolation*	*Overland Flow*
BOD	1 to 2	2 to 5	5 to 10
Suspended Solids	1 to 2	1 to 2	8 to 10
Ammonia Nitrogen as N	0.5 to 1	0.5 to 1	0.5 to 1
Total Nitrogen as N	2 to 4	10 to 15	2 to 5
Phosphorus as P	0.1 to 0.5	1 to 3	3 to 5

SITE SELECTION

Selection of a suitable land treatment site should involve a thorough investigation of physical characteristics, including soil texture and permeability, underlying geology, topography, and proximity to ground water and surface water. A land treatment site should have the capabilities of transmitting water either over land or through the soil at some desired, controllable rate, and to provide sufficient treatment so that water leaving the site does not cause degradation of the environment.

When evaluating the site characteristics and the related water reclamation capabilities, one should keep in mind that present land application facilities generally are not stressing the soil treatment system. Investigations by the Public Works Association Research Foundation indicated that most land application systems provide a large factor of safety.(11)

Soil Characteristics

In most areas, the Soil Conservation Service has summaries of physical and chemical properties of soils. Knowledge of these properties is necessary for selecting the optimum land application site and for properly designing the system. Typically, the data provided by the SCS includes:

a. Depth to bedrock or gravel.
b. Depth to seasonal water table.
c. Thickness of the soil zones.
d. Sieve analyses.
e. Permeability of each soil zone.
f. Available water capacity of each zone.
g. pH of each soil zone.
h. Salinity.
i. Shrink/swell potential.
j. Corrosivity.

The depth to ground water should generally be 5 feet or more to ensure proper renovation and root development. However, if the depth to the water table is less than 5 feet, artificial water-table control can generally be instituted by using drains or by well pumping.

For rapid infiltration systems, well-drained soils such as sandy clays, sandy loams, loamy sands and gravels are preferred, with depth to water table from 10 to 15 feet unless underdrains are used.

Soils with limited permeability such as clays and clay loams are best suited for overland flow systems.(12)

Geology

Underlying geology is an important consideration in selecting a land treatment site, because it must provide a structural base for the site and, for the irrigation and rapid infiltration methods, a repository or conveyance medium for the treated water leaving the soil zone. Limestone or dolomite areas may be suitable land treatment sites of the soil zone is sufficiently thick and well graded. The pH of the waste water should receive special evaluation when limestone forms the bedrock. Karst areas should generally be avoided because of the potential for sinkhole collapse. Areas underlain by fractured rock can be suitable land treatment sites if the soil overlying the rock is sufficiently thick to prevent piping, which can short-circuit partially treated or untreated water.

Topography

A wide variety of topographical conditions can be incorporated into land application sites; however, unusual topography can lessen the application operation and increase costs. For cultivated agriculture, a land surface slope should not exceed approximately 15 percent. However, when center pivot sprinkling systems are used, slopes of up to 20 percent are feasible. Sometimes wooded terrain is used for land application because of the nature of the soil cover. Wooded slopes of up to 30 percent are suitable. For overland flow systems, slopes of 2 to 8 percent are satisfactory.(10)

Proximity to Water

The water table underlying an irrigation site should be deep enough to ensure aerated soil conditions. Generally, 5 feet is considered adequate. Periodic increases of the water table resulting from irrigation application can bring the water table closer to the surface. In this case, special analyses are required to determine the length of time that the root zone is saturated. With a shallow water table, it is often economical to install underdrains to provide positive water-table control and to provide for easy monitoring of reclaimed water.

Valley bottom land can provide good land treatment sites for all three methods. The frequency and extent of floods should be analyzed, but other than for low lands which are frequently flooded (2 to 5 years), floodplain lands often make ideal land treatment sites.(13)

The designer should avoid potential short circuiting of waste water directly to surface water, streams or lakes. In many areas, minimum distances from land surface waste disposal sites to surface-water bodies are specified by law.

Climate

Waste-water application, except for rapid infiltration, is often restricted to the growing season which is usually defined by that period between the first and last killing frost; however, for pasture, hay and woods irrigation is often beneficial during the months preceding and following the killing frosts.

Warm climates provide special advantages for land treatment. Nevertheless, many successful projects have been operated at northern latitudes. Some rapid infiltration systems operate year-round in cold climates with the waste water being applied under the ice cover, such as at Lake George, New York.

PUBLIC HEALTH CONSIDERATIONS

Public health concerns relate to:

- Viruses and pathogenic bacteria.
- Dissolved chemical constituents.
- Crop quality and pollutant uptake potential.

- Propagation of insects.

Sprayed aerosol droplets have been a concern in the public health field because of their potential to carry viruses long distances under windy conditions.

Pathogenic Organisms

Pathogenic organisms can survive in the soil and on vegetation for a long time; some have potential lives measured in months. The survival time of organisms outside their natural habitat depends on many factors. Their survival in soil is a relatively unexplored field, though Bouwer *et al.* reports a very high degree of virus removal in their Phoenix studies under conditions which would be conducive to virus transmittal.(14)

EPA reports that "The effects of working around and handling waste water on land application sites are minimal—the health hazards appear to be no different than for activated sludge and trickling filter plants."

In Melbourne, Australia, the waste-water agency has had several generations of workers directly connected to the Werribee Wastewater Farm (a discussion of the Werribee Farm will follow later in the text). For instance, one top official with the agency was born and grew up on the Werribee Wastewater Farm. Both his father and grandfather had been farm workers. Medical records of the present 500 residents of the farm show no special problems with the waste-water farm users. In addition, the absenteeism/sick leave records all indicate normal health for the farm workers, even those who are second or third generation employees of the 28,810-acre farm.(15)

The Russians report that their public health studies on the Kiev 60,000-acre site showed no public health problems to workers or to consumers, even though 16 percent of the crop is for direct human consumption, i.e., potatoes.(4)

The Scientific Advisory Committee to Governor Lamm of Colorado has reported:

> Land application treatment of waste water is a viable alternative means to tertiary treatment in Colorado, provided proper site conditions are available. Advantages offered in the synergistic use of water, fertilizer and land resources make the potential for land treatment applications promising and the consideration of the land treatment alternative should be mandatory in waste-water treatment planning. Advantages may also exist, for gravity distribution systems, in lower energy consumption. *Land treatment is highly site specific* and the possible range of site conditions within the State is very broad, varying from relatively long growing seasons in plains areas, to extremely short seasons in high mountain locations. Therefore, blanket prescriptions of the technique cannot be made, but each alternative proposal must be separately considered. Further, site specificity not only means that land application treatment might not work for some situations but also that it might be the most well adapted technique for others. It also means that each community needs to explore a variety of land treatment adaptations before it can say definitely that no viable alternative exists.(16)

Heavy Metals

The fate of heavy metals in land treatment systems is the item which is often of most concern to the regulatory agencies. For this reason, it is important to evaluate the uncertainties of heavy metals in waste-water effluent following secondary treatment and to analyze the long-term buildup in the soils over a long period of time. Generally, one or more of these constituents is more critical than others. Because the soil will remove and store most of the heavy metal concentrations, heavy metal buildup can, in some cases, limit a particular site to a finite number of years of operation. Normal municipal effluent does not contain any significant degree of heavy metals. If they are found in the effluent at levels which are of concern, it is appropriate to trace the contribution back to its source so that pretreatment or recycling of metals can be instituted at that particular source.(3)

Toxic Substances

A well designed land application system has the capability of removing a high percentage of organic compounds, halogens and carcinogenic materials. With the advent of the Safe Drinking Water Act and its resulting regulations, removal of these materials should receive special evaluation and economic consideration.

Macro-Nutrients

Nitrogen, phosphorus and potassium are macronutrients found in municipal waste water. Land treatment removal efficiencies are indicated in Table 2.

Soil has the capability of removing and fixing

Table 2. Expected Municipal Effluent Removal Efficiency Land Treatment System(5)

	Value, Percent Removal		
Constituent	*Irrigation*	*Overland Flow*	*Rapid Infiltration*
BOD	98+	98	80-85
Suspended Solids	99	94	99
Total Nitrogen as N	85+	80	75-80
Phosphorus as P	99+	40-80	50-60

nearly all potassium and phosphorus contained in the waste water. However, nitrogen is more mobile and, for this reason, the amount of nitrogen applied by the land on an annual basis should receive special evaluation to ensure that the potential concentration of nitrate nitrogen does not result in ground-water contamination. Generally, a nitrate nitrogen limit of 10 mg/l is used as an upper limit in renovated waste water.

SLUDGE APPLICATION

Sludge utilization on land for agricultural production is encouraged by Federal law.(17) It is considered to be the ultimate disposition of sludge in a manner which will not cause environmental degradation if it is done in a planned and managed way.

Presently, the Colorado Department of Health and the State Health Board concluded that utilization of stabilized sludge on land for agriculture, silviculture or reclamation purposes is an environmentally acceptable alternative for solving the current sludge problem.(18)

Municipal sludge contains the concentrated wastes of the community. Certain components may be toxic and/or hazardous, depending on their concentration and method of application. Such application must not degrade the surface or ground waters. The salt content of sludge can inhibit plant growth if it is applied in high concentrations or at the wrong time. Thus, the key to a proper sludge application project is to have the right quality sludge applied at agronomic rates.

The nominal reason for stabilizing the sludge is to obtain pathogenic destruction, volume and weight reduction, and odor control. Stabilization can be by chemical treatment, digestion, or composting, the most common form being digestion by aerobic or anaerobic means. Stabilization in a lagoon bottom under anaerobic or facultative conditions is a low cost and effective method.

The Colorado Board of Health allows sludge application without a permit if minimum standards are met relating to nutrient concentration and trace element content. For instance, nitrogen is limited to 60,000 mg/l, zinc is limited to 3,000 mg/l, and cadmium to 30 mg/l. If standards are exceeded, the State reviews and approves on a case-by-case basis.

Colorado recommends subsurface application of sludge as a nitrogen conservation measure. With surface spreading, they estimate that 80 percent of the ammonia nitrogen may be lost.

Crops should not be fertilized with sludge if they may be eaten raw by humans unless the sludge is first stored for one year. In addition, the Colorado Health Board allows application on ice-covered or frozen land without a permit if the land slope is 5 percent or less. On land sloping in excess of 5 percent, annual soil loss must be limited to 5 tons per acre.

To protect the ground water, Colorado requires that the mean annual depth to water table be greater than 7 feet and that no domestic well be closer than 150 feet. Sludge can be applied in the floodplain as long as it is outside of the area flooded more often than once in 10 years. If these conditions are not met, then special review is needed with issuance of a permit.

Monitoring is required for municipal treatment plants of up to 10 mgd with at least one sample taken each 3 months. For larger plants, sampling each month is required.

MONITORING FOR WASTE-WATER APPLICATION

Monitoring of a land application facility is required to ensure that the waste water is being properly renovated and that the environment is being protected. The influent waste water should be analyzed in the same manner that conventional waste-water treatment plants are monitored so that the operator knows the specific quality of effluent being applied to the land. In addition, monitoring of the quality of renovated water, the vegetation, and the soils is recommended. This should be considered a part of the management of a land treatment facility.

Renovated water should be analyzed for those parameters normally monitored in drinking-water supplies, those parameters required by regulatory agencies, and specific parameters required by the engineer for quality control. Typically, nitrate nitrogen is the parameter most closely monitored.

Crops grown on the land application site should be analyzed periodically both to optimize growth and yield and to determine crop intake level of micro and macro-nutrients.

Soils should be tested periodically (quarterly) for salinity, pH, cation exchange capacity and infrequently (yearly) for considerations of various elements such as heavy metals.

CASE STUDIES

Bortnichy/Kiev State Farm, U.S.S.R.(4)

The Bortnichy State Farm outside of Kiev, U.S.S.R., is a successful land application project. The Minister of Land Reclamation and Water

Management in the Ukrainian Republic of U.S.S.R. has transmitted a report stating that "since the start of operation of the (waste-water) irrigation system the productivity of agricultural crops has doubled." (Personal communication with N. A. Garkusha dated September 24, 1976, transmitting report by A. I. Nasushkin.)

The Bortnichy Farm has 24,300 ha (60,000 acres) under production with irrigation water derived from municipal and industrial waste water generated by Kiev, a city having a population of 1,900,000. Cost of the irrigation system amounted to $47,000,000 (32,000,000 Rubles) in 1968. Unit cost was $1,940/ha ($780 per acre), which includes transmission canals, laterals, pumping plans, and all field sprinkler equipment.

Description of the System

The industrial waste-water treatment uses physical-chemical processes at the industrial sources prior to its being combined with the municipal waste water. Approximately 60 percent of the waste water is derived from industrial sources. Primary treatment consists of screening and pulverizing, followed by settling. The waste water is then routed to the secondary activated sludge plant for aeration and clarification prior to irrigation. The waste water is not disinfected prior to irrigation so as not to waste chlorine or ozone.

The sludge resulting from the primary and secondary treatment operation, which contains 3 percent solids, is carried by pipeline to sludge drying beds where it is digested using natural processes of sunlight and drying. The U.S.S.R. government is presently studying methods of direct application of the wet sludge to the fields. Currently, the dried sludge is used as a field fertilizer with good crop response. Direct application of the 3 percent solids wet sludge would reduce costs and result in reduced land use for natural drying beds.

Waste water is supplied to 300 irrigation rigs by 32 pumping stations for 24 hours per day. The rigs include the self-propelled power sprinklers DKSh-64, the "Volzhanka," which operate from a closed irrigation system. Irrigation occurs 7 months per year, from April to October. Total length of open canals amounts to 41 kilometers (25 miles) with a 1975 flow of 7.2 m^3/sec (163 million gallons per day). During the growing season 45,200,000 m^3 (36,600 acre-feet) of treated waste water is used for irrigation. There is no mixing with fresh water. All irrigation is via sprinkler system to maximize efficiency of application. The soil cover in the system is mainly gray or dark gray light clayish loamy podozols.

Table A. Use of Bortnichy Irrigated Lands

Crop	*Hectares*	*Acres*	*Percent*
Cereals	7,300	18,000	30
Potatoes	3,900	9,650	16
Fodder	7,300	18,000	30
Irrigated Pasture	3,900	9,650	16
Other Crops	1,900	4,700	8
Total	24,300	60,000	100

The various types of crops in the irrigated lands are summarized in Table A. Application rates average 1,500 m^3/ha (0.5 acre-feet per year) per season to supplement the natural precipitation of 500 to 580 mm/year (23 inches per year). Average temperature during the year is +7° C. The period with average daily temperatures exceeding 15° C is 115 days. Above freezing temperatures prevail for 165 to 170 days. The average for the freezing-free period ranges from April 19-25 to October 6-10.

Environmental Effects

Officials of the U.S.S.R. report no health problems. All effluent is regularly tested and is safe for irrigation. Fourteen years of health records of farm employees have been analyzed and no indication has been found that workers are subject to health hazards. The quality of the waste water is constantly controlled by laboratories of various ministries.

The ground-water table ranges from 3 to 16 meters (10 to 52 feet) in depth below ground surface. By carefully controlling application rates, the recharge to the ground-water table is strictly limited; however, care is exercised to insure against salinity buildup in the soil zone, for salinity increase would be sure to cause damage to the productivity of the soil in this rich agricultural region. The dissolved constituents in the waste water used for irrigation do not exceed 1,000 milligrams per liter.

The objectives of the use of waste water for the Bortnichy State Farms are to increase crop production and to reduce pollution of the Dneiper River which flows through Kiev and which provides environmental and recreational opportunities to the citizens of Kiev and the 49,000,000 residents of the Ukraine. The Bortnichy State Farm is in the vicinity of the Kiev airdrome. It provides a natural buffer against development in the vicinity of the airport, which represents an important benefit.

Macro and micro-nutrients are provided to the crops by the nutrient-rich waste water. For instance, nitrogen content in the waste water approximates 22 mg/l, phosphate is 4.5 mg/l, and potassium is 11 mg/l. The nutrients are furnished to the crops on a periodic basis with each irrigation of approximately 400 m^3/ha.

There is a leaching of salts to the ground-water table, particularly because the water applied has a TDS of 1,000 mg/l. If the Ministry used fresh water (with a salinity of no more than 600 mg/l) the leaching of salts to the ground-water aquifer would be substantially less; however, artificial fertilizers would have to be applied which would tend to add more TDS concentration.

Summary

The Bortnichy State Farm at Kiev is a highly successful waste-water irrigation farm, operated by dedicated and skillful personnel of the Ministry of Land Reclamation and Water Management of the Ukraine Republic of the U.S.S.R. The project was initiated in 1962 and construction completed in 1968. The favorable economics of the irrigation system using waste water is evident to U.S.S.R. officials and to the observer as one views the green fields and busy farmhands going about their work. Crop production has doubled with the use of the waste-water irrigation system. Potatoes for human consumption are grown. Results of careful monitoring of the system and its products show no harmful effects of using waste water for irrigation.

The economic impact in the Ukraine is significant as a result of farm income, food production, local employment, and the improved quality of the Dneiper River.

Melbourne, Australia: Werribee Farm System(9)

The Werribee Farm of the Melbourne and Metropolitan Board of Works is a highly productive agricultural and livestock enterprise as well as an efficient waste-water treatment project. The Farm was constructed in the 1890's and is presently only 22 miles from a metropolitan area with a population of 2½ million people.

The Farm covers 11,660 ha (28,810 acres), and represents the most productive agricultural land in Australia. The gross returns from the Farm's sale of livestock produced approximately $1,500,000 in gross revenues in 1974. It also provides an essential municipal service by treating waste water. In addition to cleaning the waste water, the Farm has provided beneficial environmental impacts such as providing a major wildlife sanctuary. The open space near the metropolitan area discourages urban sprawl in that direction. Many foreign and local visitors tour the Farm yearly.

Description of the System

Melbourne's sewerage system was established in 1893 and has been in continuous operation since 1896. Raw waste water is collected from the Melbourne metropolitan area and carried to the Werribee Farm in an open canal. Approximately 20 percent of these wastes are industrial in nature. The Farm currently receives approximately two-thirds of the Melbourne area wastes. These wastes have a BOD_5 of 600 mg/l. In recent years, the Farm has been treating raw wastes at a rate far in excess of its rated capacity. As a result, the Metropolitan Board of Works is currently exploring pretreatment works for the Werribee Farm. The Werribee Farm has been and will continue to be the pride of the Board of Works. (Interview with A. H. Croxford, Chairman, Melbourne and Metropolitan Board of Works, September 7, 1976.)

Waste-water treatment is accomplished at the Farm by 3 processes. During the irrigation season (6 to 7 months per year), raw sewage is applied to pasture areas totaling 10,351 acres. The applications are intermittent, being approximately 10 centimeters (4 inches) deep. Between applications, this provides excellent pasture for grazing cattle. Usually a drying out period of one week is allowed prior to grazing. Approximately one-fifth of the total waste water at the Farm is used in this manner. The irrigation operations are continuously controlled by approximately 100 shift workers. The major statistics of the operations are summarized in Table B.

The waste water not required for irrigation is treated by sedimentation and oxidation in shallow

Table B. Melbourne and Metropolitan Board of Works Werribee Farm System Parameters

	Amount	
	Metric	*English*
1974 Annual Waste-Water Supply	207,000,000 m^3	168,000 Ac-Ft
Gross Farm Area	11,660 ha	28,810 Acres
Purification Areas	7,210 ha	17,821 Acres
Land Filtration	4,190 ha	10,351 Acres
Grass Filtration	1,515 ha	3,744 Acres
Lagoons	1,446 ha	3,573 Acres
Sedimentation	62 ha	153 Acres
Average Annual Rainfall	49.3 cm	19.4 Inches

lagoons. During the winter period, the entire flow is treated by primary settling followed by grass filtration and oxidation ponds. Since permeability is not the key to this particular process, the areas used for this purpose are the heavier clay soils.

Open drains of 1.2 to 1.3 meters (4 to 5 feet) extend throughout the irrigation area. Their function is to collect surface flows and ground-water seepage for discharge into Port Phillip Bay. Water in the drains is sampled to assure the proper operation of the waste treatment/irrigation system.

System Costs and Revenues

The irrigated pastures are grazed by 15,000 head of cattle throughout the year. During the spring and summer, approximately 40,000 to 50,000 sheep are fattened and sold in the fall. About 7,000 cattle are sold annually and replaced with calves born during the year. These operations produce direct revenues for the Farm which totalled approximately $1,500,000 in 1973/74. The capital investment of $16,800,000 in the Farm was amortized long ago. The operation and maintenance costs of the Farm are reduced considerably by the revenues which it produces. The costs and revenues are summarized in Table C. The net annual cost of the system is $0.12/m^3 of waste water treated. Equivalent costs for treatment by conventional systems would be several times as great. As a result, substantial savings are enjoyed by the people of Melbourne area because of the Farm operations. The over-all benefit-cost ratio does exceed unity.

Environmental Effects

Since its inception, the Farm has had a resident population which has varied from 67 to 500. The health of these people has been similar to any other population of the area. No epidemics or disease has occurred. The livestock on the Farm have thrived. There have been some complaints of odor from the Farm. These complaints are relatively infrequent and the degree of offense has been minimal. Odor resulted from overloading of the system as the strength and volume of the raw waste water increased, coupled with occasional management laxness.

Table C. Melbourne and Metropolitan Board of Works Werribee Farm Summary of Costs (1974 Estimates)

Construction (initial costs paid off)	
Operation and Maintenance	$4,044,000
Farm Revenues (Gross)	$1,493,510
Net Annual Cost	$2,549,990
Net Annual Cost	$.012/m^3 ($.047/1,000 gal.)

The vastness of the Farm's operations has provided an open space buffer area for Melbourne. The lagoons at the Farm have also developed into an outstanding year-round bird sanctuary. In the summer months, when inland feed and water sources dry up and birds from the northern hemisphere leave their harsh winters behind, the bird population at the Farm exceeds 100,000. The Farm staff has developed an intense pride in the bird life and their welfare. The wildlife sanctuary which the Farm provides is an example of how agriculture and waste treatment can work harmoniously with nature.

There have been no reports of ground-water contamination. Application of effluent irrigation has helped provide a fresh-water barrier to the saline water of the adjacent Port Phillip Bay.

Muskegon County, Michigan System(9)

The Muskegon County waste-water system has brought 2,266 hectares (5,600 acres) of previous wasteland into productive irrigated agriculture. The agricultural aspects of the project and the high level of treatment have resulted in an economically productive and environmentally sound project. For each acre-foot of irrigation water applied to the land, the regional net benefits amount to $62.74 (U.S.). The benefit-cost ratio is currently 1.53:1.00. The annual benefits include direct revenues of $706,000 from sales of corn grain. The annual benefits arising from the basic employment of farm workers is $1,400,000 per year. A savings of $5,716,000 per year is also realized since conventional waste-water treatment facilities which would otherwise have been necessary have not been built and are not in operation.

Substantial secondary benefits include improved aquatic habitat, improved industrial siting potential and general public awareness. Dollar values for these benefits have not been included in this analysis.

Description of the System

Waste water is collected from 13 municipalities and 5 major industrial sources. Approximately 65 percent of the wastes presently treated are from industrial sources.

The volume of wastes treated currently averages 37,267,000 cubic meters (30,200 acre-feet)

Table D. Muskegon Waste-Water Irrigation System — Summary of Irrigation System Parameters

	Amount	
	Metric	*English*
1975 Annual Waste-Water Supply	37,267,000 m^3	30,200 A.F.
Capacity Annual Waste-Water Supply	58,000,000 m^3	47,000 A.F.
1975 Usable Waste-Water Supply	37,267,000 m^3	30,200 A.F.
Gross Irrigation Site Area	3,035 ha	7,500 acres
Usable Irrigation Site Area	2,266 ha	5,600 acres
Average Seasonal Rainfall (April-October)	49 cm	19.3 inches
Seasonal Rate of Application	136 cm	4.45 A.F./acre
Size Rotating Irrigation Rigs	14-57 ha	35-141 acres
Number of Rotating Rigs	54	

per year. As the waste collection system is expanded and growth occurs, this volume will increase to approximately 58,000,000 cubic meters (47,000 acre-feet) per year.

Waste water is pumped approximately 10 miles from the urban center to the irrigation site through a force main. At the treatment site, the waste water is first biologically treated. Following this treatment, the waste water is either applied immediately to the land or stored for later such use. All water is chlorinated prior to irrigation as required by State authorities.

The major statistics of the irrigation operation are summarized in Table D. The annual application of waste water far exceeds the irrigation requirement for corn in this area because the project is a combination waste-water treatment and irrigation project. The over-all economics of the project have, at least in the short-term, dictated the high waste-water application rates. The soil at the site is sandy and was considered to be nonproductive prior to the waste-water irrigation project. In 1975, the average yield of corn for the waste-water irrigation project was 5.2 m^3/ha (60 bushels per acre). Although this nearly matched the average yield of 5.7 m^3/ha (65 bushels per acre), it is felt that yields of 10.5 m^3/ha (120 bushels per acre) may be obtained as operational experience is gained with the waste-water system.

Ground-water levels at the irrigation site prior to construction varied from less than 1.5 meters (5 feet) in most places to 7.6 meters (25 feet). Perforated polyethylene pipe was installed to assure at least 5 feet of freely draining aerobic soil throughout the site. The drainage network discharges to open channels which carry the clean water to natural waterways. Monitoring of discharge within the site is provided by a network of 272 observation wells scattered throughout the property.

System Costs and Revenues

The system costs and annual revenues for the Muskegon system are shown in Table E. The cost of construction for the treatment system was $37,700,000. The operation and maintenance costs for the system are $1,822,000 per year. Labor costs make up approximately 35 percent of these annual costs.

The fertilizer value of the waste water is an important component of the project. It has been estimated that 60 percent of the nitrogen, 70 percent of the phosphorus and 100 percent of the potassium removed from the combined domestic and industrial wastes actually served as fertilizer for the 1975 corn crop. At current prices (spring, 1976), these chemicals are worth more than $190,000 (U.S.) per year.

The irrigation component of the system is the prime source of revenues. In 1975, this amounted to $706,000. In future years, these revenues are expected to increase to approximately $1,400,000 when experience is gained in the operation of the agricultural portions of the system. The capital construction is amortized at 7 percent over 20 years. After consideration for amortization, operation and maintenance, and direct revenues, the net annual cost of the system is $4,457,000 per year or $0.12/$m^3$ ($0.45 per 1,000 gallons) of water treated. When the system is operating at full capacity, these treatment costs will be reduced to approximately $0.09/$m^3$ ($0.33 per 1,000 gallons). The estimated cost of treating waste water to a lesser degree by conventional treatment systems in this area is approximately $0.15/$m^3$ ($0.58 per 1,000 gallons). This represents an initial savings of $0.13 per 1,000 gallons. When the system is fully developed, an annual savings of $0.07/$m^3$ ($0.25 per 1,000 gallons) may be realized.

The costs of agricultural production are similar to those of any other public irrigation project of this magnitude in this area. The only benefit identified under the agricultural category is the revenue received from the sale of the corn grain harvested. The revenues received in 1975 fall short of the potential revenues expected in future years. In the future, these revenues are expected to double, whereas the cost of agricultural production will increase only approximately 20 percent for the same period. Secondary benefits normally associated with agricultural products were not included in this analysis. A limited special category, however, has been included because it has special meaning for waste-water irrigation projects. This benefit is known as basic employment, as discussed previously.

In the Muskegon system, special efforts were made to convert workers to agricultural employment. These workers represent approximately one-third of those employed by the entire system. Using the multiplier factor of 8 for identifying regional national benefits, this results in a net benefit of $1,400,000 per year.

The over-all environmental enhancement of the Muskegon area has been the most visible benefit of the system. To date, 3 positive environmental impacts have emerged: a general improvement in water quality in Muskegon County, increased wildlife populations at the irrigation site, and increased aquatic life in Muskegon Lake. These benefits manifest themselves in various forms. Visual improvements in Muskegon Lake's water quality have increased the over-all pride of the local citizenry in their environment, tourist trade, stocking of more sensitive and desirable fish species in the lake, fishing activity, and has created an over-all improvement in the quality of recreational experiences in the area.

Table E. Muskegon Waste-Water Irrigation System Summary of Costs

Construction (including land cost)	$37,700,000
Operation and Maintenance (1975)	$ 1,822,000
Total Annual Cost*	$ 5,380,000
Total Annual 1975 Direct Revenues**	$ 923,000
Net Annual Cost***	$ 4,457,000
Net Annual Cost***	$0.12/$m^3$ ($0.45/1,000 gal.)

* Based upon debt retirement over 20 years at 7% interest.

** Revenues include approximately $216,400 in grants, laboratory services and other miscellaneous revenues.

*** After more operational experience is gained, a corn crop yield of 10.5 m^3/ha (120 bushels/acre) is estimated. Also, when full design flows of 58,000,000 m^3/yr (42 mgd) are realized, net annual costs will increase by about $500,000 resulting in a net annual unit cost of $0.09 /$m^3$ ($0.33/1,000 gal.).

The waste-water irrigation system is also viewed by local public officials as an important resource in the improvement of Muskegon County. The improved quality of Muskegon Lake has encouraged the City of Muskegon and private interests to redevelop the lake's waterfront as the focus for downtown redevelopment and community revitalization. Various programs for attracting industry and over-all economic development of the area stress the capabilities of the waste-water irrigation system.

Monitoring of ground-water quality at the Muskegon facility show it to be of high quality with no measureable salinity increase. Pollutants have not degraded the ground-water quality.

Sonnenberg-Sterling, Colorado System(9)

The Sonnenberg-Sterling Irrigation Project would use 3,947,700 m^3 per year (3,200 acre-feet per year) of waste water to irrigate 530 hectares (1,310 acres) of present sand hill prairieland for production of corn grain. This project is small, but the relative economic impact on the region would be substantial. The annual benefits include (1) cash crop, corn grain production of $425,800 per year based on 11.3 m^3/ha (130 bushels per acre) yield; (2) basic local employment for farm workers of $140,000; and (3) savings of $479,700 in waste-water treatment which otherwise would be necessary in the Sterling, Colorado area. (This project was first conceived in 1970 with detailed planning commencing in 1975. The project as described herein is a private enterprise system designed as an agricultural enterprise with costs based on economic agricultural construction techniques and actual bids. The project will probably not be constructed as described for institutional reasons. A federally subsidized waste-water irrigation project is anticipated.)

This waste-water irrigation system is unusual in the sense that the financing of the system would be undertaken in a partnership between private interest and government agencies. In this case, the desire to irrigate additional lands is the prime motivating force in the project development. The need to irrigate additional lands, when combined with the waste-water treatment needs in the area, has resulted in the preferred alternative of irrigation with waste water and achievement of clean water goals.

The first step in the Sterling plan is the collection and transport of the domestic and industrial waste-water flows of the area to a site approximately 4 miles east of the City. At the site, aerated lagoons are used to pretreat the waste water to avoid nuisance conditions. The nutrient-rich stabilized waste water is then stored for use as an irrigation and fertilizer supply. Rotating rigs are used to irrigate the crop land.

Description of the System

Included in the system would be wastes from 3 sources: (1) domestic wastes from the Town of Sterling, (2) industrial wastes from the Sterling factory of the Great Western Sugar Company and (3) industrial wastes from the Sterling, Colorado Beef Company. Industrial wastes represent approximately 60 percent of the total irrigation supply.

Following biological treatment in the aeration cell, the effluent would be discharged to a storage basin. Since the normal irrigation season lasts only from mid-April to mid-October, it would be necessary to store approximately a 6-month volume of waste water. The storage basin also provides for additional treatment since the solids remaining in the waste water will settle out. At the time of withdrawal from the basin, the treated waste waters are disinfected with chlorine prior to irrigation. After accounting for evaporation and minor seepage losses, about 3,580,000 m^3 (2,900 acre-feet) would be available for irrigation. The irrigation land would consist of about 530 hectares (1,310 acres) in the area of the treatment and storage basins. The waste water would be distributed for irrigation by 10 circular electric-driven irrigation rigs. Each rig is capable of irrigating 53 hectares (131 acres) and could be expanded in the future as needed to include corner systems capable of irrigating an additional 10 hectares (25 acres) each.

The primary crop grown would be corn grain for cattle feeding purposes. Flexibility remains in the design for irrigation of alfalfa, if necessary, by some of the rigs. The soil texture at the irrigation site is sandy. Sprinklers are the only practical method of irrigation; pivot sprinklers are ideally suited for this purpose. The design application rate is 67.5 centimeters per year (2.22 acre-feet per acre).

The use of sewage effluent assures that nitrogen would be applied frequently and in small amounts. Allowing for some loss of nutrients, about 280 kg/ha (250 pounds per acre) of nitrogen and 67 kg/ha (60 pounds per acre) of phosphorus would be applied. Unknown quantities of trace elements would also provide fertilizer value to the irrigation water. The expected initial yields of the system are 11.3 m^3/ha (130 bushels per acre). As the organic content of the soil increases through waste-water application and the plowing in of sludges collected in the storage basins, the expected yields would increase to the 13 m^3/ha (150 bushels per acre) range.

The major parameters of the irrigation portion of the Sonnenberg-Sterling system are summarized in Table F.

The soils of the area are well drained with ground water 25 meters (82 feet) or more below the surface. The natural drainage characteristics of the site would allow ample movement of the percolated water to the South Platte River approximately 3 miles to the north.

System Costs and Revenues

The estimated total construction cost of the Sonnenberg-Sterling system is $2,441,000. The annual operation and maintenance cost of the system is estimated to be $271,000.

The projected annual revenue for the waste-water irrigation system would develop only in the irrigation component. These revenues develop from the sale of the corn crop harvested. Based on a projected initial yield of 11.3 m^3/ha (130 bushels per

Table F. Summary of Irrigation System Parameters – Sonnenberg-Sterling Waste-Water Irrigation System

Item	*Amount* *Metric*	*Amount* *English*
Annual Waste-Water Supply	3,947,700 m^3	3,200 A.F.
Usable Waste-Water Supply	3,580,000 m^3	2,900 A.F.
Gross Irrigation Site Area	688 ha	1,700 acres
Usable Irrigation Site Area	530 ha	1,310 acres
Average Seasonal Rainfall (April 15-October 15)	30.5 cm	12.0 inches
Seasonal Rate of Application	67.5 cm	26.6 inches
Size Rotating Irrigation Rigs	53 ha	131 acres
Number of Rotating Rigs	10	

Table G. Sterling-Sonnenberg System Summary of Costs

Construction	$2,441,000
Operation and Maintenance	$ 271,000
Total Annual Cost	$ 501,000
Total Annual Direct Revenues	$ 425,800
Net Annual Cost	$ 75,200
Net Annual Cost	$0.02/m^3 ($0.07/1,000 gal.)

acre), these revenues would total $425,800 per year, but would vary depending upon actual yields of the system and the prevailing market prices. As experience is gained in the operation of the system and the organic content of the soil improves, a general upward trend in these revenues can be expected.

The costs and revenues of the Sonnenberg-Sterling system are summarized in Table G. Capital construction costs are amortized at an interest rate of 7 percent over a 20-year pay-back period. Financing of the capital construction costs is anticipated to be through industrial revenue bonds. If other methods of financing were available via municipal bonds or federal funding at lower interest rates, lower annual costs could be achieved.

After consideration is made of the direct revenues produced by the sale of corn, the net annual cost of the system would be $75,200 per year. This represents a cost of $0.02/m^3 ($0.07 per 1,000 gallons) of waste water treated. For comparison purposes, a conventional system which would provide similar water quality in this same area would be approximately $0.12/m^3 ($0.46 per 1,000 gallons). Thus, an initial savings of $0.39 per 1,000 gallons of waste water treated would be realized immediately.

The designation of benefits has been divided into 4 general categories. The waste-water treatment costs are those involved in the transport to, and pretreatment of, the wastes at the irrigation site. Since the storage basin provides treatment in addition to storing flows during the winter nonirrigation season, half of the construction cost ($303,100) was allocated to agricultural production. The regional benefit of $479,700 assigned to waste-water treatment is the estimated cost of providing treatment by a more conventional alternative. This benefit can vary substantially dependent upon local stream quality problems. In the Sterling area sulphates and nitrogen are emerging problems in the water supplies. The estimated equivalent treatment cost includes provision for nitrogen removal only.

The cost of conventional treatment is considered a benefit to the Sonnenberg system since it represents a regional investment which would be necessary in the absence of the waste-water irrigation project.

Additional benefits for over-all environmental enhancement such as water recreation and wildlife habitat have not been quantified.

The annual cost of agricultural production includes provision for harvest machinery, supplemental fertilizers and herbicides, irrigation equipment, etc. The benefits identified with agricultural production include only the direct revenues associated with the sale of the corn crop. They do not include the secondary regional benefits sometimes associated with the sale of agricultural products, which typically range on the order of 50 percent of the direct revenues. The benefits also do not include intangibles such as the enhancement of local cattle feed supplies for local feed lots, nor the development of a firm irrigation water supply.

SUMMARY

Due to the law passed by Congress recently, the rules and regulations of the Environmental Protection Agency, and the need to optimize federal funding, it is necessary to consider land treatment when planning and designing new sewage treatment facilities. Items to be weighed in determining the appropriateness of choosing a land treatment approach include site characteristics such as soil conditions, geology, topography, proximity to water, and climate. If the land treatment approach is within 15 percent of being the most cost effective, it will probably be selected. The decision must be made as to which method to use, irrigation, overland flow, or rapid infiltration. An evaluation must also be made of the aquifers and their properties so that potential problems can be identified and appropriate preventative actions taken.

A monitoring program is essential for land treatment systems so that awareness is maintained as to the actual quality of effluent being produced and the first indications of potential effects on ground and surface waters, crops, and soils.

The application of treated waste water to land can provide an economical and environmentally viable alternative to conventional waste-water treatment.

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Land Application of Waste — Important Alternative[a]

by John R. Sheaffer[b]

ABSTRACT

Land treatment uses a combination of processes to manage and beneficially use waste water. It represents a revolution in sewage treatment because it (1) transforms sewage treatment from a single purpose activity into a multipurpose activity, (2) changes sewage treatment construction grants from subsidies into investments in the production of food and fiber, and (3) requires the participation of a variety of disciplines to implement successfully. Because it is revolutionary to the sewage treatment field, three situations have developed. First, it is displacing traditional technology at a record-breaking pace. Second, its logical appeal to thinking decision makers has created a situation in which the policy makers are ahead of many technicians. Third, it is attacked with a fervor heretofore unknown in the sewage treatment field.

Land treatment has logged an enviable track record in the United States. Existing systems have produced a high quality effluent at economically competitive prices. In addition, in terms of relative risk, the threat to environmental quality from a land treatment system compares favorably with advanced waste treatment systems.

INTRODUCTION

Land treatment of waste water is a controversial issue. A part of the controversy stems from misunderstanding. As Mark Twain once said, if two minds disagree, it's for one of two reasons. Either they are using the same words to mean different things, or they are using different words to mean the same thing. This characterization describes many discussions and articles relating to land treatment. In general, discussants are perceiving different systems as they debate the performance level of land treatment.

To initiate a meaningful discussion of land treatment, it is necessary to identify first the elements of a complete system. This does not mean that a variety of abbreviated versions of land treatment system do not exist. Rather, it suggests that one should not expect an abbreviated version to function like a complete system.

There may be good reasons to abbreviate land treatment systems. These are policy decisions. However, the performance data from an abbreviated system should not be used to evaluate a complete system. When this is done it is an incorrect technological transfer. Such incorrect transfers have taken place and have influenced planning decisions.

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COMPONENTS OF A LAND TREATMENT SYSTEM

A complete land treatment system consists of a number of processes which manage and use the waste water. There are six basic components. Each component is discussed briefly.

The first component is a network of pipes to collect the waste water. This collection and transport system conveys the waste water to a selected location. The location could be contiguous to the producing area 5 miles away, or conceivably 100 miles away.

The second component provides pretreatment. Thus, a land treatment system does not spread raw sewage on the land. Rather a proper level of mechanical and biological treatment is provided before application to the land. The pretreatment reduces the BOD level of the sewage to prevent the creation of nuisance conditions.

The third component provides storage. This component provides flexibility with respect to when waste water will be applied to the land. This eliminates conflicts with respect to planting, harvesting, and irrigation. Also, it avoids the necessity of irrigating during the nongrowing season. If the pretreated waste water is to be used primarily to irrigate and fertilize crops it must be stored during the nongrowing season. The storage facility must be designed to manage potential leakage. This can be done by constructing facilities to intercept the leakage and return it to the storage basin, controlling ground-water movements by wells and drainage ditches, or lining the storage basin with an impervious layer. Disinfection of the treated and stored waste water takes place as it leaves the storage basin.

The fourth component is an irrigation site on which crops can be grown. When selecting the site, the hydrogeology and the soil characteristics should be evaluated. There is a double interest in these evaluations. First, there are the general questions regarding the use of the site for irrigation, e.g., salinity, waterlogging, and the buildup of sodium in the soil. Second, there are the questions regarding the capability of the site to purify the stored and pretreated waste water.

Initially, a field description of the site must be developed. The soil must be evaluated with regard to texture and be separated into horizons with depth. This information on soil needs to be accompanied by observations regarding infiltration, permeability, depth to zone of saturation, and direction and rate of flow of ground water.

The following group of analyses will help to establish the potential for prolonged irrigation of the soil and to evaluate its potential to purify the waste water: (1) cation exchange capacity (c.e.c.), (2) pH, (3) calcium carbonate ($CaCO_3$) if exceeding 0.1 percent, (4) particle size distribution, (5) total organic carbon, (6) total organic nitrogen, (7) exchangeable Ca, Mg, K, and Na, (8) total soluble salts, (9) chlorides, and (10) bulk density. (These parameters are gleaned from the analyses of land treatment systems provided by G. W. Leeper, consultant in agricultural chemistry to Sheaffer & Roland, Inc.) The importance of these parameters is discussed briefly in the following passages:

1. *Cation exchange capacity.* This has a role in both spheres of irrigation and purification. In irrigation, it is helpful in estimating the impact of a known amount of sodium in the irrigating water. In purification, it is used in estimating the load of heavy metal which the soil may safely carry. A useful figure that is quoted here, and one with some experimental backing, is that if the pH is 6.5, then 10 percent of c.e.c. may be held by zinc and other heavy metals. (If c.e.c. is 20 m.e. per 100 g, this means 650 ppm of zinc.)

2. *pH.* There is also a dual role for pH. A pH exceeding 8 is taken into account in assessing the impact of sodium in water; while any information about pH is useful in describing a soil's chemistry—a low pH implies low reserves of nutrients, in particular. In renovation, one desirable (or essential) side of a moderately high pH is the increased ability to hold heavy metals (Leeper, 1978). Another concern is phosphate. It is held by calcium at pH above 6 and by iron and aluminum at pH below 6.

3. *Calcium carbonate.* Information on $CaCO_3$ is in any soil study. The qualification "above 0.1 percent" is merely to avoid analyzing for trivialities. Calcareous soils have their own peculiarities in availability of trace elements. In terms of renovation, $CaCO_3$ is a powerful buffer against both heavy metals and phosphate. Against zinc, 1 percent $CaCO_3$ would certainly hold 6500 ppm zinc. Against phosphate, 1 percent $CaCO_3$ would hold 1900 ppm phosphorus.

4. *Particle size distribution.* This is a numerical way of recording what the soil survey reports as sand, loam, clay loam, clay, etc. The percentage clay is the most important single value in this analysis. It can be linked to the conduction of water through the soil, and to the c.e.c. though

different kinds of clay differ greatly in c.e.c.

5. Total organic carbon. This provides an estimate of total organic matter (given by multiplying by 1.72). While this figure is largely determined by climate it also depends on management and generally increases with fertility. Organic matter contributes to c.e.c. much more than does clay, and it holds heavy metals, atom for atom, more strongly than clay. This need not be evaluated below 2 feet.

6. Total organic nitrogen. This is easily determined and gives a little additional information to organic carbon, in terms of fertility. The carbon nitrogen ratio (C/N) is usually of the order 10 to 12 to 1. Any reduction in this ratio indicates a greater likelihood of liberating ammonia. This need not be evaluated below 2 feet.

7. Exchangeable Ca, Mg, K, and Na. These exchangeable metals are primarily of interest in coping with high proportions of sodium. They are of primary interest to the irrigator.

8. Total soluble salts. This is of interest to the irrigator.

9. Chloride. This is of interest to the irrigator.

10. Bulk density. This information is needed to make mutual transformations of parts per million and kilograms, per hectare or pounds per acre.

The fifth component is a growing crop. This provides a living filter with the potential to recycle nutrients. The crops selected must be compatible with the soil, climate, and the waste-water characteristics. A soil system with a growing crop can recycle nutrients and can extract some substances that should be confined and contained in the environment. Cadmium, an example, is an element in sewage which is efficiently extracted by crops. However, the crop keeps the cadmium out of its seed and deposits it in its stems and foliage.

The sixth component is an underdrainage system. This important component can be either natural (an area of ground-water discharge) or installed (drain tiles or wells) or a combination of the two. The purpose of the underdrainage system is to protect both the living filter and the aquifer. The living filter is protected from water-logging and excessive salt buildup by the drainage network. The aquifer is protected because of the capability to collect and recycle any pollutants which may have broken through the living filter.

Many abbreviated land treatment systems do not have an underdrainage system. In essence, they have uncontrolled recharge. The Muskegon County waste-water management system can be used to illustrate how an underdrainage system will function. The United States Geological Survey in conjunction with the State of Michigan analyzed the underdrainage system at Muskegon County (U.S.G.S., 1978). A digital model analysis was undertaken. This analysis showed that if the effectiveness of the tile to collect drainage is reduced by 75 percent—a severe planning assumption—large areas within the land treatment site would become waterlogged. However, the effect outside the waste-water site would be negligible. With this type of information, conjecture concerning the potential effects a complete land treatment system would have on off-site wells is academic, when a properly designed underdrainage system is provided.

It is important to note that many systems referred to as land treatment are not designed properly and do not contain all of the components of a complete system. In some instances, the treatment plant does not work so the effluent is conveyed to a nearby field and discharged. This is not a land treatment system. Similarly an industry with a seepage bed does not have a land treatment system. The performance of such a system should not be used to evaluate the performance of a land treatment system.

LAND TREATMENT IS SITE SPECIFIC

There is danger in repeating the design of a successful land treatment system at a new site. In this respect, land treatment differs significantly from the more conventional treatment plant technology. One should not repeat the Muskegon design throughout the country. A land treatment system must be designed to fit specific site characteristics. Even outspoken opponents of land treatment agree that it is possible to design a land treatment system that would not result in the pollution of underground-water resources.

To illustrate, one critic stated, "the impression should not be left that no waste materials can or should be placed on, in, or under the ground surface. Given the proper hydrogeological conditions and using appropriately designed facilities, there are situations when selected wastes can be disposed of into the ground without appreciably modifying the quality of the potable ground water." (Johnson, 1978).

TECHNOLOGICAL CHANGES

There are a number of significant technological changes inherent in a land treatment system. Essentially land treatment transforms sewage treatment from a single purpose activity into a multipurpose activity, changes sewage treatment construction grants from subsidies into investments in the production of food and fiber, and requires the participation of a variety of disciplines to implement successfully.

A land treatment system constitutes a change from a single purpose to a multiple purpose program. A land treatment system provides agricultural open space near urban areas. It helps to preserve agriculture—a stated goal of many urban regions.

Land treatment can be integrated with floodplain management. The Department of the Army observed that the authorities in the Federal Water Pollution Control Act Amendments of 1972 regarding the acquisition of sites for land treatment of waste water when combined with the authorities of Section 73 of the Water Resources Development Act of 1974 offer an outstanding opportunity for multiple uses of floodplains while preserving green space and providing recreational opportunities. The Army spokesman inquired, "why not use our floodplains in urban areas for crop production, golf courses, forests, and other uses which can capitalize on the nutrients in our waste water and provide tertiary waste treatment at the same time?" (Ford, 1975).

Land treatment impacts on energy. The nitrogen in a year's flow of domestic waste water in the United States requires the equivalent of two and a quarter billion gallons of crude oil to replace as fertilizer.

The implementation of a land treatment system allows a community to transfer the cost of sewage treatment (a social inflationary cost) to the positive side of the ledger (an investment in the production of future food and fiber). This is the rationale behind the 10 percent bonus in Federal construction grants for land treatment systems. When the Federal government supports a land treatment system over a conventional treatment plant, the construction grant shifts from a Federal subsidy to an investment in the production of future food and fiber.

To design a land treatment system that is site specific will involve a number of disciplines. The design of such systems requires soil scientists, hydrogeologists, agriculturalists, chemists, biologists, and engineers. Physicists should play a role since land treatment is dealing with the basic laws of matter and thermodynamics. Land treatment seeks to use the forces in nature for the benefit of humanity. To do so successfully requires the involvement of several disciplines.

EFFECTS OF LAND TREATMENT

Land treatment is replacing traditional technology at a rapid rate. A decade ago, land treatment was not considered seriously. Land treatment was viewed by some as a movement back to the Dark Ages. It was viewed as a return to honey buckets.

However, dramatic changes are now underway and land treatment is in the forefront. It is the encouraged alternative because it has been successful. In the light of its success, many policy makers have become the leaders or advocates of the approach.

Many persons in the engineering profession have chosen not to lead. This reluctance was observed by Eugene T. Jensen in 1971. Mr. Jensen told an American Society of Civil Engineers National Specialty Conference at Los Angeles: "I am ashamed to admit that . . . the old 'pros' in the field of water pollution control appear to be lagging. The people and Congress appear to have swept by us." The reaction to his challenge was somewhat predictable. Simply remove Mr. Jensen as Operations Chief of the Water Quality Control Office of EPA. The transfer took care of Mr. Jensen, but fortunately it did not take care of land treatment. Congress recognized the validity of his statement and has moved land treatment along legislatively as evident by the passage of the Clean Water Act of 1977 (P.L. 95-217). Having abdicated the leadership role, some in the engineering profession have chosen to attack land treatment. Articles have crept into the trade journals with titles or headings like "Land Disposal: A Giant Step Backward;" "Land Disposal: The Paper Tiger;" and "Land Disposal: The Environmental Blunder of the 20th Century." This terminology gives these authors away. They are so engrained with a disposal philosophy that land treatment is beyond their comprehension. The management and use of pollutants as resources out of place is not understood. Thus, these critics tend to gravitate to their familiar turf—disposal.

In the planning process, the attack on land treatment takes a different course of action. Here, technical distortions are introduced into the data to color the outcome.

A review of alternative treatment systems in

Table 1. Key Chemical Raw Materials Advertised as Being Available from Michigan

Organics	*Inorganics*	*Minerals*
Benzene	Air gases	Cement
Butadiene	Bromine/derivatives	Clays
Chlorinated solvents	Chlorine	Gypsum
Ethylene	Hydrochloric acid	Lime
Phenol	Magnesium oxide	Natural gas
Propylene	Phosphoric acid	Petroleum
Styrene	Sodium carbonate	Salt
	Sodium hydroxide	
	Sulphuric acid	

a New England State was undertaken. One system included a traditional treatment plant. The other system called for land treatment. Both of them were going to chlorinate their effluent. The study concluded that the two systems would cost essentially the same, and suggested that it would probably be easier to build a traditional treatment plant since there has been more experience in building such plants. When the cost breakdown of these systems is evaluated, a great disparity in estimating appears. The cost of the chlorination facility at the treatment plant was listed at $20,000. On the other hand, the cost of the chlorination facility at the land treatment system was listed at $360,000 (Town of Falmouth). This is simply one of many blatant examples of technical distortions which are being used in an effort to stymie the move toward land treatment.

PERFORMANCE OF A LAND TREATMENT SYSTEM

Empirical information on the performance of a land treatment system can be gleaned from the monitoring of the Muskegon system. The excellent removal experience of traditional pollution parameters by the Muskegon County Wastewater Management System is well documented (U.S. EPA, 1977a). Therefore, emphasis here will be placed on performance with respect to organics.

The Muskegon system receives an unusually large assortment of organic compounds and this is not typical of a normal municipal system. Some of the exotic materials which enter the system is evidenced from the raw materials tabulated in Table 1. The industries which discharge their wastes into the system are tabulated in Table 2.

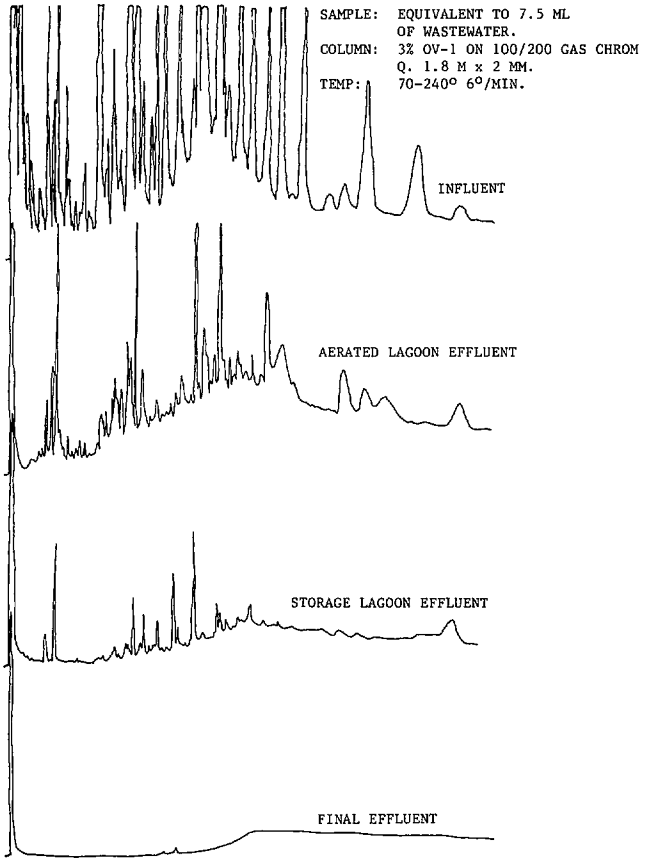
Another complicating factor is that the ground water in the nearby area has been contaminated by discharges from Lakeway Chemical Company's unsealed lagoons and Thermo-Chem Incorporated's seepage lagoons. In an effort to correct this ground-water pollution problem, two 8-inch purge wells are now in operation at the Lakeway Chemical site to pump the polluted groundwater to the Muskegon County Wastewater Management System for purification (communication with Andy Hogarth, Michigan Department of Natural Resources, August 10, 1977). The area north of the lagoons has shown steady improvement. However, the number of purge wells needed to correct the situation is likely to increase to six 8-inch wells before the ground-water pollution will be brought under control. There are two interesting observations that can be drawn from this experience. First, the Muskegon system is deluged with assorted organic discharges from industry each day (see Table 2). Second, it is serving as a pollution sink for a program that is seeking to clean up polluted ground water at a nearby industrial site. This ground-water cleanup program is enjoying a measure of success (W. Mich. Shoreline Regional Dev. Com., 1977).

The Robert S. Kerr Environmental Research Laboratory undertook a preliminary survey of toxic pollutants at the Muskegon system in August and September of 1976. The report emphasized that this was a preliminary survey conducted within a restricted time frame which considerably limited both sampling and analytical

Table 2. Chemical Process Industries Discharging into the Muskegon Wastewater Management System

Name	*Employees*	*Products*
Burdick and Jackson Laboratories	35	Fine organic chemicals
East Shore Chemical Co., Inc.	50	Specialty chemicals
Lakeway Chemicals, Inc.	140	Dichlorobenzidine dihydrochloride, benzidine sulfate slurry
Story Chemical Corporation	240	Specialty fine chemicals
Webb Chemical Service Corporation	25	Industrial and laboratory chemicals
Thermo Chemical, Inc.	25	Disposal and reprocess chemicals
Thomas Solvent Company	50	Solvents
Fisons Limited[a]	—	Agrochemicals and pharmaceuticals

[a] Not on line when survey was taken.



SOURCE: Robert S. Kerr; Environmental Research Laboratory, May 1977.

Fig. 1. Comparison by gas chromatography of neutral extracts of waste waters from Muskegon system, August 10, 1976.

efforts. Results from the analyses are presented in Figure 1. It concluded that:

> The Muskegon County Wastewater Treatment System was receiving for treatment waste waters consistently containing a great many organic pollutants of possible concern, including at least 11 compounds appearing on the EPA "List of Dangerous Pollutants." It is further apparent that, even though low levels of eight organic pollutants, including four toxic compounds, were indicated to survive the treatment sequence, the Muskegon System was relatively quite effective in removing organic pollutants from the waste water which it was treating. This is emphasized by the Figure which presents a comparison by gas chromatography of neutral extracts prepared from influent, aerated lagoon effluent, storage lagoon effluent, and final effluent samples. These chromatograms, which were obtained by chromatographing quantities of extract equivalent to 7.5 ml of each waste water, clearly show the very significant attenuation of organic pollutants across the system. It is very doubtful if any other types of treatment systems, with the possible exception of those utilizing heroic and very costly measures for polishing of final effluents would have been more effective than the Muskegon System in removing the organic pollutants occurring in the waste water being treated, especially since more than 60 percent of this waste water was comprised of industrial components. The presence in the final effluent of atrazine, trimethylisocyanurate, and those eight compounds which survived the entire treatment sequence is significant primarily because these substances necessarily traversed 5-12 ft (1.5-3.66 m) of sandy soil to reach the tile carrying the final effluent from the site. This comprises further evidence that organic pollutants, including chlorinated compounds of suspected toxicity, may survive and move significantly in the subsurface under proper conditions. Hence, the need is reiterated for developing definitive information concerning the movement and fate of organic pollutants in the subsurface environment in order that waste disposal methods which employ the subsurface as a pollutant receptor may be utilized to their full potential with minimum impact on ground water (U.S. EPA, 1977b).

This research did not show any evidence of ground-water pollution. Rather it simply showed that with heavy applications of waste water on a sandy soil, small quantities of organic compounds moved through 5-12 feet of sandy soil into the underdrainage system. It is necessary always to distinguish between ground water and a controlled underdrainage system when discussing a land treatment system.

The scientists called for more research. This is proper in light of the myriad of organic compounds which enter the environment.

The removal of chloroform by the Muskegon System is presented in Table 3. The influent averaged 870 parts per billion. A maximum contaminant level of 100 parts per billion for total trihalomethanes including chloroform is suggested for drinking water. The concentration which appears in the drainage tiles at Muskegon averages 6 parts per billion.

CONCLUSION

Land treatment systems provide an opportunity to view sewage treatment as an investment in the production of food and fiber. They can be viewed as an investment in the future, rather than an increase in social costs. Land treatment provides

Table 3. Removal of Chloroform by the Muskegon Land Treatment System (in parts per billion)

Chloroform from sample date	*Influent*	*Drainage water*[a]	*Percent removed*
8-10-76	425	3	99.3
8-11-76	440	3	99.3
8-12-76	480	1	99.8
9-7-76	360	13	96.4
9-8-76	2645	10	99.6
Average	870	6	99.3

[a] Maximum contaminant level (MCL) 100 parts per billion for total trihalomethanes including chloroform.

our nation with a positive program to deal with a negatively perceived material, sewage. In addition, clean water is achieved. It is very doubtful if any other type of treatment system could be as effective as the Muskegon land treatment system in purifying water. Biases of the past pale when the merits of land treatment are evaluated objectively. We need to know more about it.

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Land Application of Waste — An Accident Waiting to Happen[a]

by Charles C. Johnson, Jr.[b]

ABSTRACT

Half the population depends on ground water for domestic uses. Use is increasing 25 percent per decade. Ground water is generally used with little or no treatment.

Some persons would transfer the discharge of our waste products from contaminated surface streams to the land and thus relatively clean ground waters.

No standards exist that protect ground-water quality. Research necessary to give assurance that natural interaction of waste water and soils will remove, to acceptable levels, potentially harmful contaminants, organic and inorganic, that permeate today's waste streams and today's health concerns, has not been done.

Success reports on land treatment of waste water have not evaluated deterioration of ground water from organic contamination. Most waste waters contain synthetic organics in varying concentrations. EPA recommends their reduction in drinking water to the lowest possible level.

Most instances of ground-water contamination have been discovered after drinking water is contaminated. Unless the public is willing to treat ground water as it does water from surface streams, greater control of land disposal practices must be exercised. Current practice does not indicate the necessary controls are contemplated or recognized. It follows that the widespread use of the land treatment alternative is, in reality, an accident waiting to happen.

The title assigned for this session does not limit one to a discussion of waste-water treatment practices and their residuals, although I suspect this was the original intention. Inasmuch as ground-water protection is the underlying theme of this National Symposium, let's take a brief look at the tremendous waste produced in this country that helps to place our nation's vast ground-water resources in jeopardy. Each year major U.S. industries treat about 5,000 billion gallons of waste water before discharging it to the environment (U.S. EPA, 1977a). Of this volume, about 1,700 billion gallons are pumped to oxidation ponds or lagoons for treatment or as a step in the treatment process. Another 5,000 billion gallons per year of municipal waste water is discharged to the environment, with an estimated 730 billion gallons of this amount discharged to the land. In the United States, municipal sludge production amounts to about 5 million dry tons per year. Industrial sludge production is believed to be many times this amount. EPA (1977b) estimated annual solid waste production at 136.1 million tons in 1975. In addition we must deal with the millions of tons of gaseous wastes that are produced annually; the untold hundreds of million tons of mine tailings disposed of each year; and the tremendous volumes (more than 24 million barrels per day) of oil field brines produced each day. The discharge to the environment of such large volumes of waste with varying concentrations of toxic and hazardous substances must have a detrimental effect on the quality of our nation's water resources, both surface and ground-water supplies.

Because of the proclivity for waste production in this country, and as a result of the rather indiscriminant waste disposal practices that prevail, some basic concepts regarding water-supply protection have been destroyed, and some new ones that affect established policies in the water-supply field have surfaced. The paragraphs that follow will discuss some of these as they relate to land application of waste water and protection of ground-water quality.

The Public Health Service Drinking Water

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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Standards (USPHS, 1962) required that water supplies be obtained from a "protected source." In the case of ground water, the standard defined "protected source" as water resulting from the natural purification by infiltration through soil and percolation through underlying material and storage below the ground-water table. If the source was not adequately protected by natural means, the supply is to be adequately protected by treatment. Ground water for human consumption is seldom treated except for disinfection. It is generally agreed that these standards were designed to protect against bacteriological contamination and that this definition of protected source provides insufficient protection against the massive volumes of toxic and hazardous wastes that are discharged to our environment today.

It must be recognized that the number of protected underground sources are diminishing. The remaining acceptable sources are further threatened by policies being initiated without supportive studies in terms of today's health concerns, and promoted under the desire for "zero discharge" of waste water to surface waters.

Well meaning, but poorly advised persons would have us transfer the discharge of our waste products from our surface streams, which are already contaminated to the land and thus, subsequently to the ground water, which in both instances are relatively clean. This would be an excellent idea if complete reliability could be placed upon the natural action of most soils to remove the potentially harmful contaminants, organic and inorganic, that seems to permeate today's waste stream and today's health concerns. The fact is that we can not. A search of the literature has failed to reveal one instance where any qualified expert has agreed that the natural filtration and percolation of today's waste-water stream through the soil produces a water that without question is safe to drink. That is not unusual. Neither does anyone recommend that waste water receiving tertiary treatment followed by dilution with water of drinking quality is fit to drink. On the other hand, the literature is replete with examples of ground-water contamination that results from current practices—even those projects considered by some to be successful land treatment operations.

While some will dismiss these studies as being representative of archaic practices, others will recognize that they provide information that we need to know. For instance, a preliminary report discussing the subsurface migration of hazardous chemicals (Geraghty and Miller, 1977) showed substantive movement of heavy metals, cyanide, arsenic, selenium and organics through the soil and into the ground water.

A study of the long-term effects of land application of domestic waste water at Hollister, California (EPA, 1978a) revealed substantially higher levels in the total coliform count per 100 ml over control wells; also it indicated increased cadmium levels, and lead levels that sometimes exceeded drinking water standards. Further, the report stated that "the greatest void of information remaining with respect to land treatment systems is that of persistent or refractory organic compounds. Uncertainties regarding health effects from transport of these materials through the soil from land-applied waste water must be answered before essential design criteria can be established. Quantification of basic scientific data on organic substances of known or suspected toxicity and determination of safe underground travel distances are major areas where research is needed."

A report just recently released by EPA (1978b) discusses environmental changes from long-term land application of municipal effluents. In my opinion, what the report says about the impact of the practice in two communities—Bakersfield, California, and Lubbock, Texas—on ground water is most supportive of my concern for the paucity of data related to this practice and its impact on ground-water quality. The report says that "very little" is known with regard to ground-water changes underlying the sewage-effluent-irrigated farm at Bakersfield. What is known suggests that high levels of nitrate are in the ground water under the farm. By comparison it notes that ground water under farm land several miles to the east are also high in nitrates. The report states that only slightly more information is available on ground-water quality at the Lubbock irrigation farm. Total dissolved solids of 1692 ppm were one-third higher than comparison wells, and nitrates of 50 ppm were 6 times higher. From the few data available, it appears likely that the long-term effluent irrigation operation (3 farms operated for 38, 19 and 6 years) has caused increased dissolved solids and nitrate concentrations in the ground water underlying the farms.

It can be pointed out that even the quality of the ground water under the country's most heralded land treatment system—the waste-water management system serving Muskegon County, Michigan—must be viewed with a note of caution. Following a preliminary survey of toxic pollutants at the site, the report (EPA, 1977c) stated the presence of low levels of organics in the final effluent indicates the need for definitive information concerning the movement and fate of organic pollutants in the subsurface. I believe we all know that the State of Michigan does not allow the ground water at this site to be used for drinking water.

Other States also have exhibited concern for the potential health effects of ingesting over long periods of time, ground water contaminated with the waste water following its application to land. California convened a panel of experts to advise it on this question (State of California, 1976). Their report concluded that "areas of uncertainties regarding health effects can not be resolved because basic scientific knowledge is lacking." It noted that "monitoring and surveillance have not been directed at health aspects."

The California State Health Department has completed a draft version of proposed ground-water recharge regulations for use when reclaimed waste waters are used to augment underground potable water supplies through spreading (AWWA Research Foundation, 1977). Among other things these draft regulations require that the waste water receive carbon absorption treatment (30 minutes detention time), and percolate through an unsaturated aerobic zone of undisturbed soil for at least 10 feet vertically.

Almost daily we are reminded of the perils to our ground water that can result from land application of wastes. Just recently the Communicable Disease Center of the Public Health Service (1978) reported at least 759 cases of gastroenteritis associated with leakage from a municipal sewage lagoon in southern Missouri that affected the aquifer in Arkansas as well. The lagoon was over a porous limestone formation which permitted rapid movement of ground water. Hindsight tells us a lagoon system probably should not have been used at this site under these conditions, *but it was.* It is a very poignant reminder that most instances of ground-water contamination have been discovered only after drinking water has been contaminated.

The EPA recent report to Congress on waste disposal practices effects on ground water (EPA, 1977a) offers some interesting insight into this subject. Among other things it notes that:

- Ground water has been contaminated on a local basis in all parts of the nation and on a regional basis in some heavily industrialized areas, precluding the development of water wells.
- Degree of contamination ranges from a slight degradation of natural quality to the presence of toxic concentrations of such substances as heavy metals, organic compounds, and radioactive materials.
- Removing the source of contamination does not clean up the aquifer once contaminated. The contamination of an aquifer can rule out its usefulness as a drinking water source for decades and possibly centuries.
- Existing technology alone cannot guarantee that soil attenuation alone will be sufficient to prevent ground-water contamination from a waste disposal source.
- Land disposal of waste is not environmentally feasible in many areas.
- Existing Federal and State programs address many of the sources of potential contamination, but they do not provide comprehensive protection of ground water.

A review of EPA's *Land Treatment Manual* by C. Winklehaus was carried in the *Journal of the Water Pollution Control Federation* (1978). The commentary in the review in large measure summarizes some of my concerns on this treatment alternative. Mr. Winkelhaus notes that there is a tendency to overlook the fact that land treatment systems, unlike "conventional systems," have relatively open boundaries through which water and solids can pass quite freely—once applied, the waste water and pollutants are largely beyond control. Can anyone assure us that the EPA policy on land treatment as contained in the Administrator's memorandum of October 3, 1977 (Costle, 1977), and further amplified by the draft Program Requirements Memorandum (EPA, 1978c) by Mr. Cahill dated May 10, 1978, provides the safeguards required to protect our ground-water resources? In my opinion, the answer is no.

The Assistant Administrator for Water and Hazardous Materials for EPA seems to have verified these concerns in a statement (Jorling, 1978) before the Committee on Environment and Public Works of the U.S. Senate. In that statement he said "concern for ground water has emerged relatively recently as a major environmental issue. There is a great deal yet to be learned about the fate and transport of contaminants below the surface; the practices that represent the greatest threat to this national resource; and the economics of alternative ways of disposing of wastes in a manner more protective of the environment. Another reason for proceeding carefully is the sheer number of facilities that seem to have the potential for an adverse impact on the quality of ground water. Literally hundreds of thousands of wells, surface impoundments, ditches and landfills used by industry, municipalities, farmers and other private individuals are involved. Prudence dictates careful preparation in designing programs to bring these practices under control and in incurring the probable social and economic costs involved."

It is accepted knowledge that contaminants of known and unknown character and concentrations reside in all sewage effluents. The examples that have been cited in this paper certainly show that sewage effluents do percolate through the ground to the ground-water table. Contaminants in sewage without a doubt have public health significance. Little is known about the health significance of trace levels of synthetic organic contaminants that have been identified in the ground water under some of the land treatment systems. The Administrator of EPA has publicly stated that the presence of trace levels of synthetic organic chemicals in drinking water may be hazardous to the health of persons. Further, the EPA has proposed a treatment standard for public water supplies so that these contaminants can be reduced to the lowest practicable level. If EPA's statements and actions are to be taken seriously, why should anyone promote a waste-water treatment practice that adds even small increments of these contaminants to an otherwise safe water supply?

There is no doubt in my mind that from strictly a technological viewpoint we can design land disposal systems of many types that will dispose of waste water, allow the production of agricultural crops, extend the development and use of pasture land, provide for certain recreational pursuits and establish bird sanctuarys, all at a profit when only measured by the flow of dollars into the cash register. The overriding question is, where should this be done; what quality of waste water should be applied to the land; and what degree of degradation should be permitted in the quality of our ground water? In the absence of more definitive answers to these questions than those implied by current EPA policy, I would prefer the policy I understand is used by the British, i.e., only water of drinking water quality should be returned to ground-water aquifers from which drinking water will be extracted. Otherwise we must admit that we proceed in ignorance and we cannot be surprised at some future time when reality tells us the accident has happened.

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Audience Response to Session III — Land Application of Waste

Stephen A. Smith, 1423 S. College Ave., Tempe, AZ 85281: The advantages of using the soil for the application and treatment of wastes are well-known; however, although we probably have the technology to design a fail-safe system, we may not be able to afford it. Accidents can happen due to improper design, inadequate maintenance, or a lack of a complete understanding of the soil-water system.

Ground-water zoning, and the delineation of areas of possible, potential, or actual ground-water degradation, is a possible solution to this dilemma. We can, in effect, have our cake (land treatment) and be able to eat most of it (or drink the water). By siting land treatment and disposal facilities in areas designated as zones of potential degradation, we serve notice that a contamination potential exists, and special measures are necessary to ensure the safety of water supplies. For example, development in the area would have to be accompanied by public or community water systems with an outside source, or any wells drilled in the zone would have to meet rigid requirements, with sufficient casing and depth to seal off any contaminated ground water due to the waste disposal facility (zones could be three-dimensional).

To a limited extent, the zoning concept is already being applied. In Wisconsin, bacteriological contamination of ground water is a fact in a few, scattered areas where creviced dolomite is overlain by thin soils. In these areas, which are delineated on maps or described in terms of section, township, and range, drillers have been notified that they are required to emplace as much as 200 feet of casing in order to seal off the upper, contaminated portion of the aquifer. In other words, zones of actual ground-water degradation have been defined, and measures have been taken to ensure bacteriologically safe drinking water. However, these are not areas where additional land disposal facilities are encouraged; they would aggravate what is already a bad situation.

For planning future land treatment and/or disposal systems and zones of potential degradation, we obviously want to keep the zones small. Case histories of contamination incidents in the literature document the difference in the extent of contamination between incidents which have taken place in recharge areas and those which have occurred near discharge areas. I suggest that we site our land treatment and disposal facilities as near as possible to ground-water discharge areas. This will accomplish some important objectives. If an accident does happen (and Murphy's Law says that it will), the actual zone of degradation is small, and we won't waste valuable hydrogeologists' time tracking a plume across a county (let the engineers track it down a stream). In addition, if the facility is subsequently modified to correct the situation, the zone of contaminated ground water will be renovated in a relatively short time.

Mr. Sheaffer has suggested that we use floodplains for the operation of land treatment systems. Provided that a floodplain site can meet the criteria for soils and ground water set forth in most State regulations, it would be an excellent choice if we accept the discharge area concept of degradation zoning. Obviously, floodplains would be a poor choice for land disposal facilities such as solid waste sites, for which adequate protection from periodic flooding would be difficult and expensive to provide.

David E. Lindorff, Assistant Geologist, Illinois State Geological Survey, 425A Natural Resources Bldg., Urbana, IL 61801: It is perhaps obvious that an important part of any land application program is proper operation and maintenance. No matter how well designed a land disposal project may be, serious problems can still develop from lack of or improper maintenance and operation. I have visited a number of industrial spray irrigation facilities and found that, frequently, they are a low priority in terms of maintenance. We, therefore, need to be aware of this problem, not only for land disposal of waste, but for other types of waste disposal as well.

Elmer E. Jones, Jr., Agricultural Engineer, USDA, Beltsville Agricultural Research Center, Beltsville, MD 20705: Kenneth Wright implied that on-site subsurface disposal was not a satisfactory land application technique. In the last 10 years, tremendous advances have been made in on-site disposal technology. Johannes Bouma and others with Small Scale Waste Management Project at the University of Wisconsin have made four major contributions to the science of subsurface disposal, (1) Application of soil moisture tensiometry to subsurface disposal system evaluation; (2) Quantification of interface barrier resistance; (3) *Development of effluent purification criteria*, and (4) Development of innovative loading procedures to improve purification, reduce interface barrier resistance, and maintain or improve soil porosity. While the Wisconsin research has demonstrated that it is possible to design systems for higher loading rates than recommended in the *Manual of Septic Tank Practice*, I would recommend using lower rates, in effect making the subsurface disposal system an irrigation system to maximize utilization of water and nutrients by vegetation. On-site disposal can be the most economical and desirable land application technique.

Dr. Sheaffer placed considerable emphasis on the use of underdrain systems. There are sites where underdrainage is essential to satisfactory performance; however, there are other situations where increased ground-water recharge should be a major factor in encouraging greater use of land application. Some major rivers serving large metropolitan areas are deficient in surface storage for low flow augmentation. Every home or building built will increase runoff and reduce ground-water recharge. As development proceeds the rivers tend to become flashy, higher peak discharges and lower base flows. Land application of waste water to increase ground-water storage can have two very beneficial effects, reduction of waste-water discharge to the river during critical low flow periods, and increased base flow from ground water.

Robert D. Sinclair, Western Ground-Water Consultants, St. Norbert, Manitoba, Canada: In looking at this problem as a hydrogeologist and as a sanitary engineer, I see it from both sides. We are bound to have some sort of pollution.

If we are looking at any kind of waste, we have the problem of the sugar in the tea. You put the sugar in, and we have a problem trying to get it out again. I think this is the big problem with a lot of the sewage we're trying to put on the land. For example, heavy metals, if we look at the plating industry, it would be much easier and simpler in a lot of cases to tackle the problem at the source instead of trying to handle it after it is in the sewage and diluted down a couple hundred thousand times. It makes it impossible to get it out. I think we would be better spending our money in terms of looking at this type of alternative versus trying to figure out how much sludge or sewage we can put on the land and how much heavy metals we can accept in a crop. It may be easier to just get the problem out right at the start and avoid this whole mess we've got into.

In terms of adding stuff on the land we have to look at what the land can do. What sort of crops are we taking off? We're looking at crops that pass through the food cycle, we're looking at crops that can be biodegraded, so what kinds of things should we be looking at putting back on the ground as these alternatives. We're looking at food processing waste for one. There are some problems maybe with caustics in some of them but in general, if we look at waste like pulp and paper and food processing or even human waste, we are looking at some materials that can be recycled back on the land that don't have the impact of such things as heavy metals and plastics that we have in industries. They can't be handled by the soil structure. It may take them out but if they are not biodegrading they are just accumulating, and this problem with time is going to find itself 20 years down the road where we won't be able to grow the crops. They look okay now but it may be a problem in a few years.

If we look at sewage treatment, basically it is one of removing carbon. When we throw sewage in the river, we are killing the fish and causing zones of pollution. So we've gone to removing carbon which eliminates this problem. What's happening now is we don't remove too much of the nutrients in terms of phosphorus and nitrogen, and in some cases we find that algae will just take that nitrogen and phosphorus and put it right back in the stream. So in terms of sewage treatment, we haven't done anything except transfer it down the stream a little ways.

I'll give one example of what happened in Winnipeg. There was a town that was on ground water for quite a long time and could have continued it but the engineers decided to go to river water. You can see it, and it's a lot easier to use so they went to it. Now during low flows, the water going into that plant was about 50-50 sewage/river water which a lot of the people in town didn't think was too good. Now they are finding during some tests there may be problems with viruses.

If we are looking at adding things into the environment which we have to, we can only add it into the water, the air or the land and if we look at most of our waste, they are either on the land or water; we have to be able to integrate the two and have a managed system that will allow acceptable use of the environment.

Virginia Jamison, Suntech Group, Marcus Hook, PA: Sometimes I feel as if I should have a very big inferiority complex because I work for a big, bad villainous oil company. We have seven refineries in the U.S. and Canada, and we produce an awful lot of waste water and an awful lot of sludge, and we have to get rid of that. We can't dump it in the oceans, or in the streams, or in the rivers. The government laws say we can't. We have to pay and it is an expensive proposition to have it hauled away and then incinerated. Then we've got an air pollution problem.

Dick Raymond and I have spent the past ten years trying to convince our company that there is a safe way to get rid of this waste and it is land application. I think we've convinced our company of this and they are doing something about it. We are what we call "biofarming." We are applying our waste on the land and getting rid of it. I think we meet all of Dr. Sheaffer's criteria.

In the first place we don't have a storage problem because our crop doesn't cease in the winter. Our crop is bacteria and they biodegrade in the winter as well as in the summer. I don't think that, as Dr. Johnson says, "we're an accident about to happen," because we have very strict, stringent regulations and we monitor these land applications. If we monitor them correctly and put on the proper amounts of material, there is no reason why we will contaminate ground water. We have been doing this for five years now and we are not the only company. Most of the oil companies are using land farming. We feel as if it is an economical process; therefore, our company is happy. We feel that it's a natural process; therefore, we meet government regulations and it is a very safe process.

I hope that our government doesn't outlaw land farming. If it does, the oil companies have spent an awful lot of time and money in perfecting this process for nothing.

The Federal Ground-Water Protection Program — A Review[a]

by Victor J. Kimm[b]

ABSTRACT

The Nation's ground-water resources constitute a vast and often unprotected resource. The Environmental Protection Agency is about to launch a number of programs designed to protect what is, in many cases, a virtually nonrenewable resource. Separate regulatory activities mandated under the Safe Drinking Water Act, the Resource Conservation and Recovery Act and the Clean Water Act must be carefully coordinated if they are to be effective.

The current implementation efforts within the agency are being framed in view of our major principles which will be the focus of public comment in the months ahead. These principles are:

First, the administration of the related programs will be a cooperative effort involving Federal, State and local governments, all of which must participate in formulating the program if it is to be effective.

Second, the focus of the programs will be on the prevention of contamination rather than on its treatment at the point of withdrawal.

Third, the applicable standards will be based primarily on technology rather than ambient ground-water quality considerations since the effects of discharges upon ambient quality are complex, difficult to predict, and of long duration.

Fourth, there is a need to balance environmental protection, energy development and continued economic prosperity objectives so that the resulting programs fully protect public health while being realistically implementable.

All of us—government, industry and citizens, through acts of commission or omission—have contributed to the potential problem. We must work together if we are to get on with the important task of protecting the quality of the Nation's ground-water resources.

The topic I have been asked to address is the Federal Program for protecting ground water, and whether it is a matter for rejoicing or concern. I suppose in these days of Proposition 13, the easy answer is that any new or developing Federal effort is to be regarded with some suspicion. I do not share this view.

Historically, our society has chosen to approach environmental problems in the context of a national partnership. This partnership involves not only the Federal, State and local governments, but through the mechanisms of advisory councils and public participation, interest groups and the general public as well. Personally, I think this partnership is crucial to the success of environmental efforts. In drinking-water programs we have tried hard to make it work.

Our expectations about the future of the effort to protect ground water must be assessed in the context of a national partnership. And the real answer is to be found in Pogo's immortal observation that: "We have met the enemy and he is us." All of us—governments, interest groups and citizens—have a part to play. The success or failure of the national program will be a function of the manner in which *all* of us meet our responsibilities.

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How then do we in EPA view our part in the national program at this time?

GENERAL FRAMEWORK

Admittedly, EPA's efforts to protect ground water are still in the developmental stage. One focus for our efforts has been the development of certain basic principles which will guide our participation. The *first* among these I have already touched upon: a true partnership between the States and the Feds and between government and the public it serves.

With regard to the former, it is EPA's policy to consult extensively with States during the development of any regulations and this will certainly continue to be the case for ground-water protection. Furthermore, the Federal legislation either provides exclusively for State programs [e.g., the control of open dumps under the Resource Conservation and Recovery Act (RCRA)] or for primary State responsibility in the administration and enforcement of programs [e.g., the Underground Injection Control (UIC)] program under the Safe Drinking Water Act. Generally, EPA would prefer the States to retain the lead in managing ground water. The Agency's role will be to: (1) establish minimum quality and program requirements to insure national consistency; (2) provide technical and financial assistance to the States; and (3) review State progress and performance. In establishing requirements, EPA will strive to minimize any disruption of programs the States are already enforcing. We will assume direct responsibility for administration and enforcement of programs only in cases where the States fail to meet minimum national standards.

With regard to full public participation, the Agency has recently proposed new regulations on the subject and we will insist that States observe the requirements established therein.

A *second* principle that will guide our approach to ground water is that protection must rely on the prevention of contamination rather than on its abatement. Unlike flowing surface water, ground water does not readily cleanse itself. Once a contaminant is in the ground, it may be years before it reaches an aquifer and then may contaminate that aquifer for many more years. Remedial action (e.g., the excavation of the contaminated soil) is often impractical. Further, due to the slow movement of water in an aquifer, usually measured in feet per month or even per year, it may take decades or even centuries for natural processes to "flush" an aquifer of contaminants.

Drinking water taken from underground sources in most instances received little treatment prior to use. Sophisticated treatment for individual users or small systems, which constitute the bulk of ground-water consumers is prohibitively expensive. As a practical matter, the abandonment of the contaminated source is often the only choice. The switch to an alternative source of water supply is both disruptive and costly, and will become increasingly so in the future. Such considerations argue for a strong policy of protection.

The *third* principle governing our approach is a corollary to the concept of prevention. It is a reliance on technology-based standards or the use of sound engineering practices in the siting, construction, operation, closure and abandonment of facilities that have the potential for adversely affecting the quality of ground water. This is not to say that ambient water quality standards for ground water are not important because they are. However, one of the lessons we learned from earlier efforts to clean up the Nation's navigable waters is that the business of proving, in a court of law, the linkage between a specific discharge and a measured degradation in ambient quality is very difficult. This is doubly true for ground water where less is known about ambient quality, monitoring is costly and haphazard, and cause and effect may be separated by years and miles. Furthermore, the dearth of reliable knowledge about the fate and transport of contaminants below the ground make it virtually impossible to express discharge limits in terms of maximum concentration levels.

A *fourth* principle guiding our efforts is the need for balance. Ground water is a major resource that must be protected through the prevention of contamination.

At the same time, many of the practices that contribute to the degradation of ground-water quality are associated with activities that serve other national objectives. Extractive processes, for example, oil or uranium recovery, are activities that are essential to the economic well-being of the country. Our technological society will, for the foreseeable future, continue to produce a large variety and volume of waste products which must go somewhere.

Disposal practices need not have unacceptable environmental consequences. The land application of sludges low in potentially toxic substances can have important benefits for soil conditioning. Other practices, for example, deep well injection, may in fact be the most cost-effective and environmentally acceptable alternative for the disposal of some wastes. The land treatment of sewage can be used to maintain quantity and quality in the water-table aquifer and can thus have an environmentally beneficial impact.

The point is that the appropriate policy is to strike a balance among competing national objectives. Many practices serving other objectives can be carried on with little adverse impact on the environment if they are located, designed, constructed, and operated according to known ecological and engineering practices.

I might add that we have been developing Agency-wide consensus around these principles through the mechanism of a policy statement. We hope to publish this statement in the *Federal Register* for general comment in the near future.

COORDINATION WITHIN EPA

Let me now turn to the second area of EPA priority as we develop our role in the national effort to protect ground water: coordination among authorities under our jurisdiction.

As you all know, there is no single Federal law nor a single Federal agency that comprehensively addresses the protection of ground water from every form of contamination or mismanagement. At the same time, a number of sections in six Federal laws [the National Environmental Policy Act (NEPA), the Safe Drinking Water Act (SDWA), the Resource Conservation and Recovery Act (RCRA), the Clean Water Act (CWA), the Toxic Substances Control Act (TSCA), and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)] are related to or can impact ground water. These laws variously mandate the control of: (1) certain hazardous or toxic *substances*; (2) certain *actions* such as the manufacture or transport of toxic or hazardous substances; or (3) certain *physical facilities* such as injection wells or open dumps. The significant requirements in Federal legislation that bear directly on the protection of ground water include:

- The requirement to consider the effects of Federal action on ground water as part of the Environmental Impact Statements mandated by NEPA.

- The mandate to promulgate minimum requirements for State programs to protect existing and potential underground sources of drinking water from endangerment from well injection under Sec. 1421 of SDWA.

- The authority to designate an aquifer as the sole or principal source of drinking water for an area and to deny Federal financial assistance to a project that may endanger the aquifer so as to create a significant threat to public health under Sec. 1424(e) of SDWA.

- The authority to undertake a national assessment of surface impoundments (pits, ponds, and lagoons) and their potential for contaminating ground water under the SDWA.

- The authority to support State plans for the control of solid waste facilities under Sec. 4004 of RCRA.

- The requirement to promulgate regulations for State or Federal programs to control the surface or subsurface disposal of wastes defined as hazardous under Sec. 3001 of RCRA.

- The authorities to regulate the entry into the market place, use of, and the ultimate disposal of substances defined as toxic under TSCA.

- The authority to require and support through grants the development and implementation of State comprehensive water quality management plans under Secs. 106 and 208 of CWA.

In my view, there is no need for more Federal legislation. Under one section or another, EPA has more than enough authority to initiate an effective Federal role in what must be a national effort to protect ground water. The challenge that faces the Agency is to marshal these authorities in a coherent fashion that reduces confusion and burdensome overlaps on the one hand, and minimizes major gaps in coverage on the other. We are moving to meet this challenge in a number of ways.

First, EPA intends to require the phased implementation of State/EPA agreements. These agreements, to be concluded annually between the State and the cognizant Regional Administrator, are to: (1) identify the State's environmental problems related to surface waters, ground waters and solid waste disposal; (2) specify the priority problems the State intends to address in that year and the actions it intends to take; and (3) relates EPA's technical and financial support activities to the State plan. While the inclusion of program areas will be phased over FY 1979-81, the eventual goal is a fully integrated attack on related environmental problems.

Second, we are reaching agreement on the definitional framework to be used by all

EPA administrated programs that address ground water. This framework involves the three questions that are basic to any effort to protect ground water.

The first question is: What is the resource that is to be protected? I expect that EPA regulations for the UIC program and the open dumps inventory will require States to inventory their aquifers and to designate them for various uses. All current underground sources of drinking water and all aquifers that contain water with less than 10,000 parts per million of total dissolved solids (ppm/TDS) are to be designated as sources of drinking water. In the case of aquifers or portions of aquifers that do not already serve as drinking-water sources, exceptions can be made to this general rule if:

- The aquifer or its portion is located in such a fashion that the mining of water would be technically or economically impractical.
- The aquifer is already contaminated so as to make the treatment of the water for drinking purposes technically or economically impractical.
- The aquifer is oil or mineral producing.
- The aquifer or its portion has not been protected in the past and adequate alternative supplies of drinking water are available through the year 2000.

These exceptions would be subject to public hearings, EPA review, and a demonstration that the aquifer is sufficiently isolated so that other surface or ground waters would not be endangered.

In addition, an aquifer or a portion thereof that is not designated as a source of drinking water may be designated by the State for other uses. Such aquifers would be protected to a level commensurate with the designated uses.

The second question is: How is "endangerment" to be defined? Here the Agency is fashioning a protective, yet reasonable approach. Ground-water regulations under both RCRA and SDWA will define "endangerment" to occur if the activity in question has failed to meet technology standards or may cause:

- an existing or potential user of the ground water to violate any drinking-water standard.
- an existing or potential user of the ground water to treat the water more than he otherwise would have had to.
- other adverse effects on human health.

The final question is: Where is endangerment to be measured? We have considered various possible approaches such as mathematical modeling, fixed distances, the property boundary and combinations of some or all of these. Our conclusion is that the contamination pathways are different for the various practices of concern and no single approach is appropriate to all of them. A zone of endangerment can, for example, be hypothesized for well injection. Percolation from the surface, however, behaves differently.

Consequently, EPA's current policy is to encourage monitoring at several distances from the potentially endangering activity. The point at which endangerment will be considered to have occurred will be defined in a manner appropriate to the particular type of practice.

A *third* area where EPA is attempting to ensure the coherent use of Federal legislation to protect ground water is in the coordinated development of regulations. For example, an Agency-wide Implementing Task Force is charged with the responsibility of drafting the regulations to implement the hazardous waste provisions of RCRA. A number of policy directions are emerging from the coordinated approach to the development of regulations, including the following:

- The control of toxic and hazardous industrial process wastes continues to be one of the Agency's highest priorities. EPA is attempting to establish a single set of procedures for granting Federal permits under RCRA, SDWA, and NPDES. Eventually, we hope to develop a fully integrated "one stop" EPA permits program.
- The open dumps inventory under RCRA will be phased over several years. The Surface Impoundments Assessment will, among other uses, serve as a "screen" to define priority areas for future phases of the open dumps inventory.

A *fourth* area of coordination is between operating and support programs. The Office of Drinking Water and the Office of Research and Development are participating in a pilot project designed to make EPA's research efforts more directly responsive to program office needs. A Steering Committee has been mapping the research effort for fiscal years 1979 and 1980 and will continue to supervise the progress of the crucial projects.

CONCLUSION

Much of what I have sketched here is cast in developmental terms. It would be easy to conclude that all that is really happening is that a bunch of Washington bureaucrats are appointing task forces, holding meetings and writing memoranda of understanding of greater relevance to their own concerns than to the reality of protecting a vital national resource.

Some of that, I suppose, is true. However, I think we are making real progress and you will see the results in the accelerating pace of EPA activities in the months ahead. I say this because I think we have learned from the past and are developing an integrated ground-water protection program.

The pollution control dimensions of this effort are underway. The remaining challenge is the coordination of the various Federal agencies and authorities with their State counterparts. Efficient integration and cooperation among the governmental actors at all levels is a prerequisite to an effective national program to safeguard our ground-water resources. This calls for patient, open-minded, intelligent planning on all sides.

Most of all, it calls for the active participation of all involved: the public at large, American industry, and the engineering and geohydrology professions, as well as agencies of government. For the Federal Ground-Water Protection Program—my topic for today—is not a thing apart; it can function only in the context of interaction with all the other forces of our society that have a bearing on how we use our environment, how we manage and preserve our natural resources. The issues engage us all. I urge you to join the debate, letting your voices be heard in the common cause of preserving for ourselves and children the vital treasure of our Nation's ground water.

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Victor Kimm is responsible for EPA's program to ensure the quality of the Nation's drinking water. He joined EPA in 1971, and was Deputy Director of the Office of Planning and Evaluation prior to assuming his present position in 1975.

Prior to joining EPA, Kimm worked on economic development programs in the United States and Latin America. He also spent six years with consulting engineering firms engaged in the planning, design and construction of water supply and sewage treatment facilities.

Kimm is a licensed professional engineer in New York and Pennsylvania. He holds a Bachelor's and Master's degree in Civil Engineering from Manhattan College and NYU. As a recipient of a National Institute of Public Affairs Fellowship, he spent the 1969-1970 academic year at Princeton University studying economics and public administration.

Appendix I. Status Report on State Primacy for Public Water System Supervision Program

Following States Have Assumed Primacy on the Indicated Dates:

1.Oklahoma	04-30-77	21.Maryland	02-13-78
2.Connecticut	05-07-77	22.North Dakota	02-18-78
3.Louisiana	05-16-77	23.Florida	02-18-78
4.Mississippi	06-20-77	24.Wisconsin	03-02-78
5.Nebraska	06-23-77	25.Nevada	03-30-78
6.Alabama	07-10-77	26.Kansas	03-30-78
7.Arkansas	07-10-77	27.Montana	03-30-78
8.Georgia	08-07-77	28.Idaho	03-30-78
9.New York	09-10-77	29.Washington	03-30-78
10.Virginia	09-10-77	30.New Mexico	04-02-78
11.Iowa	09-23-77	31.Delaware	04-02-78
12.Minnesota	09-26-77	32.West Virginia	04-02-78
13.Tennessee	09-30-77	33.Colorado	05-07-78
14.S. Carolina	09-30-77	34.California	06-02-78
15.Maine	10-07-77	35.New Hampshire	08-18-78
16.Hawaii	10-20-77	36.Trust Terr.	09-19-78
17.Kentucky	10-20-77	37.Guam	09-09-78
18.Massachusetts	12-01-77	38.Alaska	09-22-78
19.Texas	01-30-78	39.Arizona	09-24-78
20.Michigan	02-01-78		

Following States Are Found to be Qualified for Primacy Pending Notice in the Federal Register:

1.Rhode Island

Appendix II. States Designated as Requiring an Underground Injection Control Program

Texas
Pennsylvania
Louisiana
California
Kansas
Michigan
Illinois
Wyoming
New York
Ohio
Oklahoma
West Virginia
Indiana
New Mexico
Florida
Kentucky
Utah
Colorado
Mississippi
Iowa
Arizona
Arkansas

Appendix III. Listing of Studies Mandated by The Safe Drinking Water Act

- *Report to Congress—Preliminary Assessment of Suspected Carcinogens in Drinking Water* in December 1975.
- *Impact on Underground Sources of Application of Pesticides and Fertilizers* in 1976.
- *Report to Congress—Waste Disposal Practices and Their Effects on Ground Water* in January 1977.
- *Drinking Water and Health*, a study of the National Academy of Sciences, in June 1977.
- *Impact of Abandoned Wells on Ground Water* in August 1977.
- *Underground Injection Methods Which Do Not Endanger Underground Water Sources* in December 1977.
- *Surface Impoundments and Their Effects on Ground-Water Quality in the United States—A Preliminary Survey* in August 1978.
- *Identification of Potential Contaminants of Underground-Water Sources from Land Spills* in August 1978.

The Federal Ground-Water Protection Program — Today's Hope[a]

by Charles W. Sever[b]

ABSTRACT

The necessary administrative mechanisms for protection of our underground drinking water sources, and coordination of natural resource and energy development and environmental quality programs, should be provided by a federal ground-water control program, else today's underground contaminant disposal activities will be tomorrow's undoing. Federal regulations, however, must provide flexibility to States and industry to find the least costly means of meeting national environmental goals.

A growing body of literature clearly documents cases of underground drinking water source contamination, sometimes severe, from a large variety of conditions and practices. Existing studies also indicate that this problem is pervasive: aquifers have been adversely affected in every region of the country.

A federal ground-water protection program which (1) reflects consideration of total long-range natural resource protection and environmental quality benefits, (2) regulates in a manner so that the benefits to the environment generally exceed the regulatory costs and (3) encourages more efficient ways of meeting environmental goals in the least costly manner can and must be developed by the Environmental Protection Agency. Without an effective Federal ground-water protection program, the underground contamination problem will likely worsen.

Before we start a discussion on why federal regulations are needed, let us first agree that the problem of unsafe drinking water should be primarily the concern of State and local governments but that the federal government also has the responsibility to insure the safety of the water that citizens drink.

Let us further agree that State agencies and citizens can best determine whether a need exists to regulate sources of pollution that may contaminate underground sources of drinking water, which directions to take in developing regulations, and which needs are crucial for protecting these resources.

Therefore, would it not be better to rely upon the States themselves for the evaluation of need and the direction of emphasis in the federal regulatory process? To evaluate the need for a federal ground-water protection program, we need to first look to existing State ground-water programs.

All States have encountered serious problems because of failure to use available geologic information and accepted and proven engineering practices in design and completion of injection wells, pits, ponds, lagoons, and the like.

All of the 50 States have established some type of State regulatory programs concerning ground water. Thus, the need for regulation of underground injection practices is clearly recognized by the State and local people nationwide.

A growing body of literature clearly documents cases of underground drinking water source con-

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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tamination, sometimes severe, from a large variety of conditions and practices. Existing studies also indicate that this problem is pervasive: aquifers have been adversely affected in every region of the country. Without appropriate federal ground-water protection regulations, the ground-water contamination problem will likely worsen.

For me, and I am sure for most of you, personal experience is the authority that I used for determining whether existing State programs are adequate or whether federal presence is indeed needed. During the last ten years or so, I have either observed or been personally involved with numerous ground-water contamination situations in States that thought they had adequate ground-water protection laws. These included Miami, Florida, where raw blood from an abattoir was being injected through an unregulated well directly into porous limestone of the Biscayne Aquifer which is the principal source of drinking water for the entire city of Miami.

In Camilla, Georgia, creosote, phenyls, and other organics were being injected through wells into the principal artesian limestone aquifer which supplies drinking water for all of south Georgia and north Florida including the city of Camilla. An estimated 20,000 of these unregulated wells are in use in the Georgia-Florida area today.

Each of you who have worked in ground water in the field have yourselves observed similar types of direct ground-water pollution.

But pollution is not restricted to injection into a drinking water aquifer. For example, at Wilmington, North Carolina, a 1,000-feet deep industrial injection well failed because fiberglass casing was fractured during construction and the acids being injected ate their way through the cement lining on the outside of the casing. In southern New Mexico there is a case of brines injected for secondary recovery which escaped through fractures which opened up during high pressure injection operations and contaminated ground water at the surface. A similar incident occurred in southern Oklahoma.

But, in discussing cases of contamination, we certainly do not want to leave out pits, ponds and lagoons. At Pensacola, Florida, nitric acid that was discharged from a fertilizer plant into a pit on the southeast part of town percolated downward into a sand aquifer then moved laterally and contaminated several of the city's municipal water-supply wells.

At Miami, organics from a nearby landfill have ruined their Preston well field. There is inadequate time to discuss with you today the number of times I have investigated salt-water contamination and traced it back to "abandoned" brine disposal pits associated with oil and gas production.

My personal experience has convinced me that numerous independent ground-water contamination problems have been observed by most of us. Surely we can all agree that further contamination of our existing or potential drinking water sources should not be permitted if there is any reasonable likelihood that these sources will be needed in the future to meet the public demand for drinking water and that these sources may be used for such purposes in the future.

The necessary administrative mechanisms for the protection of our underground drinking water sources, reduced property damage, coordination of natural resource and energy development and environmental quality programs, should be provided by a federal ground-water control program, else today's underground injection and contaminant disposal activities will be tomorrow's undoing. But these federal regulations must provide flexibility to States and industries to find and implement the least costly means of meeting national environmental goals.

Congress recognized the need for "federal presence" in the area of ground-water protection and indicated that it would be beneficial from the aspects of enhancing State enforcement authority, facilitating public acceptance of a State program, and insuring consistent performance from the States. Federal presence would also provide technical assistance to State programs and emergency response capabilities, and would broaden the State's jurisdiction to include federal lands and facilities within their boundaries.

In establishing an underground injection control program, as mandated by Congress in the Safe Drinking Water Act, EPA has looked to the States which had a high dependency on ground water to determine what measures these States felt *they* needed to ensure ground-water protection. Using the programs of the States such as Texas, Oklahoma and Louisiana as a model, EPA hopes to develop federal regulations which closely match the requirements felt to be necessary in States with a long experience in underground protection regulations. In other words, EPA has followed the lead of the States in determining the need for a standardization of regulations to alleviate any problems arising from the use of interstate aquifers and for more effective management and control of well systems.

EPA has been a leader in destroying the

barriers that in prior times prevented the exchange of knowledge and ideas from all sources available. We have been fortunate in developing the UIC regulations to have had such a wealth of knowledge from such diverse sources. We have come to understand the viewpoints and the concerns of the States, of industry and others. And, through understanding, EPA has, over a period of time, altered its thinking on the content of its regulations.

Whether significant pollution of an aquifer has, or has not, occurred, should not be the point. Federal programs to protect aquifers and the incorporation of ground-water concerns in related programs are appropriate: for efforts of a regulatory nature need not necessarily be of a reactionary nature. The goal should be to prevent contamination in the first place, rather than to attack problems that could have been avoided properly with reasonable controls. A federal ground-water protection program which (1) reflects consideration of total long-range natural resource protection and environmental quality benefits, (2) regulates in a manner so that the benefits to the environment exceed the regulatory costs, and (3) encourages more efficient ways of meeting environmental goals in the least costly manner, can and must be developed by the Environmental Protection Agency to protect our ground-water resources. Without an effective federal ground-water protection program, the underground contamination problem will likely worsen.

But let's also all agree that the federal government should propose no regulations for controlling subsurface implacement of fluids that (1) do not protect the nation's drinking water resources, (2) do not protect public health and welfare to the maximum extent feasible, and (3) unnecessarily interfere with or impede development or production of the nation's mineral and energy resources.

* * * *

Charles W. Sever was born in Miami, Florida in January 1931. His undergraduate work was a combination of Physics at Georgia Institute of Technology and Geology at Emory University, both in Atlanta, Georgia. He worked as a Geophysicist with the Ground Water Branch of the U.S.G.S. for 7 years from 1958 to 1966; worked as a consultant for his own company on water resource development and subsurface disposal for 5 years; then worked as regional expert on subsurface disposal with the U.S. EPA in Atlanta for 3 years. For the past 3 years he has worked as Chief of the Water Supply Branch for EPA in Dallas, Texas. He has] published numerous books and journal articles on subjects related to ground-water resources protection.

The Federal Ground-Water Protection Program — Tomorrow's Undoing[a]

by Dale C. Mosher[b]

ABSTRACT

Past and present guidance in landfilling has been based on inadequate information. More recent information indicates past and present recommendations/guidance may not be accurate. Current trends, as a result of RCRA (PL 94-580), are generally following the same recommendations. The result can be greater problems from landfills constructed now and in future years than have occurred from past landfills, such as the well-known Llangollen landfill. It is time for Congress, EPA, and others to recognize what is and is not known about the pollution potential from landfills and waste disposal, in general.

INTRODUCTION

The first thing necessary in discussing the inadequacy of Federal ground-water pollution protection programs is to put the question in proper perspective. Today's Federal ground-water protection program covered by sections of the Clean Water Act, Safe Drinking Water Act, etc. are inappropriate for "solid waste." For example, under the Safe Drinking Water Act the Underground Injection Program covers only deep well injection. Other acts cover specific toxic substances. Pits, ponds, landfills, landspreading, etc. are still today, however, virtually not covered except by a few State programs in general.

It may be presumed that such State programs are inadequate because Congress passed the Resource Conservation and Recovery Act (RCRA, PL 94-580). This act provides for total control of all waste disposal in or on the land. Essentially, Congress found that waste disposal "in or on the land . . . can present a danger to human health and the environment."

The most appropriate question is will the regulations promulgated by EPA as required by RCRA be adequate?

The RCRA requires all wastes to be disposed of in sanitary landfills which will be defined by the EPA. The act also requires EPA to develop guidelines providing a technical and economic description of the level of performance that can be attained by various waste management practices. It is this latter requirement (the level of performance) which is difficult to meet due to the inadequacies of regulations developed. A brief examination of the history of sanitary landfilling is required.

PAST HISTORY

Landfilling of waste material received limited study until the 1950's. Since that time, significant changes have occurred in the philosophy and practices deemed acceptable from the standpoint of ground-water quality.

A report published in 1954(1) indicated that keeping waste materials out of the water table would alleviate ground-water contamination problems. This concept apparently prevailed until 1961 when

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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another California publication (2) indicated that percolate (leachate) from rainfall or irrigation water infiltrating the landfill could cause impairment of ground-water quality. This represents a major change and reversal in concepts concerning protection of ground-water quality from waste disposal. A 1969 report(3) indicated that leachate could be prevented by placing an impermeable cap over the completed landfill. There is no question that leachate can be prevented if an impermeable cap is used if that is the only source of leachate entry into the landfill.

The next major publication, *Sanitary Landfill Design and Operation*(4) addressed the major potential environmental problems associated with waste disposal. This report requires further evaluation.

The report states on page 4 that "Some investigators believe that even in a sanitary landfill, leachate production is inevitable and that some leachate will eventually enter surface water or ground water." It even stated further in the same paragraph that "the present philosophy held by the Office of Solid Waste Management Programs, most States . . . . is that through sound engineering and design, leachate . . . . may be prevented or *minimized* to the extent that it will not be a problem. The most obvious means of controlling leachate production and movement is to prevent waste from entering the landfill to the *greatest extent practicable*" (italics for emphasis by the author).

While the latter statement indicates in the least that some sanitary landfills will produce some leachate, the prevailing concept was that due to sound engineering design and operation, leachate was not a problem at sanitary landfills.

Those involved with the many discussions concerning review of a paper published in *Waste Age*(5) are well aware of the numerous experts who felt that sanitary landfills did not generate leachate.

Since that time, it is now generally recognized and accepted that sanitary landfills do generate leachate. The *Waste Age* paper(5) further states that where attenuation is ineffective, leachate collection and treatment should be employed. There was, however, no guidance as to how to determine where attenuation would be effective. Further, no guidance is available as to whether minimization to the greatest extent practicable is adequate. This constitutes one of the major problems RCRA regulations face.

Probably the greatest single reason such predictive capabilities have not been developed is reflected in the limited budget that solid waste programs have had. Such research work done on an excalated scale could easily cost several million dollars per year. Over the past few years, the EPA solid waste programs have barely spent one million per year, and this has been split too far between many aspects of the problem. The second largest contributor to inadequate information has been the length of such programs.

The EPA's prior research on waste-water treatment has been of a highly structured engineering nature lending themselves to short-term (1 to 3 years) investigation. Waste disposal, however, takes place in the natural environment where there are numerous variables and many are interrelated. In such an environment, research must have adequate replication enabling the researchers to factor out influence of individual parameters. In this manner, it is then possible to discern those factors most responsible for observed variability.

A third reason for limited development is the nature of the system. Essentially, Congress required the EPA in the early seventies to publish guidelines relating to safe land disposal practices. The environmental groups pushed for rapid development of such guidelines. Based on best available although limited data, the EPA issued Thermal Processing and Land Disposal of Solid Waste Guidelines in 1974.

The problem is solved! At least the problem is solved in the minds of Congress and high level EPA management. However, at the program level EPA apparently recognized during development of the Guidelines that the problem was not solved. From 1973 through 1975, the Office of Solid Waste Management Programs has spent man-hours evaluating the potential for ground-water contamination and studying available data on real world cases. Many hours were spent in developing in-house show and tell programs to "sell" the need for funds for further investigation. Funds for the first study of existing sites was not available until 1975 and then only in very limited quantities. The first monitoring program covered 10 sites taking 5 samples over a 7 to 9 months' period of time at a cost of about $300,000 including EPA personnel time. The second study of hazardous waste disposal sites included investigation of numerous sites with existing data and 50 sites actually drilled and sampled. However, only one sample was taken from most sites.

Of these two studies, the former of municipals' solid waste only site provided the most useful information. All sites evidenced some level of contamination and demonstrated that even "sanitary landfills" can contaminate ground water. The most significant result of that study was that operation, soils, and design were of no value in explaining differences in the levels of contamination found. In short, some of the "best" sites studied were among those with the highest levels of contamination found. In most cases, the level of contaminants found did not suggest that widespread serious problems exist from municipal solid waste disposal practices.

CURRENT CONCEPTS–FACT OR FANCY

The prevalent current philosophy is that minimizing leachate quantity lessens impact on ground water. This must assume that less quantity means less pollutants. It seems, however, that many experts subscribe to the theory that minimizing leachate production maximizes contaminant concentration. Again, however, by assumption it is assumed that pollutant loading is minimized. It is quite possible that this assumption is false. The amount of percolation and ultimate leachate production is a function over soil conditions and rainfall intensity. Increasing slope and decreasing permeability will, in general, decrease the quantity of leachate formed from any given rain storm event. The key is event. The quantity of pollutants leached and, hence, leachate quality is a function of the solubilization rate within the landfill between events. As a first cut, it may be safe to assume that the rate of pollutants' solubilization within the landfill is constant (after a period of time), since under these conditions the landfill with less leachate would have higher pollutant concentrations. Both landfills, however, are leaching the same quantity of pollutants.

At this point it is the responsibility of the underlying unsaturated soil material to attenuate the respective leachates. The question is which leachate poses the greatest risk to the underlying ground waters.

LEACHATE POLLUTION POTENTIAL

Without going into great elaborate detail or using a myriad of equations, simply stated water movement (permeability) in unsaturated soils is greater than for saturated soils. Further, since leachate is formed in small quantities and moves, as the result of discrete rainfall events, leachate will generally move as discrete quantities without respect to actual quantity produced at any given time.

If we assume that all attenuating mechanisms are rate functions (except infiltration), the actual amount of attenuation will be a function of rate of water movement, thickness of the unsaturated zone and rate function of attenuation. Note that quantity of leachate at any given time is not included in this evaluation. It is, therefore, reasonable to assume that the leachate with the higher concentration will receive less attenuation and, therefore, will have a greater impact on ground-water quality. In short, under the above circumstances, minimizing leachate will have a greater impact on ground water.

THE REAL WORLD

In reality, the situation is somewhat more complicated. Although significant bodies of data do not exist to support the previous conclusion, the writer has not seen any evidence in support of the opposite view. The only firm conclusion is that current technology indeed does not allow prediction of leachate impact on ground water. This would strongly suggest that EPA cannot issue regulations under PL 94-580 which are based on technology. To do so would result in landfill practices not acceptable in other locations.

All, however, is not gloomy. In spite of the number of impressive cases of ground-water contamination, that number represents a small portion of the total number of land disposal sites in existence. An examination of ground-water data from States' files will most likely show some contamination of water quality at all sites, but generally to a limited extent.

CONCLUSIONS

If the relationship between leachate quantity and ground-water pollution potential as described are correct today, federally recommended procedures are incorrect. This will result in more landfills started within the past 10 years to start showing greater problems than the open burning dumps of the past within the next 10 years. We must keep in mind that problems which are a long time in appearing may be with us essentially forever.

If regulations are based on technology's practices rather than performance standard, the result may well be greater contamination problems in the future.

A thorough review of existing ground-water quality problems at disposal sites at this time would greatly enhance the state-of-the-art. While the task is monumental, it is feasible and perhaps the only way to properly determine the basis for and form of regulations promulgated under the Resource Conservation and Recovery Act.

Several groups are now suing EPA for not issuing regulations as required by Congress. The basis of these suits is that EPA has failed to promulgate regulations as required by Congress. It would seem logical to assume that for the most part such suits would be aimed at getting required regulations promulgated at the earliest possible date. In view of the preceding information, that may well be an error in that adequate regulations meeting the full intent of Congress cannot be promulgated at this time due to insufficient knowledge or technologies. It would be more in the interest of the environment and general public to have EPA issue performance standards and/or interim acceptable practices in a manner to eliminate practices.

Regulations of this nature accompanied by adequately funded investigative and research problems would provide the best solutions in the least amount of time. In the field of waste disposal practices, the use of "best judgement" or "best engineering" practices which are based on a limited data base are no longer adequate.

Although resource recovery is really the answer, it will not solve today's problems everywhere for many years to come. Even in the distant future it appears that many residuals will still require land disposal practices.

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Audience Response to Session IV — The Federal Ground-Water Protection Program

Boyd N. Possin, Project Manager, Roy F. Weston, Inc., Wilmette Office Court, 3330 Old Glenview Road, Wilmette, IL 60091: A popular television beer commercial these days in the Upper Midwest shows a panoramic view of the rolling hills and valleys in and around La Crosse, Wisconsin. Referring to this land (with some justification) as "God's Country," the narrator tells us that the brewer's water "comes from an underground reservoir which, some people say, stretches all the way to Canada." The implication of course is that if the reservoir, or aquifer, extends into Canada, then the water withdrawn from the wells in La Crosse might very well come from Canada. Evidently, Canadian ground water brews better beer than United States ground water.

Unfortunately this example, an aquifer as a closed pipe, is not as ludicrous as it should be to many people who should know better. Today we have heard a great deal of discussion concerning "aquifer protection." All too often this commendable goal is translated into a policy of aquifer outcrop protection, a simple-minded approach which makes no use of the modern hydrogeologic theories of ground-water movement as set forth by scientists such as M. K. Hubbert, J. Toth, R. A. Freeze, and P. A. Witherspoon. Ground water is not created in situ in an aquifer; neither does it necessarily enter an aquifer through the aquifer's outcrop area. Ground water moves along predictable paths defined topographically by identifiable ground-water flow systems. Ground-water flow systems have recharge areas and discharge areas. If the water quality at a particular location within an aquifer is to be protected, then the recharge area for the ground-water flow system which moves through that part of the aquifer must be protected. This recharge area may or may not contain parts of the aquifer outcrop area. It is a complicated set of problems for which there are seldom any simple answers. Still, the effort must be made because protecting a ground-water supply by protecting only the aquifer makes about as much sense as trying to protect a household water supply by protecting only the faucet.

Lloyd H. Woosley, Jr., P.E., Water Quality & Ecology Branch, Tennessee Valley Authority, Chattanooga, TN 37401: EPA and various other agencies through a multitude of laws and regulations, have only limited and fragmented authority for protecting the nation's ground-water quality. Such laws and regulations include UIC, sole source aquifers, NEPA, NPDES, 201, 208, State basin plans, RCRA, Surface Mining and Reclamation Act, USGS, NRC, FPC, and HUD authority, CZM, COE 404 program, plus various local, regional, and State air and water pollution control and planning programs. My concern is that there is no comprehensive, strategic plan to protect ground-water quality and to manage the resource conjunctively with surface-water resources. Mr. Kimm, how does EPA plan to use existing authority and procure additional authority to protect the ground-water quality of the nation?

R. G. Shepherd, Willard Owens Associates, Inc.,7391 West 38th Ave., Wheat Ridge, CO: I'm sure that everyone in this room would agree that any efforts to protect our aquifers from contamination and to assure safe drinking water are commendable. However, as I listened to the presentations of this session, I could not keep from thinking of the many, many supplies of drinking water, both municipal and private, that are already below minimum quality standards, especially throughout the semiarid West. For example, in Buffalo, a small town in northwestern South Dakota, the municipal supply, although the best water available, probably would be considered undrinkable by everyone in this room. Total dissolved solids are probably well into the thousands of milligrams per liter, and the water has a distinctly disagreeable odor. Remarkable, however, the local townspeople do not consider their water to be especially bad, simply because they have used it all their lives. I do not know the detrimental effects to their health, but the same situation exists for numerous farms, ranches, and other small towns all over the West; the total effect of so many people drinking poor quality water cannot be good.

I guess my basic point is that if someone from Buffalo were here, he might say that much money is being spent to protect aquifers from people, even in remote areas of the West, while no one seems to be actively working, using readily available solutions, to protect people in the same areas from the naturally unpotable water in the aquifers. Most of these small-town people probably would never understand the direction of effort reported by the EPA here today. My question is then, is the EPA interested in efforts to protect people from aquifers, instead of vice versa?

Elmer E. Jones, Jr., Agricultural Engineer, Beltsville Agricultural Research Center, USDA, Beltsville, MD 20705: Mr. Sever referred to maintaining a positive benefit-cost ratio. It is important to remember every successful public health program has a negative benefit-cost ratio. As a Fellow—American Public Health Association, the continued funding of preventative programs is of special concern to me.

Typhoid, polio and smallpox are not major problems today, but who wants them back?

Edgar A. Jeffrey, Acting Chief, Water Supply Branch (6AWS), U.S. EPA, First International Bldg., 1201 Elm St., Dallas, TX: Positive benefit-cost ratios are desirable and certainly attainable for public health programs. Without having made a benefit-cost analysis, I have an intuitive belief that with the advent of chlorination in 1912-13, and its use in large cities in the U.S., the related cost (only pennies per person per year) was, and continues to be, considerably less than the dollar benefits from disease prevention. The same holds true for poliomyelitis, which was virtually eradicated from one year to the next by the mere application of a vaccination procedure.

Benefit-cost figures for fluoridation programs, on the other hand, are readily available. It is estimated that if every community were to fluoridate its water supply to the optimum concentration, the annual savings in unneeded dental treatment would be approximately $700 million, a return of about $50 for every dollar invested. The cost again is only pennies per person per year. Detailed cost studies have been made for several cities.

Granted, public health programs related to the therapeutic stage of health care may not have such an evidently advantageous benefit-cost ratio. However, to be fair, one must distinguish between preventative and therapeutic programs. In so doing, the preventative health programs come to stand on their own as being self supporting and having a positive benefit-cost ratio.

Don Keech, Section Chief, Ground Water Division, Michigan Department of Public Health, Lansing, MI: I wanted to speak in regard to the Office of Drinking Water's standards and specifically to a comment made by Mr. Sever regarding application of these standards to ground-water quality in the aquifer. The standards really apply to drinking water as it's furnished to the customer. However, the fact that you can degrade water in an aquifer to this level or to a point that exceeds the level, as long as you can treat it to meet these requirements, is not sensible. I think that's an erroneous statement because ground water is usually not treated before passing into the drinking water system. This is true specifically in private homes, small establishments, industry and to a large extent, in small communities.

You don't degrade something that's good quality to some predetermined level. You maintain that quality at what it is. Again, I don't think this is the proper approach. Now I'd also like to make a comment regarding the secondary drinking water standards which were referred to. I understand that there was not going to be any secondary standards. There were no provisions in the law for these, they are not regulations, they're simply a guideline and again, you don't degrade water quality to some guideline but you maintain your water in a natural aquifer to the best quality that you have there to start with.

Rich DeVries, Oklahoma State University, Stillwater: I have a question for Mr. Sever. The fundamental law of gravity states that the water goes downward. In a recent report that the EPA published and put out on an oil field pollution case in Oklahoma, it was stated that the water flows upward. In this case in point, a salt-water pit was closed 25 years ago. Last year, a secondary oil recovery well was drilled across the road from this pit. This year, there is salt water flowing at the surface. EPA concluded that it was from the pit that was closed 25 years ago. I wonder if in fact we really want EPA to come in to arbitrate our salt-water pollution problems.

Charles Sever, Chief, Water Supply Branch, U.S. EPA, Dallas, TX: I think your facts are a little bit wrong. In fact the pressure at the injection formation is 1,700 feet on the land surface so there is no way the water from that depth can get to the surface. Second, we flew it and have infrared photography of it that was presented and it showed that, in fact, the pit was there, that there are 3 old brine lines crossing the property that showed breaks in them. There was no water at the surface, but there was salt and there was oil from an old oil spill. The photography showed that the salt was coming from the breaks in the lines. You could trace it, it was all there on the photography.

Rich DeVries: I agree that was in the report, but there's also a water well in the north side of the road that is flowing. Since the secondary oil recovery was started, and the only way you could start the flow is that it is being pressured from below.

Charles Sever: The point was we had them shut down the well and we made pressure measurements in the well, and the pressure in the well is at 1,700 feet below the surface. How do you get it from 1,700 feet up?

Paul Plummer, Miami Conservancy District, Dayton, OH: Many of our local water supplies either are directly induced from surface supplies or are artificially recharged. So the connection between our surface supplies and our major municipal ground-water supplies is quite close.

Why are the EPA and the water supply industry so far apart on the use of activated carbon to control trihalomethanes in water supplies; has chloroform, etc. been detected in ground-water supplies, and to what extent is this a real problem?

Victor Kimm, Deputy Assistant Administrator for Drinking Water, U.S. EPA, Washington, D.C.: I thought no one would ask. That's been the big battle for the last 6 months. Almost everyone in the industry is up in arms about our proposed organic standards. As far as trihalomethane in ground water, we have found it in some places. But generally ground water is better than surface water. As far as the legitimate public health concern about trihalomethanes and other organics, we have testimony from the head of the National Cancer Institute and the head of the National Environmental Health Sciences Institute at our D.C. hearing, saying they both believe it and they are both big in the cancer game and not directly responsive to us. Specifically, how big is the magnitude of the health problem posed by these contaminants is the kind of question I described earlier in which no one really knows. You can go through models and come up with some numbers, but they're not very meaningful. The question is, is it reasonable to go ahead through standards and force people to reduce those levels? We think it is, we proposed regulations on that basis. I think we have a pretty good agreement on that with the industry. It's the other part of the regulation that requires granular activated carbon unit processing in waters derived from surface sources highly contaminated with man-made chemicals where the real controversy lies. That's going to be a tough problem for us to deal with in the months ahead.

State Ground-Water Protection Programs — A National Summary[a]

by Richard E. Bartelt[b]

ABSTRACT

In order to discuss the adequacy or inadequacy of State ground-water protection programs, it is helpful to establish a base line which may be used as a frame of reference for the discussion. To provide that frame of reference, the 50 States were contacted and representatives were questioned as to the nature and extent of their existing ground-water programs. The survey of States produced a wealth of information relative to the structure of various State programs and this information is presented graphically in the neutral presentation. The subject of multiple agency involvement is addressed.

In addition to looking at the structure of State programs, information was collected regarding the nature of existing State statutes and regulations. Tabulation and interpretation of this information is provided to illustrate how the institutions are providing for the protection of our ground-water resources. In addition to evaluating the various types of statutes, existing enforcement mechanisms were researched and are presented for review. Graphic presentations of the national data base are used and again several States' procedures are reviewed in detail. The topic of ground-water quality standards was specifically addressed during interviews in order to note the extent of this developing regulatory technique.

The presentation will provide a national look at existing ground-water programs with in-depth analysis of certain State programs. The variations in State programs are highlighted and an attempt is made to estimate resources currently dedicated to ground-water protection at the State level.

Everyone is familiar with the old saying, "People talk about the weather but no one ever does anything about it." The purpose of this presentation is to talk about State ground-water protection programs, NOT to do something about them. The more active role in addressing this issue is left to the Pro and Con presenters to follow. Simply stated, the purpose of this article is to outline the status of State ground-water protection programs and to look at predominant trends or characteristics on a national basis. In order to simplify the task of depicting State programs, the concept of managing ground-water resources—i.e., ground-water use—has not been pursued. The is not to say that management and protection of ground water can or should be separated. It is my personal opinion that they cannot; however, the topic at hand is State ground-water protection programs and, accordingly, the emphasis was placed on protection during data collection.

A review of 1975 data compiled by the U.S. Geological Survey (Murray and Reeves, 1977) shows that far more than half of the States rely on ground water to supply 40% or more of their population

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

[b] Chief, Ground-Water Protection Section, Region V, U.S. Environmental Protection Agency, 230 S. Dearborn Street, Chicago, Illinois 60604.

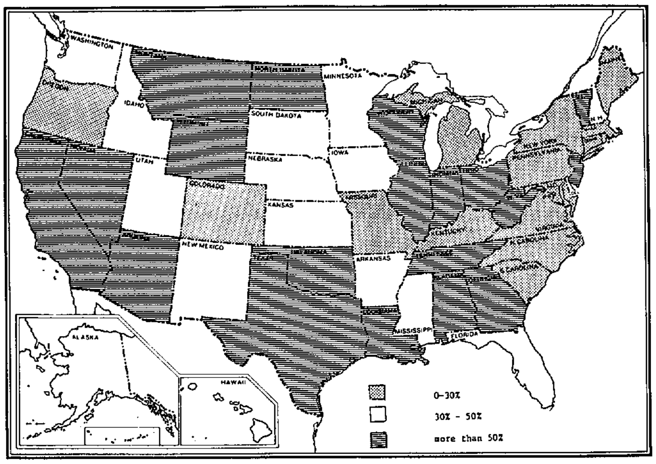

Fig. 1. Percent of population served by ground water.

(see Figure 1). On a national scale approximately 40% of the population depends on ground-water sources for their water supply. With these figures in mind it is impossible to dismiss the importance of State ground-water protection programs. The responsibility for protecting the quality of the nation's ground-water resources has, in the absence of a strong national policy, been left principally to the States. The information to follow was collected to represent current State activities in discharging this awesome responsibility.

In order to more realistically evaluate the data to be presented, it is necessary to examine the method by which the data was collected. Basically the data was collected through an extensive phone survey in which all 50 States were contacted. During the survey, all ten EPA Regions were contacted and asked to identify their key ground-water protection contacts at the State level. In addition, several lists of State ground-water representatives were consulted to insure that all States were adequately represented. Once the list of representatives was complete, the survey itself was initiated. During the survey, at least one representative of each State was contacted and interviewed regarding the nature, extent, and status of that State's ground-water protection program. In numerous incidents, it was necessary to talk to several individuals representing more than one State agency while, in other cases, several individuals, representing a single agency, were interviewed. All those contacted were asked basically the same questions, and almost all responded openly and proved most helpful. In many instances, those contacted provided not only the information requested but also volunteered more detailed explanations and insights (not to mention interpretations) into State programs and problems. The principal information solicited from the State representatives interviewed is as follows:

1. Laws under which the program is being implemented.

2. Names and functions of the State agency or agencies involved in ground-water protection programs.

3. Enforcement mechanisms used to insure ground-water protection and location of the enforcing operational unit.

4. Status of development of ground-water quality standards.

5. Estimate of person years associated with State ground-water protection programs.

It should be noted that the information presented was collected solely for the purpose of adequately depicting national trends. With limited resources it was not possible to contact representatives of all involved State agencies. In addition, collecting and categorizing the data collected required a certain amount of extrapolation and drawing some conclusions. It is hoped that we have adequately represented the national picture and in so doing have not grossly misrepresented any particular State.

In evaluating the information collected, the logical starting place is the body of laws under which the programs are being implemented (see Figure 2). Our compilation of the data revealed that the State agencies involved in ground water operate under various and diverse laws. The most common is the broad environmental law governing pollution of what is defined within as "waters of

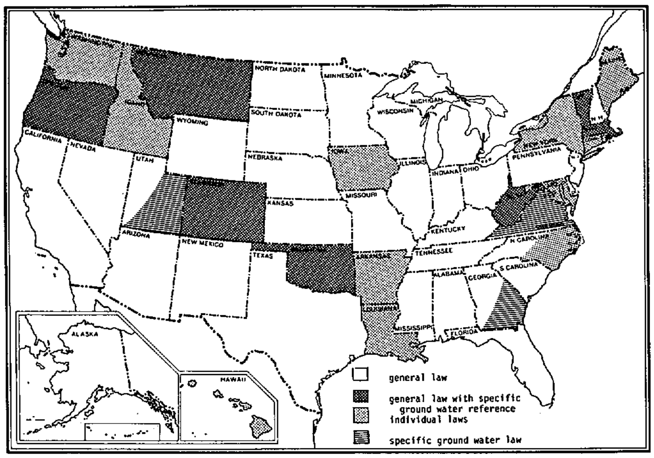

Fig. 2. State ground-water laws.

the State." The term "waters of the State" can be typically defined as, "All streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, reservoirs, aquifers, irrigation systems, drainage systems, and all other bodies and accumulations of water, surface and underground, natural and artificial, public or private, which are contained within, flow through, or border upon, the State or any portion thereof." This definition is used by Minnesota in its Environmental Protection Law, Chapter 115. Approximately 60% of the States currently rely on general laws as a basis for ground-water protection.

Eleven, or approximately 20% of the States, rely on what we have termed individual laws for their ground-water protection authorities. Individual laws can be characterized as separate pieces of specific legislation which deal with particular sources of pollution, usually activities, and aspects of ground-water protection. These statutes may be used in addition to existing environmental laws as in the case of North Carolina, or they may be adequate in themselves to provide the requisite ground-water protection, as in Washington and Idaho. Washington, for example, relies on the following statutes:

Pollution Source	Laws & Regulations
Waste Injection	SDWA, UIC
Soluble Sludge Disposal	State Guidelines
Ground Discharge Treatment of Effluents	Clean Water Act NPDES
Non-Point Sources	Federal Water Pollution Control Act
Toxic Chemical Storage	Hazardous Waste Law, State Regulations
Chemical & Oil Spills	State Water Pollution Control Act
On-Site Waste Disposal	Clean Water Act

In seven States, general environmental protection laws with specific reference to ground water are used to effect ground-water protection. Our investigations identified only three States which had specific ground-water laws. Georgia has its Ground-Water Use Act of 1972 which provides protection in conjunction with the Water Quality Control Act which employs the waters of the State concept. The Utah Water Code has a specific section relating to ground water and is used in conjunction with the State Water Pollution Control Act. Virginia's Ground-Water Act, passed in 1973, has provided for the implementation of that State's ground-water management program.

Looking back at the kinds of laws currently being used to protect ground water, it is important to note that, in many cases, States must rely upon legislation which was not specifically designed to protect ground water and, as such, is cumbersome and often difficult to litigate. In other cases, State laws may be bypassed in favor of federal statutes. This happens most often in the case of individual laws, as can be seen in the State of Washington. Since the federal government has no singular comprehensive ground-water protection statutes, the limitations of relying solely on federal laws are obvious. It should also be pointed out that the classification of States is not based on accepted criteria for evaluating State laws, but, rather, represents our interpretation of the data collected during the interviews.

Having considered the State laws being used to protect ground-water resources, it is important to look at the agencies involved in ground-water protection. Figure 3 depicts the number of agencies involved in ground-water protection in the various States. It would be impossible to address the nature of the agencies involved as an adequate treatment would take volumes as opposed to the paragraphs at hand. Lehr *et al.* (1976) have addressed this issue in a previous EPA publication. Looking at the data on the number of agencies involved we see that eleven States involve three agencies, and five States involve three or more agencies in their implementation programs. This leaves only nine States with a single agency responsible for ground-water protection. In collecting this data we considered an agency involved in ground-water protection when it possessed regulatory authority. Other agencies commonly associated with ground water, such as

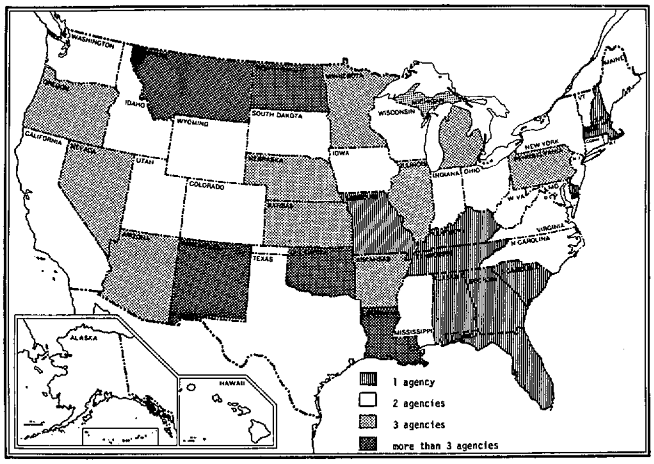

Fig. 3. Number of State agencies involved in ground-water protection.

State geological surveys, which typically are involved in data collection and research, are not included in Figure 3. During the data collection we found various arrangements and combinations of involved organizational units. In portraying this data, we are not attempting to infer that single agency involvement is better than multiple agency involvement or vice versa. We are merely trying to depict what exists in the States.

With the type of laws and number of State agencies involved in ground-water protection fresh in mind, it is illuminating to look at the enforcement mechanisms the States rely on to implement their ground-water protection programs (see Figure 4). Enforcement mechanisms vary widely among the States with the most common method (40%) being through the State's Attorney General. In this instance, a violation would be identified and resolution attempted by the involved State agency. In the event that resolution fails, a case would be prepared by the technical/professional staff of the agency and turned over to the Attorney General for prosecution. (This is an obvious simplification of a complex administrative procedure.) Upon completion of a case and rendering of a decision against a violator, penalties may vary from censure to cease and desist orders to considerable fines. In eighteen States, agency attorneys are responsible for enforcement actions. In two States, Kansas and Nebraska, a major share of the responsibility falls to the county/district attorney. In at least seven States, no court action has been taken against ground-water polluters to date, thus leaving State procedures untested. These States are Washington, Montana, Wyoming, Louisiana, Vermont, Massachusetts, and Hawaii. In a small number of States we were unable to ascertain whether fines or penalties could be levied so the purpose of enforcement in these cases was limited to cease and desist. In other States it could be established that fines could be levied but the enforcement mechanisms were unclear.

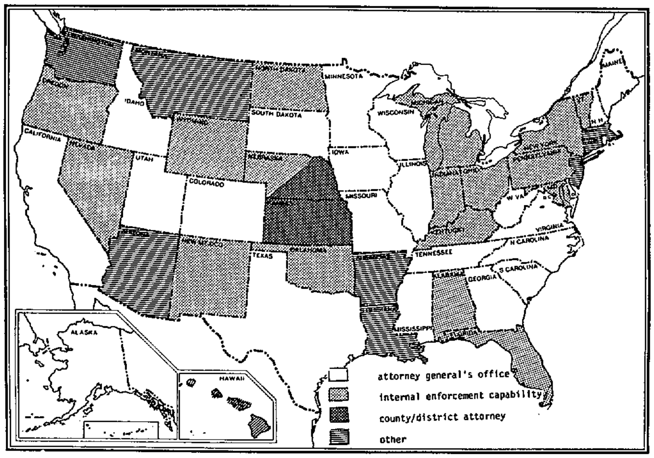

Fig. 4. Enforcement of ground-water protection programs.

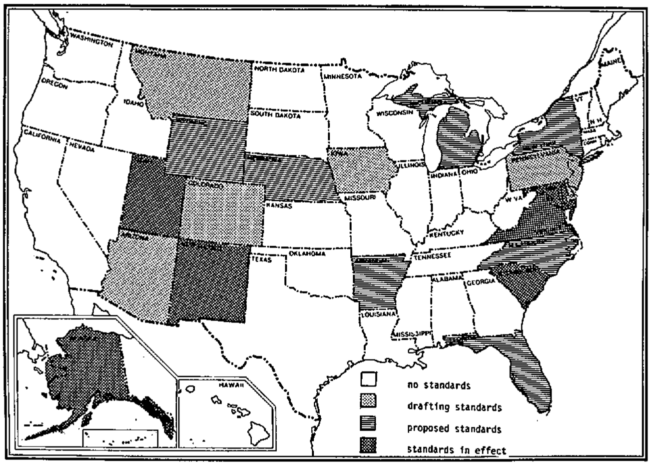

Fig. 5. Ground-water quality standards.

In order to round out the general information needed to give a reasonable picture of existing State ground-water protection programs, we attempted to devise a "progressive" barometer which could give an indication of the progressive nature of State programs in general. We selected ground-water quality standards as this barometer, simply because there seems to be a growing interest in this particular ground-water protection tool. Figure 5 depicts the responses we received. We found that five States have standards in effect, six are currently reviewing or processing proposed standards, and another seven are currently involved in drafting ground-water quality standards. Thus, nearly 40% of the States are taking, or have taken, steps to develop specific standards to protect ground-water quality. In numerous other cases, interviewees in States not developing ground-water quality standards indicated interest, or intent to do so. The number cited deals with specific ground-water standards, but does not include standards relating to drinking water, effluent quality, or discharges which may contribute to ground-water protection but are not solely designed to protect ground water.

It should be pointed out that ground-water quality standards may be very different from State to State with each State emphasizing the parameters and levels needed to insure ground-water protection. Maryland, for example, has standards which classify the producing aquifer based on its transmissibility, permeability, and total dissolved solids.

Other States define discharge standards which are relatively independent of the aquifer. New Mexico has identified the parameter of Total Dissolved Solids and the limit of less than 10,000 mg/l as requiring protection. Maximum contaminant levels have been established for three separate categories: (1) human health standards, (2) domestic water-supply standards, and (3) irrigation use. In addition, there are also detailed provisions for discharge plans, application approval, and reporting and monitoring of ground water. On the other hand, Nebraska's proposed ground-water quality standards are based on a non(anti)-degradation policy. Maximum contaminant levels are established in terms of health and aesthetic quality. Non-degradation is also the focal point of Michigan's ground-water standards which place emphasis on regulating discharges, preparing hydrogeologic reports and monitoring. Alaska and South Carolina rely on more general ground-water quality standards. In the case of Virginia, several hydrogeologic regions have been identified and specific standards are being applied to each region.

It is difficult to assign a major significance to the number of persons or person years involved in State ground-water protection programs. As Figure 6 shows, the level of involvement varies among the States. Variations in organization of the State programs make it difficult to relate the outputs of five person years in Maine to five person years in Arizona. We do feel that in general the numbers can serve as an indicator of the States' awareness and possibly commitment relative to ground-water protection. Estimates of the person year involvement of the various States were almost always identified as very rough. Multiple agency involvement and mixed responsibilities of those involved in the ground-water programs make it almost impossible to derive accurate figures. The data presented represents our compilation of these guesses and serves to document, at least to a limited degree, the resources currently committed to ground-water protection at the State level.

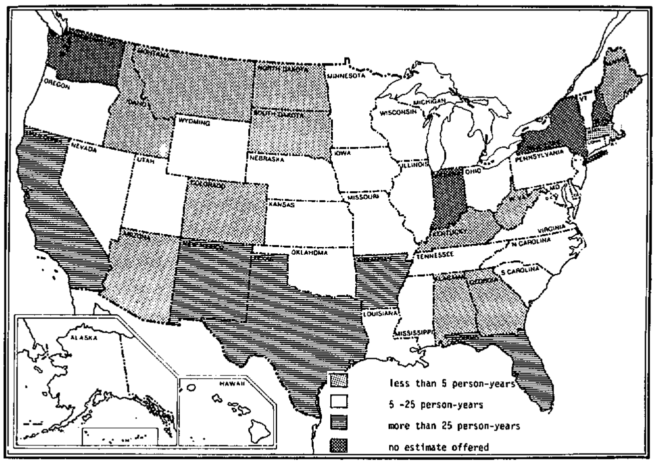

Fig. 6. Person years dedicated to ground-water protection.

It is obvious that State staffing and budgeting limitations will, for the most part, determine the ultimate form and organization of ground-water protection efforts. Based on our discussion with the States, it appears that no State has the resources or the funding it needs. A broad extrapolation of the data collected regarding person years currently involved in State ground-water protection programs, indicates that less than 700 person years may be involved nationwide. This figure includes all administrative and support functions which typically can be estimated as ¼ of the work force. Thus, we can crudely say that approximately 525 person years of professional/technical effort are expended by the States each year to protect ground water.

In summary, we have tried to present a brief overview of the state of State Ground-Water Protection Programs. It is difficult to collect and present this data without making some assumptions and drawing some conclusions; hopefully, these liberties have not biased significantly the data presented. In conjunction with the subsequent Pro and Con presentations, we hope the evaluation of legal authority, State organization, and person power will allow the attendees of the Fourth National Ground Water Quality Symposium to determine for themselves whether "State Ground-Water Protection Programs" are adequate or inadequate.

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Murray, C. R., and E. B. Reeves. 1977. Estimated use of water in the United States in 1975. Geological Survey Circular 765.

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Richard E. Bartelt graduated in 1970 with a B.S. in Civil Engineering from Iowa State University. Subsequently he served 2 years in the Army as a Lieutenant in the Corps of Engineers. Upon completion of active duty he returned to Iowa State University where, in 1973, he received a Master's degree in Sanitary Engineering. For the past 4½ years, Rich has worked for the U.S. EPA, Region V, in Chicago. The past year and a half he has been the Region's ground-water protection representative and is currently serving as Chief of the Ground-Water Protection Section, which represents the Region in most ground-water related issues. For the past year Mr. Bartelt has participated in the national work group responsible for drafting and executing the Surface Impoundment Assessment.

State Ground-Water Protection Programs — Adequate[a]

by Edwin H. Ross[b]

ABSTRACT

An assessment of the adequacy of State involvement should include a historical perspective of resource management in the nation. A review of the record indicates that up until the 70's, Federal policy was virtually nonexistent with respect to ground-water protection programs.

Efforts of the ground-water industry and related scientific community to gain legislative action has, within the last few years, shown progress within State government. The Federal EPA, in response to efforts of the only significant constituency, the NWWA, is now requiring ground-water protection in their regulations.

Institutional arrangements, whether national, State or local, will at least for some years to come by political necessity require central involvement of the States in ground-water protection.

The legislative and executive branch in many States have shown their willingness to act; however, without an active political constituency, legislative appropriations are provided after actual problems arise due to drought or contamination problems. Rainfall provides extra time to address quantity problems but there may not be a second chance to protect ground-water quality. These branches of government have the monetary and legal authority to act once the need is demonstrated. The record of the judicial branch indicates a need for the legislative and executive branch to design and manage programs that will avoid the necessity of court action. Continued advocacy efforts for ground-water protection programs yet remains the responsibility of the water well industry and a small ground-water technical constituency. The public and the politicians need to be further informed and educated about the need for ground-water protection.

INTRODUCTION

The purpose of this paper is to provide an analysis of the political perceptions of the adequacy of State ground-water programs. Whether a program is adequate in the politician's view appears to be closely related to the immediacy of a crisis.

Webster (1970) defines adequate as:

1. Enough or good enough for what is required or needed; sufficient, suitable.

2. Barely satisfactory; acceptable but not remarkable.

Adequacy is a relative term and may be judged differently by various people. In assessing the adequacy of the State ground-water protection programs, Bartelt and Dawson (1978) made a survey of State agency professionals throughout the nation. Adequacy of State ground-water programs could be related to:

1. Needs as addressed by Federal programs.
2. Needs as addressed by private foundations.
3. Needs as perceived by the politician.
4. Actual needs for ground-water protection.

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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FEDERAL AND PRIVATE FOUNDATION PROGRAMS TO PROTECT GROUND-WATER QUALITY

In an assessment of the adequacy of State ground-water quality programs, it would be of interest to make a comparison with Federal programs and private foundation efforts to protect ground-water quality.

Dana (1956), in his survey of Federal natural resource programs, documents no programs for ground-water quality protection. Not until 1969 was there any significant Federal program to protect ground-water quality. The National Environmental Policy Act of 1969, PL91-190, provided a mechanism to identify environmental problems (Hagman, 1974).

Legislation passed in the early 1970's, including the Water Pollution Control Act, PL92-500, and the Clean Air Act, PL91-604, forbids or limits the disposal of waste into surface waters, the oceans, or the atmosphere, but these pollution control programs are resulting in ground-water degradation (Gillies, 1978). Pollutants that are removed from the air and surface water are now being dumped on the land surface or into wells resulting in the contamination of ground water.

The Safe Drinking Water Act, PL93-523, limits the protection of ground water to the designation of certain "sole source aquifers" and to the control of underground injection of waste fluids. Studies authorized under the act demonstrated the urgent need for further ground-water protection and led to the passage of the Resource and Recovery Act, PL94-580, which controls the disposal of solid and hazardous waste. The act requires the U.S. Environmental Protection Agency to develop an inventory of hazardous substances produced in the nation. The Toxic Substances Control Act, PL94-469, seeks to limit or prohibit entry into the environment of chemicals potentially hazardous to human health. The Surface Mining Control and Reclamation Act, PL95-87, singles out specific sources of contamination such as injection wells. This controls coal mining, both surface and underground, and requires hydrogeological studies before disposing of mining waste or filling of a mine. Most of these Federal acts are administered and enforced by the States, many of which have primacy over the acts by virtue of setting up their own regulations following Federal directives. Enactment of these environmental protection laws demonstrate that the Federal and State governments are becoming increasingly more concerned about the protection of ground-water resources.

Foundation research on public policy issues has significantly influenced passage of much legislation in the United States. There are approximately 25,000 private foundations in this country. Even though some of the foundations have impressive assets, the Ford Foundation being the largest with over 3.6 billion dollars, the private foundations have not been found to have much concern over ground-water protection (Ford Foundation, 1974; Nielsen, 1972). The Rockefeller Foundation has funded research into the quality of the environment since 1969, but the program was phased out in June 1978. The Ford Foundation is decreasing its funding of projects in environmental protection. A search of funding done by other private foundations (Council of Foundations, 1975; Conservation Foundation Report, 1958, 1959) revealed almost no foundation-sponsored research in the areas of water resources, ground-water quality protection or the related areas of resource recovery, hazardous waste or toxic materials handling.

STATE PROFESSIONALS' PERSPECTIVE

Bartelt (1978) and Dawson (1978) have made extensive surveys of the States to solicit the views of the professionals concerning State ground-water programs. Dawson reports that the majority of State agency personnel questioned feel their ground-water protection programs are inadequate in providing total resource protection.

ONE STATE'S PERSPECTIVE – MINNESOTA EXPERIENCE

In contrast to the nationwide surveys of Bartelt (1978) and Dawson (1978), the author has confined this paper primarily to the question of adequacy of ground-water programs in Minnesota over the past 20 years. A description of water resources and the importance of ground water to public need is included with a discussion of funding and personnel provided for ground-water programs as contrasted to total State expenditures and political perceptions of the needs of constituents and pressure groups.

MINNESOTA WATER RESOURCES AND THE IMPORTANCE OF GROUND WATER

Minnesota is a head-water State (Figure 1). Minnesota does not receive surface water in appreciable amounts from beyond her boundaries (Ross, 1976). Most surplus water flows from the Rainy River in northern Minnesota and the Mississippi River below the Twin Cities (Figure 1). Although Minnesota is the land of 10,000 lakes, the majority of these lakes lose more to evaporation than they gain from precipitation in a year's time (Figure 2). Topography and land-use priorities do not provide natural sites for dams to impound significant amounts of surface water. Ground water is the water supply for 93 percent of the communities in Minnesota. Over 2,500,000 or 66 percent of the State's population is served by ground water.

MINNESOTA PROGRAMS

Between 1956 and 1970, when the first ground-water hydrologist was employed by the Department of Conservation (now Department of Natural Resources) (Table 1), State personnel engaged in ground-water programs in Minnesota increased only slightly. In 1972, public concern for water quality was reflected in the staff additions to the Pollution Control Agency. The additions in 1973 and 1975 were primarily for the solid waste program. The additions in 1977 were primarily for the requirements of the underground injection control programs of the Federal Safe Drinking Water Act.

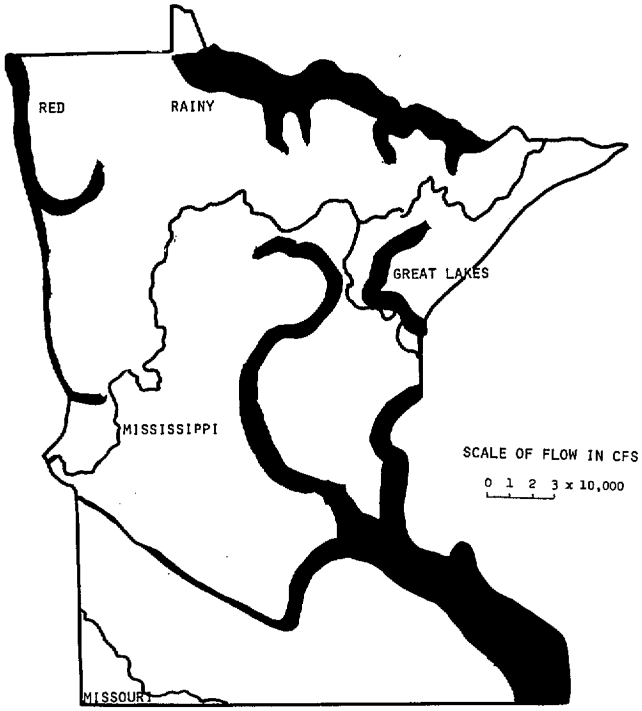


Fig. 1. Flow of Minnesota streams (width of stream indicates the relative magnitude of average flow).

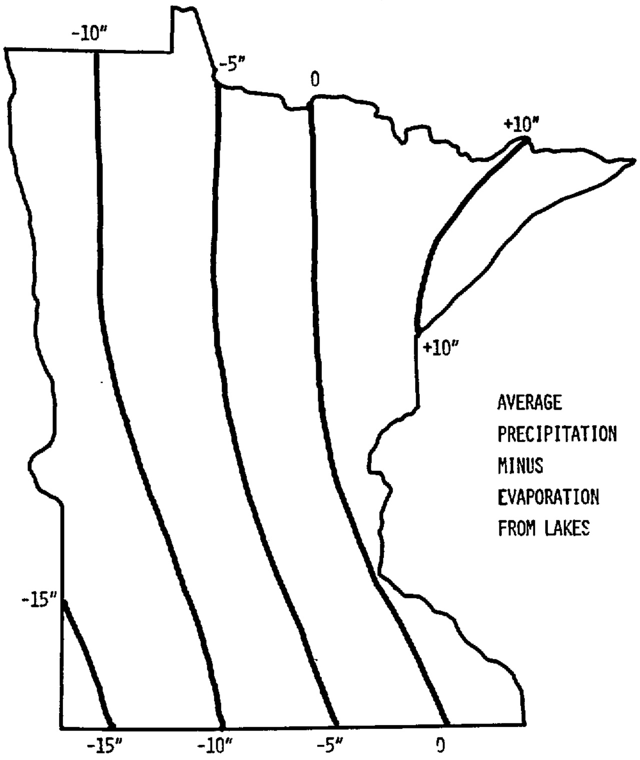


Fig. 2. Minnesota's average precipitation minus evaporation from lakes.

Other additions to staffing of the Health and Natural Resources Departments and the Minnesota Geological Survey resulted from the near public panic caused by the drought of 1976 and 1977 (Figure 3).

Table 1. Professional Ground-Water Personnel Minnesota State Government

	MDH	*MPCA*	*DNR*	*MGS*	*Total*
1977	5	20	11	5	41
1975	2	12	5	3	20
1973	1	8	5	3	16
1971	1	3	4	3	11
1969	0	1	4	2	7
1967	0	1	4	1	6
1965	1		4	1	6
1963	1		4	1	6
1961	1		4	½	5½
1959	1		4	0	5
1957	0		4	0	4
1955	0		1	0	1
1953	0		0	0	0

MDH – Minnesota Department of Health
MPCA – Minnesota Pollution Control Agency
DNR – Department of Natural Resources
MGS – Minnesota Geological Survey

Politics, drought dominated '76 Minnesota scene

Iceberg eyed for irrigation

TO ASSESS STATE IMPACT

Perpich creates drought panel

Mississippi down to third of normal

Several state cities turn to wells as drought is expected to continue

ITASCA LISTS 144 DRY WELLS

Old man river trickles along

DROUGHT Will History Repeat?

$1.5-billion state crop loss estimated

Rain 'blessing' for state farmers

City asks cut in sprinkling, car-washings

ast, youths find

Twin Cities water supplies said adequate

Drought hurting rural areas,

Energy shortage, drought still threatening state

Fig. 3. Drought, 1976-77.

POLITICIANS' PERSPECTIVE

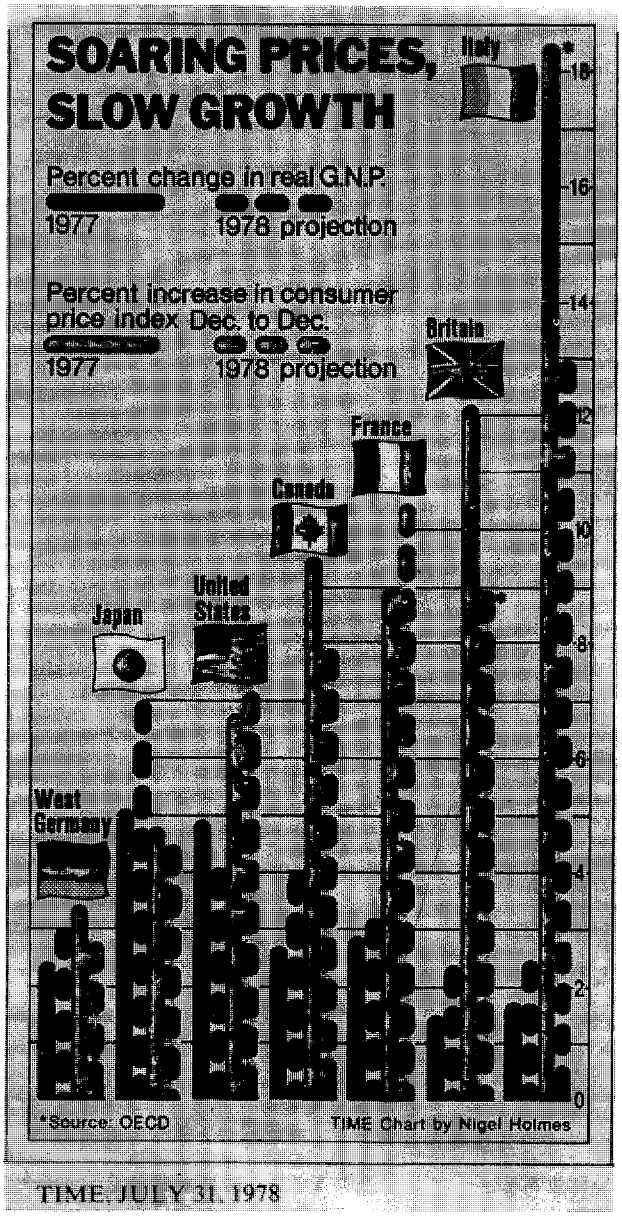
Politicians strive to provide programs to meet the needs of their constituents. To be successful the politician should continually assess the adequacy of governmental programs. Accordingly, the adequacy or inadequacy of any public program will be the result of the politicians' perception of the public's needs and wants.

As the surveys of Bartelt (1978) and Dawson (1978) have indicated, State ground-water professionals throughout the nation are of the opinion that ground-water programs are inadequate. However, Minnesota aspirants to political office in the Summer of 1978 indicate a contradictory perception of public wants and needs to that of most State ground-water professionals.

In 1978, the Minnesota politician has an obvious lack of concern for issues other than the high cost of government and the need to cut taxes. One can only conclude that the public policy makers at this time are of the opinion that State ground-water programs are adequate. Because of the average wage earner's problems in meeting everyday expenses, the concern for taxes and the cost of government has accelerated this year. The consumer price index increased faster than the real growth in the gross national product (Figure 4). Because of the progressive income tax rates, the average wage earner's taxes increase disproportionately to his cost-of-living salary adjustments. The projections of revenue for Federal programs seemed to be rather dismal a few years back but the inflation and progressive tax laws provided a solution (Figure 5). State and local budgets are now generally in sound condition (Figure 6).

A sudden change in public attitude erupted when California voters sent a loud and clear message to their elected officials by passing Proposition 13, and reducing property taxes by 57 percent (Figure 7).

In Minnesota, the politician is responding to the issue with his concern for the high cost of government (Table 2), but in a way qualified so as to not alienate the most influential special interest constituency. Although there are about 900 special



*Source: OECD

TIME Chart by Nigel Holmes

TIME, JULY 31, 1978

Fig. 4. Soaring prices, slowing growth — percent change in real from national product, and percent change in consumer price index.

interest groups represented by about 1300 lobbyists registered with the Minnesota Ethical Practices Board, none are as powerful and influential as the education lobby. In early September 1978, newspaper headlines announced, repeatedly, the governor's opposition to increasing taxes as well as spending. The headlines did not announce the entire story as revealed in the text of the newspaper articles: "Two of the biggest budget items are school and property tax relief, which includes aid to local governments (schools*); programs the

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*Inserted by author.

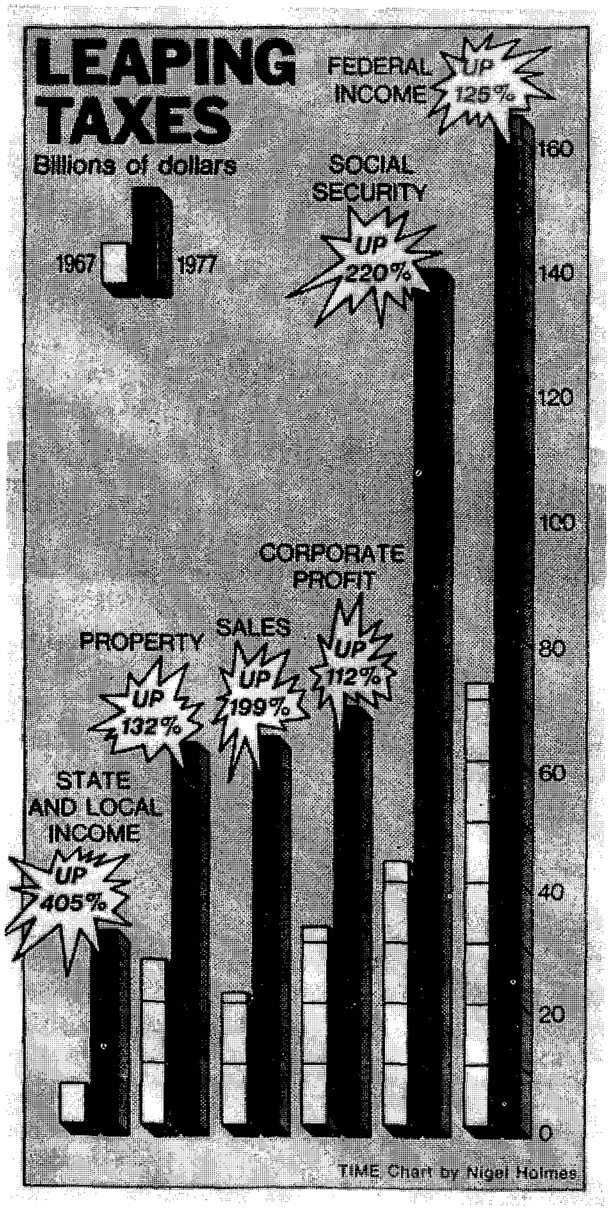

Fig. 5. Leaping taxes, billions of dollars.

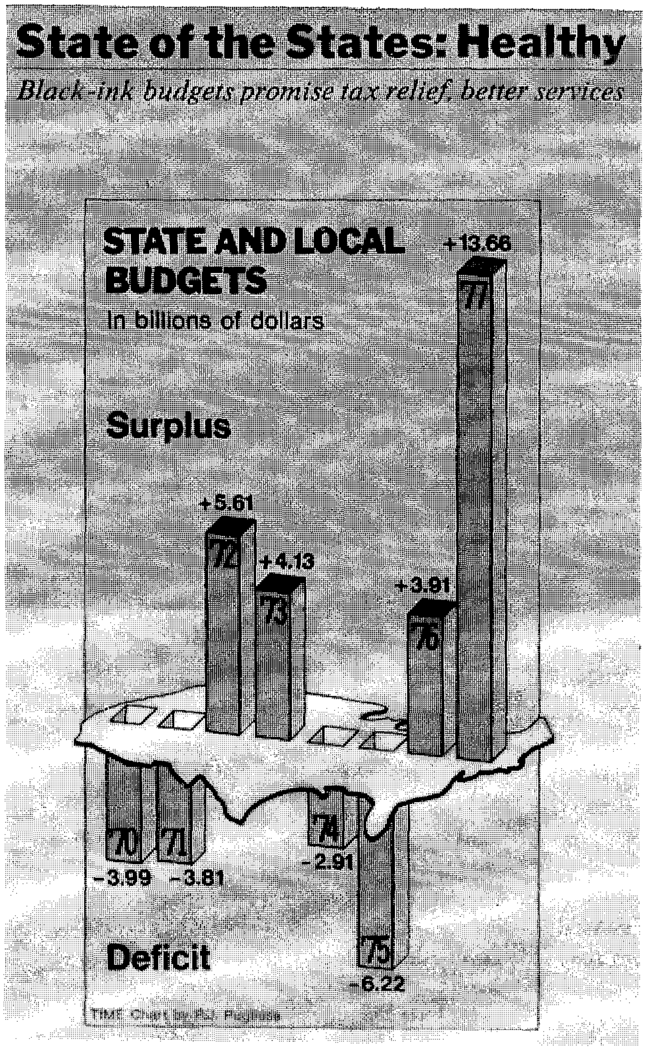

Fig. 6. State and local budgets in billions of dollars.

ALEXANDER SAYS GOODBYE

Rudy blasts bureaucr
takes EPA man by surp

28 million-plus
aved by state
urbing waste

Perpich again says no increases next year

SHORT CALLS FOR SUBSTANTIAL TAX CUT OF 50 BILLION DOLLARS

SHORT warns that government is too big

Perpich says 'no increase'

Easy money rolls in to state

Fig. 7. Proposition 13.

Table 2. Minnesota Summary of Legislative Appropriations by Function

	Federal Funds	*State Funds*	*% of State Funds*
Education	$ 216,074,424	$4,378,244,266	62.07
Welfare	864,407,849	892,358,607	12.65
Transportation	156,744,147	693,486,873	9.83
State Agencies	269,690,571	643,625,523	9.12
Open Appropriations		270,111,206	3.83
Miscellaneous		125,149,850	1.77
Legislative	83,000	34,366,806	.49
Judicial	276,688	16,610,592	.24
Total Federal Funds	$1,507,276,679		
Total State Funds		$7,053,953,723	100%
Tax Refund		428,430,000	
		$7,482,383,723	
Federal Funds		1,507,276,679	
Grand Total Appropriation		$8,989,660,402	

legislature has committed itself to finance at a substantial level. The governor said he will go along with a 1978 legislative promise to increase school aid next year." What the governor said illustrates a consensus of viewpoints of most aspirants to public office.

To fully explain the politicians' sensitivity to the needs of education in Minnesota would require a rather detailed and somewhat subjective analysis; however, it may be sufficient to say that State funds are provided beyond the strict needs of the student. Eighty percent of the total number of State tax-supported employees (Table 3) are employed in education. Politicians are strangely silent to the seemingly popular opportunity to discuss the fact that the most dramatic and obvious place to cut spending would be in elementary education.

By 1980 the budgetary needs of the school age population (Minnesota State Planning Agency, 1972, 1975) will only be 80 to 85 percent of the 1970 levels, and by 1985 the needs will only be 70 to 85 percent of the 1970 levels (Figures 8 and 9). In 1978 dollars this could represent a saving of more than $500 million per year and yet the governor and the legislators are promising to provide more school aid instead of cutting spending for education. Considering that this savings is almost equal to the total amount provided to all of the State government agencies and that funds provided for ground-water programs is less than $2 million per year, it is obvious that the politicians are of the opinion that ground-water programs are adequate and education is inadequate (Minnesota State Senate, 1977).

Of the total State biennial budget (Table 2), only $.25 per capita is allocated to the professional staff involved with the ground-water program and $.025 per capita goes to the professionals working with the water well program. All the funds spent by the State averages out to $1,750 per capita and the funds appropriated for the State agency

Table 3. Analysis of Employee Complements Financed in Whole or Part by State Funds

		Positions	
Education			
Department of Education	521		
Higher Education	14,342		
Elementary and Secondary School Teachers	53,588		
Support Staff	33,016	101,467 –	79.2%
State Departments		11,889 –	9.3%
Welfare and Correction		8,427 –	6.6%
Transportation		5,023 –	3.9%
Legislative		761 –	0.6%
Judicial (Including Attorney General's Office)		529 –	0.4%
	Total	128,096 –	100%

(Data from: Minnesota Population Projections, 1970-2000, Minnesota State Planning Agency, November 1975; Minnesota Socio-Economic Characteristics (from 1970 Census), Minnesota State Planning Agency, April 1972; Minnesota State Senate – A Fiscal Review of the 1977 Legislative Session, December 1977; and Minnesota Tax Payer's Association.)

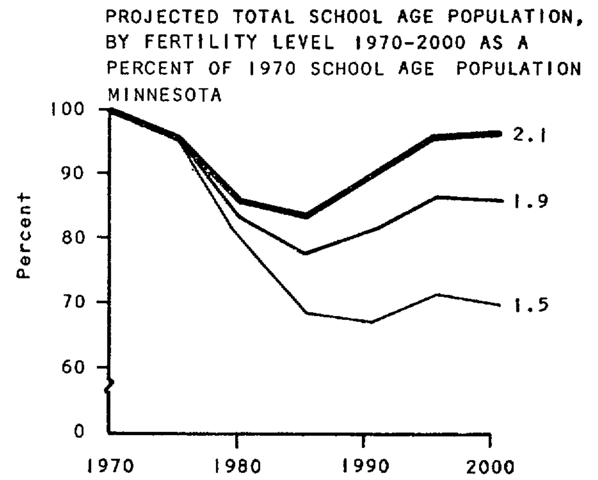

Fig. 8. Projected total school age population of fertility level, 1970-2000, as a percent of 1970 school age population—Minnesota.

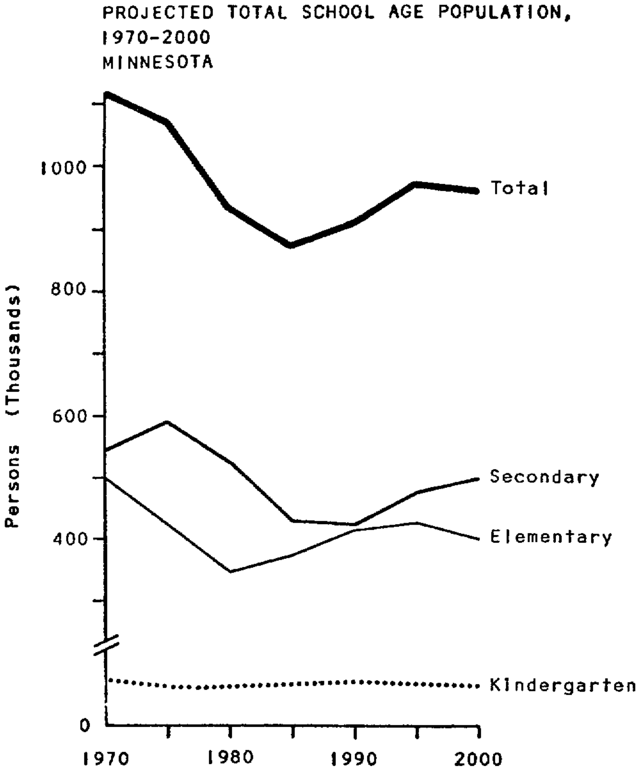

Fig. 9. Projected total school age population 1970-2000—Minnesota.

functions excluding transportation and welfare averages out to about $160 for each person in the State.

CONCLUSION

Problems with protecting ground-water quality continue to grow (Figure 10). Recent discoveries of damage to the drinking-water aquifers reveal a frightening consequence to the affected communities in both health and financial costs. Land-use practices that severely contaminate the land surface may, in future years, cause severe contamination to subsurface- (ground-water) water supplies. There is evidence that the ground water in some areas is becoming contaminated. Inadvertent and accidental spills and discharges enter the ground water. Increased loading of the soil with fertilizers, insecticides, and herbicides, plus the thousands of synthetic substances manufactured each year are contaminating this valuable resource. Landfills,

Poisons seep from affluent U.S.

Minnesota wasting away

Highly toxic chemical founc after costly 3-month hunt

3M vows to fight waste dump site

Metropolitan

4 possible sites for unwanted dump selected

view

The garbage you drink may be your own

Solid and Hazardous Waste Where will it go?

hazardous waste

Disposal choice: effort or crisis

Poor site for chemical wastes

Waste: Disposal solution is sticky

Chance seen to recover arsenite

Proposed Eden Prairie hazardous chemical dump faulted at hearing

Diggers unearth insecticide drum but spill contents

Fig. 10. Ground-water contamination.

pipelines, and improperly constructed wells add to the pollution of the ground water.

An explanation of this dilemma could be that in the area of public resource management and protection, it apparently makes little difference what the facts are or what the professionals' observations are if the public or politicians' perceptions are of a different or indifferent persuasion.

If ground-water quality is threatened and if it is ever to be protected, a concerned public must be the primary motivating force in providing the necessary means to assure adequate protection. To provide a responsible role to the public in this regard, the scientist, technician, bureaucrat or academician must inform the public of all available facts needed to arrive at a consensus opinion consistent with the public's responsibility and welfare (Figure 11). Jefferson (1795) wrote: "The people of every country are the only safe guardians of their own rights, and are the only instruments which can be used for their destruction. And certainly they would never consent to be so used were they not deceived. To avoid this, they should be instructed to a certain degree." (Koch and Peden, 1944.)

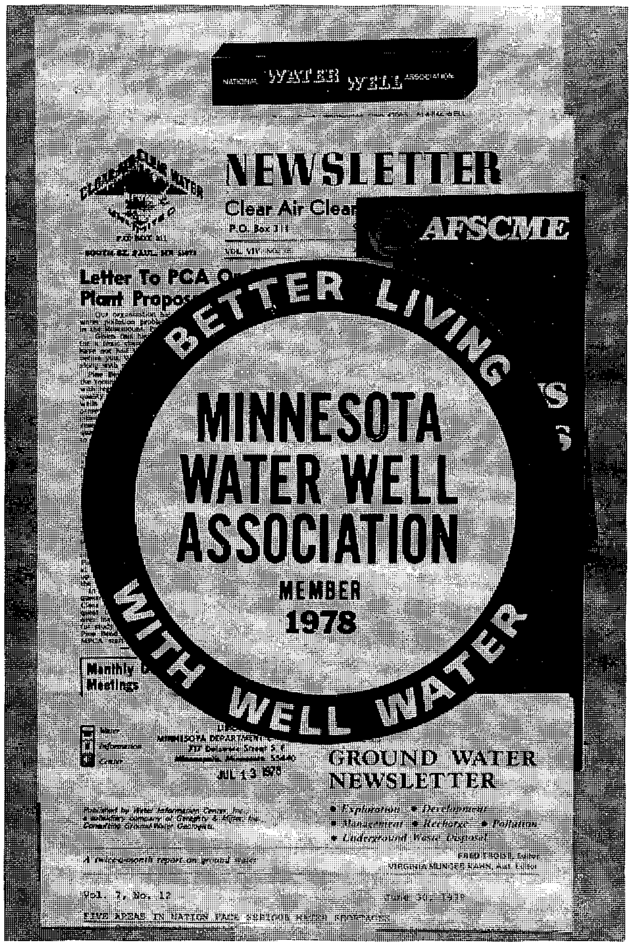

Fig. 11. The constituency.

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State Ground-Water Protection Programs — Inadequate[a]

by James W. Dawson[b]

ABSTRACT

The primary reason State ground-water protection programs are inadequate is that the resource is misunderstood, surrounded by misconceptions and, due to its occurrence, is "out of sight and out of mind." To most people, ground water is a very elusive and somewhat magical resource, whose significance in the over-all picture of water resources has not been realized by those who have the power and authority to rectify the present state of affairs. The need for adequate protective legislation and sufficient financial and manpower resources commitment is even more difficult to justify because there has not, to date, been a citizenry outcry for such measures.

To ascertain the status of current State ground-water protection programs, a survey of State legislation concerning ground water was undertaken; additionally, a questionnaire was sent to the agency in each State responsible for administration of ground-water protection programs. The results of this survey indicate that most States have broad authority over ground-water resources through general water resources legislation, but the majority do not have specific ground-water protective legislation. In many cases, the broad legislative authority is inadequate or, if legislation is adequate, implementation of legislative mandates is not sufficient to provide adequate protection. Lack of ground-water quality and quantity data is severe to the point that many agencies do not have a realistic characterization or identification of the ground-water resources they are to protect.

This discussion concerns some deficiencies of State ground-water protection programs and emphasizes the fact that the majority of State agencies contacted feel their programs are inadequate in providing true resource protection. While protection immediately implies the prevention of contamination, management is an integral part of protection, since the act of protecting is "to shield from injury, damage or loss; guard; defend" (Guralnik, 1972). For State ground-water protection programs to be considered adequate, they must, by definition, be directed towards the total resource, i.e., both quality and quantity. Without management authority, State programs cannot provide total resource protection.

The method of data collection must be considered when evaluating the data presented herein. Two survey questionnaires were sent to the primary State agency concerned with ground-water resources which requested both subjective evaluations of some program areas and delineation of specific program elements; telephone interviews were conducted to complete data collection. (Note: Survey questionnaires were not sent to the Virginia State Water Control Board, Bureau of Water Control Management. Program evaluations utilized in this discussion are those of the author and do not constitute official Agency response to the questionnaires.) In most of the States, program implementation is divided between two or more agencies and input from sister agencies was provided, in many cases, through the efforts of the primary contact.

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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The survey was not as detailed as would be required for a comprehensive analysis of State ground-water protection programs; however, the effectiveness of such programs can be demonstrated by considering the following factors:

1. Legislative basis for development of programs and the adequacy of that legislation.

2. Ability of the State to collect ground-water resources data.

3. Protection of the resource through proper development.

4. Ground-water quality standards as an enforcement/regulatory tool.

5. Regulation of ground-water users and management of the resource.

6. Implementation of existing programs and the flexibility to expand those programs, or develop new ones, to address ground-water problems.

Adequate legislative authority is a prerequisite for development of State ground-water protection programs. All States have general water resources legislation which declares (in one rhetorical form or another), as public policy and legislative intent, the protection, enhancement and management of State waters for the public health, safety and welfare; the definition of State waters usually includes both surface water and ground water. Most of this legislation is pollution control/abatement-oriented and is directed primarily towards surface water, with only broad authority over ground water. A few States have specific ground-water legislation, but for the majority of States, ground-water protection is provided through several different statutes which mandate, to one or more agencies, the development of sufficient programs to achieve the intent of the legislation. Figure 1 depicts the legislative basis for development of State ground-water protection programs (Bartelt, 1978) and the State's evaluation of the adequacy of that legislation to provide for protection and management of ground-water resources is presented in Figure 2.

The majority of States (56%) rely on general laws for development of ground-water protection programs; seven States utilize general laws which specifically mention ground water; 12 States have individual laws which address specific pollution sources (usually activities) and their effect on ground water; and three States have specific ground-water legislation. Twelve (12) States felt existing legislation was adequate, 15 States indicated it to be partially so, and 23 States felt their legislation was inadequate. In all, 38 States (76%) felt that their legislative basis was inadequate or had deficiencies, with lack of management authority cited as the predominant factor; fragmented and incomplete legislation (i.e., specific problem areas not addressed) and legislative ambiguities were also cited.

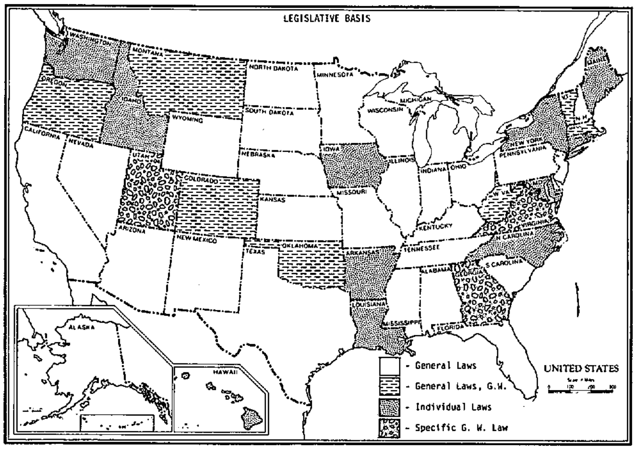

Fig. 1. Legislative basis.

Comparison of legislative basis and evaluations reveals that seven States felt a general law basis was adequate, ten States noted deficiencies and 11 indicated that this basis was inadequate. General laws which specifically mention ground water were termed adequate by one State, deficient by two and inadequate by four. Four States felt the individual law basis was adequate, while two indicated deficiencies, and six felt it was inadequate. Of the States that have specific ground-water legislation, one noted deficiencies, and two felt it was inadequate. These evaluations, I contend, emphasize that ground water is a complex subject which has not received sufficient

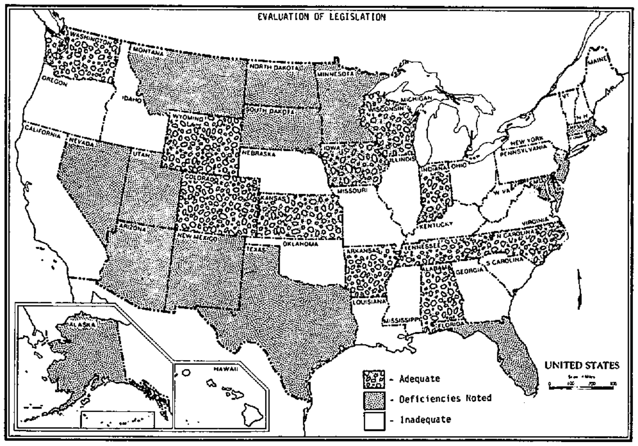

Fig. 2. Evaluation of legislation.

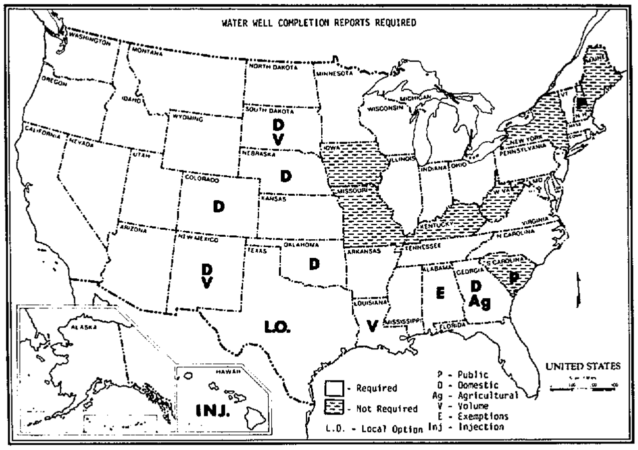

Fig. 3. Water well completion reports required.

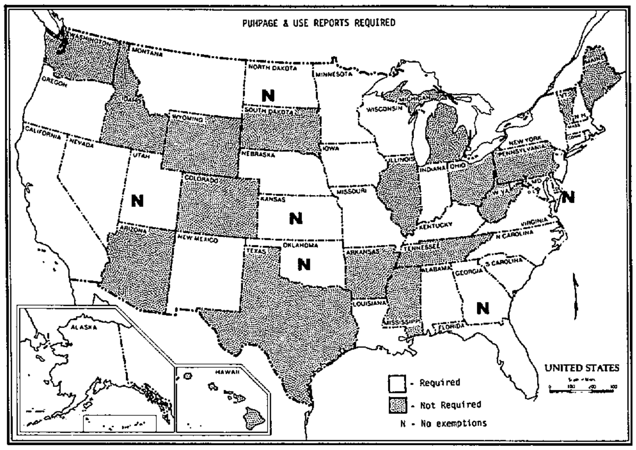

Fig. 4. Pumpage and use reports required.

consideration by those who have the legislative responsibility to mandate adequate protection.

A fundamental aspect of any protection program is collection of necessary information regarding characteristics of the resource because insufficient data precludes accurate resource identification or inventory and thus, protection and realistic management becomes difficult, if not impossible. Such data collection usually includes submission of water well completion reports (or some similar reporting vehicle), pumpage and use reports, and background quality information. Figure 3 reveals that 42 States indicated water well completion reports were supposed to be filed, although exemptions (for one reason or another) existed for nine of those; eight States indicated that no completion report or similar form was required. Adequate yield tests are necessary for determination of many aquifer parameters, but only six States require pump tests for all wells and 18 States indicated that pump tests were required for public supply and/or high capacity wells. Although not required by the majority of States, many indicated that the results of yield tests were frequently filed with water well completion reports; however, comments indicate that the tests were usually inaccurate due to the method of testing (bailing or airlift) and insufficient test duration. In regard to pumpage and use reports (Figure 4)—vital data for management purposes—32 States responded that they were required, although approximately 80% of those indicated that exemptions exist (high volume users, public supply systems or certain users in designated areas are usually the only ones required to submit such reports); five States indicated that they had the option to require such reports if they wanted to. Although background quality data collection was not specifically addressed in the survey, such data collection is dependent upon manpower and budgetary constraints which can limit sufficient data accumulation (several comments indicated a lack of basic ground-water quality data).

These survey results indicate that a large number of States are unable to develop a sufficient data base and the data that is collected is typically spotty, inaccurate or incomplete, with collection based primarily on voluntary cooperation. Enforcement of regulatory provisions for data submission was indicated to be minimal or non-existent, due to either fiscal limitations (manpower, budget appropriation, etc.) or, in some cases, because legislative or regulatory ambiguities preclude enforcement. As a result, many States do not have a realistic determination of what it is they are supposed to protect.

Protection of the resource through proper development is basic to preventing contamination, with water well construction being one of the most significant vehicles available for ground-water contamination. Water well drilling codes (Figure 5)

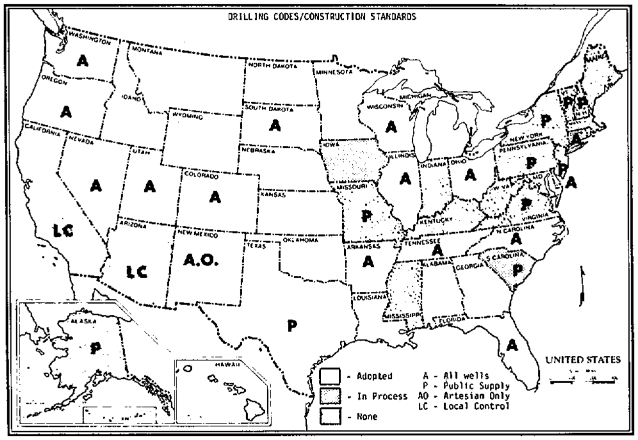

Fig. 5. Drilling codes/construction standards.

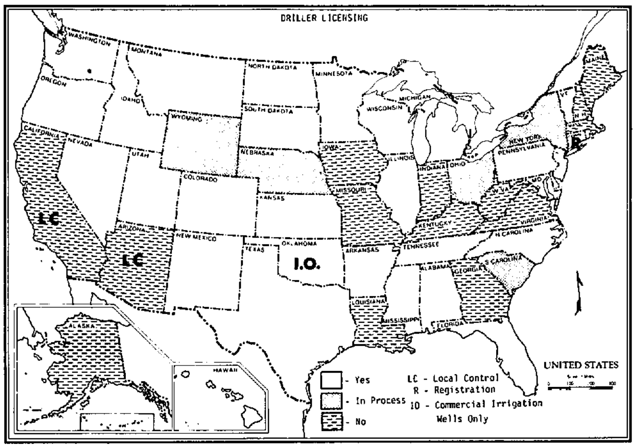

Fig. 6. Driller licensing.

which promulgate mandatory construction standards or provide recommended minimum standards, have been adopted by 30 States, while three States are developing such codes (Adams, 1978). The integrity of public water-supply wells is fairly well established through adequate well construction standards (40 States have mandatory requirements). However, for domestic water wells (which constitute a larger user population) there are not mandatory standards in most States (20 States indicate no standards adoption and of those who have such standards, many are recommended with only voluntary compliance and thus, non-enforceable).

Licensing of water well contractors (Figure 6) is another means of encouraging adequate well construction, with 30 States requiring licensing (one State requires it only for commercial irrigation wells), 14 States with no licensing (two States leave this for local control), five States with licensing procedures in process and one State that requires driller registration (Adams, 1978). However, licensing in itself assures the competency of the contractor, not necessarily that adequate construction will be employed. Most citizens do not know what constitutes adequate well construction and therefore, State-mandated minimum construction standards for all wells seem to be in order from a resource, as well as a consumer, protection standpoint.

Ground-water quality standards (which refer specifically to ground-water quality and are not concerned with discharge standards, drinking water standards or any other such regulatory standard) have received considerable interest recently as a means of facilitating ground-water protection; in fact, such standards can significantly affect a State's ability to enforce its programs. In numerous instances, ground-water pollution or contamination is difficult or impossible to prove if degradation from some previous quality standard cannot be demonstrated; further, regulation of ground-water dischargers can be difficult if background quality has not been established. Ground-water quality standards provide the necessary reference point for comparison and regulation. Since ground-water quality is not constant, adoption of a non-degradation policy, in addition to specific parameter concentrations, can prove beneficial in enforcement proceedings. Figure 7 indicates which States have adopted specific ground-water quality standards: five States have done so; two States have surface-water quality standards which apply to ground water; 11 States have standards in the developmental or proposed stages; and 32 States have no specific ground-water quality standards (Bartelt, 1978), although ten of those have adopted standards for drinking water supplies which utilize ground water. As mentioned earlier, most States do not have the reference point (standards) which is essential in demonstrating water quality degradation and providing regulatory basis and thus, quality protection of the resource is diminished.

Statewide regulation (Figure 8) of ground-water users can greatly enhance a State's ability to inventory and protect the resource. State-issued permits for ground-water use are required for some users in all but 17 States; however, exemptions for certain uses or volumes exist in 22 of the 33 States that do issue permits for ground-water use; only 11 States require permits for all wells, while three States leave this issue for local control. The fact that the majority of States do not permit or regulate all ground-water users indicates that most States do not have an accurate determination of the level of ground-water development and thus, realistic management of the resource is impossible.

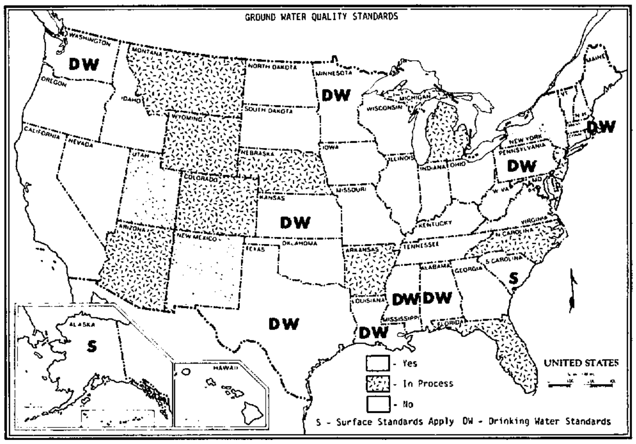

Fig. 7. Ground-water quality standards.

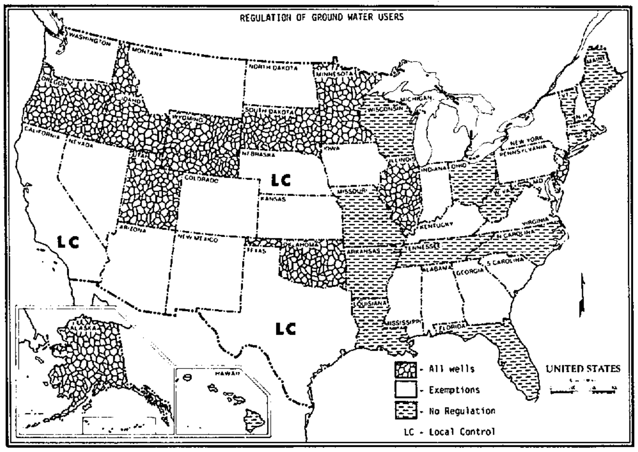

Fig. 8. Regulation of ground-water users.

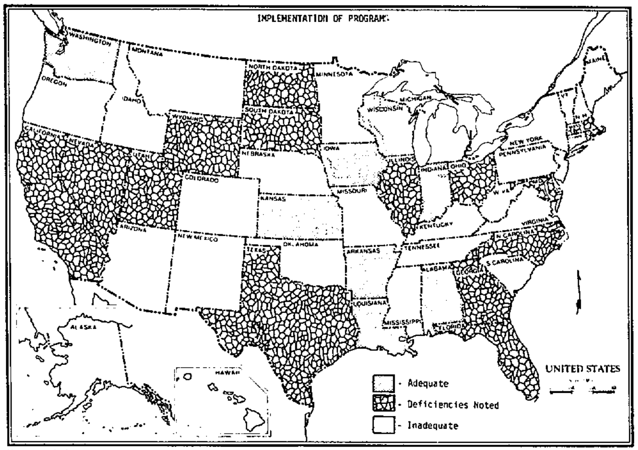

Fig. 10. Implementation of programs.

Private domestic wells and small volume users (between 5,000 and 50,000 gpd) are typically exempt from regulation and it is recognized that eliminating these exemptions could significantly increase the regulatory workload. But in certain cases, the total combined effect of these users can be greater than that of the permitted users. For adequate resource inventory and management I contend that regulation of *all* ground-water users is a necessity.

As previously mentioned, management of ground-water resources is innate to any adequate protection program. The specific management tool (e.g., beneficial use, prior appropriation, ground-water mining, sustained yield, etc.) is not the topic of discussion, but rather, the State's authority to implement management alternatives, if warranted. Declaration of ground-water management areas (included in this term are capacity use basins, adjudicated basins, critical ground-water areas, etc.) is the most common means of implementing management alternatives. Figure 9 depicts that 24 States can declare management areas (survey results indicate that exemptions and "grandfathered" users can significantly reduce the effectiveness of management plans that are implemented); one State has legislation in process that would authorize such areas; two States have such areas in the State, but cannot delare similar areas in other portions of the State; and, 23 States have no such provision. Without this authority, State ground-water protection programs cannot provide total resource protection (many comments identified this as a major program deficiency).

Implementation of legislatively mandated programs is a significant factor in evaluating the effectiveness of State ground-water protection programs. As seen in Figure 10, implementation of existing programs was termed inadequate by 27 States, with 14 States indicating that the existing program implementation was deficient in certain areas. Comments received generally fell into the categories of insufficient manpower, budgetary limitations, ambiguities in underlying legislation and non-enforcement of regulatory provisions. Figure 11 depicts the number of State agencies

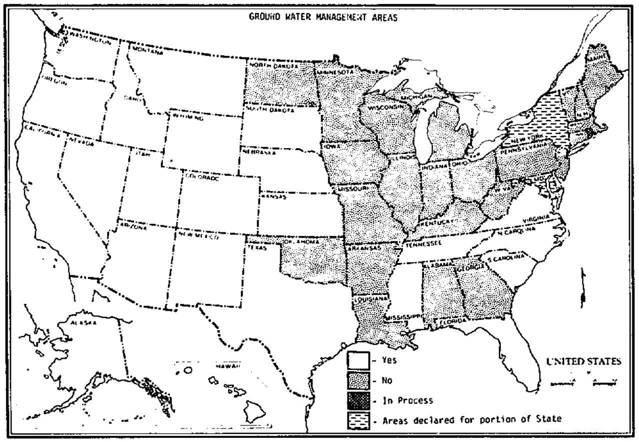

Fig. 9. Ground-water management areas.

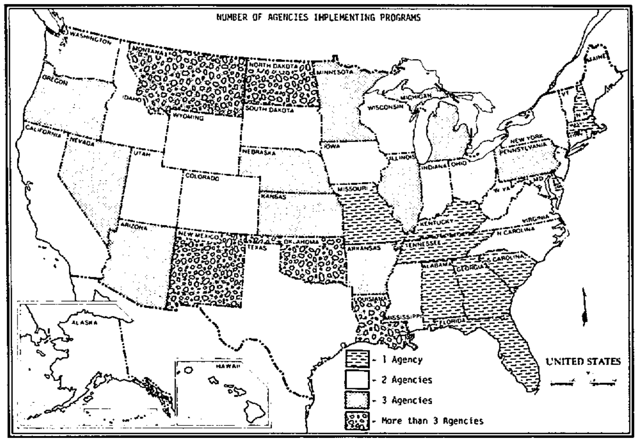

Fig. 11. Number of agencies implementing programs.

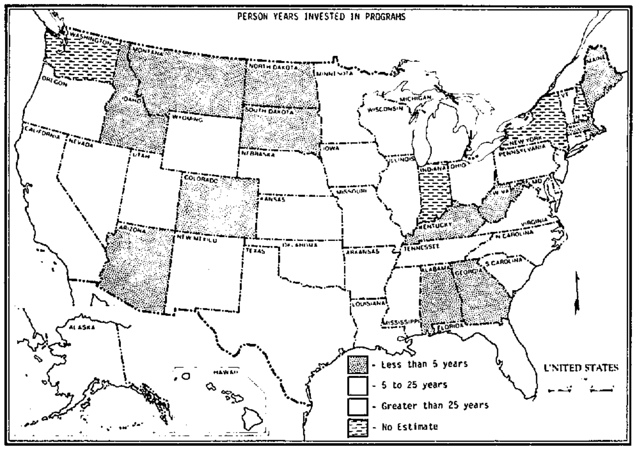

Fig. 12. Person-years invested in programs.

involved with implementation of programs (Bartelt, 1978) and it lends credence to the adage, "too many cooks spoil the broth." In many cases, this situation results in jurisdictional overlaps and ambiguous delineation of agency responsibilities, spawns inter-agency conflicts, leads to duplication of efforts in some areas and fosters the lack of any substantial programs in other areas. The net result is a hit and miss program, plagued with inefficient administration, which does not provide adequate protection and does not achieve legislative mandates.

Figure 12 depicts an estimation of the amount of person-years invested in each State for program implementation (Bartelt, 1978). Comparison of person-years invested with implementation adequacy (Figure 10) emphasizes the variability of ground-water conditions throughout the country. In many cases it was difficult to derive even a "ball park" estimation; however, it is obvious that increased staffing is warranted (numerous comments indicated insufficient program staffing).

A further indication of the effectiveness of State ground-water protection programs is the flexibility of the responsible agency, or agencies, to expand existing programs, or develop new ones, to provide for increased protection of the resource. Most enabling legislation mandates to a particular agency the responsibility of developing programs sufficient to achieve the intent of that legislation, with promulgation of rules and regulations after public hearing. The major deficiency with this procedure is the fact that this regulatory flexibility is usually restricted to legislative-specific items and consequently, if a particular item is not mentioned in the enabling legislation, an agency can be essentially powerless to address that problem. This situation dictates that amendments to existing statutes, or new legislation, be developed and fed into the legislative grist mill where they may not be well received or undergo debilitating changes. The net result is that problem areas are not addressed in a timely manner and the program's effectiveness in providing adequate protection for ground-water resources is reduced.

SUMMARY

A detailed analysis of State ground-water protection programs must consider other factors and program elements which have not been mentioned in this discussion; however, the majority of State agencies feel their ground-water protection programs *are* inadequate in providing total resource protection. Several States feel that they have done a pretty good job considering the limitations under which the programs must operate, although practically all States indicated that programs could be more effective if the deficiencies discussed herein were alleviated.

The fact that the majority of the States feel their current programs are inadequate is indicative, I contend, of more fundamental problems concerning ground-water protection:

1. Ground water is a highly misunderstood resource and, due to its occurrence, is "out of sight, out of mind"; its significance in the total water resources picture, and its vulnerability, have not been realized; and,

2. Mankind's capacity to zealously *react* to a problem, rather than to rationally *act* to prevent the problem from occurring in the first place.

These reasons combine to prevent, or impede, program development because improper understanding of the resource and the factors that affect it makes justification for truly adequate programs difficult, if not impossible. Further, significant ground-water problems have not developed in most States and many people feel that there are no real problems that need action at this time, even though widespread bacterial contamination and specific instances of more serious contamination have been reported (EPA, 1977). However, remedial programs for the majority of contamination problems can require such enormous financial commitment and extensive time periods that they are prohibitive and effectively irreparable; additionally, cases of physical damage to an aquifer are irrevocable. PREVENTION is the key to ground-water protection and this can only be realized if these fundamental problems are alleviated.

Improvement of existing programs will require legislative change, governmental reorganization or realignment and a substantial financial investment that will not have an appreciable return at the present time; although the benefits of such programs may be realized at some future date—20 years, 50 years, or even later. With reliance on ground water increasing at 25% per decade (EPA, 1977) and as land disposal (both surface and subsurface) of waste materials increases, it behooves the States to develop adequate protection programs to assure that ground water remains an economical and high quality water source. Is comprehensive federal legislation the answer? The majority of States felt it was not, although comments indicated that a federal program—with financial and technical assistance—for development of adequate State ground-water protection programs would be beneficial.

The majority of State agencies feel that their ground-water protection programs are inadequate and, I contend, these programs will remain so until the need is recognized to develop adequate programs. This need may be recognized through:

(a) Adequate understanding of the resource by those who have the legislative responsibility to mandate adequate programs (be they federal or State legislators); or

(b) When ground-water problems achieve a level that will force the development of adequate programs.

I only hope that the former, not the latter, situation results in development of adequate State ground-water protection programs.

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Audience Response to Session V — State Ground-Water Protection Programs

Ray Kazmann, Louisiana State University, Baton Rouge: I've listened to these presentations with a great deal of interest. Protecting aquifers and defining aquifer qualities is a great idea. Mr. Bartelt, I have a question for you. When you have several aquifers, one underneath the other, with water of varying quality in each one and differing within the aquifer itself, how do you devise an aquifer water quality standard? That's the problem in Louisiana.

Richard Bartelt, U.S. EPA, Region V, Chicago, IL: If I knew how to protect those aquifers, I probably wouldn't be working for the Environmental Protection Agency, I'd be working for one of the States. We are not involved in ground-water quality standards right now, and I have no idea how you'd handle the situation. When I said States did or did not have ground-water quality standards, I didn't mean to infer that I was suggesting that they go out and develop them, I just wanted to state this was my interpretation of the progressive step that is being used by approximately 40 percent of the States in the U.S. I'm not trying to cast an aspersion on a State that doesn't have it.

Ray Kazmann: It all depends on the hydrogeology. Mr. Dawson, I have a couple of questions for you. Why do you feel you have to control the quantity of water being taken out of the ground as well as the quality? Why do you expand this method of protection? You're protecting the ground water from whom?

James Dawson, Virginia State Water Control Board, Roanoke: That's a good question. I guess in a way it sort of depends on how you look at the resource in general. I, for one, hold the philosophy that we ought to use our common sense. We ought to approach problems or manage our resources. First of all, we're in a finite world, and I think that the problems that we've seen in south central Arizona with ground-water mining, the problems that were evident in parts of Texas which have been turned around a little bit by taking into account management actions—we have to beneficially utilize our resources, and there's nothing worse than for us to develop our civilization or particular urban area and then find out that we're out of water. What do we do now? We truck it in from 150 miles away. I think that the State should have the flexibility to implement management alternatives if it wants to. If it decides to mine ground water, well it's their business, but the point of the matter is that a large number of the States don't have the flexibility to implement management alternatives if they want to. So I think that as a total resource, you have to hit both the quality and the quantity aspects in your protection programs. They go hand in hand.

Ray Kazmann: Who is going to decide whether water shall be mined or not? In the final analysis, the people that own the land are trying to make a living and need the water, if they mine it, it's better used mined than left there protected against something else. I don't know what. It's like saying we don't need the petroleum in the ground and the coal in the ground because of the limited stock and we're going to run out. What are you protecting when you protect petroleum in the spaces?

James Dawson: Well, I've never fooled around with petroleum except to put it in my car, but I think the point is, you seem to be thinking that I'm professing a preservationist attitude which I'm not. In preservation, a preservationist implies no use, and I'm saying that we ought to at least take a look at the resource and use it wisely.

The 208 Planning Approach to Ground-Water Protection — A Program Overview[a]

by Merna Hurd[b]

ABSTRACT

Ground-water protection is one of the water quality management priorities that Section 208 planning is addressing. Examples are derived from the experiences of selected 208 planning agencies, among them Nassau-Suffolk Regional Planning Board (NY), Old Colony Planning Council (MA), and Ventura Regional County Sanitation District (CA). These agencies have used 208 funds to identify problems such as salt-water intrusion and contamination from storm runoff. Through ground-water studies, each assessed the extent of the problems and used their analysis to produce protection and control recommendations.

Section 208 requires that designated State and area-wide agencies plan for ongoing water quality management to meet the 1983 goal of restoring and maintaining the chemical, physical, and biological integrity of the Nation's water. The Section, which originated with the Federal Water Pollution Control Act of 1972, contains the only extant provision for nonpoint source pollution control. Opportunities for integration of 208 with other Clean Water Act programs as well as with programs established under the Safe Drinking Water Act and the Resource Conservation and Recovery Act are now being explored as a means of increasing water quality management efficiency and quality.

As Director of the Environmental Protection Agency's national Water Quality Management program, I welcome this opportunity to address such recognized ground-water experts concerning the 208 planning approach to ground-water protection. While I am relatively new to EPA, having assumed my current responsibilities in January, I am not new to water quality management. Prior to my arrival in Washington, I was on the front lines, so to speak, in the battle for clean surface *and* ground waters, having served as Director of the New Castle County, Delaware 208 Agency. From those perspectives, I will tell you straight out that it is my philosophy that the achievement of the Clean Water Act objective "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" requires the conjunctive management of both surface and ground waters. There exists a compelling case for the significant involvement of 208 agencies in the planning and management of ground-water protection; I intend to make that case here.

PROGRAM OVERVIEW

I feel in somewhat of a paradoxical position, however, speaking to you as a Federal official on the subject of ground-water protection. There exists no Federal statute devoted solely to ground-water concerns, no Federal program exclusively devoted to problems unique to the ground waters and no national ground-water policy (although we at EPA

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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are, through an intermedia effort, attempting to develop a ground-water policy statement). Rather, there exists fragmented authorities whose implementing responsibilities are divided among various Environmental Protection Agency water, and water-related, programs.

Currently, various sections of six Federal statutes directly impact ground-water concerns. These laws are: the Clean Water Act (CWA), the Safe Drinking Water Act (SDWA), the Resource Conservation and Recovery Act (RCRA), the Toxic Substances Control ACT (TSCA), the National Environmental Protection Act (NEPA) and the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). As my colleague, Vic Kimm, has already given you an overview of the relationship between these statutes and ground water, I won't be repetitive. I will say, however, that all of the necessary authorities appropriate to the Federal role in ground-water protection are probably contained within various sections of these laws. The challenge is ours to coordinate their implementing programs in such a way that effective ground-water quality management occurs. That task is complicated somewhat by State ground-water allocation laws which, in most cases, allow landowners the right to withdraw extensive amounts of ground water while imposing few limitations. State law relating directly to ground-water quality is virtually nonexistent.

The primary responsibility of the Water Quality Management program, under Sections 106 and 208 of the Clean Water Act is to integrate the water pollution control efforts of the Federal, State and local governments in order to achieve the 1983 "goal of water quality which provides for the protection and propagation of fish, shellfish and wildlife and recreation in and on the water . . . . " It provides a State and local government with a mechanism to develop and enforce controls for point and nonpoint source and ground-water pollution.

The program is important in other respects. It is intended to assist State and local governments in the development of institutional capacities—to create or strengthen their substantive abilities in this field. It is also a mechanism whereby economic, fiscal, social and political factors affecting water pollution control can be integrated into State and areawide plans. 208 agencies may also be the focal point for the education of local elected officials, operating agency personnel and the interested public concerning local or regional problems and recommended solutions.

I am aware of the arguments, upon the passage of P.L. 92-500, concerning a usurpation by the Federal government of what were historically State and local prerogatives. Whatever the merit of those discussions, I believe it worthwhile to note that the Water Quality Management program is another example of our Nation's experiment in Federalism. This Federally initiated program was conceived to be State and locally operated. As such, it was intended to be reflective of the regional nature of the water pollution problem, the tendency on the part of most Americans to want to solve their problems locally and to provide opportunities for innovation within the system. Clearly, local engineers and planners have a better understanding of their own water quality problems and priorities and the ability of their communities to address them than do Federal engineers and planners. As the initial Environmental Protection Agency role was to set up the program and to develop its guidance and regulations, I can say without reservation that the Water Quality Management program exemplified the American Partnership.

But it does more than bring governments together in a sharing process. It also brings to one place key elements of the Clean Water Act so that those governments might more efficiently achieve the Act's goals and requirements. Section 208 provides that water quality management plans regulate within their jurisdictions, point source discharges, including publicly owned treatment facilities. In addition to point source controls, it is important to note that Section 208 contains the only Clean Water Act requirement for nonpoint source control (including agricultural, silvicultural and mining practices). Section 208 also requires that plans are to include processes to identify and control saline intrusion, residual wastes and the disposal of pollutants on land or in subsurface excavations to protect surface and ground-water quality.

The structure of the Water Quality Management program, then, lends itself well to the protection of our ground waters. State and local governments are primarily responsible for developing solutions to their water quality problems and all Clean Water Act and other water, or water-related programs, can be applied in concert through this mechanism. All areawide impacts upon ground water including nonpoint sources, landfills and withdrawals can be identified and plans for their control developed. Likewise, ground-water impacts upon receiving streams due to withdrawal or contamination of the aquifer can be considered.

Ultimately, a plan will be developed which will have considered virtually every alternative for the improvement and protection of water quality on a comprehensive, intermedia basis.

I am referring here to the broadest variety of programs. Because 208 agencies will have developed areawide water quality expertise, I can envision a role for them to play in the sole source aquifer designation and management process and in the regulation of pits, ponds and lagoons. There is also a role for them in the siting and regulation of local landfills, as well as the more traditional role of siting and regulating the construction of waste treatment facilities.

I would like to mention just a few examples of those 208 agencies which have been addressing ground-water problems. Among them is my old agency at New Castle County, Delaware. Its planners have examined the state of septic system usage in the planning area. They have found deleterious water quality effects caused by suburban septic systems. Costly relief projects are necessitated by these failures and their impact is expected to increase as septic tank popularity continues to rise because they represent a least cost alternative to sewering. The New Castle 208 has recommended that the County take action, which at a minimum, might include more stringent regulations or more strict enforcement to control the problem.

The Nassau-Suffolk Regional Planning Board and the Old Colony Planning Council in Massachusetts have also been concerned about septics. Both Nassau-Suffolk and Old Colony planners have emphasized good septic system management and nonstructural solutions. Nassau-Suffolk has also addressed the problem of nitrates which have been leaching into the ground water from indiscriminate lawn fertilization. That agency has also cited storm-water runoff as a greater threat to ground-water pollution than is domestic sewage. As solutions to the problem, Nassau-Suffolk planners have proposed street sweeping programs, recharge basin modifications and zoning changes.

Salt-water intrusion has been addressed by a number of 208 agencies including the Ventura County Regional Sanitation District in California. The Ventura 208 has recommended that a moratorium be declared on building wells into the upper, intruded aquifer. Wells would be permitted into the lower zone. An intermediate strategy is to modify the pumping patterns so that pumpage from the upper zones will be reduced, and salt-water intrusion may stabilize and possibly reverse. 208 planning *is* doing its job; problems are being identified; alternatives examined and solutions proposed.

OVERVIEW OF THE PROBLEM

There exist four primary sources of ground-water pollution: saline intrusion associated with ground-water pumping; the movement into ground water of bacteria, nutrients, salt, toxics and other pollutants from agricultural runoff, landfills and septage fields; the percolation of bacteriological and chemical contaminants into and between aquifers caused by improperly installed wells, or by abandoned wells not properly plugged; and the movement of contaminants between interconnected ground- and surface-water bodies.

As you know, due to the extremely slow movement of ground water within an aquifer and to subsurface geological discontinuities, pollutants introduced into an aquifer at one location will usually constitute a localized or, perhaps, a regional problem. Since ground waters lack any significant assimilative capacity such pollutants will likely remain in the aquifer as we have discovered no cost-effective way to remedy the contamination. Six factors, all local or regional in nature, determine the extent of ground-water pollution. Four of them, soil, geology, climate and hydrology exist in nature and are beyond man's capacity to control, although they may be modified. The other two factors, land use and growth patterns are subject to control by man through planning and management utilizing techniques from zoning ordinances to Best Management Practices (BMP's).

State ground-water law must also be understood in order to define further the ground-water protection problem and to place the Federal role in its proper perspective.

The conclusion to be drawn from any study of State ground-water law is that water quality protection is not a significant factor in making ground-water allocation decisions. With regard to percolating waters upon which most State ground-water law is based, there exist five basic categories of law in use among the various States.

The absolute ownership rule, reasonable use rule, and restatement rule fail to address the issue of depletion of a ground-water reservoir. Under the absolute ownership rule a landowner may withdraw ground water without regard to either the impact on neighboring landowners or the depletion of the ground-water reservoir. Under the reasonable use rule a landowner's right to withdraw ground water will be restricted only if it is wasteful, is located on distant or nonoverlying lands, or both. Otherwise, a landowner may withdraw ground water without regard to ground-water reservoir depletions. The restatement rule makes landowners liable for their unreasonable interference with other ground-water uses, but deliberately leaves the issue of ground-water reservoir depletions for legislative resolution.

The correlative rights doctrine addresses depletion of ground-water reservoirs in theory by prorating the "safe yield" of an aquifer among ground-water users.

Approaches for dealing with ground-water depletions vary under prior appropriation. The basic principle that a junior appropriator must stop using water when his withdrawals conflict with those of senior appropriators provides one method for resolving disputes among ground-water users, but does not prevent the depletion of ground-water reservoirs. In some appropriative States the amounts of ground water withdrawn may be reduced in critical ground-water areas. This is essentially a modification of the correlative rights doctrine with an administrative determination of the allowable level of ground-water withdrawals.

Some sources of ground-water pollution are directly related to ground-water allocation policies. Saline intrusion often occurs in coastal areas where ground-water withdrawals result in ground-water levels lower than salt-water levels, allowing the intrusion of salt water into the aquifer. In the West, use of ground water for irrigation may also cause ground-water pollution. Excessive ground-water use may result in the leaching into the aquifer of agricultural chemicals including nitrates from fertilizer and organic decomposition, herbicides and pesticides.

Ground-water allocation policies also affect surface waters. Where excessive withdrawal occurs, ground-water contributions to stream flow decline, inducing aquifer recharge from stream flow. Eventually, stream flow is reduced, reducing the surface body's assimilative capacity and its ability to sustain fish and wildlife. In some situations, the stream may dry up.

To cover adequately the major causes of ground-water pollution, I would like to discuss briefly the relationship of landfills, septage fields and wells to ground-water contamination.

Innumerable waste materials and natural and man-made products with the potential to pollute our ground waters are stored or disposed of on or beneath the land surface. There are over 150,000 land disposal sites in the Nation. Contaminants found in the ground water beneath these sites cover the entire range of physical, inorganic and organic chemical, bacteriological and radioactive parameters. Waste materials are often stored or deposited on land surfaces whereby percolation of rain through the material will carry certain of its constituents downward modifying the natural quality of the underlying aquifers.

Ground-water contamination is also caused by the discharge from on-site disposal systems (septics) of water containing dissolved and other constituents which eventually reach the water table. The threat of pollution becomes more serious if the system is not regularly pumped. The most critical factors influencing ground-water contamination on a local and regional basis, however, are the density of on-lot disposal facilities, the permeability of the ground and the depth to water.

Improperly constructed wells are also a cause of ground-water degradation. If they do not contain a surface seal, or if the seal leaks, poor quality surface water may enter subsurface waters. To avoid contamination, proper well design must consider the type of aquifers penetrated, the quality of waters in each and the relative water or pressure levels existing. Poor quality aquifers must be sealed off to prevent interaquifer exchange.

WATER QUALITY MANAGEMENT PROGRAM DIRECTION

Ground-water problems are generally local or regional in nature. State law historically has placed few restrictions on withdrawals from underground reservoirs, and therefore, indirectly foster ground-water pollution. Ground-water protection through regulation is best accomplished by the States or by regional entities who know best what community needs are and will be, who know best how to balance competing demands upon capital and operating budgets and who know best how to operate within their unique ground-water legal systems.

But what of the Federal role? The appropriate ground-water protection role for the Environmental Protection Agency is to develop programs which will allow the Agency to utilize its resources to help States and local governments solve their own problems. The Agency should provide technical and financial assistance to State governments and areawide agencies which implement the relevant programs. Evaluation of State or areawide programs for progress achieved and substantive quality is also a necessary Federal function.

But I do not see, given the facts, a direct, overarching, Federal role. It is simply not the right level at which to address the problems of ground-water protection.

While there exist several separate and distinct EPA ground-water protection programs, including the Underground Injection and Sole Source Aquifer Programs under the Safe Drinking Water Act and the RCRA land disposal program, among others, I believe that the Water Quality Management program will prove to be the invaluable Federal mechanism in the prevention of ground-water pollution.

As we have seen, the Water Quality Management program brings together all levels of government and all relevant point and nonpoint sources and ground-water quality programs. Available resources with which to plan and implement abatement and prevention programs, whether for ground or surface waters, can be brought to bear through the water quality management process. State and local experts, assisted by Federal funds and technical know-how, will develop plans to solve their own ground-water problems. It is likely that integrated into their recommendations will be regional socioeconomic, demographic and political considerations.

As the Water Quality Management program has developed over the years, it has acquired a wealth of experience concerning water quality control. From the initial emphasis on getting the program going and developing guidance, we have had an opportunity to analyze where we have been and where we want to go. We have acquired a better understanding of water quality problems as they relate to water quality management. We have assessed our successes and failures, our strengths and weaknesses and the proper role of the Federal government in water quality management. We have determined that our process is unique and can accommodate most every program impacting water quality. And, as we are on the verge of receiving the initial round of 208 plans, we have had to think about their implementation.

The State/EPA Agreement is the major tool with which we have decided to reorient our Program. Next year this mechanism integrates water quality planning, management, implementation and evaluation programs. In the future all water programs and other EPA efforts will be included.

Its major feature is that it permits the States, in consultation with the EPA Regional Administrator, to determine their own needs and priorities. Programmatic problems, perhaps institutional, resource deficient or legal in nature will be identified and prioritized as well. The States will also consider the broad panoply of programs and funding sources, both Federal and State, which might be brought to bear to resolve their priority problems. They will be limited only by EPA's own national goals, eligibility requirements and most of all, by their own creativity in determining their approach to getting the job done. Their focus is upon problem resolution, not upon programs.

The Agreement will serve as a management tool for both the States and the Federal government. It represents a State commitment to accomplish its own identified and prioritized outputs in the coming year. It includes a detailed, integrated, intermedia workplan (which by itself serves to reduce the paperwork burden). By identifying all State and Federal sources of funding in advance, the States and EPA Regions can better determine whether sufficient funds are available for obligation, whether they may be used for the purpose intended, or whether alternatives to proposals exist.

The Agreement, then, sets a baseline for State and Federal evaluation efforts with which we can more accurately measure success and pinpoint accountability.

The State/EPA Agreement applies to ground water as well as it does to any other resource problem. The separate States each have their own water quality problems. Some have ground-water problems and others do not. Of those that do, some are more severe than others, and the causes of the contamination may differ. Each of these categories may be addressed in the Agreement.

Each State having a ground-water problem is free to assign a priority to that problem in relation to its other water quality management needs. We can assume that such problems will be assigned high, middle or low significance depending upon the State's own ranking. The State will also identify the sources of funding which may be applied to problem resolution. To solve a ground-water problem a State may use funds from the Clean Water Act under the Program Grant (106), Construction Grants (201) and the Water Quality Management (208) sections. Relevant sections of the Resource Conservation and Recovery Act may also be utilized.

Programs too, will be State designed. If a land disposal site, for example, is polluting an underlying aquifer, a program to remedy the problem can be fashioned and implemented through the Agreement. An areawide agency may be identified to complete planning and a management agency may be designated, upon appropriate State and local approvals, to implement the plans. In this case, sections 106 and 208 of the Clean Water Act, section 1424, Sole Source Aquifers, of the Safe Drinking Water Act and the 3000 series, Hazardous Wastes, of the Resource Conservation and Recovery Act are, at a minimum, applicable to the development of a comprehensive solution to the problem.

The State/EPA Agreement contains benefits for the States and for EPA. Its major advantage is that the States will be able to bring maximum resources together to solve their priority problems in a systematic manner.

I would like to thank you for this opportunity to speak to you today. In closing I will pledge the efforts of the Water Quality Management Team of EPA to do our share in solving the ground-water protection problems of this country. I firmly believe that with the 208 program and other EPA programs melded together through the State/EPA Agreement, States and local governments will have the Federal tools to solve their existing and potential ground-water problems.

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The 208 Planning Approach to Ground-Water Protection — A Foot in the Door[a]

by Donna Wallace[b]

ABSTRACT

The benefits of employing the 208 planning approach in the protection of surface water or ground water are twofold—one, involvement of the public early in the planning process and two, determination of solutions that are implementable. With increased public awareness precipitated by the required involvement in Water Quality Management Planning (WQMP), the ensuing public interest will ultimately force ground-water issues which have been neglected for many years. The preparation of a "5-Year Strategy" in each State coupled with USEPA's new emphasis on aquifer protection as a priority issue will provide the mechanisms for funding ground-water planning under 208 programs. As the cry for ground-water management planning is adopted by the public as well as technicians, emphasis will shift and programs will develop. In addition, planning programs under 208 are usually regional in nature in contrast with the ground-water studies in recent years which have been site-specific, directed toward the identification and alleviation of local problems. Since the management approach requires that the evaluation of available alternatives include those mechanisms necessary to implement the recommendations, viable alternatives without either management agencies or financial considerations will not be acceptable. Therefore, the strength of the WQMP approach to ground-water protection lies in those concepts that make planning under 208 a new breed of governmental program.

INTRODUCTION

Ground-water management planning becomes more significant each year as the disposal of wastes is directed away from rivers and streams and toward the land. In an effort to provide cleaner streams, regulations require removal of most pollutants before discharge to surface water. These contaminants are later placed in sanitary landfills in the form of sludge or liquid wastes. Both hazardous/toxic and nontoxic residual wastes from industries find their way to land disposal as well as those leftover materials from man's activities in general. As pollutants move toward the land, the potential for ground-water pollution increases, and ground-water protection becomes more significant. Until recently, ground-water management planning has been generally overlooked, but a new planning approach has begun to offer some hope in terms of ground-water planning issues. The 208 planning approach is a combination of some old programs that produced, or were to produce, water quality management plans, and the addition of a very new concept in Federal planning programs designed to put the plans formulated under the 208 program into practice. The general opinion at both the State and Federal level is that the 208 approach has a better chance of being functional than past planning programs. If this is found to be true and if ground-water quality management planning can be drawn under this umbrella, States may finally find the mechanism for the long-awaited planning needed to protect ground-water resources.

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THE GROUND-WATER PLANNING PROGRAM IN ILLINOIS

Ground-water protection in Illinois is similar to that in many States, significantly behind a few progressive States, and somewhat ahead of a few seriously lagging States. In general, when ground-water pollution problems are discovered, detailed site-specific studies are designed, data collected and evaluated, causes identified, solutions determined, and, when necessary, enforcement cases prepared. This type of activity could be more accurately termed "remedial action." The protection portion of the ground-water activity in Illinois centers on the Illinois regulation that no source may cause or contribute to causing a water quality violation. Since ground water continues to be considered waters of the State, ground-water pollution is also covered under this regulation. The improvement or maintenance of water quality resulting from regulation is, however, dependent upon the degree of enforcement applied. In ground-water pollution, as in that of surface-water quality, only the major cases of pollution justify the time required to prepare legal action and to provide the data necessary to prove that pollution can be attributed to a single source. Therefore, in reality, water pollution, both surface and ground, is held to a minimum level as much as possible within the resources of the existing programs. Although this approach provides a reasonable degree of protection in terms of control, there is not a high degree of planning for the management of future ground-water quality and quantity.

Illinois can rightfully claim to have a reasonably successful statewide 208 Water Quality Management Planning Program, although it has not been advanced in terms of ground-water planning. Due to the levels of Federal funding available for statewide planning, certain decisions were made early in the program to limit the pollution sources to be studied to those most likely to result in implementation. This narrowed the scope of the program but aided in maintaining realistic objectives that allowed planning to progress beyond the problem assessment phases in those areas under study. Ground-water pollution problems were not seen as belonging in the category likely to yield solutions. In fact, the history of ground-water management planning in Illinois suggests a small commitment to address ground-water planning that managed to get smaller. More importantly, in terms of the initiation of ground-water planning, the lack of commitment appeared to be common with both the Illinois EPA and the USEPA.

Two major obstacles stood in the path of ground-water planning initiation in Illinois. First, the three designated areas in Illinois where specific problems had been identified were funded early. This left the statewide agency, IEPA, significantly underfunded and programs were severely restricted as noted earlier. In designated areas where funding was more realistic, the areas covered were so small, 19 of 102 counties, that results of studies completed within them were not representative of the State as a whole. Therefore, localized studies were not likely to result in statewide policy decisions.

Second, Illinois has an extremely comprehensive historical ground-water quality data base scattered among half a dozen State agencies. However, only one of these agencies has the data readily available on a computer. No agency engages in ground-water management planning as a major portion of its activities. This requires that Illinois begin ground-water efforts at the data compilation phase. Data evaluation efforts appear productive and even data collection efforts seem reasonable, but there is little marketable in data compilation efforts. Program managers understood that neither the public nor USEPA can visualize data compilation as providing early outputs. Therefore, once the initial 208 program was defined with minimal ground-water emphasis, it became even more difficult to secure funding.

THE 208 PLANNING APPROACH

Although in most States surface-water quality management planning has been addressed for five to ten years, Federal and State programs have not been totally successful. Past approaches to planning for surface-water protection have resulted in data collection, evaluation, and the preparation of plans that generally were not implemented. This is where the 208 approach differs from past planning programs. The 208 concept addresses three new requirements for plans prepared with Federal funding. (1) Plans must have continual public involvement, (2) alternatives must include the definition of mechanisms for implementation and (3) plans must be updated annually to reflect the results of each year's progress. This suggests that the public must have a hand in determining which solutions should be selected since funding for implementing alternatives is not provided in the 208 program. In addition, the solutions are to be implemented and not simply discussed and shelved, and changes in solutions may occur as a result of additional studies. To ascertain that implementation strategies be carried out, much of the Federal funding for other State pollution programs has been tied to the success of 208. Therefore, there is reasonably strong Federal support for successful State 208 programs—addressing surface-water pollution.

The mechanisms built into the design of 208 planning which aid surface-water planning will aid in the establishment of direction of 208 studies for ground-water quality as well. Under the 208 approach, nonpoint sources are addressed in the following general manner:

1. Problem assessments are designed and performed to determine the relative contribution of each source and priorities are established.

2. Alternatives are defined for control of significant pollution sources and evaluated in terms of the ability to implement each alternative.

3. Recommendations of alternatives that best fit the needs are determined from an examination of costs versus benefits.

4. Implementation strategies for the recommended alternatives are determined and put into practice.

5. Evaluations of the effectiveness of the alternatives are conducted after implementation has occurred.

6. New recommendations are made based on new information or if old recommendations are shown to be ineffective.

Although site-specific studies and evaluations are allowable and in some cases necessary, the 208 planning approach requires that nonpoint problems be addressed on a statewide basis. Therefore, if 208 planning operates properly, controls will not be placed on one source of ground-water pollution (wastes placed in sanitary landfills) while ignoring others (improper installation of ground-water monitoring wells). In most cases, these controls will also be applied in a similar manner on a statewide basis.

But until recently, 208 has been of little value in producing any direction for ground-water planning in other States as well as Illinois. Initial 208 plans in most States barely address ground water, if at all. Federal funding for the States' portion of 208 planning has been at a minimum due to the late recognition of the necessity of statewide 208 planning. The bulk of the early Federal funding for 208 planning was provided to areas where specific sources of pollution could be identified and planning was initiated early to address those identified sources. With funding levels low, State program administrators were required to identify those issues most significant and familiar; and, with implementation a major issue in 208, priority was given to those sources of pollution most likely to provide implementable solutions. Generally ground-water pollution did not qualify as either significant or familiar. A few token studies were initiated but, as ground-water technicians were quick to realize, funding levels were far too low to provide definitive results.

Once the initial 208 plans have been completed nationwide, a more favorable climate should exist in terms of ground-water studies. Most States will have found that the control of point sources has been defined but that the contribution of these sources to surface-water quality is relatively low compared to that of nonpoint sources. In addition, the most significant nonpoint sources in each State will have been addressed and the level of contribution defined. In only a few States, ground water itself was identified as a major nonpoint source. Program administrators and planners will begin to identify the degree of control that will be achieved as a result of implementing these initial 208 plans so that the scope of future planning programs can be redirected. Since 208 has required elaborate public participation programs from its inception, this direction for the future planning programs will have to come, in part, from the people. If planners are to be successful in determining the relative contributions of nonpoint sources so that pollution problems may be controlled, planners will also influence the direction of the program.

THE FUTURE OF 208 PLANNING

While future 208 programs are being designed at the State level, some significant activities have occurred at the Federal level which will impact the States' decisions. Since the 1977 Clean Water Act called for the examination of all State water quality management programs in terms of overlap or gaps, USEPA has defined an expanded list of priority areas for 208 funding. This list includes, among other point and nonpoint sources, salt-water intrusion and aquifer protection. The USEPA rationale is that (1) 208 has proven itself to be a viable program for the solution of water pollution problems and (2) funding for planning is not presently available under related Federal programs

(Safe Drinking Water Act, Resource Conservation and Recovery Act, etc.). Thus, USEPA has laid the groundwork for including planning for ground-water protection in future 208 planning programs.

It must be understood that recognition of ground-water issues by water quality planners is only an initial step. Once their attention has turned to ground water, the second major issue of overlapping authority among State agencies can be addressed. Although surface-water quality authority is relatively fragmented, responsibility for ground-water quality and quantity appears to be even more so. Control of the various pollution sources rests with one group of State authorities while the quality and relative availability of the ground water itself rests with a second group. With little funding directly tied to ground-water management, efforts in most areas have been minimal, of necessity, and fragmented. It is obvious that a program to address all aspects of planning for ground-water protection must be established. The importance of such a program will not lie in which agency is actually performing the data collection, analysis, and description of alternatives but instead in the interrelationship of the proposed alternatives, in the inclusion of all significant sources of ground-water pollution, and in the determination of the levels of protection that are both technically and economically reasonable.

Federal guidelines suggest that USEPA also recognizes this need. As mentioned previously, ground-water programs have been added to the list of sources to receive priority Federal funding; and USEPA has determined that preplanning of future directions of 208 will occur prior to the release of the remaining 208 funds. The mechanism to establish this preplanning, called annual Water Quality Management Planning (WQMP) programs, is the requirement that States prepare a "5-Year Strategy" delineating the status of planning, the problems not yet solved, and the programs to be initiated to solve these problems. In terms of ground water, one of the most significant requirements is that this "Strategy" not be prepared solely by State program administrators. 208 calls for public involvement and the strategy follows suit. Not only do citizens have to be allowed to react to the proposed programs but other agencies must describe how their activities will be related to that which is proposed. As the program progresses, the strategy must be fine-tuned and updated annually. But most importantly, this strategy must actually describe the studies to be performed, who will be responsible for completing the work, how much it will cost, and when each study will be initiated. The first "5-Year Strategy" for each State is to be submitted to USEPA in September. Once this document is approved, some form of interagency coordination will be required. Therefore, development of planning for ground-water protection will require the coordination of all agencies involved in ground-water studies.

THE FUTURE OF 208 GROUND-WATER PLANNING IN ILLINOIS

The outlook for ground-water planning began to improve late in 1977 when two proposals were submitted to USEPA in request of supplemental FY'77 funding. The first would have expanded the ground-water studies to a minimally acceptable level. The second was to assess the impact of oil field brine disposal. Although USEPA rejected the first proposal, they did fund the second, concerning oil field brine pollution.

It appeared that Illinois EPA was beginning to recognize the need for ground-water planning but USEPA still seemed hesitant. The turning point came in early 1978 when USEPA agreed that if ground-water proposals were included in the requests for FY'78 funds, they would be given careful consideration. True to their word, Illinois has just received $120,000 in USEPA 208 funding to begin ground-water management planning on a statewide basis. And the situation is still improving.

In September, Illinois submitted to USEPA their strategy for the funding of Water Quality Management Planning studies over the next five years. The commitment to ground water was ten percent of total budget or two and a half million dollars. The initial studies were, of necessity, data compilation efforts. Once the data compilation and collection is completed, the following studies address problems concerning the major sources of ground-water pollution. Two full years have been devoted to actual policy preparation and evaluation for ground-water management. Following are the five-year objectives for the ground-water program:

1. To compile the existing data to provide a comprehensive data base for use in management decisions.

2. To locate and determine the contributions of significant sources of ground-water pollution.

3. To determine the ground-water contributions to surface-water quality in those areas where background concentrations cannot be explained in

terms of known point and nonpoint sources.

4. To determine the regional flow systems and the recharge areas for ground water.

5. To determine which areas have a high potential for ground-water contamination.

6. To examine the problems associated with existing and abandoned public water supply wells and nonpublic water supply wells.

7. To evaluate the impacts of industrialization, underground injection, artificial recharge, and land disposal on ground-water quality.

8. To project future ground-water quality based on existing and proposed practices.

9. To develop the necessary State policy, regulations, and/or legislation to control ground-water degradation.

THE OUTLOOK FOR GROUND-WATER PROGRAMS IN OTHER STATES

The initial directions that ground-water management planning will take should be fairly well defined by late 1978, considering the schedules established by USEPA. It is the fine-tuning that will occur after this time that will more significantly influence the ground-water planning in the nation. Initial strategies will probably address ground water in terms of some planning studies identified, but development of the alternatives required for protection of ground water will only come as a result of the problem assessments once they have been completed. Although past experience with surface-water planning will aid in the development of ground-water planning, control programs require time for development, and implementation is slow. A possible scenario for minimal ground-water planning follows.

> "Point and significant nonpoint sources of surface pollution will be identified and reasonable controls determined. The resultant water quality will be evaluated, often by means of complicated water quality modeling. This water quality to be expected, following implementation of previously identified controls, will then be evaluated as to the relative contributions that can be attributed to other nonpoint sources and those that can be claimed as naturally occurring and therefore not controllable. That contribution claimed as natural background will be described as the result of geologic conditions including the ground-water contribution."

At this point, if ground-water quality management has not received sufficient emphasis, the technical and social outcry will be loud. Efforts to claim excessive levels of unusual contaminants (heavy metals, for instance) to be naturally occurring in ground water will immediately establish the need for more detailed ground-water evaluation. If program managers miss this important linkage, the public, who will be expected to pay the bills for other controls, will not. Therefore, the evaluation of initial 208 programs will force ground-water quality evaluations on a regional basis.

Obviously, all ground-water problems may not be addressed if the needs of ground-water quality studies and planning are not recognized on their own merit. Quite possibly, the entire ground-water question could result in the definition of the contribution of ground water to surface-water quality and little else. Should this occur or appear likely to occur, the public may well express the opinion that such conclusions are a whitewash and more careful examination is not only warranted but required.

Past experience with 208 planning has shown that the public, especially special interest and environmental groups, are remarkably well informed and certainly vocal. This group, the informed public, is unlikely to be satisfied with the basic description of ground-water quality as naturally occurring. So that, if program managers fail to move into meaningful ground-water management planning programs, the public will insist on evidence that polluted ground-water quality should be claimed as natural. If ground-water pollution is shown to be caused by man and his activities, solutions will have to be forthcoming. Since 208 cannot avoid public input, it cannot totally ignore public advice or comment. Therefore, regardless of early or late recognition, the results will ultimately be unavoidable and ground-water planning will be initiated.

The real question facing the ground-water planning proponents is how this process can be insured or better yet, hurried. It seems apparent that NWWA has recognized the positive aspects of the 208 planning approach since this topic was included in a program addressing significant ground-water issues. It would also seem that those who attended the Symposium see a need for ground-water planning. Obviously, there is no cookbook remedy for lagging ground-water efforts but a number of opportunities are now available to those believing in both the need for and value of 208 planning.

First, as a citizen, planner, or technician, insist on a copy of your State's "5-Year Strategy." Check carefully for the direction of ground-water planning as envisioned by program managers. One of the significant aspects of strategy development is the requirement for an annual revision; therefore, the lack of a well defined program for ground-water planning is not irreparable if recognized.

Second, get involved in the 208 planning program. States are required to have elaborate public participation programs with weight on the participation of local elected officials. Remember local mayors and councilmen may not understand the impacts of ground water in their areas. Visit them and explain your concerns.

Third, and most important, share your interest and abilities with those involved in doing the actual planning. Do not smile knowingly when ground-water quality is generally claimed as a "given" or worse—natural. Forget apathy, get involved, be heard!

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Donna Wallace is the 208 Program Coordinator for Illinois' Water Quality Management Planning Program and is also responsible for the ground-water portion of the technical studies being performed under this program. Donna holds an M.S. in Geology from Iowa State University at Ames and has taken post-graduate studies in both environmental engineering and public administration. During her five years of employment with Illinois EPA, she has been responsible for the implementation of the State's ground-water monitoring program for sanitary landfill sites and coordinated the preparation of the State's Basin Plans, the predecessor of 208 planning.

The 208 Planning Approach to Ground-Water Protection — What Is Wrong and What Can Be Done About It?[a]

by Kenneth D. Schmidt[b]

ABSTRACT

Generally, the 208 planning approach is deficient in a number of ways. Its origin lies in Public Law 92-500, which focuses on protection of surface water and special uses of water for fish, wildlife, and recreation. Little ground water is used for these purposes. Nonpoint sources have not been defined in terms that have hydrogeologic significance. Local and State regulatory agencies have often been unsuccessful in controlling ground-water pollution, yet the 208 approach tends to disregard the reasons for this situation. The reasons for ground-water pollution in an area must be understood before meaningful control measures can be enacted. These include both technical and institutional problems.

Planners are placed in the forefront of many 208 programs at the local level and often their backgrounds are inadequate in ground water. There is a great lack of ground-water professionals in regulatory agencies involved, particularly in the Southwest. This deficiency is paramount at high levels and in many regional offices of EPA. There are no provisions in the approach to insure that qualified ground-water geologists or hydrologists will be involved. Academic training in ground water is presently oriented toward ground-water development and not pollution. Lastly, public participation is greatly limited by the general lack of knowledge regarding ground water and its pollution.

Successful 208 programs in terms of ground water have been enacted when ground-water professionals have had major roles. Changes are necessary in the academic training of ground-water geologists and hydrologists. The public must be educated concerning the long-term consequences of ground-water pollution. Lastly, ground-water professionals must assume the leadership in ground-water protection.

There are numerous deficiencies in the 208 planning approach, particularly with respect to ground water. Many of these deficiencies are common to other water pollution control approaches at the Federal and State level. It is the author's objective to discuss what is wrong with the 208 planning approach in terms of ground-water quality protection. In addition, remedial measures are proposed that could correct some of the deficiencies in the present approach.

One of the major problems with the 208 approach is obvious in reading Section 101 of Public Law 92-500. Although the objective of the act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters," a number of specific goals and policies were stated that effectively ignore ground water. Navigable water, waters of the contiguous zone, and the oceans were all given special attention. Also, special uses of water were to be protected, namely fish, shellfish, wildlife, and recreation. On the other hand, the major uses of ground water

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in the U.S. are for irrigation, public supply, domestic, industrial, and mining purposes. It is my opinion that these are far more important than the special uses designated for protection in Public Law 92-500, as only an insignificant amount of ground water is used for the special uses.

A careful review of Public Law 92-500 clearly indicates an overwhelming emphasis on surface-water quality. This emphasis has hopefully resulted in some improvement in surface-water quality since 1972; however, much of this improvement has occurred at the direct expense of ground-water quality. The number of potential sources of ground-water pollution was greatly increased through implementation of portions of Public Law 92-500 and air pollution regulations. Examples include disposal of sludge and effluent from new and expanded sewage treatment plants, and on-site disposal of wastes formerly disposed indiscriminantly to sewers. The present emphasis on land disposal or treatment will undoubtedly create numerous new potential sources of ground-water pollution.

Despite the fact that the Safe Drinking Water Act (Public Law 93-523) indicates a strong concern for the quality of drinking water, there has apparently been no similar concern at the Federal level to protect water used for irrigation, industrial, and mining purposes. In the western U.S., much more ground water is used for these purposes than for drinking water.

CONCERNS IN ARID LANDS

Besides virtually ignoring ground water, Public Law 92-500 also deals primarily with humid area problems. An example is emphasis on treatment of sewage and industrial wastes which often were formerly dumped untreated or poorly treated into streams, particularly in the eastern U.S. While sources such as sewage, industrial wastes, and storm runoff may comprise the major sources of surface-water pollution, they may be but minor sources of ground-water pollution. There are no perennial streams in much of the Southwest and wastes are disposed to the land or to intermittent or ephemeral streams. The major uses of such streams are obviously not for the special uses to be protected, as specified in Public Law 92-500. Instead the major use may be for ground-water recharge. Curiously enough, the use may apply to the stream bed instead of the water in the stream.

A common situation in arid lands that may be unusual in many humid areas is the long time required for pollutants to travel from the land surface to the water table. This travel time is commonly decades or even centuries in arid areas. Additional time is required for pollutants to travel from near the water table to the producing zone of a well and thence to the well. Ground-water pollution ordinarily cannot be seen even when it occurs. The combination of these and other factors renders ground-water pollution a much different entity than surface-water pollution, particularly in the western U.S. Public Law 92-500 fails to recognize this difference and its importance for protection of ground-water quality.

DEFINITION OF SOURCES

In terms of surface water, a point source may be rather obvious—namely, a waste discharge from a pipeline or other discrete structure. The term "nonpoint source" has been used for diffuse sources of pollution. An example is storm runoff into streams, whereby pollutants can be introduced over a great distance and not just at one point. The terms "point and nonpoint sources" as used in Public Law 92-500 have limited significance in terms of ground water. For example, in some 208 programs, "point source" has been used for sewage, regardless of the method of disposal of the effluent or sludge. Alternative disposal methods include ponds, normally dry stream channels, irrigation, and landfills. All other sources of pollution are termed nonpoint sources, regardless of the type of waste or the method of disposal.

Sources of ground-water pollution should be defined in terms that have hydrogeologic significance. Hydrologists have customarily spoken of recharge from point, line, and diffuse sources. Schmidt (1976a) proposed a similar use of this terminology for sources of ground-water pollution. Point sources occur over small areas, and include percolation ponds, landfills, and disposal wells. Line sources have the length dimension much greater than the width, and include discharge to a normally dry stream channel and leaking sewers. Diffuse sources occur over large areas, and include suburban areas on septic tanks and return flow from crop irrigation. The type of source is important in designing monitoring programs and formulating control measures. Since an evaluation of ground-water pollution starts at the source, the importance of source evaluation should not be overlooked. Several EPA publications dealing with nonpoint sources (U.S. Environmental Protection Agency, 1973 and 1976) have little direct relevance to ground water.

WASTE TREATMENT MANAGEMENT

Much of Public Law 92-500 deals with waste treatment management. "Waste treatment" is somewhat of a strange concept to ground-water geologists and hydrologists. Most specific types of waste treatment have been directed toward disposal of wastes to surface water, odor considerations, or some other concern. An example is reduction of suspended solids content and biochemical oxygen demand for sewage. Few examples of waste treatment designed specifically for ground-water disposal can be found in the literature. Instead, the usual procedure has been to evaluate the soil and other nonstructural factors. If these factors cannot be managed to preclude ground-water contamination, a liner is used to limit infiltration or seepage loss. This concept is in diametric opposition to classical structural solutions. These "solutions" emphasize removing specific pollutants from a waste stream prior to discharge.

The concept of areawide waste treatment management discussed in section 208 is but one approach. An alternative approach begins with an evaluation of the ground-water quality. The impact of waste disposal is determined, and then the type and degree of waste treatment is specified, if any is necessary. Sewering is an informative topic relevant to this concept. It is questionable on a national scale whether sewering has improved ground-water quality or not. Certainly new sources have been created, such as thousands of miles of sewers that may leak. Secondly, the concentration of wastes in small areas due to regionalization of facilities, which was formerly widely promoted as the best alternative, tends to pollute ground water. The latest findings for disposal of effluent by percolation suggest that primary treatment is preferable to secondary treatment for nitrogen removal, which is one of the major concerns. Also, chlorination of effluent may not be desirable if disposal is by percolation. Sewering in itself can adversely affect ground-water quantity in an area due to export of pumped ground water to downgradient areas. It is now becoming widely known that the adverse effects of septic tanks were greatly exaggerated in many areas in order to promote sewering. These and other factors bring into focus the question of the meaning of "areawide waste treatment" in terms of ground water. On a national scale, many of the wastes that we are attempting to treat are not the major sources of ground-water pollution. Secondly, the method of treatment selected often has nothing to do with ground water. Thirdly, the method of treatment chosen often has a side effect of polluting the ground water, due to the production of sludge and other factors.

LOCAL IMPLEMENTATION

At the local level, 208 planning has often been attempted by the planning community. In general, this group is deficient in both academic training and work experience in geology, water, soils, water quality, and ground water. All of these disciplines are integral parts of a 208 program where ground water is to be properly considered. The end result in many 208 programs where there has been insufficient input by ground-water professionals has frequently been a waste of large amounts of money and several years of time. Without qualified ground-water geologists and hydrologists involved, meaningful plans cannot be formulated to protect the ground water. In fact, plans may be formulated which can seriously pollute the ground water.

FORMULATION OF CONTROL MEASURES

The 208 approach focuses on formulation of control measures for nonpoint sources of pollution. As opposed to surface-water pollution, ground-water pollution takes a much longer time to manifest itself. Only some of the present sources of ground-water pollution are susceptible to immediate control measures. This is because little or no monitoring is available in most situations to determine the nature and extent of the problem. Thus only the most obvious sources offer potential for immediate control. Examples include disposal of brines and hazardous wastes in percolation ponds or wells, where direct pollution of the aquifer may occur. In most cases artificial liners may be necessary to prevent seepage. The majority of nonpoint source ground-water pollution is caused by diffuse sources. Such sources will require decades of monitoring before the impact on ground water can be determined. The 208 approach focuses too much attention on formulating control measures and not enough on problem definition and monitoring. In most cases, extensive monitoring is necessary prior to development of realistic control measures. This monitoring includes source monitoring, assessing infiltration potential, and evaluating pollutant mobility in the vadose zone and aquifer.

A common strategy in many 208 programs is to rely on existing data, without accomplishing site-specific monitoring. Often this entails using previous reports which were not prepared for the purpose of protecting ground-water quality. Numerous recycled mythologies are quoted for decades in some areas, based merely on opinion and not on actual water quality data. For example, in the alluvial valleys of southern Arizona and parts of the San Joaquin Valley of California, it has been frequently stated that ground-water salinity is increasing beneath irrigated areas. Also, it is frequently stated that overdrafting increases the salinity of ground water. Neither of these generalities is supported by actual data. For example, extensive chemical analyses of ground water in the Salt River Valley of Arizona since the 1920's indicate that the predominant long-term trend has been a constant salinity. The second most frequent long-term trend has been a decreasing salinity. The most infrequent trend has been one of increasing salinity, which has occurred only in two specific areas due to altered ground-water flow directions. Salt balance calculations have been made which contain the assumption that there is no dissolution of minerals or precipitation of salt in the soil-aquifer system. Substantial increases in salinity of ground water with time are projected from such calculations. The results of these calculations frequently do not agree with historic ground-water quality records. Use of recycled mythologies can lead to implementation of costly control measures for no reason.

In many areas, an abundance of records are available, but may not be collected or well organized. Data collection and organization itself may take several months or years, and must be done before interpretation is possible. With little or no understanding of the present or historical situation, there is little likelihood of meaningful control measures being formulated. Natural factors often exert a predominant influence on ground-water quality on a regional scale. The 208 approach does not focus on distinguishing between natural and man-made factors that affect water quality. Such a distinction is necessary if man's activities are to be evaluated. Although natural factors may not be subject to control, information on them can be extremely useful for future management of ground-water quality.

REASONS FOR GROUND-WATER POLLUTION

If meaningful protective measures for ground-water quality are to be formulated, the exact reasons for ground-water pollution in an area must be known. Causative factors include: (1) indifference or lack of knowledge of polluters, (2) lack of knowledge and awareness of public, and (3) regulatory agencies. In some cases polluters are unaware of the impact on ground-water quality of their operation. However, in many cases wastes are merely swept under the rug and into the ground water. Limited data now available indicate that there has been an extreme lack of concern, particularly for disposal of hazardous wastes. Protection of ground-water quality requires a long-range perspective by water users and potential polluters, often difficult in today's economic climate.

The public lack of knowledge of ground water is extensive throughout the nation, as attested to by the prevalence of water witching. The meaning of the word "hydrologist" is not understood by many people. Presently there is little concern for problems that seem decades away. As such, the public is susceptible to acceptance of the easy or cheap short-term solution. With the public lack of knowledge and apathy, it is difficult for the public interest to be protected in matters of ground-water quality. The environmentalists and consumer advocates have yet to enter the field of ground water in most areas. Politicians have had little incentive to protect ground-water quality when there is no pressure to do so. The long-term solutions are often contradictory to short-term interests.

An important aspect of ground-water pollution lies within the regulatory agencies themselves. In my experience, they are often part of the problem. The 208 planning approach is to go through the State and local regulatory agencies. Ground-water professionals familiar with the national state of ground-water pollution must ask – "What have these agencies done in the past, and what are they doing now to protect ground water?" Often the answer is little or nothing. This situation is well documented in the excellent report on ground-water pollution by hazardous wastes (Geraghty and Miller, Inc., 1977). In many cases, regulatory agencies have dealt with polluters behind the scenes, away from public scrutiny. As such it is difficult for the public interest to be protected. Perhaps the biggest problem is the lack of qualified ground-water professionals in local, State, and Federal regulatory agencies. This is particularly true in the Southwest. Often sanitarians, sanitary engineers, or civil engineers are at the forefront and their knowledge of ground water is usually inadequate. As proven in some States, excessive amounts of money coupled with extensive regulations do not insure ground-water protection.

HYDROLOGIC INPUT

The 208 approach was developed with little apparent hydrologic input. My opinion is that a number of politicians and administrators and staff of EPA throughout the country still lack adequate knowledge of ground water. This is suggested by numerous recent publications in which surface water is still given predominant attention; for example, the publication on nonpoint source guidance–hydrologic modification (U.S. Environmental Protection Agency, 1977). On a national scale, there has been no mechanism developed to enhance hydrogeologic input to regulatory agencies. There is no provision in the 208 approach to insure that ground-water professionals will be involved. Hydrologists and geologists have taken a back seat in most 208 programs to engineers, planners, lawyers, sanitarians, soils scientists, and others. The same situation is true in many other EPA programs.

Land disposal or treatment is another area where there has been a lack of hydrogeologic input. Numerous evaluations of the impact of land disposal of wastes have been reported in the literature by researchers with little or no training in ground water (Schmidt, 1978). "Land treatment" has been widely promoted and is given special consideration under present Federal policy. In fact, qualified people are not available to operate the numerous proposed land treatment systems. Secondly, there are not enough ground-water professionals to properly monitor such systems. Thirdly, little data is available from existing systems due to monitoring deficiencies.

Probably the only 208 programs in the country where ground-water quality has been successfully considered are ones where experienced ground-water professionals have assumed paramount roles, such as the Long Island, New York and Phoenix, Arizona programs. Ground-water geologists and hydrologists must be placed in the leadership in ground-water quality protection if meaningful results are to be expected. This includes professionals at high levels in EPA. Registration or certification in ground water is urgently needed.

TRAINING OF HYDROGEOLOGISTS

In many respects, academic training of ground-water professionals has a similar orientation to that of a decade or two ago. Prime consideration is usually given to ground-water development and aquifer testing, and water quality may receive only a minor consideration. The recent survey of university classes in ground water on a national basis by NWWA indicates only a few classes devoted specifically to water chemistry or ground-water quality. Also, ground-water training has historically focused more on the part of the soil-aquifer system below the water table than that above. Investigations of ground-water pollution also involve the vadose zone, particularly for diffuse sources and in arid areas. Pollution sources and the vadose zone are more important considerations in some situations than the aquifer itself. Also, many hydrogeologists tend to be poorly trained in chemistry. Soils chemistry, water chemistry, and geochemistry are all important aspects of ground-water pollution evaluations. Many new ground-water professionals are being asked to work extensively on ground-water quality problems. Obviously, their academic training is often inadequate for this purpose. Schmidt (1976b) proposed a new approach for the academic training of hydrogeologists who specialize in ground-water quality. This approach includes specific training on pollution sources, including courses in sanitary engineering, mining, agriculture, and other fields. Ground-water quality specialists must be well trained in water chemistry, soils chemistry, and geochemistry. Newly developed classes on ground-water quality are necessary. Water and pollutant movement through the vadose zone must receive greater attention in academic education.

SUMMARY AND CONCLUSIONS

The basic deficiencies of the 208 planning approach relative to ground water stem from the fact that the goals and policies set forth in Public Law 92-500 emphasize protection of surface water. Secondly, special uses are to be protected which do not coincide with the major uses of ground water. Many politicians and EPA administrators and staff in decision making positions have an inadequate understanding of ground-water pollution. This was true when Public Law 92-500 was formulated and is still true today. There is a serious lack of ground-water professionals in local, State, and Federal regulatory agencies. There are no provisions to insure that qualified ground-water professionals are involved in 208 programs. Lastly, ground-water professionals are often poorly trained in ground-water quality, partly because of the past emphasis on ground-water development and the quantitative aspects.

Solutions to these problems include placement of more ground-water professionals in local, State, and Federal regulatory agencies. Ground-water geologists and hydrologists must assume leadership roles in ground-water quality protection. Provisions are needed in the 208 approach to insure that ground-water professionals are involved. The public should be educated on a long-term basis about ground water and pollution. Academic training in ground water needs to be expanded and ground-water quality elevated to the same level as ground-water quantity. There is an urgent need for registration in the field of ground-water hydrology and additional development of the profession.

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Audience Response to Session VI — The 208 Planning Approach to Ground-Water Protection

Russ Stein, Chief, Division of Ground Water, Ohio EPA, 361 E. Broad St., Columbus, Ohio 43215: I agree with both positions on this topic. I think in theory the idea of 208 planning is certainly a foot in the door, but I see some problems because I think the preliminary plans that have been developed so far are a terrible joke. I think the reason for this is the fact that the 208 program has been put together under a very strenuous schedule of completion.

Our 208 staff consists of a large number of young men and women who do not have any training; they do not have any experience and their disciplines do not in fact coincide with the job they're supposed to be doing. As it turns out, they really don't know what they're doing. Consequently, we're ending up with biologists who are working on sewage treatment plant plans, and what geologists we do have are not working on ground water. They are not that experienced in ground water. They're right out of school, probably interested in other specialties in geology. This was a job, a lot of money available. So consequently, I think there's a great need to provide at some level, the training of these people. Maybe it's too late now. I guess it is.

My greatest problem with 208 planners is the fact that I work in the same building with them and I'm not a 208 planner. I would love to be able to sit down with these people and possibly help train them, but I just simply don't have time to do this. Every other day I've got a young man or a young woman coming down to ask me a lot of questions that I could handle if I had the time.

I would like to ask a question of Donna and possibly Merna and Ken if you'd like to respond. Donna, did the State of Illinois have this problem, and if you are progressing on this program, how do you approach this within your time frame?

Donna Wallace, Illinois EPA, 107 S. Douglas, Springfield, Illinois 62704: Is your question do we have a problem with the quality of the people doing the planning?

Russ Stein: Yes, that, and the training aspect of getting some experience and expertise in this area to do the job.

Donna Wallace: You bet. The 208 program builds on top of the 303-E base and planning program which builds on top of numerous other programs that came before. When we got 208 planning in Illinois, we had a planning staff doing 303-E planning, which for Illinois was data collection only. All we did was add more people, and essentially the more people were two different kinds. One, a group of technicians which are still inadequate but we're still building, and a group of management public participation type people who knew how to get to the public because they had some experience in planning the agencies in general. We're not there yet either, and our first plan is going to be pitiful. I think it's magnificent that we've gotten this far. But I think it's significant only in that we're off the ground and moving, and this is a very new field for almost everyone.

Jay Lehr, Executive Director, NWWA, 500 W. Wilson Bridge Rd., Worthington, Ohio 43085: Perhaps some advice we might offer Merna is that the initial plans completed anywhere close to the deadline might be taken with a grain of salt and some mechanism developed where they could be reviewed and revised, especially with Ken's point of view that a lot of it was recycled mythology.

Merna Hurd, U.S. EPA, 401 M St., S.W., Washington, D.C. 20460: I don't disagree that the plans we have coming are first drafts. We do have to manage our water resources and somebody's going to have to do it. We've taken the first step. One of the things we've tried to do in working is to gain stability for the program. First of all, 208 was faced with the problem of trying to retain staff all of a sudden, and a matter of a few weeks and months to take on a project for a short period of time. I was very fortunate in having one of the first agencies. As more and more agencies received money, it was very difficult to really be able to hire people that would come for a short period of time. We're trying to get stability for a longer period of time — 5 years to start with so that you can have some kind of confidence in hiring. The second step is to gradually try to train these people as they work in the program.

Gerald Hendricks, President, Seico, Inc., 309 Washington St., Columbus, Indiana 47201: The data we've had presented at these meetings so far indicates the States have not appropriated enough money to take care of their problem on ground water and ground-water pollution. It's unfortunate that we seem to have to keep proving that there is pollution of ground water. More serious damage is occurring each year. It bothers me that 25 years ago, I observed the first loss of a well due to a chromium problem in an industrial plant in my home town from the plant itself. And yet, we keep reinventing the wheel here. It bothers me that we keep creating these problems.

I disagree with the urgency associated with trihalomethanes along with the AWWA group. Why not leave that thing alone for a little while and spend our energy where it's needed?

I think the Federal government should control the development of new chemicals. Why do we allow this continual addition to the problem? It's going to be very expensive to build some new water plants that may not be needed. If we take the same resource and control a product which is not yet even on the market, which may be a problem, I think it would be more productive. I can get along without new products but I can't get along without my water supply. So I think we're off on the wrong track here.

My second point is that States be required to establish pollution standards for ground water and then control the violations. How on earth can you take anything to court on general, broad concepts? That's our problem. I think somebody should have to prove something when they claim pollution.

Richard Cadwgan, Hydrogeologist, GZD Geotechnical Consultant, 30 Tower Road, Newton Upper Falls, Massachusetts 02164: I come from a very densely populated part of eastern Massachusetts and was fortunate to participate in a very well funded drilling program in the Boston area.

I specifically would like to ask a question of Mrs. Hurd. It seems to me that an immediate near-term impact of the 208 planning process would be the construction of a large number of sewage treatment plants. Together with that, there are ongoing NPDES programs. I think the State of Massachusetts is trying to write pretreatment standards for industrial discharges to sewer systems. I gathered that the pit, pond and lagoon inventory is going to also lead to the production of both the installation of brine ponds and the reuse of industrial waste water. All three things—plants, pretreatment standards and the inventory of ponds and lagoons—are going to lead to a tremendous volume of sludge generated in my part of the State of Massachusetts. We don't have any place to put it; we don't know how to treat it. What thought is being given to help our State agencies deal with this problem?

Merna Hurd: I don't know if I have an answer for that. Unfortunately, this is what happens when you have individual programs dealing with one little individual part. There have been billions of dollars in treatment facilities, and this is why this has been such an active program. What we need to do is look at our waste products which are going to end up either in the air or the water or on the land. We've got to decide where best they should be placed and how best they should be managed. I can't tell you right now how you should manage sludge in Boston or in your State. In a State resource management program, we have some very difficult political problems, because we deal with more than one agency within a State. We need to put those State agencies together and the programs together to decide how best to handle those problems. Of course, sludge is also a political problem because the city is faced with large volumes of it, and nobody wants it outside of the municipal boundary. EPA's role is trying to pressure the agencies in different jurisdictions to solve their problems together because they are not going to go away.

Daniel P. Waltz, Hydrogeologist, Layne-Western Company, Inc., P.O. Box 1322, Mission, Kansas 66222: My comment is re a case history involving the Ohio Environmental Protection Agency. Columbus and Southern Ohio Electric Company wanted to run an aquifer test on the Hocking River flood plain near their Poston Run Power Station just south of Chauncey, Ohio. They were told by a representative of the Ohio EPA that they would have to obtain a point discharge permit. C&SOEC was only planning to pump ground water from a test well and release it on the surface. They were not putting it to any use and the water was not being altered in any way. Although the Ohio EPA was aware of this, they continued to insist on a point discharge permit. It took almost a full 12 months for approval of the point discharge permit. It seems to me that this is a gross misuse of the authority granted the Ohio EPA by the Ohio legislature. If the Ohio EPA were to enforce this on every well drilled in the State of Ohio, nobody would even be able to test pump the well which they just finished without obtaining a point discharge permit. With a similar 12-month delay, all of the well drillers in Ohio would be put out of business.

W. Bradford Caswell, State of Maine, Department of Conservation, Augusta, Maine 04333: The impact of Maine's 208 program on maintenance of ground-water quality was not necessarily a terrible joke, but certainly a disappointment. The basic problem was that funds were put into the hands of planning groups with little or no prior experience in ground-water research and management. Although honest, hard-working people, the 208 program ran out before many knew what to do. As a result, a large part of the Round II 208 funds is going directly to the support of established ground-water programs of the Maine Geological Survey. The State needs most of all better continuity of the 208 program, but also Federal oversight that is both critical of our activities, and sensitive to our particular needs. The demand to implement 208 ground-water management schemes that have been designed from a paucity of basic ground-water data, for example, may not be in the best interests of Maine people.

Controlled Degradation and/or Protection Zones — The Way It Looks[a]

by David W. Miller[b]

ABSTRACT

The support for controlled degradation and/or protection zones arises from the fact that cleaning up existing bodies of contaminated ground water, almost without exception, has not been successful because of technical difficulties and extremely high costs inherent to abatement procedures. With regard to potential future sources of ground-water contamination, controlled degradation and/or protection zones are attractive because the state-of-the-art for containment of pollutants has not advanced to the degree that full ground-water protection can be guaranteed. Methods used to carry out a program of controlled degradation and/or establishment of ground-water protection zones can be applied on both a regional and site-specific level.

The concept of controlled degradation and/or protection zones is based on the assumption that at least some of man's activities will always contaminate ground water regardless of technological and regulatory safeguards. Where extensive degradation of ground water has already occurred, zoning is used to protect the present or future water well user rather than to clean up the aquifer.

Creation of controlled degradation zones requires application of special regulatory alternatives to areas where contamination of ground water has already occurred or is expected to occur. The regulatory mechanism established for controlled degradation zones may prohibit ground-water pumpage for potable supply in selected areas, may concentrate all potential polluting activities within the zone, and may allow for application of the most practical, but not necessarily the most rigid, pollution control practices.

Protection zones are normally areas that are still rural and/or where high quality aquifers have not been adversely affected by land-use and waste disposal practices. In these zones, very strict regulatory controls are instituted. They might rule out the use of facilities for storage or disposal of industrial waste on the land, require very low density housing development, and limit the use of such potential contaminants as highway deicing salts, lawn fertilizers, and organic chemical septic tank cleaners. In this paper the major emphasis is directed toward the use of controlled degradation zones.

Any discussion involving strategies for ground-water quality protection must acknowledge the existence of two distinct types of contamination problems. The first involves new sites where wastes are to be stored or disposed of in the future, in facilities such as waste-water impoundments and landfills. The second involves existing sources of contamination, including not only old landfills and lagoons but also areas of heavy industrial activity and urbanization where many and diverse individual sources of contamination are concentrated.

Regulations reflecting recent legislation will improve design and management at new disposal sites. However, improvements will be difficult to implement at existing sites where long-term land disposal has already contaminated aquifers beneath the land receiving the wastes. In addition, the complexity of permit systems, accompanied by vociferous public opposition to the establishment of new industrial waste disposal sites, casts serious doubt upon the ability of localities to issue permits for new sites regardless of their apparent hydrogeologic suitability. Programs of public participation will not be helpful unless the participating public is first educated to awareness that safe sites are technically possible, and that failure to approve sites will result in even greater environmental hazards. The shortage of secure sites for the disposal of industrial wastes is evolving as a critical national problem.

If it is assumed that standards for site selection and engineering of new sites are sufficient to minimize the possibility of contaminants migrating to underlying earth materials, the philosophy of controlled degradation may be defined as the provision of safety measures in the event that engineering design fails or that spills and poor housekeeping at the facility result in ground-water contamination. The strategy requires establishment

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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of adequate buffer zones around the waste disposal site. The time required for migration of contaminants to adjacent critical aquifer areas is then sufficient to allow for a reasonable planning period for correction of the engineering design or improvement of management procedures. Proper monitoring, an essential part of this strategy, will provide early warning of impending problems. In addition, the zone must be large enough to accommodate some attenuation of contaminants. Control of the buffer zone is assured by either outright ownership of the land around the facility, purchase of water rights in the direction of ground-water flow, or control over ground-water diversion to limit the use of the aquifer area that might be affected by escape of contaminants from the facility.

The use of controlled degradation zones has a much wider application to cases where ground-water contamination has already occurred. At older waste disposal sites in humid parts of the country and in areas of concentrated industrial and urban activity throughout the nation, there has been enough time for chemical contaminants to move uncontrolled through significant thicknesses of heavily used aquifers. The contaminants may have moved beyond the limits of such informal buffer zones as property boundaries of industrial sites and vacant land surrounding many municipal landfills. In such cases, where the water quality of an extensive portion of an aquifer has been degraded, rehabilitating ground-water quality to its natural state is rarely technically or economically feasible. The cost of pumping large quantities of ground water in order to treat relatively small concentrations of contaminants is normally beyond the means of any private or public entity. In addition, it is not always possible to intercept and remove all of the contaminated ground water because the interceptor wells would require periodic relocation and/or the quantity pumped would have too great an interference effect on water levels in unpolluted sections of the aquifer.

The most usual practice involves condemnation of wells used to produce drinking water or, if possible, treating the ground water at the well head or mixing it with nondegraded water before distribution. Pumping and treating contaminated ground water has been used successfully when the objective is only containing the polluted ground-water body within a certain area or controlling the rate of migration of contaminants. The quantity of water removed from the aquifer is much less than would be required if the objective of the pumping and treating is actual purging of contaminants from the aquifer system.

Another major problem associated with aquifer cleanup has to do with the magnitude of the task nationally. As monitoring of ground-water quality is more widely applied, accompanied by increased ability to analyze for synthetic chemicals at lower and lower concentration, there is little doubt that the number of ground-water pollution cases discovered and brought to local and national attention will increase on a logarithmic scale.

USEPA estimates that 80 percent of the 46 million tons of potentially hazardous industrial waste produced in this country each year is disposed of on the waste generator's site in more than 100,000 waste-water impoundments or industrial landfills. There are about 20,000 active and thousands more abandoned sites where hazardous wastes were stored, treated, and disposed of on the land overlying important aquifers (The Bureau of National Affairs, 1978). Facilities were engineered to prevent ground-water contamination at only a few of these sites. In most cases, ground water was used as the discharge mechanism to carry the pollutants away from the site, with little or no understanding of the future problems being created. Unfortunately, each typical significant source of contamination may require millions of dollars to clean up. The long-term economic implications are clear. While money may be invested by government and industry to clean up the first few startling cases of ground-water contamination in a region, the funds will soon dry up as the number of instances proliferates.

The diversity of individual sources of contamination in an area which has become heavily urbanized and industrialized further complicates the development of ground-water strategies. The combination of such diverse sources as landfills, waste-water impoundments, septic tanks, leaky sewers, and spills, makes it extremely difficult to determine the priority that should be given to correct any particular source of contamination without a long-term and statistically valid monitoring program. Efforts are typically directed toward the more obvious sources which may or may not actually represent the key problems in the region. Correction of these more obvious sources at great cost to private organizations or to the public may not result in significant improvement of ground-water quality.

Finally, the size and type of some pollution sources essentially prohibits securing them from the environment or physically removing them for detoxification or disposal at another location, for example, hazardous wastes buried in large landfills and sludges deposited in extensive lagoon systems. Even if it were feasible to dig up the wastes and transport them elsewhere, there are few places for disposal favorable enough to warrant the high cost and environmental risk. Elimination of other sources, i.e. septic tanks and leaky sewers, involves substantial expenditures of public funds for large-scale construction projects. In addition, the slow recovery of an aquifer from widespread contamination makes it obvious that other alternatives must be considered for managing ground-water systems where the water is severely degraded.

One such alternative is the zoning of aquifers on the basis of variations in permeability, recharge and discharge relationships, potential effects on surface waters, existing ground- and surface-water quality characteristics, and present and proposed land use. In this way, priorities for ground-water protection can be established based on sound environmental planning and economic principles.

Controlled degradation and protection zones as a ground-water management technique have been used in the development of the Long Island Comprehensive Waste Treatment Plan, a 208 project covering Nassau and Suffolk Counties, New York (Nassau-Suffolk Regional Planning Board, 1978). Ground water beneath Nassau and Suffolk Counties is the only source of potable water for almost three million people. Total withdrawal from the three principal aquifers currently approaches 400 mgd. Long Island lies within the Coastal Plain physiographic province. Major patterns of ground-water flow are such that the deep ground-water reservoirs are mainly replenished over a broad area in the central portion of the region. Recognition of this flow system and areawide effects of past land-use and waste disposal practices, prompted the definition of critical watersheds or protection zones for the 208 region. For example, in one zone of more than 100 square miles, good quality ground water still exists in the major aquifers. Moreover, since the hydraulic conductivities of the aquifers are high, there is considerable potential for water-supply development in this zone. Much of the area is woodland. The 208 plan recommended that the zone should be protected by applying land-use restrictions which would severely limit future urban and industrial development. Strict control over potential nonpoint sources of pollution and prohibition of facilities for land disposal of waste were also recommended. In other words, the entire zone would be governed by nondegradation regulations.

In another zone of about 25 square miles, serious ground-water quality problems have been experienced over the past few years, primarily due to the presence of organic chemicals and high concentrations of nitrate. Land use is characterized by mixed commercial/industrial and high density housing. Where practical, identified sources of contamination are being eliminated or their impacts minimized. Industrial pumpage, presently about 10 mgd, is being encouraged to prevent contaminants from migrating into adjacent zones containing high quality ground water. The zone would not be governed by nondegradation regulations. In other zones within the 208 area, depending on local hydrogeologic factors, recommended waste-water management alternatives are designed to achieve a balance between present land-use and water quality conditions and environmental controls so that the quality of ground water can be maintained to assure its continued use as the regional water supply.

In summary, a uniform set of environmental controls cannot be applied across the board as a solution to all real or potential ground-water contamination problems. Man's impact on ground-water quality is determined by too many variables including land-use and local geologic and hydrologic conditions. To manage ground-water quality correctly, we must be able to accept the fact that it is too late and too costly to undo many of the past mistakes. However, we must also have sufficient foresight and creativity to protect high quality aquifer areas by means of strict land-use controls and advanced engineering design.

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Controlled Degradation and/or Protection Zones — Sense[a]

by Ronald A. Landon[b]

ABSTRACT

It is herein submitted that the nearly universal phrase "shall not cause pollution of the ground waters and surface waters" written into the State regulations for waste disposal operations not only refutes a sound technical alternative, but is impractical, uneconomical and often unworkable.

It is a fact that all ground waters are *not* created equal, as governed by certain irrefutable physical laws including the water budget equation and Darcy's Law which states that the quantity of ground water available is subject to wide variation from location to location. While an aquifer is a relative term, major, minor and nonaquifers can be identified within a given geographic area with respect to cost-effective ground-water resource development. Likewise, the natural quality of ground water is also a significant variable with certain parameters often exceeding drinking-water standards. The land application of wastes overlying the ground waters of an area should, therefore, also be subject to a certain degree of flexibility for prudent management of both the waste operation and the ground-water resources.

Numerous investigations and empirical data can be cited to substantiate the fact that many wastes and their associated leachates can be safely assimilated into the environment with reliance on attenuation and controlled degradation of ground water by utilization of a mixing zone or zone of renovation with a specified distance from a disposal operation. As increased emphasis is placed on the land disposal/management of wastes/residuals and as the cost of these operations continue to mount, it is strongly recommended that controlled ground-water degradation be utilized in those areas where a "true" ground-water resource does not exist. Protection of such a "true" ground-water resource is obviously necessary as our demands for a potable water supply also continue to grow.

I would like to begin by stating a well-worn phrase, "What this country needs is . . . . ," and I'd like to add another to that long list. What this country needs is a set of regulations governing the land disposal and land treatment of wastes that are more realistic with respect to the impact of those wastes on ground-water and surface-water quality.

The thesis that I would like to build on is that we don't have those realistic, flexible regulations today and in many cases we are painting ourselves into a corner whereby we are refuting a sound technical alternative—that alternative being of controlled degradation. I've found in working for both regulatory agencies and consulting firms that many times the regulations become impractical, uneconomical and just plain unworkable. I'd like to clarify my stand on this issue by saying that I am not in favor of uncontrolled pollution, but I am definitely in favor of controlled degradation, and I think that there is a difference between the two.

We have just heard an excellent presentation on a number of case histories that show very practical applications of controlled degradation. I would like to build on the *concept* of controlled degradation. I think we have only to look at the quantitative and qualitative aspects of ground water to realize that this concept does, in fact, make some sense. All ground waters do not exist with the same degree of value and all ground waters, therefore, are not created "equal." A very definite natural variation exists for both geology and ground-water flow systems. While that is not news to most, I think we often lose sight of that fact.

There are several very basic irrefutable physical laws that govern the occurrence, movement and quality of ground water. The water budget equation, for example, states that precipitation, runoff and evapotranspiration will vary in any

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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given region and, therefore, the net recharge to ground water will also vary in accord with the others. Likewise, Darcy's Law states that the quantity flow is proportional to the permeability, gradient, cross-sectional area, with permeability being the most important criteria. Although ground water will be recharged at a certain rate at any given locality, its movement and withdrawal rate will vary according to the permeability of the host deposits. Similarly, there is variation in ground-water quality which is dependent upon the quality of the recharged water and the geochemical reactions in the unconsolidated and consolidated deposits through which that ground water is moving.

It would appear to make sense, therefore, that with the realization that the natural hydrogeologic system is variable, there is a need to apply that realization for more sound waste management practices. We are in essence between the hard-hat and the boulder, as they say. We have both a need to protect the ground-water resources in the country, while at the same time we have a growing need to dispose of wastes we generate. I am a very strong advocate of that, with more emphasis being placed on those resources. We have a need, therefore, to balance the two interests. This is perhaps best exemplified by a United Kingdom publication addressing that very issue entitled, "Balancing the Interests Between Water Supply and Waste Disposal."

The concept of controlled degradation is based on another concept of a zone of renovation, assimilation, or a mixing zone. I personally dislike the phrase "zone of degradation" since degradation implies a negative. I would rather turn it around in a positive sense and say a "zone of assimilation" or "mixing zone." Numerous studies have been conducted, several of which I have been fortunate to have been a part of, that have contributed a large bank of empirical data to the literature which state that leachate produced by landfills, sludge sites, spray irrigation sites, and other land treatment/land disposal facilities can, in fact, be safely assimilated into the environment by attenuation. There are various forms of attenuation; major among them are precipitation, adsorption-desorption, and, not the least important, dilution. I am a strong advocate of using the natural environment, including dilution, at a controlled rate to assimilate wastes. This zone of attenuation or assimilation may be strictly within the ground-water flow system depending on the size of the facility and the site hydrogeology, or it may also include the surface water as a receiving stream for the point of ground-water discharge.

For controlled degradation to be a viable waste management approach, several critical factors must be considered. Obviously, the basic hydrogeology is a critical factor for any given land disposal site. I believe, again, that perhaps one of the more important criteria in the hydrogeologic regime is that of the permeability. Based on a significant amount of empirical data and experience, it would appear that a permeability in a moderate to moderately low range of 1×10^{-4} to 10^{-5} cm/sec or a silty sand deposit has repeatedly proven to be adequate for renovation or assimilation of waste leachates emanating from land disposal facilities. Distances of 200 to 600 feet are commonly cited in the literature as being adequate to assimilate leachates from rather sizable landfills and other land disposal areas. A permeability is desired that will control this diffuse leachate discharge at a rate that is not so low as to result in a concentrated buildup of leachate and, at the same time, is so rapid (i.e. fractured rock or very permeable sand and gravel) as to result in rapid and far-reaching migration of leachates and associated adverse impacts on water quality.

Another important concept which is being more frequently discussed with respect to controlled degradation is that of waste disposal zoning. Actually, the concept of waste disposal zoning has been around a long time. I can think back easily ten years ago when this concept was discussed. It is time to realize that we should zone land from a hydrogeologic standpoint as well as from a political standpoint. Again, there is a need to balance the interests between water supply problems and needs and waste disposal problems and needs. Waste disposal zoning would entail designating waste areas in areas of intense land use, particularly highly industrialized, or areas where the natural ground-water quality or the man-made ground-water quality is already altered. Waste disposal zoning also implies that the major aquifers in any given region will be designated. It may be necessary to look beyond the limits of the formational boundary to recharge boundaries as well, but the point is that for any given area we can designate major and sole source aquifers as well as those areas that have minimal value as a ground-water resource.

Another critical factor is the need for waste segregation, particularly at the disposal site, and if possible at the source itself. Controlled degradation or a zone of assimilation does not apply to any or all wastes. What is needed is a waste segregation based upon a classification system similar to that in use in California, or what Texas and Illinois and others are developing. Toxic and truly hazardous wastes must be disposed of either in a secure landfill or by some other method such as incineration or encapsulation. But I do believe that there are many "wastes" that in fact are nontoxic, decomposable, that can be applied to the land in a managed and environmentally compatible manner.

Perhaps one of the weakest links in the whole waste management chain is that of poor operator training or knowledge. There is a definite need to have training and certification of land disposal operators comparable to what exists for water treatment and waste-water treatment plant operators. All too often a problem arises because the person in charge of the daily field operation frankly does not know what he's doing. While engineering plans are required, the plans are often misapplied or in fact never implemented. Certification and training of these people to be present and accountable for a day-to-day technical professional input to that operation are needed.

Finally, I think we need an attitude change by the regulatory and legal personnel. There is no doubt that the socioeconomic, political and legal aspects of solid waste management all take precedence over the technical issues. This attitude change is necessary, therefore, to apply the concept that waste disposal zoning and controlled degradation, in fact, make sense—not for all wastes, but for select wastes.

In summary, I would hope that what may have initially appeared to be a radical concept is not so radical after all. We have only to look at the fact that there have been numerous waste operations conducted in the past which have not caused significant impact prior to enactment of the increasingly stringent environmental laws existing today. Granted, we do have the Love Canals and other similar horror stories which, to my way of thinking, are largely a case of the wrong waste in the wrong place and/or poor management practices. We do have literally thousands of waste operations which have been conducted over the years that have not caused significant impact and I would state again, therefore, that controlled degradation does make sense. I think that it is a very sound technical alternative which is workable, practical and economical.

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Controlled Degradation and/or Protection Zones — Nonsense[a]

by Herman Bouwer[b]

ABSTRACT

Man's activities are an ever-increasing threat to ground-water quality. New EPA policies encourage cities to discharge sewage effluent on land. Irrigated agriculture is incompatible with high-quality ground water where deep percolation water is not removed by drainage. Present drinking-water quality standards cannot be used to determine the suitability of water for potable use if such water is waste-water-derived. Where sewage effluent is applied to land, persistent trace organics occur in underlying ground water. Some of these organics may be carcinogenic or otherwise toxic, and much additional research is needed. Controlled degradation of ground water still is degradation. High-quality ground-water resources either are to be protected, or aquifers eventually must be abandoned as sources of high-quality drinking water. In the long term, there is no in-between. The choice will be dictated by economic and environmental considerations. For example, the most economical use of aquifers below irrigated valleys ultimately may be to serve as facilities for treatment, storage, and conveyance of municipal waste water from surrounding communities, so that this water can be used again for unrestricted irrigation. While such uses of aquifers may be far off, they should be anticipated now to allow proper planning.

The discovery in the early part of this century that chlorine could be used to make polluted surface water bacteriologically safe for drinking gave cities a license to dump sewage effluent into streams and lakes, which in turn led to widespread pollution of our surface water. Let's hope the illusion that controlled degradation of ground water is permissible will not do the same to our underground-water resources. Controlled degradation is still degradation—the only difference between controlled and uncontrolled degradation of ground water is that controlled degradation takes longer; either way, the day of reckoning will come.

As an example, let's take an irrigated valley. Such a valley is essentially a large evaporation pan. Salt accumulates in the root zone of the crops. Since salt injures plant growth and eventually makes agriculture impossible, it has to be leached out of the root zone by regularly or periodically applying more irrigation water than is needed for evapotranspiration. The salt leachate from the root zone, often called deep-percolation water, then moves down and eventually ends up in the underlying ground water. Some areas have a high water table and are "poorly drained." Although this is agriculturally undesirable and forces farmers to install tile drains to control the water table, it is a blessing from the standpoint of protecting ground water, because the deep-percolation water is intercepted and disposed of on the surface. In irrigated areas, however, ground water is pumped from most aquifers, and water tables have declined enough that

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the overlying land does not need artificial drainage. This is good for farmers but, unfortunately, all deep-percolation water ends up in the underlying ground water. Consequently, the quality of ground water and well discharges deteriorates, mostly as total dissolved salts (TDS) and nitrate concentrations increase.

A number of things can be done to reduce or delay the ground-water degradation that deep percolation from irrigated agriculture causes. For example, farmers can irrigate more efficiently, applying the water uniformly and in amounts that do not exceed crop evapotranspiration and the leaching required to maintain a salt balance in the root zone. This produces less deep-percolation water, but this water will have a higher salt content. The higher salt concentration increases precipitation of carbonates in the vadose zone, thus reducing the salt content as the water percolates downward. The lower deep-percolation rate also results in less leaching of salt from weathered minerals or from deeper, saline formations. Despite these beneficial effects, total salt loads on underlying ground water are still severe. Efficient irrigation practices do, however, slow downward movement of the deep-percolation water through the vadose zone. This is advantageous where ground-water tables are declining, because it reduces the rate at which deep-percolation water joins the ground water. As a matter of fact, pumping ground water out so fast that deep-percolation water does not catch up with the declining ground-water level is about the only way to protect ground-water quality in irrigated areas.

Another potential threat to ground-water quality is land application of waste water such as sewage effluent, wet sewage sludge, and agricultural wastes (manure slurries, processing plant effluents, etc.). Land application of sewage effluent will probably increase dramatically in the near future because secondary and tertiary treatment cost so much and require so much energy and because new EPA policies favor land treatment over conventional, in-plant treatment. The policies include increased reimbursement for costs of land treatment systems, higher priority for the systems on State project lists, free modification or replacement of land treatment systems if they do not do the job properly, and the requirement that cities not electing land treatment must explain why in their application for sewage-plant construction grants.

Land application of sewage effluent has a number of very attractive features. Where the effluent is used directly for irrigation, the nitrogen and phosphorus in the effluent serve as nutrients for crops, so that land rather than surface water is being fertilized. If the effluent is applied according to nitrogen requirements of the crop, the amount of nitrogen leached to underlying ground water will probably be about the same as that from conventional farming.

Another form of land treatment of sewage effluent is the rapid-infiltration system. This is more like a ground-water recharge system, where effluent seeps into the ground from infiltration basins. The soils and aquifers are then used as natural filter systems to remove almost all of the biological oxygen demand (BOD), suspended solids, bacteria, viruses, and phosphorus and most of the nitrogen from the effluent water. The system produces renovated water that can be pumped from the aquifer and used for purposes with a higher economic or social return than direct irrigation with sewage-plant effluent (for example, irrigating vegetables and other high-value crops, recreational lakes, etc). The problem with this system is that, although the renovated water is of much better quality than the effluent that entered the soil, it often is not as good as the native ground water. The problems are associated not only with nitrogen or metals, but also with refractory and other trace organics, including known carcinogens like trihalomethanes and other chlorinated hydrocarbons. More research is needed on the identity and toxicity of these organics in renovated sewage water. Normal drinking-water standards cannot be used in determining the safety of renovated waste water for drinking, because these standards apply to relatively unpolluted surface-water resources. In waste-water reuse, renovated waste water is guilty until proven innocent.

Encroachment of renovated effluent water upon native ground water can, theoretically, be controlled by taking the renovated water out of the aquifer with wells or drains at a certain distance from the infiltration basins. The native ground water beyond these collection facilities is then protected against encroachment by the renovated water. In practice, these systems require careful management and monitoring of ground-water levels so that water from the renovation system never flows into the native ground water. This could pose problems in the winter or whenever the demand for renovated water is less than the amount that must be collected to protect the aquifer. Plans and facilities for handling "surplus" renovated water or sewage effluent thus must be an integral part of any rapid-infiltration system.

Another approach toward protecting native ground-water resources against spread of renovated waste water is treating the waste water until it is essentially of drinking-water quality before it is applied to the land. This is California's philosophy, where proposed regulations call for treatment of sewage effluent to reduce the total organic carbon content (TOC) to less than 3 mg/liter (TOC of secondary effluent is about 20 to 30 mg/liter) before it is applied to land from which it can enter aquifers used for drinking water. Concentrations of arsenic, barium, cadmium, chromium, lead, mercury, nitrate, and selenium must also meet drinking-water standards. While such treatment is laudable from the standpoint of ground-water protection, it may lead to costlier systems than necessary because it does not take advantage of the organic carbon removal, denitrification, and other quality-improvement processes that take place on a renewable basis in a soil-aquifer system. More research is needed to determine the optimum combination of pre- and post-treatment in rapid-infiltration land treatment systems.

Where degradation of ground water by man's activities is inevitable, and controlled degradation only means delay of execution, the solution may well be abandonment of aquifers as sources of high-quality water. The best use of the aquifers may then be to receive, store, and renovate waste water. This sounds like heresy, but it is already done for surface water—for example in West Germany, where the Ruhr is protected but the parallel flowing Emscher is used as a waste disposal stream. Both streams are tributaries to the Rhine. This is a good solution for the Emscher-Ruhr area, but it does nothing for the downstream users of Rhine water, who get the dirty water anyway.

Abandoning aquifers as sources of high-quality ground water may be the best ultimate solution in irrigated areas that are becoming urbanized. The amount of land that was originally irrigated in such areas, and the population that such areas can support, often are limited by available water supplies. Thus, urbanization can cause conflicts between municipal and agricultural-water demands. Assuming that the area has a certain ensured water supply from a river or other outside source, agriculture and urban development can coexist if the municipalities use the water first and agriculture uses the renovated sewage effluent for irrigation. A good way to achieve this would be to concentrate the urban developments in the higher areas (desert, foothills, etc.) around the irrigated lands, leaving the agricultural land intact. Each town around the valley would then have its own sewage treatment plant, and the effluent would be applied to rapid-infiltration basins for ground-water recharge. This would produce renovated water that would move downgradient through the aquifer to the lower, agricultural areas, where it would be pumped for irrigation. The aquifer would then serve as a medium for receiving, renovating, transmitting, and storing effluent water.

In summary, we see that controlled degradation eventually may lead to ground-water contamination. There may only be two choices: complete protection of aquifers and high-quality ground-water resources, or degradation and eventual abandonment of aquifers as sources of high-quality ground water. Since restoring contaminated ground water to drinking-water quality will be more expensive than conventional drinking-water treatment, there may be no in-between.

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Herman Bouwer received B.S. and M.S. degrees in land reclamation, drainage, and irrigation from the National Agricultural University at Wageningen, The Netherlands, and a Ph.D. degree in agricultural engineering (water management) from Cornell University. He was associated with Auburn University's agricultural engineering department in Alabama from 1955 to 1959. He then joined the U.S. Water Conservation Laboratory, U.S. Department of Agriculture, in Phoenix, Arizona, where he was appointed Director in 1972. He is leader of a research group in subsurface water management and ground-water recharge with sewage effluent, and teaches ground-water hydrology at Arizona State University.

Audience Response to Session VII — Controlled Degradation and/or Protection Zones

Richard Dalton, Principal Geologist, New Jersey Division of Water Resources, 1474 Prospect St., Trenton, New Jersey 08623: First, I was quite shocked when I saw the delineation and writing off of the Raritan outcrop area under Dave Miller's controlled diagram. What happens when this unit is also the most heavily utilized ground-water source for the State of New Jersey?

Second, many times when we get plans in for a landfill or a ground-water control system, the consultant appears to slant his argument toward the client. Do you think this is fair?

David Miller, Geraghty & Miller, Inc.,44 Sintsink Dr. E., Port Washington, New York 11050: I knew you were going to attack me. That is shocking isn't it. The concept for eventually writing off an area is what I was trying to put across; eventually a very large portion of that yellow section, and some of it very quickly, is already being written off. Actually, to put down on a slide the entire area was an exaggeration to put a point across. I don't have the power to write off anything. New Jersey is actually doing it, however, whether they know it or not. They are zoning the pine barrons. There are certain areas in that yellow band where people are beginning to talk about abandoning ground water, and either going to surface water or going to the next zone and taking ground water. New Jersey is protecting that area that they can move into, and that's really zoning.

As far as clients are concerned, yes, I try and represent my client.

Ronald Spong, Environmental Specialist, Bloomington Health Department, 1772 Ashland Ave., St. Paul, Minnesota 55104: I'm not persuaded by the argument that controlled degradation is a good idea. I speak from a public health point of view that perhaps is not well represented here among the hydrogeologists, geologists, consultants, etc.—not from the standpoint so much as a technical problem but more from the standpoint of perspective. Perspective first of all is garnered from retrospect; in other words, how well have we been able to control our programs in the past? We've had quite a bit of discussion on the value, the performance, and accountability at the State and Federal levels—whether or not the job is getting done, who is going to be doing the monitoring and enforcing the rules. Are the consultants going to be more biased for their employers? Are the relevant facts going to be brought forward so that we actually know some of the truisms that exist in particular ground-water aquifers that are going to be degraded? Retrospect also from the standpoint that prevention is a goal in public health and unfortunately, prevention is very seldom ever achieved.

In prospect our problems must include the catastrophic consequences of earthquakes, floods, etc. Perhaps if we were talking just about aquifers in glacial drift materials, it might not be a tremendous problem, but aquifers in granitic rock will be a much greater problem. Are we going to continue to perpetuate the myth that our society continue to waste tremendous amounts of material without looking towards resource recovery or in fact, lowering our expectations? Are we, in fact, going to encourage ground water to be a repository for waste by voting for "controlled degradation"? We have it on the land, we had it in the air, we had it in the surface waters. Out of sight, out of mind, has been mentioned many times. What are we going to do about this?

Ronald Landon, Roy F. Weston, Inc., Weston Wing, West Chester, Pennsylvania: Just a couple of quick points on that. I happen to feel, with respect to domestic waste, that land treatment, land disposal of waste, is in fact a resource recovery operation by the fact that we are recovering some of the nutrients out of that waste, and again, I think it's putting the balance in perspective that we're not necessarily going to get locked into preserving all waters to be of drinking-water quality. There can be use of the land for waste treatment or a waste disposal facility and use of the underlying water for such things as irrigation, as Dr. Bouwer mentioned, or for industrial pumping, which Dave has mentioned, where drinking-water standards are not necessary. One other item you mentioned earlier, I think we all have to share the blame for being a little too late, but we can begin to close a few loops here. You questioned the technology; certainly, we have to question the technology, but we've also heard comments here that many of the State programs are not adequately staffed or funded. If they are adquately staffed the proper staff personnel does not in fact, make the regulations or get involved with the implementation of those regulations. These are very real problems as well.

Fred Lahman, Lahman Well Drilling Co., Hines, Minnesota 56647: What happens to a land disposal system using an aquifer for the filter that is set up to run for 20 years? Eventually the water in the aquifer runs into a river or a lake. If this is set up to operate 20 years, then the system is abandoned and the water is returned to the natural static water level. The irrigation pumps are shut off; what happens to the contamination that's in the system that moves further down into the ground-water system?

Herman Bouwer, U.S. Water Conservation Lab., 4331 E. Broadway, Phoenix, Arizona 85040: Most of the accumulation of pollutants in a land treatment system occurs in the top 3 or 4 feet of the soil. And primarily what you get is really a mineralization of the organic matter and you get precipitation of phosphates and then reversion through insoluble pumping of the phosphates, so it will remain immobilized. I don't think there's much of a chance really that when abandoned, some of these materials like phosphates and metals that have accumulated in the soil will be remobilized and show up in the ground water. Same as bacteria and viruses that have been removed by the system, they usually don't survive longer than half a year or so. So the ground water will not pick up any large amount of bacteria.

Daniel P. Waltz, Hydrogeologist, Layne-Western Company, Inc., P.O. Box 1322, Mission, Kansas 66222: I compare "controlled degradation" to being only a "little pregnant." Either the water being affected is polluted or it isn't polluted. There can be nothing in between. In the past there has been too much leniency as far as water pollution is concerned. I feel that there is no good reason for polluting any water. If the industrial process requires special treatment of waste water being produced by the company then the cost of such treatment must be passed on to the consumer. The consumers must be aware that the product they are buying is difficult to produce and that if they intend to use the product they must be responsible for the pollution it produces, at least financially. I repeat: "There is no just reason for pollution. All water should be returned to its original state, or at least as close as possible." I enthusiastically support recycling of industrial water and pretreatment of industrial waste water for pollutants which are not removed in normal municipal waste-water treatment processes. I do not endorse the idea of controlled degradation and/or protection zones.

Lloyd H. Woosley, Jr., Water Quality and Ecology Branch, Tennessee Valley Authority, Chattanooga, Tennessee 37401: It is quite evident that many waste disposal facilities, such as surface impoundments and landfills, are capable of degrading local ground-water quality. The area affected may require a management technique such as zoning for controlled degradation and limited use. But, Mr. Miller, the investigation you presented dealing with the implementation of such a management technique failed to evaluate water quality degradation in an integrated fashion—that is, surface and ground waters were not considered as a total resource. Aren't the investigations by the hydrogeologic industry deficient in the same way as those of environmental engineers by neglecting to evaluate ground water and surface water as a single resource?

Ground-Water Computer Models — State of the Art[a]

by Thomas A. Prickett[b]

ABSTRACT

This paper addresses both the pros and cons of ground-water modeling and is presented from a neutralist's standpoint. The list of individual modeling pros and cons is extensive but is condensed into three main points for each side of the ledger.

The three main characteristics that put the use of ground-water models into the class of intellectual toys are as follows. First, the wrong model is frequently chosen for problem solving of which overkill by use of an overly sophisticated model is an example. Secondly, the paying agency or client is often disillusioned with the model results because of frequent modeler oversell in the early stages of project planning and budgeting. Thirdly, the problems are often solved with a numerical code that is a mystery to all except the modeler himself.

The three main characteristics that make ground-water models very practical tools are as follows. First, there is no doubt that the models of today can solve extremely complex ground-water flow problems. Having methods available for solution of complex problems is an advantage that we have not always had. Secondly, the models of today are available to virtually everyone in the ground-water business. The days of specialty laboratories for complex ground-water model solving are over and the tools are now in the hands of those doing the local work. And thirdly, having a computer code and data deck available is a perfect tool for transferring information to another person as to how a problem was solved. There is no doubt as to the exact assumptions used and the step-by-step solution of the problem which produces the results of the entire analysis.

This paper also includes a very brief description of the state-of-the-art of ground-water modeling and a very comprehensive reference list of useable models.

INTRODUCTION

I was invited to this conference to present the neutralist's viewpoint on the subject of ground-water modeling as a practical tool or as an intellectual toy. I see both pros and cons to the modeling business and am glad to point these out in writing. This paper is assembled in four parts. The first part is a quick state-of-the-art report on ground-water modeling. The second part includes the discussion of ground-water models as practical tools. The third part includes the discussion of models as intellectual toys. The final part includes a summary of the main points and some thoughts about ground-water modeling in the future.

STATE-OF-THE-ART OF GROUND-WATER MODELING

Let me begin by stating my definition of what a ground-water model is. Any system that can duplicate the response of a ground-water reservoir can be termed a "model" of the reservoir. The operation of the model and manipulation of the results is termed "simulation." Various models for simulating ground-water flow are used to the extent that they simplify solution of ground-water problems. Presently, there are four broad classes of ground-water models including (1) analytical formulas coupled with experience, (2) numerical—including finite-difference and finite-element models, (3) analogs, and (4) physical. In my opinion, the order above is by the often used model. Let me quickly discuss each type of model and comment on its state-of-the-art. The following discussion is brief.

Analytical formulas coupled with experience. This is the first time that I have written a paper and included experience as any type of a model for

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solving ground-water problems. I am mentioning this since the "experience" model is always one of the first to be applied in solving a ground-water problem and, at the same time, is the model very few speak about. Again, this particular model can greatly reduce the time and effort necessary in assembling a solution to a ground-water problem. In some cases, you simply don't need any other model other than experience coupled with use of available analytical formulas to get a solution to a problem. The state-of-the-art of the analytical formulas—experience model is user dependent and ranges from completely missing the point on up to getting one to within 20 percent or so of the correct answer. The references of this paper list several textbooks and articles that give analytical solutions. In combination with recent journal article reviews, the analytical formulas available in textbooks are extremely valuable models.

Numerical models of the finite-difference and finite-element type are commonly available today to solve almost any type of ground-water problem. The numerical techniques only differ from one another in the way the applicable differential equations are approximated and solved with a digital computer.

Most of the numerical modeling was conceived in the last 10 years. Computer codes have become available and are being used by nearly all ground-water hydrologists. Published articles on the subject of numerical methods in ground water are presently coming from nearly all corners of the world. The references of this paper give a collection of published articles that contain computer codes that cover solution methods for a large segment of common ground-water problems.

There is, however, a problem with finding computer codes in useable form (listing, operator's manual, thoroughly debugged programs, comparisons with theory, and practical applications example). I believe this situation exists because most authors find that the solution to a problem is most important and there is rarely enough money alloted for proper documentation. There is, I believe, also an attitude of unimportance attached to the rather boring job of documentation. It appears that the arguments between finite-difference versus finite-element techniques for solving ground-water problems are presently fairly well settled. Each technique has its advantages and disadvantages and neither one is the universal panacea for solving ground-water problems.

Analog modeling techniques had their hayday in the 1950s and 1960s. Today, such models as the electrical resistor and resistor-capacitor networks, viscous fluid-parallel plate, and thermal systems are hard to find. To my knowledge, only a few universities teach analog design beyond a very cursory level. The versatility, availability, and convenience of the digital computer for solution of ground-water problems were the main reasons why analogs lost popularity.

It is interesting to note that recent advances in electronic miniaturization and printed circuitry technology has not caused a resurgence of use of electrical analogs. One of the greatest advantages of the analogs is that time does not need to be discretized. The necessity of using time increments in numerical modeling is always somewhat of an aggravation and source of possible error that you didn't have to be concerned with greatly when using analogs.

The physical models that I am referring to are of the scaled-down sand tank type. These models have been around since Darcy's time and will continue to be used, especially in the area of ground-water quality and pollution research. A great deal of work is still needed in the area of dispersion, diffusion, ion exchange mechanisms, and heat transport phenomena. The physical sand tank model will continue to play a part in this needed work area.

One development in the sand tank model area worth special note has been the recent fresh-water storage in saline-water aquifers study by Kimbler *et al.* (1975). Kimbler includes both design of so-called "mini-aquifers" and finite-difference models for studying two liquid flows in porous media.

GROUND-WATER MODELS AS PRACTICAL TOOLS

In assembling ideas for this paper, I made a list of pros and cons of modeling. That list was quite lengthy with all of the details. Upon reflection on these ideas, I realized that most of the individual items on the list were actually related. Upon final analysis I reduced the list to three main points on each side of the practical tool/intellectual toy ledger.

In my opinion, there are three main characteristics that make ground-water models very practical tools. First, there is no doubt that the models of today provide a means for solving extremely complex ground-water problems. Having methods available for solution of complex problems, without making a large number of gross approximations, is an advantage that we have not always had.

Secondly, the models of today are available to virtually everyone in the ground-water business. The days of the specialty laboratories are over and the tools are now in the hands of those doing the local work. And thirdly, having a numerical code and data deck available is a perfect record and tool for transferring information as to how a problem was solved. With this information, there is no doubt as to the exact assumptions used and the step-by-step solution of a problem. Let me expand on these thoughts.

It is not hard to remember the time when analytical formulas and experience formed the principal means for ground-water problem solving. However, in applying these formulas the number of assumptions that had to be made was large concerning such items as aquifer heterogeneity, boundary geometry, multiple layering effects, and other geologic conditions. Presently, digital computer modeling techniques can include the variation in these parameters and there is no longer a need (other than not having sufficient data) to make these assumptions. If you know that these parameters change in space or with time, it is a relatively straightforward process of entering these variations as computer data input. There are existing computer models that can accommodate extremely complex geologic and hydrologic conditions. Since about 1972, there has been an avalanche in development of numerical modeling techniques. Both water quantity and water quality modeling techniques are now available. Simply stated, present ground-water models provide a means for solving complex problems. There may be differences in opinion as to whether the models are suitable for practical application, but it is my thought that a sufficient number are to the extent that present ground-water models are indeed very practical tools for solving complex problems.

A problem solving technique can be judged practical if it is used by a large percentage of all ground-water hydrologists. Presently, ground-water models are, in fact, being used by the majority of ground-water people. Ten years ago you could not say that. Today, the ground-water modeling is done locally where the problem area exists. There is no longer a need to send the data to a distant specialized laboratory for a solution as was the case 10 years ago when labs such as the Analog Model Unit of the USGS existed. The use of ground-water models is commonplace now. Thus, the facts that ground-water models are being used by so many researchers and men in the field and that central specialized equipment labs no longer exist is a good indication that ground-water models are very practical tools.

It may seem strange to consider a ground-water model computer code itself a practical tool other than as a means of solving a problem. I believe, however, that the actual code contains information just as important, if not more important, than the solution of the problem under study. The computer code contains the precise method by which the problem was solved. The code does not contain assumptions, differential equations, or the jargon associated with a written report. You thus have a perfect means for transferring information. Never mind the claims made in the accompanying report as to what the model can do; see exactly what it can do by looking at the program code.

Studying a ground-water model computer code reveals a great deal about the validity of the solution and the care in which the author solves problems and documents exactly the model capabilities. The shape of the model code is not only a very good means of transferring information, but it reveals information as to the degree to which the model is a practical tool or an intellectual toy. In summary, having a precise record of how a problem was solved makes computer modeling very practical.

GROUND-WATER MODELS AS INTELLECTUAL TOYS

In my opinion, there are three main characteristics that put the use of ground-water models into the class of intellectual toys. First, the wrong model is frequently chosen for problem solving of which overkill by use of an overly sophisticated model is an example. Second, the paying agency or client is often disillusioned with model results because of frequent modeler oversell in the early stages of the project planning and budgeting. Finally, the problems are often solved with a numerical code that is a mystery to all except the modeler himself. An amplification on these thoughts follows.

Using a model which is overly sophisticated for the problem at hand is a common occurrence. Probably, lack of geohydrologic input data accounts for the largest number of these occurrences. The choice of model for the solution of a problem should be based upon matching the two together. As mentioned previously, there are many problems that can be solved by experience and application of formulas. On occasion a computer model is chosen when an application of a formula would do. On the other hand, I am aware that public relations and audience impact are sometimes important and choosing a computer model is done for these purposes. In these cases, one has to be cautious. In any event, choosing an overly sophisticated model which doesn't fit the problem is a case of applying the wrong model. The result becomes more of an intellectual exercise than anything else.

Excessive modeler claims and oversell of the power of computers, can lead to client disillusionment with the over-all modeling process. Most of these panacea-oversell problems come to light soon after the results of the field-computer calibration runs become known. Because the data base for ground-water studies quite often is something else to be desired, this situation often occurs and backlash from the paying agency or client results. I believe this oversell problem is a serious one at times and requires restraint on the part of those in charge of project budgeting and planning.

Solving a ground-water problem and not giving an adequate description as to how it was done is a situation that commonly occurs in the modeling business. Documentation of computer codes is not a popular job. The usual procedure is to explain the problem in a report, discuss the differential and approximating equations involved, explain in words that a computer program was developed and used to solve the equations, and then give the results. The missing gap is the computer program. From my own experience, that is a big gap that needs work. There are problems that need solving, and if someone has taken the time to write a program and publish the results, why not let us benefit by that work and also publish the code? The answers vary around the theme that it would be easier to develop your own code.

It is my opinion that undocumented programming, other than providing the immediate solution sought, is mostly a wasted effort. In addition, if the documentation is not done along with the development of the code, six months afterwards when your memory has faded, the code is virtually worthless. Then, it would be easier to develop your own code. With the one exception of immediate necessities that will not need to be repeated, the undocumented ground-water model is an intellectual toy of the first magnitude.

SUMMARY

In summary, ground-water models, in my opinion, are mainly intellectual toys when principal investigators choose an overly sophisticated model for the problem at hand, when the paying customer finally realizes that the model is not a panacea for his problem, and when the principal investigator does not adequately document his work. Models, as very practical tools, are in evidence today since most every investigator now has available models to solve very complex problems. Furthermore, the existence of the computer code precisely tells the entire story of how a problem was solved.

In my opinion, the future looks exciting as more models will be developed, more investigators at the grass-roots level will be effectively using models, and low-priced computer equipment will become commonplace for nearly everyone's use.

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Ground-Water Computer Models — Practical Tools[a]

by Russell E. Darr[b]

ABSTRACT

One of the most valuable and practical tools the ground-water manager can use is the computer model, be it wellfield, conjunctive, solute transport, or statistical. Although these models vary in complexity, the end product is purely a function of the user's ability to select the appropriate level of modeling for a particular project. Any professional working in the field of hydrogeology should adapt to and use ground-water models to be truly efficient.

There are a number of terms in the title of this paper which need defining. For example, at one time a computer was a very sophisticated, expensive, cumbersome machine. Nowadays, there are hand-held units capable of performing everything that the machine called the computer could do a few years ago. These hand-held machines are also called computers. Are they computers? Webster defines a computer as a programmable electronic device that can store, retrieve and process data. It is this definition that is used throughout this paper. There is little doubt that the hand-held machine falls into the computer category.

We think of a model as a description or analogy used to help visualize something that cannot be directly observed, as defined by Webster. The word practical has been defined as something being in effect, not theoretical, and capable of being put to use. A model is a tool, an instrument necessary for the practice of a profession, and a means to an end. Therefore, we see a very broad definition, as used in this paper, of computer models as practical tools.

Ground-water management must be practiced effectively and efficiently if we are to bring about the best possible applications for our valuable ground-water resource. One of the most valuable tools to the ground-water manager is the computer model. The model may be a mental conceptualization; an empirical relationship; a physical device; or a collection of mathematical, statistical, and/or empirical statements. Models can be programmed on small or large computers and programmable calculators.

Management models fall into four basic categories: wellfield models, conjunctive use models, solute transport models, and statistical models. There are many levels of complexity in computer modeling as well as a wide variety of programs available to the user. The state of the art today is such that any professional working in the field of hydrogeology should adapt to and use ground-water models in order to be truly efficient.

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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Wellfield models may range from the simple, single well model in a homogeneous, isotropic, infinite, aquifer to complex models requiring the pumping of several points having multiple boundary conditions, both barriers and recharge. The purpose of the wellfield model can range from simply a desire to determine the drawdown at a given point due to a given pumping scheme; to maximizing the efficiency of a pumping schedule for an entire wellfield comprised of several wells. These wellfield models can and, if used effectively, will decrease the operating costs both from the standpoint of energy consumption as well as pump maintenance.

Conjunctive use modeling is a necessity in the State of Colorado. A specific example is the South Platte Rules and Regulations Case which requires the determination of stream depletion due to well pumping. Items taken into consideration for modeling are the pumping schedule, the application of the water (i.e., sprinkler or flood irrigation), consumptive use, and the return flows back to the aquifer and eventually to the river system. The input from a conjunctive model is then used to develop an augmentation plan. This augmentation plan provides for the pumping of the well in the alluvial aquifer without creating injury to senior vested surface-water rights. One of the most common equations used to model stream depletion is the complimentary error function. Work published on this subject can be found in *Transient Groundwater Hydraulics* by Professor Robert E. Glover.

Another use for conjunctive modeling would be models developed for entire basins including hundreds or even thousands of square miles. Such models have been developed in Colorado to look at the effects of well pumping on recharge to and discharge from the aquifers. A number of nodal points on such a model and the number of layers can produce a model which could be cost prohibitive, because of the amount of input data required, number of iterations, and total number of calculations.

Solute transport models can be used to determine the rate and area of flow from discharges such as those associated with leaky landfills. In addition, such models can also be used to study salt-water intrusions into fresh-water aquifers. A great deal of work has been done in studying the plumes associated with ponds containing rather toxic materials. An example is the Colorado State University study of pollutant leakage from a waste disposal pond from a chemical plant located near Denver. A model utilizing the method characteristics successfully predicted the areal extent relative to the concentration of contaminants traveling from the pond to a nearby stream through the alluvial aquifer.

The fourth practical modeling technique to be discussed in this paper is the statistical models. These models have been discussed in literature for the last couple of decades. However, it has been in the last decade that significant advances have been made in this field of hydrogeology due to digital computers and calculators. For example, it is now quicker, more efficient and accurate to determine transmissivity using a Jacobs Simplification Method with a hand-held calculator and statistical methods, than it is to do the entire solution graphically and mathematically. Using the method of linear regression, the time drawdown data can be analyzed in the form of $Y = A + B$ natural logarithm of X. It thus works out that A = the intercept at $T = 1$ minute, B = the slope of the line necessary in determining the transmissivity. Using an additional statistical method called Coefficient of Determination, a comparison of the fit of the data to the least squares line can be made and R^2 value of 1 would indicate a perfect fit. Another beauty of this method is that the intercept time of the intersection of the line with the static water level can be mathematically determined with high accuracy. Therefore, the transmissivity and Coefficient of Storage are statistically modeled in order to determine more accurate values.

In order to analyze hydrologic data where the data are extensive, statistical models have been used to reduce that data and give it meaning. Some of the statistical models used include: frequency analysis, scatter diagram analysis, bivariate correlation, factor analysis, discriminate function, and trend analysis. All of these methods have been used in modeling the ground-water conditions within the Piceance Creek Basin of Colorado.

In summary, the digital computer, as well as the analog, and combinations thereof, can and are being used throughout the United States very effectively. There are also, however, many documented cases of what we have all known for a long time, garbage in and garbage out. There are two basic fundamentals that must not be violated when using the wellfield, conjunctive use and solute transport computer models. These are a mass balance i.e., that of any given cell or any given point in a model, the water in must equal the water out plus the water stored. This continuity requirement is essential and often overlooked. The second fundamental is of course, Darcy's Law. Many people will argue that if you have enough data to build a computer model, you already have the answer. But, on the other hand, computer models are most useful when there is little data. Computer simulation models can be used to conduct a sensitivity analysis quickly and efficiently, thereby allowing the researcher to determine a range of values for which an answer should be reasonable.

Ground-water computer models, which can be classified as practical tools, vary in complexity from a Theis Solution of a single well, programmed on a hand-held calculator to multilevel finite element or difference codes programmed in a large computer such as a CDC 7600. The cost of such practical tools and their use can be minimal or extensive, i.e., a few dollars or a few tens of thousands of dollars. The practicality of such models and their results is purely a function of the intelligence of the user, his ability to select an appropriate level of modeling for a particular project, and his ability to communicate the results to those who need the information.

Models do not eliminate the need for data gathering efforts, practical human experience, judgement evaluations and common sense. They are only tools, which are practical when these criteria are combined with the speed and accessibility made available by the use of modern day computers.

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Ground-Water Computer Models — Intellectual Toys[a]

by Henry A. Baski[b]

ABSTRACT

Ground-water computer models are, certainly, toys which provide intellectual stimulation. They can be useful tools for advancement of the ground-water profession, but I believe that they have been blown out of proportion and that this might cause irreparable damage to our profession.

It is important to see where computer models fit into the ground-water problem-solving process. I believe that ground-water computer programs are simply a complicated "turn the crank" tool for making projections. They're one type of tool out of several which requires aquifer and confining bed characteristics to facilitate making projections. A second approach for making projections involves the direct extrapolation or manipulation of data which does not require transmissivity, storage coefficient, leakance, and other interpreted characteristics. Further, I believe that the collection and evaluation of data are of greater importance than the projection methods and/or tools in arriving at answers.

Advantages of ground-water computer models include: speedy analyses once a program is working, ability to handle many parameters, and utilization of a large data base. The disadvantages include: use of computer models as end goals, tendency for misapplications, time-consuming setup, a waste of time and money in some cases, and diversion of human talent from useful ground-water work.

I believe that ground-water computer models can destroy our ground-water profession! They are, certainly, intellectual toys that can keep people entertained for long periods of time.

There is a disease creeping into this computer modeling business and I'll call it "computerism." Some of the symptoms—misapplication, oversell and mysterious methods—were brought up by Tom Prickett. Also, there is an important item Tom didn't mention. I think that there are occasions when computer models are deliberately used to keep people busy and to spend time and money. This has to stop!

Models can be practical tools; but when they are used as toys, it can destroy people's confidence, both outside and within our profession. In some parts of this country people have more confidence in water witches (or dowsers) than they do in ground-water professionals and their computer models. This is because the dowser goes out there with a stick and these people see something happening with that stick. Then the dowser says, "If you drill here, you're going to get water." Lo and behold, they drill there and they do get water! And the water witch gets credit for it! Actually, he could hardly go wrong. When my brother, Dad, and I were drilling in northeastern Minnesota, we encountered only one completely dry hole out of about 2,000. Anyway, people do not see something happening with a ground-water computer model, though it comes up with answers (four or

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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five significant figures). They seldom have a reliability attached to them. The reliability of the answers cannot go beyond the reliability of the data base. However, there is a tendency to make projections beyond the data base and this is where we get into trouble.

I have to mention an article which was on the front page of the *Denver Post* on December 1, 1977. According to it, a complex computer program was proposed for the Denver Basin. Study for it was estimated to take seven years and cost $687,000. Three years would be for collecting data; then during the fourth year, the characteristics of the aquifers would be measured. The model would be designed to simulate the water levels and movements in the fifth and sixth years—maybe. This is absurd! It shouldn't take seven years to study the Denver Basin. I think that the purpose of this proposal is to crank out a ground-water computer model . . . it's a disease! And it can adversely affect our profession.

Where do computer models fit in? We have our ground-water hydrogeology business which involves everything from drilling, collecting data, evaluating data to making projections. Concerning the latter, there are two classes of projection methods. The first class of projection methods which is most familiar uses aquifer and confining bed characteristics as input to models. It is vital to have transmissivity and storage coefficient, boundary conditions, recharge effects, etc. when using models. Tom had a very good list of models. However, he had experience as a model by itself; I beg to differ with him. I think experience is a vital part of all of the models. You cannot use models effectively without experience. If a computer model doesn't work, the hydrologist who has experience and good judgment can make it work. Computer models are one type of many models used in the first class of projection methods. This is where they fit . . . though, the importance of computer models is sometimes blown out of proportion.

The second class of projection methods which is not so familiar uses direct extrapolation of data. I don't know if it is being taught in any of the college ground-water courses. But I frequently solve problems (like dewatering of mines) using field data, and trends of data plus ground-water flow theory without knowing aquifer and confining bed characteristics. For example, if you're going to have a well field with six wells and you want to know what is going to happen at the end of twenty years, put in six wells and at the end of twenty years you will have your answer. Now, that is the simplest; but it takes too long! Let me work backwards to indicate what extrapolation means. Suppos you pump six wells for ten years, and plot the data. It is not difficult to extend the plots to twenty years. Furthermore, you can pump one well for one year or less and extrapolate it for six wells for twenty years. Eventually, we might see computer models use this extrapolation method.

I believe that the collection and interpretation of data are more important than any projection method. Projection methods include flow nets, well formulas, heat flow formulas, computer programs, extrapolations, etc. I have found that projections are usually within plus or minus 20 percent providin one starts with the same data and assumptions. However, the data, aquifer and confining bed characteristics, and assumptions can easily vary by a factor of 2 to 10. This emphasizes the absurdity of many computer printouts which have answers with four to five significant figures and no reliability indicated. Does this mean an accuracy of plus or minus one part on 10 thousand? No! It doesn't mean that. But it could be misleading. I cannot stress enough the importance of the collection and interpretation of good basic data.

Short-term and long-term projections are different. I push things to their extreme to simplify problems and make them easier to solve. Short-term productions depend on transmissivity values—forget recharge; forget storage coefficient. What is the production of the well for the first day, or for the first couple of months? It's a function of transmissivity! For a well field, it's transmissivity! Computer programs have their nodes, finite elements, finite differences, and equations of water going in and out, but transmissivity is a key item. We all feel confident on short-term analysis. What happens on long term? Transmissivity becomes much less important. We have to know recharge and storage. If you fill a bath tub with water, it will resemble the kind of ground-water basins we have in the western United States. We do not care what the transmissivity is, nor do we care whether you use two or ten straws, when it is pumped the water levels drop! Recharge is negligible. Who needs a computer model for that! It's mining of the water! There may be some socioeconomic and legal consideration on how fast we mine it. Conversely, in areas like Florida, the Floridan aquifer's long-term pumping rate is a function of storage and recharge; on the longer term it is dependent on recharge of precipitation (leakance). With leakance values being more difficult to obtain than storage coefficient, it is a problem to arrive at valid projections . . . with or without computer models.

The above discussion illustrates that computer models are only one type of model which may be applied in one class of projection methods. In addition, I believe that the collection and analysis of data are more important than the two classes of projection methods for arriving at valid answers. Therefore, the over-all importance of computer models is limited and they can be intellectual toys of the highest order.

I'd like you to ask yourself the following questions regarding your projects. They are related to stopping or, at least, reducing this disease which we have. (1) What is the purpose of the ground-water program or study that you are working on? Is it to go out and collect data? Is it to come up with an answer? Or is it to keep busy? (2) How accurate should your answer be? Believe it or not, there are ground-water problems in which yes or no is all the client needs to know. Like, is the water level going to go down or is it going to come up? Or will mine dewatering be more or less than 5,000 gpm? (3) Does the data base justify the method of analysis that is used? Or are you cranking out that program just to keep busy? (4) Is the cost in line with the purpose, accuracy and data base of the ground-water program? (5) The last question is, "Are any of the symptoms of computerism present in the jobs which you are working on?" If so, do something about it!

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Henry A. Baski has 17 years experience ranging from drilling of wells to completion of technical reports. He has worked in 12 States and his specialties include: data collection programs, air lift pumping tests, surface-water/ground-water interactions, short- and long-term projections, and mine dewatering analyses. Prior to becoming an independent ground-water consultant, he was a senior hydrologist with Dames & Moore, and he had been an associate of Wright Water Engineers, Inc. Previously, he had been a partner in a family well drilling business. Mr. Baski received a bachelor of Geophysics from the University of Minnesota, and he is a member of the NWWA, GSA, SPE, RMAG, and AWWA.

Audience Response to Session VIII — Ground-Water Computer Models

Raphael Kazmann, Louisiana State University, 231 Duplantier Blvd., Baton Rouge, Louisiana 70808: One of the big troubles with computer models of all sorts is that it is possible that something is going on that you don't understand. I remember an organization made a big analog model of the Gulf Coast and they didn't take into account that some of the clays acted as osmotic membranes and are losing water to the Gulf, although the water level on the land is below sea level already. We saw water coming into the Gulf, the potentiometric surface was measured regularly and we could tell you exactly where it intersected at sea level and it kept on going down. Water was moving and we didn't know where it was going and for 10 years we were puzzled about that until finally Paul Jones figured out that there was an osmotic relationship between the fresh water in the aquifer and the salt water in the Gulf and the water was moving straight up into the Gulf, with a driving force of about 600 lbs psi. This big model didn't take this into account, and this phenomenon existed over 150 miles of shore. So there's one big deficiency in many of our models. They don't take all of the natural phenomenons into account. My own feeling about these things is that we don't trust any model, mathematical or otherwise until we test it out with a physical test of some sort and make sure that we haven't omitted any of the major assumptions. Furthermore, many fine mathematical program results are likely to be very, very wrong, simply because someone is always coming in and doing something that was not assumed in any of the initial configurations.

Tim Cleath, James M. Montgomery Consulting Engineers, Inc., 555 E. Walnut, Pasadena, California 91101: I have one simple question based on an experience I had recently with a ground-water model in the south San Francisco Bay area. There was a ground-water model made by the Department of Water Resources with which we really had a lot of problems. Because of this ground-water model, one of the local agencies has drawn up ground-water basin water level contour maps. They've combined both the unconfined aquifer water levels and the artesian wells all in the same map. I don't know if you can imagine what that would look like, but it is definitely a wrong interpretation and my question is, once you've got one of these models and it isn't right, what do you do with it?

Russ Darr, Wright Water Engineers, 2420 Alcott, Denver, Colorado 80211: I've seen the same thing done by the U.S.G.S. which came out with a composite water level map. It has value. I think if you know the transmissivities of the two aquifers you can separate the various heads by a formula developed by Dr. Dan Foegle. I think there's a discussion of that in Professional Paper 908. What do you do with a model that doesn't work? My guess is that you throw it away and start all over again.

Francis A. Kohout, U.S.G.S., Water Resources Division, Woods Hole, Massachusetts 02543: The mention of Robert E. Glover's name by Mr. Darr brought to mind a number of refreshing incidents associated with some of the early work in mathematical and computer hydrology. Since I won't be around much longer, I thought the audience might enjoy hearing several of these in the form of anecdotes.

Well the first occurred at an NWWA annual meeting about 25-odd years ago. Bob Stallman had become very excited about the finite-difference approach to solving hydrologic problems. He recognized that many of the practical problems were too complicated to resolve by rigorous mathematics. Having an engineer's background, Bob was greatly influenced by Southworth's book on numerical analysis and he proceeded to wear out numerous mechanical calculators in the process of "reducing the residual to zero" at the nodes of a relaxation net. Pretty soon he got bored with wearing out his fingers on the hand calculators and began monkeying around with electronics—first with Teledeltos paper, silver paint, a razor blade, a power supply, and a voltmeter. Then he really went into the electronics business, learned how to build constant-current and constant-voltage power supplies, etc., and put together a machine with nodes, as I recall, about 10 by 10—a total of 100 nodes. This was all built up in a big 6-foot-tall electronics rack with all kinds of meters and volume control knobs, etc.—a very impressive piece of machinery on which boundary conditions could be simulated and which could be used to measure simulated heads on the water table, drawdowns at pumping wells, withdrawal rates, and so on. Well, Bob was demonstrating this to anyone who would listen as part of the U.S.G.S. exhibit at the NWWA meeting. And as it so happened, an interested passerby was a crusty, old, leather-faced well driller. Bob carried on, explaining and demonstrating with meter readings and knob turnings, and lauding the wonderful things this machine could accomplish. Well, after about 15 minutes, Bob thought he had really made a conquest and asked if there were any questions. The well driller promptly spoke up: "But how in hell do you get it down the well?"

The second anecdote is related to Robert Glover whose name was mentioned here a couple of times by Mr. Darr. Hilton Cooper headed up the U.S.G.S. salt-water diffusion project, and I had been involved with field studies of salt-water encroachment in Florida. As anyone who has been involved with hydrology knows, Hilton is not an insignificant mathematician in his own right—more or less oriented toward rigorous mathematics. As part of the studies, Hilton invited Professor Glover to visit Miami to get familiar with the field test site at Cutler; and after he returned home, he wanted me to give some comments about his approach—so I wrote a long letter about our discussions and sent it through Hilton. This was before Xerox, I think, because Hilton proceeded to cut up my letter with scissors and passed along the remainder of it. One of the surviving things was something to the effect that we needed to hit the mathematics head-on. Now, rigorous mathematicians confronted with difficulty rarely ever did hit things head-on. If a technique was found to work, it was used over and over until a dead end was reached. Then they would usually find a sneaky little way of catching up to the problem by making an assumption, or sliding sideways around the problem. The report came from Hilton that Professor Glover's comment was an emphatic, "Well, I just can't hit this problem head-on."

But things have changed. With modern day computers, problems can be solved that could not possibly be attempted before. But one shouldn't overlook some of the questions of boundary conditions—for example, those which I presented earlier in this meeting in regard to the occurrence of relatively fresh ground water under the Atlantic Continental Shelf. We believe this water was recharged into the offshore aquifers during low stand of sea level in Pleistocene time and that it is now serving as a buffer for present-day salt-water encroachment. We have Atlantic City pumped down to a hundred feet below sea level: Savannah, Georgia, pumped down to 100 feet below sea level; and more—and yet we have not had extensive salt-water encroachment in these aquifers. And I say this in spite of the fact that Henry Barksdale, 40 years ago, predicted that Atlantic City was in imminent danger of salt-water encroachment. It may well be, but the fact of the matter is that we are just beginning to find the whereabouts of the fresh-salt transition zone in the offshore area. Clearly, a very fundamental aspect of any computer analysis is to have a realistic idea of what your initial boundary conditions are.

Now, the last item I wanted to mention is again related to Professor Glover. You know I have the greatest respect for him, because we are coauthors on a U.S.G.S. Water-Supply Paper. Nevertheless, I can't resist passing along this anecdote.

This again dates back about 20 years. Hilton Cooper, at the time, wanted to have a laboratory experiment and analysis of the dispersion process, so he got Ivan Johnson, then head of the U.S.G.S. Hydrologic Lab at Denver, to set up a hydraulic model in which the fresh-salt interface was to be modeled—no oils or other substitute fluids—just plain fresh and salt water, dyed for visibility. The interface was then going to be oscillated back and forth to form a zone of diffusion in a permeable medium. Hilton was at the lab looking over this model with Ivan and talking about how it was to be operated. Professor Glover was there also. Hilton said, "Well, I'd like to have some little holes drilled in this model so we can stick some hypodermic needles through rubber plugs and suck out some water, and make some chemical analyses on the dispersion zone." Whereupon Glover's response was: "But, Hilton, you don't have to bother with that. I've already calculated that distribution."

Gordon Nelson, Hydrologist, U.S.G.S., 1209 Orca St., Anchorage, Alaska 99501: I am not opposed to computer models. In fact, I use them in my work. However, I think you should be aware of one danger of computer models which has not been addressed. That danger is that people put a tremendous amount of faith in computers. After building or calibrating a model, you may discover that you have written a new gospel which some will believe with fervor equal to belief in the other four, Matthew, Mark, Luke, and John. Even if you explain the error limits, you may find them ignored unless you make them abundantly clear. It is easy to lose sight of the error limits in a model just as is often the case with radiometric age dates. How often have you seen a rock dated as, for example, 20 ± 5 million years and then heard a geologist describe it as a 20 million-year-old rock? And don't criticize planners for misusing models; even hydrologists or hydrogeologists who build the models may lose sight of the difference between what the computer tells them and what they tell the computer. I listened to a speaker on Wednesday say that the computer model told him there was no flow from one side of a basin to the other. It seems to me that he identified the boundary conditions in the field and then *he* told the model that ground water did not flow from one side of the basin to the other. In another instance a colleague recently related to me a case of a glacier model in which the author said that the model indicated the glacier would not advance beyond a certain point. However, the modeler had overlooked the fact that *he* had built in that requirement. It was a requirement of the model, not the glacier. Again he had lost sight of the difference between what he told the computer and what the computer told him. My last example of the pitfalls of modeling is a basin-runoff model in which the modeler had such complete faith in the model that he told a field hydrologist that he had failed to measure a flood peak. In this case the hydrologist who had been up to the top of his hip boots in an icy stream did not take kindly to the statement that the discharge measurement was a figment of his imagination. I guess the main point of this last example is, don't change the data to fit the model, and don't put more faith in the model than in real data.

All of us here today are professional hydrologists, hydrogeologists, and engineers, and most of you probably feel that you wouldn't make such mistakes. All I can say to that is: "GOOD," neither would I, I hope!

Graham E. Fogg, Research Associate, The University of Texas at Austin, Bureau of Economic Geology, University Station, Box X, Austin, Texas 78712: As a hydrologist who has both studied and used ground-water models, I have learned that they can be either practical tools or intellectual toys, depending on the competence of the modeller.

Mr. Prickett pointed out that ground-water models have existed for years in the forms of mathematical models and experience. However, the controversy about the practicality of ground-water models has become heated only recently, reflecting the increased usage of numerical models. The numerical models are by far the most powerful tools ever available for solving ground-water problems. Naturally, the chief drawback of any powerful tool is that with only slight misuse it can bring disastrous results. Such misuse of numerical modelling has resulted in many models which are no more relevant than intellectual toys.

A user of numerical ground-water models needs a firm understanding of the following: (1) ground-water hydraulics and the complexities of geology that affect ground-water flow, (2) field data collection, (3) the theory of well hydraulics, (4) the theory behind numerical ground-water models, and (5) sound scientific judgment. In other words, the modeller should understand how natural ground-water systems work and how accurately these systems can be represented by numerical models. Items 2 and 3 are needed to help assess the worth of model input data, which are usually sparse and often inadequate. A mastery of the theory of well hydraulics (item 3) is requisite for assessing results of aquifer pumping tests. Most ground-water modellers appear to be weakest in either 1 or 4.

Below are listed several basic mistakes and misconceptions which seem to reduce the validity of many numerical modelling studies.

(1) As mentioned by Mr. Prickett, the wrong type of model (i.e., experience, mathematical or numerical) is often chosen. One needs competence in numerical modelling not only to use numerical models, but also to know when not to use them.

(2) Many hydrologists believe the sole purpose of constructing a ground-water model is to predict future conditions. In most cases even numerical ground-water models are not representative enough of field conditions to justify their use for predicting the future. Then what is so powerful about numerical models? They are the only means of collectively analyzing a large quantity of ground-water data as a coherent system. Some ground-water systems can be adequately understood only by this approach. Once a system is adequately understood, many of the crucial problems can often be reduced to (using Mr. Baski's terms) yes or no questions.

(3) Many hydrologists believe numerical models can be calibrated to accurately predict future ground-water conditions, regardless of the available data. This is false. Model calibration, or the adjustment of model input data (e.g., transmissivity, recharge, storativity) such that model output (i.e., hydraulic head) matches field measurements, can improve the predictive capability of a model. However, the success of a calibration is directly proportional to the amount of reliable input data and the skill of the modeller. Calibrations commonly entail the simultaneous adjustment of more than one input parameter. These generally yield unreliable results, since two or more parameters cannot be adjusted in a unique fashion. In fact, it is usually difficult to adjust one parameter in a unique fashion. For example, in a steady-state model with known pumpage and prescribed head boundary conditions, there are an infinite number of different transmissivity distributions which yield the same model-computed values of head. To successfully calibrate such a model, the modeller must have good initial estimates of transmissivity and head in addition to the earlier mentioned qualifications. Above all, modellers and water managers should realize that the ability of a calibrated model to mimic past ground-water conditions does not necessarily verify its ability to predict future conditions.

(4) Numerical models constructed for large regions are sometimes being used to solve site-specific problems. This is improper because inherently the regional models are too general to represent local conditions reliably.

(5) Recently much work has been devoted to developing numerical models for the simulation of solute transport in ground water. This is very worthwhile research from which we can learn much about the solute transport problem. However, there exist several unresolved problems which limit the usefulness of numerical solute transport models as practical tools. One such problem involves the ground-water velocity field, usually the most important input into a solute transport model. Heterogeneous aquifer characteristics cause considerable variations in the direction and magnitude of velocity (in both two and three dimensions). These velocity variations are generally critical controls on the movement and dilution of a ground-water contaminant. Unfortunately, the velocity field is seldom known in sufficient detail to make a solute transport model reliable. Usually the best method of estimating the velocity field in any detail is through ground-water flow modelling (numerical); and therefore the construction of a solute transport model should in most cases be preceded by construction of a valid flow model. Other serious difficulties in solute transport modelling include: the estimation of representative dispersion coefficients (on both the regional and local scales), estimation of rates of solute adsorption onto the solid matrix, and accurate representation of the solute transport equation through numerical methods.

I agree with Mr. Baski's statement that our profession of hydrology may be damaged by numerical modelling. My fears stem from the following disturbing observations: (1) many ground-water models are poorly constructed and interpreted, (2) in some cases water managers are using these models to make broad reaching decisions regarding their ground-water resources, and (3) many hydrologists and administrators are now distinguishing the good ground-water studies from the bad ones by assuming the former are those in which numerical models are employed. Surely, these actions can only produce untenable ground-water studies and management programs; and the end result may be a loss of confidence in hydrologists and their models. Such consequences can be avoided through a rational and deliberate approach to modelling, careful model calibration through testing, and realistic applications of model results.

Waterborne Disease — A Status Report Emphasizing Outbreaks in Ground-Water Systems[a]

by Gunther F. Craun[b]

ABSTRACT

A total of 192 outbreaks of waterborne disease affecting 36,757 persons were reported in the United States during the period 1971-1977. More outbreaks occurred in nonmunicipal-water systems (70%) than municipal-water systems; however, more illness (67%) resulted from outbreaks in municipal systems. Almost half of the outbreaks (49%) and illness (42%) were caused by either the use of untreated or inadequately treated ground water. An unusually large number of waterborne outbreaks affected travelers, campers, visitors to recreational areas, and restaurant patrons during the months of May-August and involved nonmunicipal-water systems which primarily depend on ground-water sources. The major causes of outbreaks in municipal systems were contamination of the distribution system and treatment deficiencies which accounted for 68% of the outbreaks and 75% of the illness that occurred in municipal systems. Use of untreated ground water was responsible for only 10% of the municipal system outbreaks and 1% of the illness. The major cause of outbreaks in nonmunicipal systems was use of untreated ground water which accounted for 44% of the outbreaks and 44% of the illness in these systems. Treatment deficiencies, primarily inadequate and interrupted chlorination of ground-water sources, were responsible for 34% of the outbreaks and 50% of the illness in nonmunicipal-water systems.

INTRODUCTION

This report deals exclusively with acute waterborne disease and summarizes the data available on waterborne outbreaks in the United States during 1971-77 emphasizing outbreaks in ground-water systems. It is nevertheless important to remember that chronic diseases, such as cardiovascular disease and certain cancers, and human physiologic changes have been epidemiologically associated with long-term exposure to various drinking-water contaminants and types and treatment of water supplies. It is much more difficult, however, to present a status report on these diseases because the data are often incomplete in regard to specific populations affected or incomplete in that additional research is required. For example, although much research has been conducted to show that populations in hard-water areas have lower mortality due to cardiovascular disease than populations in soft-water areas, it is still unclear whether the high concentrations of calcium or magnesium in hard waters offer some protection or whether the higher concentrations of metals leached from water piping in soft, corrosive waters are detrimental (Craun and McCabe, 1975; Craun, Greathouse *et al.*, 1977). Recent epidemiologic studies have indicated a relationship between the type of water source and treatment, especially chlorination, and cancer of certain sites; however, these have generally been hypothesis generating studies of large population groups and additional studies are required to account for confounding variables due to individual life styles and patterns (Cantor, 1975; Cantor and McCabe, 1978; Cantor, Hoover *et al.*, 1978; Cooper, Kanarek *et al.*, 1978).

DEFINITIONS

Only outbreaks associated with water used or

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intended for drinking or domestic purposes are included. To be considered an outbreak, at least two cases of infectious disease must be reported before a common source can be noted and investigated. Except in unique circumstances, such as a case of chemical poisoning in which the chemical was identified in the water, a single case cannot be recognized as having been caused by drinking water. The waterborne outbreaks reported here are those in which drinking water has been implicated epidemiologically as the vehicle of transmission of the illness. In most of the outbreaks the water was also found to be bacteriologically or chemically contaminated. In only a few outbreaks, however, was an etiologic agent isolated from drinking water.

For analysis the water systems were classified as municipal, semipublic, or individual. The definitions of municipal and semipublic differ slightly for the periods 1971-75 and 1976-77. The definitions used for the 1971-75 data are consistent with reports from previous years (Craun and McCabe, 1973; Craun, McCabe and Hughes, 1976; Craun, 1977). Definitions used for classifying water systems involved in outbreaks during 1976-77 were modified to correspond to those used in the Safe Drinking Water Act (P.L. 93-523). Municipal systems are now defined as public or investor-owned water supplies that serve large or small communities, subdivisions, and trailer parks of at least 15 service connections or 25 year-round residents regardless of the number of service connections. This corresponds to the Act's definition of community-water system. Semipublic-water systems are those systems that serve transients and include institutions, industries, camps, parks, hotels, and service stations which have their own water supply available for use by the general public. This corresponds to the Act's definition of noncommunity-water system. The definition of individual system remains unchanged. Individual-water systems are those used by single residences in areas without municipal systems or by persons travelling outside of populated areas (e.g., backpackers).

The major effect of this definition change will be in the analysis of trends because small subdivisions and trailer parks which had previously been classified as semipublic systems are now classified as municipal systems. This change in definition resulted in the reclassification of only one system in 1976 (e.g., one system classified as municipal in 1976 would have been classified as semipublic had the 1975 definitions been applied) and two systems in 1977.

SURVEILLANCE SYSTEM

A cooperative effort between the Health Effects Research Laboratory, Environmental Protection Agency (EPA), in Cincinnati, Ohio, and the Center for Disease Control (CDC) in Atlanta, Georgia, to investigate, document, and report waterborne-disease outbreaks in the United States has been in existence since 1971. Local and State health departments investigate waterborne outbreaks and at times request assistance from CDC and the EPA. As part of the reporting system, State epidemiologists and engineers in State water supply surveillance agencies cooperate in providing data on waterborne outbreaks to EPA and CDC annually.

Although reporting has generally improved since 1971, it is recognized that more waterborne disease outbreaks occur than are reported. Reporting depends upon many factors, including the type of water system, severity of disease, number of individuals affected, and interest and capabilities for recognition and investigation at the State and local level. For example, 28% of all waterborne outbreaks since 1975 were reported by Pennsylvania. It is felt that the primary reason for this large number of outbreaks in Pennsylvania is the diligent surveillance and investigation by State and local public health officials of problems in smaller-water systems. It is difficult to ascertain the number of waterborne outbreaks that go undetected or unreported. One estimate, based on data collected from 1945-70, indicated that about one-half of the waterborne outbreaks in municipal-water systems and about one-third of those in nonmunicipal systems are detected and reported (Craun and McCabe, 1973). A study of foodborne outbreaks in Washington State after initiation of an improved surveillance system and investigation indicated that only one outbreak in ten had been recognized and reported (Barker, Sagerser *et al.*, 1974). This number may be applicable to waterborne outbreaks as well, since both depend upon the recognition of acute illness in several individuals to initiate an investigation.

Outbreaks in municipal-water systems, which number about 40,000 and serve about 177 million people, are probably the most likely to be reported. Outbreaks in semipublic systems, which number about 200,000 and serve numerous transients, are the next most likely to be reported. The least likely to be reported are outbreaks in individual-water systems, which number about ten million.

Table 1. Waterborne Disease Outbreaks in the U.S., 1971-1977

	1971	*1972*	*1973*	*1974*	*1975*	*1976*	*1977*	*Total*
Outbreaks	19	29	26	25	24	35	34	192
Cases of Illness	5,182	1,638	1,774	8,356	10,879	5,068	3,860	36,757

OUTBREAKS

During the period 1971-77 a total of 192 outbreaks of waterborne disease, affecting 36,757 persons were reported (Table 1). Two deaths were associated with these outbreaks.

Historical data on waterborne disease over the past five decades indicate that outbreaks are no longer on the decline in the United States (Craun and McCabe, 1973; Craun, McCabe and Hughes, 1976; Craun, 1977). The number of waterborne outbreaks decreased steadily from an average of 41 per year in 1936-40 to 10 per year in 1951-55; however, since then, an increase in the number of waterborne outbreaks has occurred, especially during the 1970's, to an average of 35 per year in 1976-77. The reason for this apparent increase is difficult to ascertain, but it may be primarily the result of increased reporting and follow-up by engineers and epidemiologists.

ETIOLOGY

An etiologic agent was determined in only 43% of the 192 outbreaks (Table 2). The remaining outbreaks were categorized as acute gastrointestinal illness. This category included outbreaks characterized by symptoms including abdominal cramps, nausea, vomiting, and diarrhea occurring 24 to 48 hours after comsumption of water and outbreaks of "sewage poisoning" which is presumably caused by coliform organisms or enteric viruses that have yet to be fully characterized. In many of the outbreaks the search for an etiologic agent included only stool cultures for *Salmonella* and *Shigella;* in others the investigation and collection of clinical specimens were delayed because of late notification that an outbreak had occurred or samples were not collected because the outbreak was investigated after the illness had subsided.

Twelve percent of the outbreaks were chemical poisonings involving arsenic, chlordane, chromate, copper, cutting oil, developer fluid (hydroquinone, paramethylamino phenol), ethyl acrylate, fluoride, fuel oil, furadan, lead, leaded gasoline, a mixture of lubricating oil and kerosene, phenol, polychlorinated biphenyl, selenium, and an unidentified herbicide.

The most commonly identified pathogen was *Giardia lamblia. Giardia lamblia* is a flagellated protozoan responsible for giardiasis. Twenty waterborne outbreaks of giardiasis were documented during 1971-77; 18 involved surface-water systems. All but two of the giardiasis outbreaks in surface-water systems occurred as the result of drinking untreated surface water or surface water whose only treatment was simple disinfection. Small municipal systems or semipublic systems in recreational areas were primarily affected.

Outbreaks occurring in ground-water systems were examined separately to determine if the etiologic agents were different. The diseases in ground-water systems were generally similar to those in surface-water systems with the exception of giardiasis. Only two outbreaks of waterborne giardiasis occurred in ground-water systems: in one, the well was influenced by water from an adjacent stream and in the other the well was heavily contaminated by human sewage. The percentage of outbreaks categorized as acute gastrointestinal illness was slightly higher in ground-water systems, no outbreaks of illness caused by toxigenic *E. coli* were identified in ground-water systems, and the percentage of illness due to shigellosis (30%) was higher in ground-water systems.

Many individual wells in some areas of the United States have high nitrate concentrations. Infantile methemoglobinemia, a disease related to the nitrate concentration of drinking water, is not included in the tabulation. This disease is not reportable in the United States and its incidence is not known. Numerous cases associated with individual wells high in nitrate were reported in the United States in the 1940's and 1950's;

Table 2. Etiology of Waterborne Disease Outbreaks in the U.S., 1971-1977

	Outbreaks (Percent)	*Cases of Illness (Percent)*
Acute Gastrointestinal Illness	57	58
Chemical Poisoning	12	3
Giardiasis	10	18
Shigellosis	9	14
Hepatitis A	8	1
Salmonellosis	2	3
Typhoid	2	<1
Enterotoxigenic *E. coli*	<1	3
	100	100

however, only three investigators have been motivated in the past 17 years to describe cases that have come to their attention (Comly, 1945; Waring, 1949; Walton, 1951; Vigil *et al.*, 1965; Miller, 1971; Jones *et al.*,(1973). Cases in European countries continue to be described in the literature (Jablonska-Ulbrych and Frelek-Karska, 1974; Faivre, *et al.*, 1976; Kantecka, 1976; Bochynski *et al.*, 1977). Our laboratory is currently conducting a study to determine the incidence of this disease in areas of the United States with high nitrate ground water and the influence of health education and changes in infant feeding practices on this disease.

OUTBREAKS BY TYPE OF WATER SYSTEM

More outbreaks (70%) occurred in the nonmunicipal-water systems, but most of the illness (67%) resulted from outbreaks in municipal systems (Table 3). Outbreaks attributed to municipal systems affected an average of 425 persons per outbreak compared to 106 persons in semipublic systems and 10 persons in individual systems.

Consistent with previous trends, outbreaks in semipublic systems peaked during the summer months (Table 4). There appeared to be little seasonal variation for outbreaks in municipal systems during this period or in previous years.

Table 3. Waterborne Disease Outbreaks in the U.S., 1971-1977, by Type of System

	Outbreaks (Percent)	*Cases of Illness (Percent)*
Municipal Systems	30	67
Semipublic Systems	58	32
Individual Systems	12	1
	100	100

Table 4. Waterborne Disease Outbreaks in the U.S., 1971-1977, Seasonal Distribution

	Municipal	*Semipublic*
January	2	3
February	3	2
March	6	2
April	4	8
May	4	15
June	5	23
July	9	25
August	7	15
September	4	4
October	4	5
November	6	5
December	3	5
Unknown	1	–
	58	112

A large number of waterborne outbreaks each year affects the travelling public using semipublic water systems which depend primarily upon ground-water sources. In 1971-77, 78% of the outbreaks in semipublic-water systems affected travelers, campers, and visitors to recreational areas or restaurant patrons. Seventy-five percent (75%) of the outbreaks involving this transient population occurred in May-August, the period when outdoor activities such as picnicking, camping, and vacationing are most common.

Outbreaks in systems using untreated ground or surface water were also examined by month of occurrence to determine if contamination is more prevalent during certain seasons (Table 5). There appeared to be little variation by season for outbreaks caused by use of untreated surface water. However, a distinct increase in outbreaks caused by the use of untreated ground water and springs was noted in the summer; 34 (53%) of the 64 outbreaks occurred in June-August. This implies there is either increased contamination of these water sources during this period or if it is assumed that the supplies are always contaminated, use by greater numbers of susceptible individuals during this period.

CAUSE OF OUTBREAKS

The majority of outbreaks (79%) and illness (73%) were caused by the use of untreated or inadequately treated water (Table 6). Use of untreated, contaminated water resulted in 90 (47%) outbreaks and 11,534 (31%) illnesses; deficiencies

Table 5. Seasonal Distribution of Waterborne Disease Outbreaks in the U.S., 1971-1977, Use of Untreated Water

	Ground Water & Springs	*Surface Water*
January	4	0
February	0	2
March	1	1
April	3	0
May	7	2
June	14	3
July	10	4
August	10	3
September	2	6
October	5	0
November	5	2
December	2	2
Unknown	1	0
	64	25

Table 6. Causes of Waterborne Disease in the U.S., 1971-1977

	Outbreaks	*Cases of Illness*
1. Use of Untreated Water:		
Surface Water *	25	6,060
Ground Water	57	4,539
Springs	8	935
	90	11,534
2. Treatment Deficiencies:		
Surface-Water Systems	19	3,599
Ground-Water Systems	38	10,829
Spring-Water Systems	4	1,179
	61	15,607
3. Distribution System Deficiencies:	26	9,058
4. Miscellaneous and Unknown	15	558

* Includes outbreaks of giardiasis in which surface water was chlorinated but not filtered.

in treatment, primarily inadequate or interrupted chlorination, accounted for 61 (32%) outbreaks and 15,607 (42%) illnesses. Distribution system deficiencies such as backsiphonage, cross-connections, water main breaks, contamination of treated water storage reservoirs were responsible for 26 (13%) outbreaks and 9,058 (25%) illnesses. The remaining outbreaks and illnesses were caused by miscellaneous problems such as contaminated ice or containers and unknown or undetermined causes.

Almost half of all outbreaks (49%) and illness (42%) were caused by either the use of untreated or inadequately treated ground water. Fifty-seven (63%) of the 90 outbreaks that were caused by the use of untreated, contaminated water occurred in ground-water systems compared to 25 (28%) outbreaks in surface-water systems. Of the 61 outbreaks that were caused by treatment deficiencies, 38 (62%) outbreaks affecting an average of 285 persons per outbreak occurred in systems using ground water compared to 19 (31%) outbreaks affecting an average of 189 persons in systems using surface water.

The 95 outbreaks in ground-water systems were further examined to determine the specific causes responsible for the outbreak (Table 7, 8). Distribution-system related outbreaks can occur in any type of water system and were excluded from this analysis. Also excluded were outbreaks caused by miscellaneous deficiencies and unknown causes. Overflow or seepage of sewage, primarily from septic tanks or cesspools, was responsible for 42% of the outbreaks and 71% of the illness caused by use of untreated ground water. This includes the four outbreaks where contaminants travelled through limestone or fissured rock. Contamination of ground water by various chemicals (arsenic, ethyl acrylate, leaded gasoline, phenol, polychlorinated biphenyl, selenium) and surface runoff or flooding resulted in 12 (21%) outbreaks and 421 (9%) illnesses. There were insufficient data to establish a source of contamination for the remaining 21 (37%) outbreaks in systems using untreated ground water, emphasizing the need for better investigation and reporting if these problems are to be understood and corrective action taken.

The removal of iron and manganese for aesthetic reasons and disinfection only are the primary means of treatment for ground water. Ground-water systems usually depend on a relatively good quality water, and disinfection is sometimes provided to protect against possible contamination of the distribution system. In these situations unexpected contamination of the source could completely overwhelm the disinfection provided. For ground-water systems using a source known to be frequently or intermittently contaminated with bacteria, continuous disinfection is necessary to insure potability of the water. Outbreaks in these systems are caused by interruption of disinfection due to the malfunction of equipment or lack of maintaining a sufficient supply of disinfectant and inadequate disinfection because disinfectant dosages had been reduced below prescribed levels or no attention was paid to maintaining the proper residual of disinfectant.

Interruption of disinfection was responsible for most of the outbreaks (74%) and illnesses (86%) caused by treatment deficiencies in ground-water systems. Seven (18%) outbreaks resulting in 1,176 (11%) illness occurred because of inadequate disinfection of the ground-water sources. Most of the outbreaks were usually the result of improper chlorination since this is the most widely used

Table 7. Waterborne Disease in the U.S. Due to Source Contamination of Untreated Ground-Water Systems, 1971-1977

	Outbreaks	*Cases of Illness*
Flooding	1	88
Contamination through limestone or fissured rock	4	138
Chemical contamination	6	102
Contamination by surface runoff	5	231
Overflow or seepage of sewage	20	3,100
Data insufficient to classify	21	880
	57	4,539

Table 8. Waterborne Disease in the U.S. Due to Treatment Deficiencies in Ground-Water Systems, 1971-1977

	Outbreaks	*Cases of Illness*
Problems in chemical addition	3	374
Inadequate disinfection:		
Iodine	1	72
Chlorine	6	1,104
Interruption of disinfection:		
Iodine	3	71
Chlorine	25	9,208
	38	10,829

method of disinfection in the United States, however, four outbreaks resulted from inadequate or interruption of iodine disinfection. In these outbreaks, iodination was used by small semipublic systems serving a primarily transient population.

There were three outbreaks caused by the addition of other chemicals to ground water. The two largest are of interest because they illustrate the need for increased surveillance and operator training in fluoridation practices. Both outbreaks involved semipublic-water systems at elementary schools. In one, 201 students and 12 adults became ill minutes after consuming orange juice made from the school's water supply. Laboratory analysis of the juice revealed a fluoride concentration of 270 mg/l. Investigation of the water system showed that fluoride feeder pump at the well site had malfunctioned, causing fluoride to be fed continuously even while the water pump was not operating. The second outbreak involved 150 children who became ill after drinking Kool Aid made with school water. It was later found that the fluoride feeder was purposely run while the water pump was off because the operator was concerned that the fluoride level was not high enough in the system. The third outbreak also involved a semipublic system serving a school. The pH of the ground water was 4.9 and pH adjustment was applied at the well site. Prior to the outbreak, chemical feed was interrupted and high levels of copper (12.5 mg/l) were leached from the copper plumbing. The concentration of copper in the ground water prior to distribution through the plumbing was 0.3 mg/l.

The causes of outbreaks and resulting cases of illness were also classified by type of water system. As in previous years, the major cause of outbreaks in municipal-water systems was contamination of the distribution system; 40% of the outbreaks in municipal-water systems occurred because of deficiencies in the distribution of finished water primarily through cross-connections and backsiphonage. Most of the resulting outbreaks were quite contained, affecting relatively few people. However, two large outbreaks in 1975 accounted for most of the illness in this particular category: an estimated 5,000 cases of acute gastroenteritis in Sewickley, Pennsylvania, felt to be related to contamination of an uncovered storage reservoir for treated water and 1,400 cases of a similar illness in Sellersburg, Indiana, traced to sewage contamination of a water main during construction.

Use of untreated ground water was responsible for most illness in municipal-water systems during previous years; however, during 1971-77, there were only 6 (10%) outbreaks and 151 (1%) cases of illness because of the use of untreated ground water by municipal systems. In other municipal system outbreaks in 1971-77, 28% of the outbreaks and 39% of the cases of illness were related to treatment deficiencies; 14% of the outbreaks and 23% of the cases of illness were related to use of untreated surface water; 8% of the outbreaks and 1% of the cases of illness were related to miscellaneous problems such as ice contamination or unknown deficiencies.

In nonmunicipal-water systems, use of untreated ground water was responsible for most of the outbreaks and illness during previous years. Use of untreated ground water was still an important problem in 1971-77, but deficiencies in treatment were also responsible for many outbreaks and illness in nonmunicipal systems during that period. In 1971-77 use of untreated ground water accounted for 44% of the outbreaks and 44% of the cases of illness in semipublic systems, and deficiencies in treatment were responsible for 34% of the outbreaks and 50% of the cases of illness. Use of untreated surface water accounted for 13% of the outbreaks and 4% of the illness in nonmunicipal systems.

CASE HISTORIES

The three largest outbreaks involving ground-water systems occurred in Pico Rivera, California (3,500 cases), Comerio, Puerto Rico (2,150 cases) and Richmond Heights, Florida (1,200 cases).

Between July 20 and August 7, 1971, approximately 62% of the people living within a 1¼-square-mile area of Pico Rivera became ill with gastroenteritis (McCabe and Craun, 1975). The outbreak was confined to the Pico County Water District (PCWD) and did not affect any part of Pico Rivera served by other water companies. Within the PCWD, the outbreak was most severe in the west portion of the water district, close to a reservoir. A chlorinator provided disinfection to water entering the reservoir via a gravity line from a well. It was discovered that the chlorinator had broken on July 20 and was not repaired for approximately one week. Water samples taken from the reservoir, from a gravity water line feeding the reservoir, and from a trailer park within the area revealed heavy contamination by fecal coliforms, but no pathogens. The most likely source of the contamination was along the gravity line serving the reservoir, since samples collected from the well supplying the gravity line yielded no fecal coliforms.

The second largest outbreak, an estimated 2,105 cases of shigellosis, occurred in Comerio, Puerto Rico in 1976. *Shigella sonnei* was isolated from clinical specimens but could not be isolated from water samples collected two weeks after the epidemic peaked. High coliform counts were found in the water distribution system during the outbreak, and during the investigation one of seven wells supplying the system was found to be contaminated with total coliforms of $>4900/100$ ml and fecal coliforms of 230/100 ml. Although the wells were chlorinated, insufficient chlorine contact time was provided prior to distrubution, and the facilities were not maintained to provide continuous, effective disinfection. ECHO 8 virus was also found in the water from the contaminated well; however, its significance was not evaluated by epidemiologic studies.

Between January 17 and March 15, 1974, approximately 1,200 cases of acute gastrointestinal illness occurred in Richmond Heights, Florida, a residential community of 6,500 (Weissman, Craun *et al.,* 1976). Stool specimens from ten ill individuals yielded *Shigella sonnei,* and since symptoms of other patients correlated closely with those of culture-positive cases, *S. sonnei* was considered as the most likely cause of the cases reported as gastrointestinal illness. Epidemiologic investigation disclosed that consumption of tap water was significantly associated with illness, and it was found that one of the two wells providing water to the community was continuously contaminated with excessive levels of fecal coliforms. The source of the contamination was traced by dye studies to the septic tank of a church and a day-care center located approximately 150 feet from the well. A breakdown in chlorination enabled approximately 1 million gallons of unchlorinated or insufficiently chlorinated water from the contaminated well to be distributed to the community 48 hours before the epidemic began. This outbreak is a good example of why good disease surveillance is necessary to detect outbreaks. Initially only ten cases of shigellosis were recognized by health authorities, but upon further investigation 1,200 illnesses were found to have occurred. If local health authorities had not been conducting shigellosis surveillance, the initial ten cases might never have been recognized as an unusual occurrence and a waterborne outbreak as large as this might not have been detected.

On November 16, 1971, a trailer court tenant in Anchorage, Alaska, telephoned local health authorities to complain of water that was "dirty" and had a bad odor (McCabe and Craun, 1975). That morning a sanitary engineer investigated the complaint and found what appeared to be gross sewage contamination of the well-water supply. Raw sewage was found standing in the well house to the top of the well casings. Further investigation revealed 89 of 114 persons exposed were ill. Symptoms included nausea, vomiting, abdominal pain, fever, and diarrhea caused by *S. sonnei.* The water source was two approximately 242-feet deep wells, steel cased and enclosed in a well house. The well house floor was 3 feet below ground level; the well casings extended to 1 foot above the well-house floor. Routine periodic water samples from the trailer court had consistently been negative. Sometime prior to the morning of November 16, a "soft plug" had obstructed the borough sewer and caused a backup of sewage in the trailer-court sewage system. Sewage backed up through the drain in the well-house floor and spilled over the casings into the wells. Subsequently, raw sewage was pumped into the trailer-park water system.

Another outbreak of shigellosis occurred in November 1972 at a junior high school in Stockport, Iowa (Baine *et al.,* 1975). Some 208 cases of gastrointestinal illness were reported among the 289 students and 25 staff members. A similar illness affected 12 of 26 visiting basketball players. Rectal swab specimens were found to be positive for *S. sonnei.* Epidemiologic investigation revealed the vehicle of infection to be the water supply, a shallow well in the schoolyard. Fluorescein dye introduced into a shower drain appeared in the well water within 30 minutes. A sample of tap water at the school showed high levels of coliforms and yielded *S. sonnei.*

A waterborne outbreak of gastrointestinal illness where *Yersinia enterocolitica* was isolated from well water occurred during this period (Eden *et al.*, 1977). An epidemiologic survey estimated that some 750 cases of gastroenteritis occurred among 1,550 guests and 350 employees at a Montana ski resort during December 6, 1974, through January 17, 1975. A significant association was found between drinking water and the illness. Two 60-foot deep wells developed in sand and gravel supplied water to the resort. A sewer line was found to pass near the wells and samples collected from the wells after the outbreak yielded *Y. enterocolitica* and coliform organisms from 1 to more than 16 per 100 ml. Routine bacteriological surveillance during the previous three years had not detected coliform contamination of the wells. Chlorination of the wells stopped the outbreak. Although *Y. enterocolitica* was isolated from well-water samples, the significance of this finding was unclear because rectal swab cultures from acutely ill persons were not examined for this organism.

An outbreak of 98 cases of viral hepatitis in Polk County, Arkansas, in 1971 is a good example of how waterborne outbreaks may occur in areas where geological formations allow drainage of septic-tank effluents into ground-water supplies (McCabe and Craun, 1975). The outbreak was traced to commercially made pellet ice, either through patronage of a restaurant that used the ice or by direct purchase of ice from a general store. The ice was made from well water at the general store. Both the ice and well water showed heavy coliform contamination. Dye studies revealed that sedimentary rock strata in the area permitted lateral drainage of a septic tank effluent from a nearby home occupied by residents who had infectious hepatitis six weeks previously.

The largest reported outbreak of typhoid fever in the United States since 1939 occurred during this period at the South Dade Migrant Farm Labor Camp, Florida (Pfeiffer, 1973; Saslaw *et al.*, 1975). Epidemiologic investigation of the 210 cases which occurred in February and March 1973 implicated the camp's water supply as the vehicle of infection. Two wells, 6.1 meters deep, supplied water to the camp; the water was disinfected prior to distribution. An engineering evaluation revealed that in early February, chlorination of the water was interrupted for a period of time, and it was felt that contamination of the water supply occurred then. The aquifer was composed of solution channels, and the wells had a history of intermittent contamination. Fecal coliforms were found as late as March 2. A young mentally retarded child who developed typhoid fever in January and who attended a day-care center located adjacent to the well was felt to be the index case and source of contamination.

Between April 4 and May 22, 1972, five cases of typhoid occurred in a residential area near Yakima, Washington, that was served by driven well points and septic tanks (McCabe and Craun, 1975). Upon investigation, a typhoid carrier was identified in the area, and dye flushed through the sewage system in his home was traced within 36 hours to numerous wells in the area including the ill family's well which was 210 feet away. The water from this well also yielded typhoid bacillus and coliforms. The soil in the area is extremely pervious gravel, and at the time of the outbreak, the ground-water level was at or near its seasonal peak.

The following example illustrates the need for chemical surveillance of ground-water supplies (McCabe and Craun, 1975). In May 1972, a contractor built a warehouse and an office structure on the outskirts of a small town in Minnesota. A well was drilled to supply water. During the next 2½ months, 11 of the 13 individuals employed by the contractor became ill; two were hospitalized. The hospitalization led to the discovery of elevated urine-arsenic levels in both patients. Samples obtained from the well on two occasions yielded arsenic concentrations of 21.0 and 11.8 mg/l. Area residents reported that grasshoppers had been a serious problem in the late 1930's and that a grasshopper bait composed of arsenic, bran, and sawdust had been prepared and stored on the property now occupied by the warehouse and office. The bait was apparently kept on the ground and was believed to have been buried in the area. Soil samples on the property revealed arsenic concentrations of 3,000 mg/l at 20 cm-2 m and 12,600 mg/l at 2 m.

Chemical spills have also affected ground-water quality and caused outbreaks. Two that occurred during this period are described. Accidental spillage of 10,000 gallons of 100% phenol in 1974 resulted in the chemical contamination of a number of wells in a rural area of southern Wisconsin (Horwitz, Hughes and Craun, 1976). An illness characterized by diarrhea, mouth sores, burning of the mouth, and dark urine was reported by 17 persons exposed to the phenol-contaminated water. Gasoline spilled at a service station in Pennsylvania affected ten individuals using private wells near the station; 10 mg/l leaded gasoline was detected in the wells.

DISCUSSION

Waterborne outbreaks continue to occur in the United States. A significant number of outbreaks and illnesses occur because of the lack of treatment of ground water and because of the interruption of disinfection and inadequate disinfection of contaminated ground water. Additional surveillance of small ground-water systems is necessary to prevent outbreaks from occurring. Emphasis must be placed on obtaining water quality data for all ground-water sources, insuring through sanitary surveys that wells are adequately protected from surface water and sources of contamination, such as septic tanks; providing adequate treatment when required; and providing for proper operation to maintain continuous, effective disinfection when ground-water sources are known or suspected to be intermittently or continuously contaminated with bacteria.

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Waterborne Disease — Current Threat[a]

by Robert C. Cooper[b]

ABSTRACT

Control of epidemic waterborne disease of an infectious nature has been made practical through modern drinking-water treatment practices. Certainty of such control depends upon treatment plant reliability. The possibility of the transmission of newly recognized infectious diseases by the water route must be considered. The presence of trace amounts of chemicals in drinking water that are potential agents of chronic disease, particularly cancer, poses many questions concerning the safety of our water supplies.

During the last half of the nineteenth century through the observation of such men as John Snow (1854), William Budd (1873) and William Sedgwick (1900) it became clear that certain infectious diseases were associated with fecal material and that drinking water was an important vehicle in the transmission of these diseases. These observations gave impetus to the development of the art and science of water treatment as we know it today. Because of the long-term interest in the infectious agents present in contaminated water and because of extensive experience in their control, it is reasonable to state that modern practical water treatment technology, particularly disinfection, can reduce the number of *known* pathogens to levels that presently render the water acceptable from a public health point of view. This latter statement assumes treatment plant reliability, an assumption which may be questioned. For example, of the 969 water supplies examined in the United States in 1969, 12 percent were not meeting bacterial standards (Taylor, *et al.,* 1972).

In situations in which drinking water is not treated there is always the possibility for contamination and resultant epidemics such as occurred in Riverside, California, in which 18,000 cases of Salmonellosis was associated with a nondisinfected ground-water supply (Ross, *et al.,* 1966). One should not overlook the chances of cross connections in which even a well-treated water supply could be grossly contaminated. Thus even in this practiced area of drinking-water management, acute waterborne disease is always a threat and quality control must be maintained.

During the past few years much concern has been expressed regarding animal viruses in waste water and in drinking water. This concern has been stimulated because of the recognition that certain enteric viruses are proportionately more resistant to chlorination than are the standard coliform indicators. Thus processed water that meets coliform requirements may be contaminated with viruses. With the exception of the incident in New Delhi, India, in the 1950's (Viswanathan, 1957), in which thousands of cases of infectious hepatitis were associated with treated municipal drinking water, there have been no recorded incidents in which an epidemic of viral disease has

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been associated with properly treated municipal drinking water. However, it can be hypothesized that with some frequency a small number of viruses may be introduced into a distribution system. There is a probability that a member of the exposed community will receive this viral dose in a glass of water and concomitantly that the dose received will produce disease in some proportion of those exposed. This results in a case of viral disease which then may be transmitted horizontally through the family. Because of the less than explosive nature of such an episode, it would be unlikely that an epidemiologist would associate the incident with the drinking-water supply. Thus, it may be that water supplies that meet bacterial standards produce point sources of disease which are then spread from the primary contact to other members of the community via personal contact, food, etc.

We cannot allow ourselves to become overconfident of our knowledge concerning microbial diseases transmitted by water. Newly recognized microbial phenomena are continually being uncovered such as the occurrence of enteropathogenic *Escherichia coli* in waterborne disease outbreaks (*Morbidity and Mortality Report,* 1975), the apparent increasing incidence of waterborne giardiasis in the United States (Craun, *et al.,* 1976) and the recent recognition that the legionnaires' disease bacterium is associated with cooling tower water and surface water (*Morbidity and Mortality Report,* 1978a, 1978b).

There are a number of chemical agents in water which may affect man's health. A number of inorganic chemicals are known to be toxic at certain concentrations. These would include such agents as arsenic, cyanide, lead, mercury, and nitrates. This latter ion has been recognized to be associated with methemoglobinemia in young infants.

Other inorganic substances in water are suspected of being associated with chronic disease in man. In 1960, Schroeder (Schroeder, 1960a and 1960b) examined the 1949-1951 vital statistics dealing with the annual age-adjusted death rate from cardiovascular disease in the United States and compared these data to the weighted average hardness in water used for human consumption. He found a negative correlation (higher disease rate with softer water) between deaths from cardiovascular disease and hardness in the water supply. Since that time, there have been a number of studies in various parts of the world that, for the most part, substantiate this relationship (Morris *et al.,* 1961; Crawford *et al.,* 1968; and Neri *et al.,* 1971).

A negative correlation between water hardness and infant mortality has been reported by Morris *et al.* (1961) and Crawford *et al.* (1968, 1972). These investigators point out that it has been known for a long time that social conditions have a significant impact upon infant mortality; however, when these factors are accounted for, there appears to be a significant negative correlation between neonatal mortality and water hardness, and with calcium in particular. One suggestion was that the more corrosive soft water might increase the heavy metal content of drinking water in low calcium areas.

In 1957 Penrose suggested that anencephalus (a condition in which major portions of the brain are missing) might be associated with the amount of calcium in water supplies. In 1970, Fredrick examined the relationship between anencephalus among children born in certain areas of the United Kingdom and water hardness and found a negative correlation. He also pointed out a significantly higher incidence of death from spina bifida (a disease related to anencephalus) in soft water areas of the United States.

Asbestos is an inorganic substance found in certain waters, originating from natural sources or from industrial pollution, which has been suspected as a possible contributor to the cancer incidence in exposed populations (Cooper and Copper, 1978). Recently in our laboratory, indirect epidemiological evidence has been developed which shows a significant positive correlation between levels of asbestos in domestic drinking water of the San Francisco Bay Area and cancer incidence (Kanarek, 1978). Table 1 is a summary of these results. As is the case in the water hardness-cardiovascular disease relationship, cause and effect is not proved but the data are very suggestive.

Since the early 1970's, there has been a growing concern among Federal, State and local agencies regarding the health implications of organic chemical compounds in the country's drinking-water supplies. A large number of these chemical compounds have been found and generally their concentrations have been in the microgram per liter range. The trihalomethanes, and chloroform in particular, have been singled out as target compounds since they seem to be formed during water disinfection with chlorine. The public health implications of the presence of trace amounts of many of these organic compounds in water is uncertain at the present time. This is so because of the chronic nature of diseases

Table 1. Cancer Sites in White Males and Females That Correlate with Asbestos Levels in Drinking Water in the San Francisco Bay Area (adapted from Kanarek, 1978)

Cancer Site	*Male*	*Female*
Stomach	+	+
Peritoneum**	+	+
Pleura*	+	—
Trachea, bronchus, lung**	+	—
All respiratory**	+	—
Digestive related organs**	—	+
Gall bladder**	—	+
Kidney*	—	+
Esophagus*	—	+
Pancreas**	—	+

* $p < 0.05$.
** $p < 0.01$.
\+ = correlation exists.
— = no correlation exists.

suspected to be associated with these chemicals (such as cancer); because health risk data are usually generated using animals receiving relatively high doses of suspect compounds; because such data must be extrapolated to estimate dose response at much lower concentrations; and because such extrapolated data must be further extrapolated from animal to man.

The evaluation of the impact upon the morbidity of cancer in populations exposed to low concentrations of known or suspected carcinogens present in drinking water is plagued with the same difficulties as just noted for toxic organic chemicals. Added to the problem is the question as to whether or not the concept of a threshold dose is valid. This question arises because of: (1) the self-replicating nature of the cancer cell, (2) the probability that the tumor-causing event is irreversible, and (3) the possible occurrence of cancer long after the disappearance of the carcinogen from the body (W.H.O., 1974).

In a recent article, Stokinger (1977) stated his conviction that threshold concentrations do exist for carcinogenic compounds and that drinking-water standards should be developed from that point of view. He draws most of his supporting data from industrial exposures and animal experimentation. He strongly feels that toxic response is frequently much different at low concentration of toxic chemicals and therefore extrapolation from "high" dose experiments to estimate "low" dose response is invalid.

Others such as Mantel and Bryan (1961) feel that a no-response dose of carcinogen may not exist; rather, there is some risk of contracting the disease regardless of dose and that risk increases with increased exposure; i.e., is dose related. Such risks are determined using a variety of statistical methods. Mantel and Bryan suggested that one extrapolate from high dose response data to an appropriate risk level using a probit slope of 1 to 1.5 probit per 10-fold increase in dose. This assumes that response frequency is normally distributed. Probits are calculated as standard deviations about the mean of normal distributions giving zero deviation (the 50 percent response point) a value of 5. This method is commonly used and is considered to give conservative values as it does not include: (1) the probabilities that the individual involved will be overshadowed by some competitive health risk; (2) the probability that an individual will receive a given exposure; and (3) the age of the individual when the cancer will occur.

The risk of developing cancer during a lifetime of exposure to known or suspected carcinogens that might be found in water was reported by the National Academy of Science (1977). These values were determined using a mathematical risk model which would allow an estimation of the increment of risk of disease due to consumption of suspect compounds in water. Selected values are shown in Table 2.

Thus, based upon these calculations, there would be one excess case of cancer per 37 million people who drink water containing 1 μg/l of chloroform. If these are accurate estimates, then as the level of compound increased to 100 μg/l, it could mean an increase of more than 600 excess deaths among this country's 220 million due to chloroform in drinking water. Tardiff (1977) estimates the disease risk from the daily consumption of 0.01 mg of chloroform per kilogram of body weight using a variety of risk

Table 2. Estimated Lifetime Risk of Cancer from Consumption of Selected Carcinogens in Water

Compound	*Upper 95% Confidence Estimate of Risk**
Vinyl chloride	5.1×10^{-7}
Dieldrin	2.6×10^{-4}
Heptachlor	4.2×10^{-5}
DDT/DDE	1.2×10^{-5}
Lindane	9.3×10^{-6}
Chloroform	3.7×10^{-7}
Trichloroethylene	1.3×10^{-7}

* Risk per microgram per liter of water consumed over a lifetime.

Source: National Academy of Science, Drinking Water and Health, 1977.

models including probit, log linear, and two-step methods. A dose of 100 μg/l per day to a 10 Kg infant would be equivalent to 0.01 μg/Kg which, from human data, should not cause any liver damage. Using such models, it was calculated that the incidence of cancer should be increased by 1.6 per million population per year, or of approximately 300,000 cancer deaths annually in the United States, 252 might be attributed to chloroform in tap water. Tardiff concludes that the risk lies somewhere between zero and the above figure at a chloroform concentration of 100 μg/l.

At present there are no time proven standards for acceptable levels of trace organics in water. Recently, the Environmental Protection Agency has put forth a target level for trihalomethanes (including chloroform) in drinking water of 100 μg/l. The level of THM will be greatly affected by chlorination procedures in both the waste-water and drinking-water treatment plants and by the amount of precursors of THM present in the raw water.

Epidemiological evidence is accumulating that indicates correlations between trihalomethane level in drinking water and cancer morbidity/ mortality at various anatomical sites (Environmental Protection Agency, 1978). Correlations between water source (surface and ground) and cancer have also been shown (Page *et al.,* 1976). In this latter case the cancer rates are frequently higher among populations that take their drinking water from surface streams than among those who use ground water. The difference is assumed to be due to the generally poorer chemical quality of surface water because of its greater vulnerability to contamination.

There will always be a threat of waterborne disease. The magnitude of the threat is our major concern. Modern water treatment practices have certainly reduced the threat of infectious disease and in this regard it is a question of treatment process reliability and quality control. A quote from Sir John Simon's report to the London privy council in 1867 is appropriate:

> The public is hitherto very imperfectly protected against certain extreme dangers which the malfeasance of a water company, supplying perhaps half a million customers, may suddenly bring upon great masses of population. Its colossal power of life and death is something for which till recently there has been no precedent in the history of the world; and such power, in whatever hands it is vested, ought most sedulously to be guarded against abuse.

Newly recognized microbial disease agents arise from time to time and under certain circumstances can be associated with water, as for example, legionnaires' disease with cooling tower water. This certainly poses a waterborne disease threat to those exposed.

Major concern is presently being expressed about the presence of inorganic and organic chemicals that may be present in water and their association with chronic disease, particularly cancer. At this time there is growing evidence that a health threat exists but its magnitude is at present poorly defined. One of the major tasks before those interested in water quality and health is to define the risks involved when these compounds are present in a community water supply.

Is waterborne disease still a threat? The answer is, of course, yes. It will always be a threat. We cannot afford to allow ourselves ever to become lulled into a complacent attitude towards this question.

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Waterborne Disease — Historical Lesson[a]

by Ira M. Markwood[b]

ABSTRACT

While it is true that waterborne diseases are still with us, and probably always will be, we cannot classify them as a current threat in the sense that they were 100 years ago. The discovery that chlorine would disinfect water supplies removed these diseases from a "current threat" category to the "historical lesson" category. We are not faced with unknowns which we are unable to attack. We have only to look at what others have done to protect themselves and follow the same or improved practices.

If the record of waterborne outbreaks in public water supplies in this country from the end of World War II up to the present is examined, it will be found that all are caused by breakdowns in disinfection procedures or carelessness. The record is replete with statements such as "improper disinfection after repair," "breakdown or lack of disinfecting equipment," "back siphonage," and other similar statements all pointing to failure to follow practices which the history of water treatment has shown to be necessary for protection against waterborne disease. Carelessness allows recurrence of disease outbreaks. If the lessons of history were followed, the conquest of waterborne disease transmission by public water systems could be complete.

In discussing whether waterborne disease is a current threat or a historical lesson, it must be borne in mind that, in this case, the semantics are quite important. If we define a current threat as one where great activity must be taken in new areas, where there is much to learn in order to control the problem, and where, in many cases, we are helpless to protect ourselves against the ravages of the threat, then it immediately becomes obvious that waterborne disease in the United States does not fall into this category.

One hundred years ago there were great epidemics of typhoid and cholera, to name two of the most common waterborne diseases, which ravaged the country and which were completely beyond the ability of the population to halt or minimize with the knowledge then available to them. Since then, particularly in the first quarter of this century, much has been learned. We now know that these diseases can be prevented by proper precautions, and that these terrible epidemics need no longer occur. We are not faced with unknowns which we are unable to attack. We have only to look at what others have done to protect themselves and follow the same or improve practices.

If the record of waterborne outbreaks in public water supplies in this country from the end of World War II up to the present is examined, it will be found that all are caused by breakdowns in disinfection procedures or carelessness. The record

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[a] Presented at The Fourth National Ground Water Quality Symposium, Minneapolis, Minnesota, September 20-22, 1978.

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is replete with statements such as "improper disinfection after repair," "breakdown or lack of disinfecting equipment," "back siphonage," and other similar statements, all pointing to failure to follow practices which the history of water treatment has shown to be necessary for protection against waterborne disease. Modern technology presents methods for removing any substance from water. The only limiting factor is cost. However, even the most common methods, such as flocculation, coagulation and sedimentation, will remove a high percentage of the microbiological contaminants. In addition, the pathways by which contaminants can enter drinking water are well known, and, with reasonable precaution, be closed so that the water will be protected against the entrance of pathogens. The use of proper disinfection methods, in addition, allow 100% protection against the transmission of waterborne disease by this method.

Therefore it can be said conclusively that waterborne disease is now in the class of a historical lesson. We need only to look back to see what has been done to prevent transmission of disease by water, and use these methods as the lesson to continue such prevention for the protection of the water consumers.

Carelessness allows recurrence of disease outbreaks. If the lessons of history were followed, the conquest of waterborne disease transmission by public water systems could be complete.

* * * *

Ira M. Markwood, Manager of the Public Water Supplies Division, Illinois EPA, received his Bachelor's degree in Chemical Engineering from New York University and his Master's degree in Chemical Engineering from Virginia Polytechnic Institute. He is a Registered Professional Engineer in New York, New Jersey and Illinois. In 1972, Markwood joined the Illinois EPA and was named Division Manager two years later. He is a member of a number of professional societies, and has been active in working with the U.S. EPA to promote reasonable regulations for public water systems under the Safe Drinking Water Act.

Audience Response to Session IX — Waterborne Disease

Elmer E. Jones, Jr., Agricultural Engineer, USDA, Beltsville Agricultural Research Center, Beltsville, Maryland 20705: I believe the incidence of waterborne disease in rural areas is much higher than generally suspected. Many diseases are treated symptomatically without full diagnosis. Normally two or more cases must occur to be considered an outbreak. One case in a family of four is a 25% incidence. If this occurred in a city of 10,000 it would probably make all the major papers in the world.

For some diseases the number of organisms required to produce a clinical case is extremely high. I believe typhoid requires about 100,000 organisms in a glass of water for a 50% incidence among individuals lacking immunity. At lower doses most individuals acquire immunity. That herd immunity is a factor in control of waterborne disease in rural areas is indicated by the high percentage of waterborne disease cases in rural areas that involve transients. Herd immunity offers no protection to new diseases.

It is important for regulatory officials to recognize that within the well bore is a man-made structure involved in the protection of public health. As such it should be subject to periodic inspection and maintenance as required.

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16. ABSTRACT

The Fourth National Ground Water Quality Symposium was held in Minneapolis, Minnesota, September 20-22, 1978, in conjunction with the annual convention of the National Water Well Association.

The Symposium was dedicated to the late George Burke Maxey and the keynote address was given by Courtney Riordan, Associate Deputy Assistant Administrator, Office of Air, Land & Water Use, Office of Research and Development, U.S. Environmental Protection Agency.

Nine sessions highlighting the theme "The Issues of Our Time" were conducted through a debate format featuring national authorities presenting neutral, pro, and con views followed by audience participation.

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