Conference

Proceedings

Protecting Ground Water From The Bottom Up: Local Responses To Wellhead Protection

Sponsored By

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UNDERGROUND INJECTION
UIPC
PRACTICES COUNCIL
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New England
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Ground water is America's silent, hidden source of drinking water. It lies in vast stores below ground, flowing softly through bedrock and unconsolidated deposits of sand and gravel. Ground water is an essential component of the nation's ground water supply, and is critical to our economic growth, national agricultural productivity and the overall quality of life.

In New England, ground water is a particularly precious resource. As a whole, more than 50% of the region's drinking water comes from underground sources, whereas residents in rural areas are nearly 100% dependent. But this important resource is threatened - in recent years, hundreds of water supply wells in New England have been shut down due to contamination.

Although there are numerous federal and state regulations that prevent contaminants from entering the ground, much of the power to protect water supplies rests at the local level, with land use planners and local regulators responsible for future land use development within the resources and the tools which can be used to protect them.

This ground water conference is designed to share experiences gained both nationally and regionally, and to develop a better understanding of the technical and regulatory interrelationships involved in protecting New England's ground water resources, now and for the future.

October 2-3, 1989
Danvers, Massachusetts

TABLE OF CONTENTS

PROTECTING GROUND WATER FROM THE BOTTOM UP: LOCAL RESPONSES TO WELLHEAD PROTECTION

The Sheraton-Tara Hotel, Danvers, Massachusetts
October 2-3, 1989

AGENDA

SUNDAY, October 1

6:00 - 7:30 Hospitality

MONDAY, October 2

8:00 - 8:45 Speakers/Moderator Breakfast
8:00 - 9:00 Registration
9:00 - 9:20 Opening Remarks:

Paul Roberts, President, UIPC Research Foundation
Raymond Raposa, Executive Director, NEWWA
David A. Fierra, Director, Water Management Division, EPA

SESSION I - Setting the Stage for Ground Water Protection Programs

Moderator - Jerome J. Healey, Chief, Ground Water Management and Water Supply Branch, U.S. EPA Region I

9:20 - 9:40 The Wellhead Protection Program: A National and Regional Overview - **STEVEN ROY,** Office of Ground Water Protection, U.S. EPA Headquarters

9:40 - 10:00 Developing and Passing State-wide Aquifer Protection Programs Connecticut: A Case Study - **ERIC BROWN,** Murtha, Cullina, Richter & Pinney

10:00 - 10:20 Walpole Board of Health: Ground Water Protection Program Implementation - **ROBIN CHAPPELL,** Walpole Board of Health

10:20 - 10:30 **Discussion**
10:30 - 10:45 **Break**

SESSION II - Creating Regional and Local Ground Water Programs

Moderator - Robert E. Mendoza, Chief, Ground Water Management Section, U.S. EPA Region I

10:45 - 11:05 Case Study of Regional Effort: Wellhead Delineation as a Tool for Fostering Regional Cooperation - **MARILYN COHEN,** North Kingstown Planning Department, Timothy Brown, Kent County Water Authority

11:05 - 11:25 Model for Rural Communities to Assess Threats to Their Ground Water Quality - **LYNN RUBINSTEIN,** Franklin County Planning Department

11:25 - 11:45 The Fox(borough) Guarding the Aquifer Coop: Local Control at Work - **KIMBERLY NOAKE,** SEA Consultants

11:45 - 12:15 Ground Water Protection Evolution: Acton's Experience - **DUNCAN WOOD,** Goldberg-Zoino & Assoc., Ronald Bartl, Acton Town Planner

12:15 - 12:30 **Discussion**
12:30 - 1:45 **Lunch on Own**

SESSION III - Water Utilities' Experience in Ground Water Protection

Moderator - Savos Danos, Superintendent, Littleton Water Department

1:45 - 2:05 Easton's Experience and the Canoe River Aquifer Advisory Committee - **WAYNE SOUTHWORTH,** Easton Water Department

2:05 - 2:20 Wellhead Protection for Public Drinking Water Wells in N. Windham, Maine - **DANA PERKINS,** Portland Water District

2:20 - 2:40 Bridgeport Hydraulic Co. Aquifer Protection Plan - **MARK JOHNSON,** Bridgeport Hydraulic Company

2:40 - 3:00 Aquifer Protection Through Large-Scale Computer Modeling, Westfield, Massachusetts - **DAVID EDSON,** Dufresne-Henry Company

3:00 - 3:15 **Discussion**
3:15 - 3:30 **Break**

SESSION IV - Delineation of Recharge Areas to Water Supply Wells

Moderator - Michael Frimpter, Chief, Water Resources Division, U.S. Geological Survey, Boston, Massachusetts

3:30 - 3:50 Determining the Area of Contribution to a Wellfield: A Case Study and Methodology for Wellhead Protection - **JAMES GRISWOLD,** Jack Donohue, BCI Geonetics

3:50 - 4:10 The Use of Time of Travel in Zone of Contribution Delineation and Aquifer Contamination Warning - **JAMES HALL,** U.S. Geological Survey

4:10 - 4:30 Ground Water Modeling and Particle Tracking Analysis of Recharge Areas to Public Water Supply Wells in Stratified Drift Aquifers - **PAUL BARLOW,** U.S. Geological Survey

4:30 - 4:45 **Discussion**
4:45 p.m. **Session Adjournment**

GROUND WATER PROTECTION VIDEO SESSION

7:30 p.m. A selection of videotapes on ground water protection will be shown at this time

1. "**The Power to Protect: The Local Role in Ground Water Protection**", 1989. A 25 minute documentary about four communities which have gone through the process of developing ground water protection programs. This program, which is sponsored by U.S. EPA., Massachusetts Audubon Society, New England Water Works Association, and others, will be unveiled at this time.

2. "**Your Water, Your Life**". 1988. A 30 minute program on the importance of community awareness in ground water protection. Produced by the Public Interest Video Network, Washington, D.C.

3. "**The Clean Water Game**". 1989. A 10 minute video describing the importance of developing a state clean water strategy. Produced by the New England Interstate Water Pollution Control Commission, Boston.

4. "**Leaking Underground Storage Tanks...Little Time Bombs Ticking**". 1987. A 25 minute program about the LUST problem, by the Connecticut Department of Environmental Protection, Hartford.

5. "**The Planning Process for Local Ground Water Protection**". 1988. This 25 minute video describes the process used by the community of La Moine, Maine to develop a ground water protection program. Produced by the Maine State Planning Office.

TUESDAY, October 3

SESSION I - Contaminant Source Inventory and Risk Assessment

Moderator - David Edson, P.E., Defresne-Henry, Inc.

8:30 - 8:50 Role of Local Governmentsin Implementing a Class V - Underground Injection Control Program - **FRANCOISE BRASIER,** Chief, UIC Branch, Office of Drinking Water, EPA Headquarters, Washington, DC

8:50 - 9:10 Development of Aquifer Protection Zones and Evaluation of Contamination Potential in the Town of Chelmsford, Massachusetts Water Supply Wells - **DONALD W. PODSEN,** Charles Myette, Wehran Engineering

9:10 - 9:30 Determining the Development Potential Within Wellhead Protection Areas and Resulting Impacts from Nitrogen Loading - **SCOTT HORSLEY,** Jon Witten, Mark Wilson, Horsley Witten Hegemann, Inc.

9:30 - 9:50 Evaluation of Local Regulatory Efforts in Identifying and Controlling the Threat of Underground Fuel Storage Tanks - **CHARLOTTE STIEFEL,** George Heufelder, Barnstable County Health Department

9:50 - 10:05 **Discussion**
10:05 - 10:20 **Break**

SESSION II - <u>Contaminant Source Inventory and Risk Assessment Continued</u>

Moderator - Jeffrey S. Lynn, UIPC, Technical Director

10:20 - 10:40 Federal-Local Partnerships for Implementing the Class V Program: Two Case Studies - **JOHN MALLECK,** Susan Osofsky, U.S. EPA, Region II

10:40 - 11:00 The UIC Class IV-V Well Survey in Maine, a Multi-Faceted Approach to Inventory, Assessment, and Compliance - **MARY RUDD JAMES,** Maine Department of Environmental Protection, Tony Pisanelli, U.S. EPA Region I

11:00 - 11:20 Planning Techniques for Estimating Ground Water Impacts of On-Site Systems - **CAROL LURIE, ELIZABETH BEARDSLEY,** Camp Dresser & McKee, Inc.

11:20 - 11:40 Road Salting Impacts in Massachusetts - **JAMES BARRETT,** Matthew Dillis, Normandeau Engineering

11:40 - 11:55 **Discussion**
11:55 - 1:15 **Lunch**

SESSION III - <u>Geographical Information Systems and Data Management in Ground Water Programs</u>

Moderator - Gregory P. Charest, GIS Coordinator, Information Management Branch, U.S. EPA Region I

1:15 - 1:35 Creation of Ground Water Protection Programs: A EPA/Local Partnership at Work - **STUART KERZNER,** U.S. EPA Region III

1:35 - 1:55 A Computerized Data Management System for Wellfield Protection - **THOMAS JENKINS,** Guy Jamesson, Malcolm Pirnie, Inc.

1:55 - 2:15 Ground Water Resource Based Mapping: Nashua Regional Planning Area, New Hampshire - **DAVID DELANEY,** U.S. EPA Region I

2:15 - 2:30 **Discussion**
2:30 - 2:45 **Break**

SESSION IV - Ground Water Protection and Private Wells

Moderator - **Michael Rapacz,** Program Manager, Division of Water Supply, Massachusetts Department of Environmental Quality

2:45 - 3:05 A Model Community Program for Private Wells - **ROY JEFFREY,** Karen Filchak, University of Connecticut Cooperative Extension

3:05 - 3:25 Board of Health Protection for Private Wells and Ground Waters - **WILLIAM DOMEY, P.E.,** Marcia Benes, Massachusetts Association of Health Board

3:25 - 3:45 Private Well Protection in Coastal Sand and Gravel Aquifers - **WILLIAM KERFOOT,** K-V Associates, Inc.

3:45 - 4:05 Massachusetts Private Well Guidelines - **CYNTHIA TOMLINSON,** Massachusetts Department of Environmental Quality

4:05 - 4:20 **Discussion**

4:20 - 4:30 **Wrapup and Adjourn**

THE WELLHEAD PROTECTION PROGRAM - NATIONAL OVERVIEW

Steven Roy, US. EPA,
Office of Ground-water Protection
Washington, D.C. 20460

The 1986 Amendments to the Safe Drinking Water Act (SDWA) formalized the concept of State Wellhead Protection (WHP) Programs to protect wellhead areas to public water supply wells from contamination. The Act contains requirements for the minimum program elements necessary to develop and implement a WHP program.

June 19, 1989 was the statutory deadline for submission of state WHP programs. This paper presents a summary of those programs that have been submitted and provides a status report on the review and approval process. Specific state examples are presented to demonstrate innovative approaches to each of the program elements. Implementation issues and the role of the local government are explored. Transfer of WHP concepts from other areas of the country to the northeastern states is provided.

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Steven Roy is currently the manager of the Source Management Unit in EPA's Office of ground-Water Protection. His responsibilities include overseeing the management of the Wellhead Protection Program and developing technical assistance materials for state and local officials on ground-water protection.

Prior to joining EPA, Mr. Roy worked for eight years as Ground-Water Program Manager and Water Management Director for the State of Massachusetts. There he developed numerous ground-water protection programs including the Aquifer Land Acquisition Program and a water allocation/permit program.

Also, Mr. Roy worked for the Berkshire County Regional Planning Commission in Pittsfield, Massachusetts as an environmental planner.

Mr. Roy has a B. S. in Forestry from the University of Massachusetts, Amherst and an M. S. in Water Resources from the State University of New York, Syracuse, N. Y.

DEVELOPING AND PASSING STATEWIDE WELLHEAD PROTECTION PROGRAMS

CONNECTICUT: A CASE STUDY

Eric J. Brown

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Designing a comprehensive statewide wellhead protection program which is effective, workable, and politically feasible poses serious challenges to any state. The process is particularly difficult for those regions such as the northeast where the general public has yet to perceive of severe shortages or widespread contamination of their drinking water supplies. Yet proactive approaches to address the growing pressures on ground-water supplies can be successfully developed and are clearly preferable to the potential health and financial costs associated with reactive approaches. One example of such a proactive approach is the aquifer protection legislation recently adopted in Connecticut.

There are many methods and approaches which a state may use to develop ground-water legislation. In Connecticut, a legislative task force supported by a committed Department of Environmental Protection and spearheaded by strong legislative leadership proved to be an effective mechanism for generating the structure of their aquifer protection program. The open and cooperative process which the task force utilized in formulating recommendations was a major factor in the program's ultimate success in the legislature. Other important, yet distinct processes included forging the task force recommendations into sound legislative proposals, designing a legislative strategy, and shepherding the proposals through an often treacherous legislative process.

Although the obstacles to developing comprehensive, statewide wellhead protection programs are many, the unanimous votes in both chambers of the Connecticut General Assembly offer strong evidence that such hurdles can be overcome.

I. Introduction

Clean drinking water is generally considered to be a basic right of every citizen and is a resource which most take for granted. How is a concept so fundamental and seemingly uncomplicated as clean drinking water becoming a controversial issue giving rise to a growing number of angry well owners, heated local debates, and environmental lawsuits? The answer, at least in part, is uncertainty about how clean is "clean" coupled with a philosophy of "don't tread on me." The federal government continues to release updated standards on what constitutes clean drinking water. These standards are, for the most part, a list of six syllable chemical names with concentrations which are difficult to envision, subject to change, and meaningless to the average citizen. Additionally, "clean" is a relative term whose meaning and significance varies with the individual. Most of us remember our dad or uncle taking a big gulp from a canteen or bottle of soda and passing it over to us. Some of us heartily grabbed the container taking an equally big swig without giving a single thought to germs or bacteria. For others, the unsterilized bottle neck held the seeds from which the world's next great plague would surely sprout.

Coupled with the issue of what constitutes "clean" drinking water is the problem that protecting ground-water supplies means protecting specific areas of land which lie above it. Most of us are willing to send money to help storm victims we have never met, pitch in and work for weeks to help a neighbor rebuild a house or a barn lost to fire, perhaps even risk our lives to save a friend, neighbor or even a stranger facing some imminent peril. Just don't try to tell us how we can and cannot use our land, particularly when our neighbor may not have to abide by the same constraints. Upon consideration of the societal notions of private property along with public uncertainty regarding the severity of the threat to their drinking water supplies, the concept of clean groundwater and its protection assumes a very couplex nature with a strong emotional component.

In light of these underlying tensions, how can a local, state, or federal government effectively assure its citizens a plentiful supply of safe drinking water to which they have a fundamental right? The answer is they cannot--at least not unilaterally. Ultimately, the people must decide how much government regulation they are willing to endure in ensuring themselves a drinking water supply which will remain reasonably plentiful and safe. Realizing this fact, many have advocated a grass roots educational approach to protecting groundwater drinking water supplies. Unfortunately, educating the public about one specific issue in today's complex society generally requires either a tremendous amount of time and money or a major catastrophe. Attempting to address an issue with the complexity of ground-water protection in a proactive, grass roots fashion could involve a prohibitive time span as growing development, population, and land prices place increasing pressures on drinking water supplies from groundwater.

The remainder of this paper offers an alternative to a purely grass roots approach to generating wellhead protection legislation. The contents are based on the experiences of Connecticut which recently passed broad, flexible, and effective wellhead protection legislation at the state level using a team approach. It is hoped that some of the material herein will be useful for individuals and organizations seeking to institute state groundwater protection measures as well as to communities working to protect their ground-water drinking water supplies at the local or regional level.

II. Team Approach

A. Legislator

The most important person in the process of developing and passing ground-water legislation is likely to be the legislator who will ultimately be the chief sponsor of a wellhead protection bill. This person acts as coach and general manager of a widely diverse team. The legislator must be willing to place wellhead protection at the top of his or her priority list for perhaps several legislative sessions and therefore will probably represent a district having a major interest in protecting ground-water resources. Because of their critical role in the process, only legislators who are committed to the successful development of wellhead protection legislation are likely to be successful. It is also advantageous for this role to be filled by a member of the majority party and of the legislative committee responsible for environmental matters as this is the first legislative committee which will have to approve the wellhead protection bill. While neither extensive experience nor possession of a legislative leadership position is necessary to achieve a successful result, political savvy and having the respect of their legislative colleagues are strong benefits.

B. State Agency

A second critical player in developing successful wellhead protection legislation is the state agency responsible for environmental protection. The agency must be willing and able to actively support the project by providing personnel and technical assistance as required. In most instances, the agency will have extensive experience in resource management as well as knowledge of what types of protection programs have proven to be workable and effective. This experience and knowledge are vital to the ultimate success of the project.

C. Task Force

Once the legislator and the environmental agency are in a position to go forward with the project, the most efficient way to proceed may be to have the agency and the legislator work together in formulating legislation. However, this method will probably fail as it likely is too far removed from a purely grass roots approach. Input from a wider variety of interested parties is required. Accordingly, the legislator and agency should work to establish a legislative body charged with studying and making recommendations regarding wellhead protection legislation. Such a body is not only necessary to flush out and address the many complex issues involved in wellhead protection, but also lends credibility to the ultimate proposals. In Connecticut, the General Assembly allocated funds for the creation of a legislative task force to study and make recommendations for protecting the state's public drinking water supplies drawn from groundwater. The task force provided the forum for identifying issues, along with developing and evaluating proposals. So critical was Connecticut's Aquifer Protection Task Force that a closer look at the structure and operation of such an entity is merited.

1. Composition

The goal of a task force is ultimately to advise the legislature on how to address the issue of protecting groundwater resources used for drinking water. Accordingly, the legislator who will be the bill's chief sponsor should chair the task force. If feasible under legislative rules, a colleague from the other legislative chamber (House of Representatives or Senate) of the General Assembly should act as co-chair of the task force. This is an important consideration as successful legislation will require a "champion" to politically usher it through many potential pitfalls in both chambers of the General Assembly.

Other House and Senate members, both Republicans and Democrats, should also be named to the task force. As discussed below, task force legislators will likely be the most knowledgeable sources regarding the legislation on the floor of the General Assembly. Having informed legislators in each political "camp" will be important as the bill makes its way through the legislative process.

In addition to legislative members, the state Environmental Protection Agency should be represented at the highest level possible. Having a highly-ranked and experienced agency representative on the task force will help assure that the maximum possible amount of Agency resources will be available to the task force and will also reflect the level of commitment which the Agency holds for wellhead protection.

The remaining members of the task force should be chosen as carefully as the co-chairs. It is important to have members who are knowledgeable, committed to the project, and have flexible schedules which will allow them to attend meetings arranged on short notice or on an inconsistent time basis. Most critical to the selection process is to ensure that many different perspectives are represented on the task force. A valid approach in this selection process would be to list all the broad interest groups which one would typically expect to oppose land use control and increased commercial or industrial regulation. These groups are generally well organized and often politically powerful. It is therefore imperative that they be brought into the process at the outset and that their concerns are understood and addressed early. To this list should be added local, state, and possibly federal governmental representatives whose agencies and constituents might ultimately be affected by the recommendations of the task force. The task force membership should be geared to represent as many of these listed individuals, groups, or agencies as possible. Care should be taken not to underestimate the importance of the agency which handles state finances. Comprehensive wellhead protection is not free and the task force needs to have an indication of the state's fiscal response to its developing proposals.

Examples of those groups represented on the Connecticut Aquifer Protection Task Force include: Connecticut Business and Industry Association, Home Builders Association, town planners, local first selectmen, environmental lawyers, private and public water utilities along with representatives of the state Departments of Agriculture, Health Services, and Environmental Protection.

The final critical element in assembling a task force is full-time staffing. There are a multitude of administrational demands in operating an effective and efficient task force for which the members themselves cannot possibly take responsibility. Specific responsibilities and suggestions on effectively staffing a task force are discussed below.

2. Operation and Function

In Connecticut, Task Force meetings were conducted in formal surroundings with room for interested citizens who wished to attend. This setting provided an excellent forum for raising issues and discussing well researched and concisely presented proposals. However, the meetings proved to be a rather ineffective forum for debating specific problems in detail. Members often had difficulty with effectively debating a point of contention with another task force member who could be 20 feet away and only visible above the circular committee dais from the neck up while two dozen other heads looked on. For this reason, the meetings of the Connecticut Task Force were generally designed to raise issues and review specific proposals on how major issues might be addressed.

Once the major skeletal elements of the protection program were defined, the co-chairmen of the Connecticut Task Force requested that members volunteer to serve on subcommittees formed to address specific issues associated with each element of the program. Examples included the agriculture, water softener, land acquisition, regulation, and mapping subcommittees. The subcommittees generally consisted of 4-7 persons and often included non-Task Force members as well. Groups of this size were able to work informally around small tables, over coffee or lunch and hammer out innovative and mutually agreeable proposals. Each subcommittee was responsible for assembling and presenting a report to the task force outlining their discussions and proposals. Each task force member was then given an opportunity to review these reports prior to discussing them collectively at a subsequent task force meeting. The subcommittee approach proved very successful in Connecticut and was a critical element in efficiently achieving a consensus on detailed solutions to specific problems.

3. Use of Staff

Having at least one full-time employee to staff the task force is an important element in maximizing its efficiency and productivity. The main role of the staff is to act as a facilitator. Specifically, staff should organize and monitor task force, subcommittee, and other meetings; conduct research on issues related to the task force's goals; maintain and utilize an updated mailing list of interested individuals and organizations keeping them informed on the progress of the task force; be available to quickly address crises as they arise; and generally act as a vehicle of communication for the task force co-chairs. It is important that the staff be able to work well with all parties involved in the process including task force members, lobbyists, and other legislative staff involved with researching and writing environmental legislation. The staff may also play a significant role in writing and editing reports which will be used to communicate the work and proposals of the task force to legislators, lobbyists, interest groups, state and local government officials, and interested citizens.

IV. Other Resources

The task force should be prepared to take maximum advantage of all the resources at its disposal. This section highlights three examples of resources which played important roles in assisting Connecticut's Aquifer Protection Task Force.

A. Lobbyists

Lobbyists are often portrayed as legislative mercenaries ready to carry any flag for a price. In the vast majority of cases, this is not only a false perception, but can be a terminal mistake for many legislative proposals. Lobbyists should rather be viewed as potentially vital assets to the task force in developing successful legislation as they represent a valuable source of both technical and political knowledge. Additionally, lobbyists who are incorporated into the process of developing proposals, will often feel an extra incentive to work for the legislation ultimately written. When the bill actually makes its way to the General Assembly. lobbyists can be valuable foot soldiers responding quickly and competently to sudden circumstances which may threaten the legislation. Again, it is important to emphasize that having the environmental, conservation, and water company lobbyists on your side is very helpful. The proposals have a significantly better chance of surviving, however, if you can also count organizations which represent developers, municipalities and business organizations as your allies. A bill which protects clean drinking water and has the support of such organizations is very difficult to vote against. However, such support is likely to be achieved only if representatives of these organizations are brought into the process early and given every opportunity to participate in the development of the proposals.

B. Municipalities

Early on in the process of developing proposals, Connecticut's Aquifer Protection Task Force arranged a trip for themselves and interested individuals to visit two towns facing different challenges related to protecting drinking water supplies from groundwater. The group heard presentations from local officials regarding their efforts to develop ground-water protection measures and the frustrations they encountered during this process. Present and future wellfields were visited on tours of each town hosted by local planning, utility, and conservation officials. During these tours, different types of land uses near the wellfields were observed in order to instill an appreciation for the real life issues which face individual towns attempting to unilaterally protect their groundwater. The trip proved valuable not only as an education experience, but also helped to established a close relationship between the task force and the towns. These communities constituted a continually expanding resource of knowledge gained through experience which the task force could consult with as their work proceeded.

C. Private Consultants

Inviting a private consulting firm to make a presentation to the task force may serve several purposes. If skillfully constructed, such a presentation can help improve the technical understanding of task force members on the scientific aspects of protecting groundwater. Additionally, such an event can help to establish a working relationship whereby the firm could be called on informally for technical advice and expertise.

In Connecticut, task force members needed to expand their understanding of groundwater cleanup technology in order to weigh this as an option in designing a wellhead protection program. The presentation, along with follow-up discussions, allowed the task force to make an informed decision on this matter and to effectively communicate their decision in the annual report.

V. Annual Report

For each legislative session, the task force should prepare an annual report to the legislature. This should be done even if not required as such a report documents the work and proposals of the task force for the year and helps to define the challenges yet to be faced. Most importantly, a well written report will enhance the reputation of the task force and lend credibility to its proposals.

There are several issues to consider regarding the report. Most importantly, the report should be well written, contain clear and understandable visuals which assist the reader in synthesizing the scientific and socio-political elements involved with wellhead protection, and be readable to a wide range of citizens. It is fair to assume that many readers will not even know what a wellhead or aquifer is. Protecting these resources, even at the state level, will involve local officials and board members many of whom are volunteers with little or no understanding of groundwater and the complex issues involved in protecting it. Therefore, the report should start the reader at this elementary level and gradually lead them to an understanding of the issues considered by the task force and conclude with an explanation of the ideas proposed to address these issues. It is a good idea to have several persons unfamiliar with the work of the task force, but experienced in writing public information documents, review the draft and make editorial suggestions. In Connecticut, a draft version of the 1989 report was widely circulated utilizing the mailing list mentioned earlier. Additionally, a public hearing was held by the task force solely to gather testimony regarding the draft report. A copy of the finished report should be sent to each state legislator in order to raise their awareness of groundwater issues, the work of the task force, and the specific proposals.

VI. Legislation

Writing the actual wellhead protection legislation involves a substantially different process than that of writing the task force report. Here the emphasis must be on technical correctness. As the proposals are likely to be broad in scope and detailed in nature, writing the bill will be an arduous and painstaking process for those unfamiliar with the intricacies of the proposals. For this reason, it is important to have the legislative staff responsible for writing environmental legislation fully informed on the progress of the task force and its evolving proposals. The more involved these staff people are with the task force, the more skillfully and efficiently they will be able to draft language which is readable, understandable, and technically accurate. Furthermore, as the legislation makes its way through the legislative process, it will likely be subjected to close scrutiny and intense debate making some changes to the bill inevitable. Having a staff attorney who is fully familiar with all the subtleties of the bill will permit these changes to be made with maximum efficiency and in such a way as to minimize their impact on the carefully constructed framework of the legislation developed by the task force over months or years.

VII. Legislative Process

Once the task force proposals have been synthesized into a legislative bill, the final major challenge is shepherding the bill through the legislative process. Much of the success in meeting this challenge will depend upon the political sense and savvy of the chief legislative sponsor who must develop a strategy to guide the bill through a legislative process full of pitfalls and trap doors.

The overall goal of the legislative strategy should be to anticipate problems before they arise and to have all of the various resources cultivated during the task force deliberations on hand and solidly prepared to address, in an efficient and effective manner, any challenges which may threaten the bill.

In Connecticut, part of this strategy consisted of writing the legislation as a House bill. In doing so, the larger chamber, composed of a wider range of backgrounds and perspectives, had the first opportunity to debate the bill. If an agreement could be reached which would allow the bill to pass by a comfortable margin in the House, it was hoped there would be a greater opportunity for successful consideration of the bill in the generally less volatile Senate.

A fundamental consideration in developing a legislative strategy is that not every member of the legislature need be an expert on the details of the bill. Those legislators who served on the task force will be the primary "experts" within the legislature along with members of the Environment Committee to a lesser extent. These legislators will provide the first line of defense, on both sides of the isle, against any technical questioning or sudden attacks on the bill occurring on the floor of either chamber. Assuming that not every member of both the task force and the Environment Committee will be strong advocates of the bill, it will be important for those who do support the bill to work actively on its behalf. Off the floor, the corps of lobbyists who participated in developing the bill should be kept up-to-date on any challenges or changes to the bill during legislative debate. As major allies of your efforts, lobbyists must be totally familiar with at least those portions of the bill which affect their clients in order to function as effective advocates as the tense hours of legislative debate unfold.

Along with legislators opposed to the bill, procedural pitfalls of the legislature may pose a threat to the bill's survival and should not be underestimated. Task force staff should have a good rapport with the staff of legislative leadership and where possible, with the legislators themselves. Keeping track of deadlines, filing requirements, and other procedural formalities is extremely important as even a small oversight in this area can extinguish the bill's chances even to be considered by the legislature.

Eventually, debate on the bill will come to a close. Months, perhaps years of preparation, attention to detail, and dozens of concerted attempts to address everyone's concerns will stand against the ultimate legislative test. A certain sense of accomplishment is justified in having reached this point. Hundreds of bills will have died in committee, been amended beyond recognition, or are doomed as they lie dormant on the legislative calendar.

In Connecticut, most of the major concerns regarding the bill were identified prior to the start of debate on the floor of the House. The cooperative efforts of legislators, lobbyists, and staff allowed these concerns to be quickly addressed with clarifying language and reasonable compromises. Formal debate on the floor was principally composed of answering questions for the record in order to provide a clear documentation of legislative intent.

Ultimately, HB 6594 "An Act Concerning Aquifer Protection Areas . . ." unanimously passed the House of Representatives 137-0 and quickly won unanimous approval in the Senate after a predictably short debate.

Substitute House Bill No. 6594

PUBLIC ACT NO. 89-305

AN ACT CONCERNING AQUIFER PROTECTION AREAS, AND LOCAL FLOOD AND EROSION CONTROL BOARDS.

Be it enacted by the Senate and House of Representatives in General Assembly convened:

Section 1. (NEW) The general assembly finds that aquifers are an essential natural resource and a major source of public drinking water; that reliance on groundwater will increase because opportunities for development of new surface water supplies are diminishing due to the rising cost of land and increasingly intense development; that numerous drinking water wells have been contaminated by certain land use activities and other wells are now threatened; that protection of existing and future groundwater supplies demands greater action by state and local government; that a groundwater protection program requires identification and delineation of present and future water supplies in stratified drift aquifers supplying drinking water wells; that a comprehensive and coordinated system of land use regulations should be established that includes state regulations protecting public drinking water wells located in stratified drift aquifers; that municipalities with existing or proposed public drinking water wells in stratified drift aquifers should designate aquifer protection agencies; and that the state should provide technical assistance and education programs on aquifer protection to ensure a plentiful supply of public drinking water for present and future generations.

Sec. 2. (NEW) For the purposes of this act:

(1) "Regulated activity" means any action or process the commissioner of environmental protection determines, by regulations adopted in accordance with section 3 of this act, to involve the production, handling, use, storage or disposal of material that may pose a threat to groundwater, including structures and appurtenances utilized in conjunction with the regulated activity;

(2) "Commissioner" means the commissioner of environmental protection;

(3) "Well field" means the immediate area surrounding a public drinking water supply well or group of wells;

(4) "Area of contribution" means the area where the water table is lowered due to the pumping of a well and groundwater flows directly to the well;

(5) "Recharge area" means the area from which groundwater flows directly to the area of contribution;

(6) "Aquifer" means a geologic formation, group of formations or part of a formation that contains sufficient saturated, permeable materials to yield significant quantities of water to wells and springs;

(7) "Affected water company" means any public or private water company owning or operating a public water supply well within an aquifer protection area;

(8) "Stratified drift" means a predominantly sorted sediment laid down by or in meltwater from glaciers and includes sand, gravel, silt and clay arranged in layers;

(9) "Municipality" means any town, consolidated town and city, consolidated town and borough, city or borough;

(10) "Aquifer protection area" means any area consisting of well fields, areas of contribution and recharge areas, identified on maps approved by the commissioner of environmental protection pursuant to sections 22a-354b to 22-354d, inclusive, of the general statutes, as amended by this act, within which land uses or activities shall be required to comply with regulations adopted pursuant to section 8 of this act by the municipality where the aquifer protection area is located; and

(11) "Best management practice" means a practice, procedure or facility designed to prevent, minimize or control spills, leaks or other releases that pose a threat to groundwater.

Sec. 3. (NEW) (a) On or before July 1, 1990, the commissioner of environmental protection shall adopt regulations in accordance with chapter 54 of the general statutes for land use controls in aquifer protection areas. The regulations shall establish (1) best management practice standards for existing regulated activities located entirety or in part within aquifer protection areas and a schedule for compliance of nonconforming regulated activities with such standards, (2) best management practice standards for and prohibitions of regulated activities proposed to be located entirely or in part within aquifer protection

(b) The soil and water conservation district where the aquifer protection area is located shall establish and coordinate a technical team to develop each plan. Such team shall include a representative of the municipality in which the land is located and a representative of any affected water company upon request of such municipality or water company. In developing a plan, a district shall consult with the commissioners of environmental protection and agriculture, the college of agriculture and natural resources at The University of Connecticut, the Connecticut Agricultural Experiment Station, the soil conservation service, the state agricultural and conservation committee and any other person or agency the district deems appropriate.

(c) The plan shall include a schedule for implementation and shall be periodically updated as required by the commissioner. In developing a schedule for implementation, the technical team shall consider technical and economic factors including, but not limited to, the availability of state and federal funds. Any person engaged in agriculture in substantial compliance with a plan approved under this section shall be exempt from regulations adopted under section 8 of this act by a municipality in which the land is located. No plan shall be required to be submitted to the commissioner before July 1, 1991, or six months after completion of level B mapping where the farm is located, whichever is later.

(d) On or before July 1, 1990, the commissioner of environmental protection, in consultation with the commissioner of agriculture, the United States Soil Conservation Service, the cooperative extension service at The University of Connecticut and the council for soil and water conservation, shall develop regulations in accordance with chapter 54 of the general statutes for farm resources management plans. Such regulations shall include, but not be limited to, provisions for manure management, storage and handling of pesticides, reduced use of pesticides through pest management practices, integrated pest management, fertilizer management and the location of underground storage tanks. In adopting such regulations, the commissioner shall consider existing state and federal guidelines or regulations affecting aquifers and agricultural resources management.

Sec. 7. (NEW) The zoning commission, planning commission or planning and zoning commission of each municipality with an aquifer protection area shall delineate on any map showing zoning districts prepared in accordance with chapter 124 or 126 of the general statutes or any special act the boundaries of aquifer protection areas, including areas of contribution and recharge areas as shown on level A maps approved pursuant to section 22a-354c of the general statutes, as amended by section 22 of this act.

Sec. 8. (NEW) (a) Each municipality in which an aquifer protection area is located shall authorize by ordinance an existing board or commission to act as such agency not later than three months after adoption by the commissioner of regulations for aquifer protection areas pursuant to section 3 of this act and approval by the commissioner of mapping of areas of contribution and recharge areas for wells located in stratified drift aquifers in the municipality at level B pursuant to section 22a-354d of the general statutes. The ordinance authorizing the agency shall determine the number of members and alternate members, the length of their terms, the method of selection and removal, and the manner for filling vacancies. No member or alternate member of such agency shall participate in any hearing or decision of such agency of which he is a member upon any matter in which he is directly or indirectly interested in a personal or financial sense. In the event of disqualification, such fact shall be entered on the records of the agency and replacement shall be made from alternate members of an alternate to act as a member of such commission in the hearing and determination of the particular matter or matters in which the disqualification arose.

(b) Not more than six months after approval by the commissioner of mapping at level A, pursuant to section 22a-354d of the general statutes, the aquifer protection agency of the municipality in which such well is located shall adopt regulations for aquifer protection.

(c) At least one member of the agency or staff of the agency shall be a person who has completed the course in technical training formulated by the commissioner pursuant to section 16 of this act. Failure to have a member of the agency or staff with training shall not affect the validity of any action of the agency and shall be grounds for revocation of the authority of the agency under section 13 of this act.

Sec. 9. (NEW) (a) The aquifer protection agency authorized by section 8 of this act shall, by regulation, provide for (1) the manner in which the boundaries of aquifer protection areas shall be established and amended or changed, (2) the form for an application to conduct regulated activities within the area, (3) notice and publication requirements, (4) criteria and procedures for the review of applications and (5) administration and enforcement.

(b) No regulations of an aquifer protection agency shall become effective or be established until after a public hearing in relation thereto is held by the agency at which parties in interest and citizens shall have an opportunity to be heard. Notice of the time and place of such hearing shall be published in the form of a legal advertisement, appearing at least twice in a newspaper having a substantial circulation in the municipality at intervals of not less than two days, the first not more than twenty-five days nor less than fifteen days, and the last not less than two days, before such hearing, and a copy of such proposed regulation shall be filed in the office of the town, city or borough clerk, as the case may be, in such municipality, for public inspection at least ten days before such hearing, and may be published in full in such paper. A copy of the notice and the proposed regulations or amendments thereto shall be provided to the commissioner of environmental protection, the town clerk and any affected water company at least thirty-five days before such hearing. Such regulations may be from time to time amended, changed or repealed after a public hearing in relation thereto is held by the agency at which parties in interest and citizens shall have an opportunity to be heard and for which notice shall be published in the manner specified in this subsection. Regulations or changes therein shall become effective at such time as is fixed by the agency, provided a copy of such regulation or change shall be filed in the office of the town, city or borough clerk, as the case may be. Whenever an agency makes a change in regulations, it shall state upon its records the reason why the change was made. All petitions submitted in writing and in a form prescribed by the agency requesting a change in the regulations shall be

(f) Any regulations adopted by an agency under this section shall not be effective unless the commissioner of environmental protection determines that such regulations are reasonably related to the purpose of groundwater protection and not inconsistent with the regulations adopted pursuant to section 3 of this act. A regulation adopted by a municipality shall not be deemed inconsistent if such regulation establishes a greater level of protection. The commissioner shall provide written notification to the agency of approval or the reasons such regulations cannot be approved within sixty days of receipt by the commissioner of the regulations adopted by the agency.

Sec. 10. (NEW) (a) The commissioner of environmental protection or any person aggrieved by any regulation, order, decision or action made pursuant to sections 8 to 14, inclusive, of this act, by the commissioner or municipality, within fifteen days after publication of such regulation, order, decision or action may appeal to the superior court for the judicial district where the land affected is located, and if located in more than one judicial district, to said court in any such judicial district, except if such appeal is from a contested case, as defined in section 4-166 of the general statutes, such appeal shall be in accordance with the provisions of section 4-183 of the general statutes and venue shall be in the judicial district where the land affected is located, and if located in more than one judicial district to the court in any such judicial district. Such appeal shall be made returnable to said court in the same manner as that prescribed for civil actions brought to said court. Notice of such appeal shall be served upon the aquifer protection agency and the commissioner. The commissioner may appear as a party to any action brought by any other person within thirty days from the date such appeal is returned to the court. The appeal shall state the reasons upon which it is predicated and shall not stay proceedings on the regulation, order, decision or action, but the court may, on application and after notice, grant a restraining order. Such appeal shall have precedence in the order of trial.

(b) The court, upon the motion of the person who applied for such order, decision or action, shall make such person a party defendant in the appeal. Such defendant may, at any time after the return date of such appeal, make a motion to dismiss the appeal. At the hearing on such motion to dismiss, each appellant shall have the burden of proving his standing to bring the appeal. The court may, upon the record, grant or deny the motion. The court's order on such motion shall be a final judgment for the purpose of the appeal as to each such defendant. No appeal may be taken from any such order except within seven days of the entry of such order.

(c) No appeal taken under subsection (a) of this section shall be withdrawn and no settlement between the parties to any such appeal shall be effective unless and until a hearing has been held before the superior court and such court has approved such proposed withdrawal or settlement.

Sec. 11. (NEW) (a) If upon appeal pursuant to section 10 of this act, the court finds that the action appealed from constitutes the equivalent of a taking without compensation, it shall set aside the action or it may modify the action so that it does not constitute a taking. In both instances the court shall remand the order to the aquifer protection agency for action not inconsistent with its decision.

(b) To carry out the purposes of sections 8 to 14, inclusive, of this act, a municipality may at any time purchase land or an interest in land in fee simple or other acceptable title, or subject to acceptable restrictions or exceptions, and enter into covenants and agreements with landowners.

Sec. 12. (NEW) (a) If the aquifer protection agency or its duly authorized agent finds that any person is conducting or maintaining any activity, facility or condition which violates any provision of sections 8 to 14, inclusive, of this act, or any regulation or permit adopted or issued thereunder, the agency or its duly authorized agent may issue a written order by certified mail, return receipt requested, to such person conducting such activity or maintaining such facility or condition to cease such activity immediately or to correct such facility or condition. The agency shall send a copy of such order to any affected water company by certified mail, return receipt requested. Within ten days of the issuance of such order the agency shall hold a hearing to provide the person an opportunity to be heard and show cause why the order should not remain in effect. Any affected water company may testify at the hearing. The agency shall consider the facts presented at the hearing and, within ten days of the completion of the hearing, notify the person by certified mail, return receipt requested, that the original order remains in effect, that a revised order is in effect, or that the order has been withdrawn. The original order shall be effective upon issuance and shall remain in effect until the agency affirms, revises or withdraws the order. The issuance of an order pursuant to this section shall not delay or bar an action pursuant to subsection (b) of this section. The commissioner may issue orders pursuant to sections 22a-6 to 22a-7, inclusive, of the general statutes, concerning an activity, facility or condition which is in violation of said sections 8 to 14, inclusive, if the municipality in which such activity, facility or condition is located has failed to enforce its aquifer protection regulations.

(b) Any person who commits, takes part in, or assists in any violation of any provision of sections 8 to 14, inclusive, of this act, or any ordinance or regulation promulgated by municipalities pursuant to the grant of authority herein contained, shall be assessed a civil penalty of not more than one thousand dollars for each offense. Each violation of said sections shall be a separate and distinct offense, and, in the case of a continuing violation, each day's continuance thereof shall be deemed to be a separate and distinct offense. The superior court, in an action brought by the commissioner, municipality, district or any person shall have jurisdiction to restrain a continuing violation of said sections, to issue orders directing that the violation be corrected or removed, and to assess civil penalties pursuant to this section. All costs, fees and expenses in connection with such action shall be assessed as damages against the violator together with reasonable attorney's fees which may be allowed, all of which shall be awarded to the municipality, district or person bringing such action.

(c) Any person who wilfully or knowingly violates any provision of sections 8 to 14, inclusive, of this act, shall be fined not more than one thousand dollars for each day during which such violation continues or be imprisoned not more than six months or both. For a subsequent violation, such person shall be fined not more than two thousand dollars for each day during which such violation continues or be imprisoned not more than one year or both. For the purposes of this subsection, "person" shall be construed to include any responsible corporate officer.

Sec. 13. (NEW) (a) The commissioner of environmental protection may revoke the authority of a municipality to regulate aquifer protection areas pursuant to sections 8 to 14, inclusive, of this, act upon determination after a hearing that such municipality has, over a period of time, consistently failed to perform its duties under said sections. Prior to the hearing on revocation, the commissioner shall send a notice to the aquifer protection agency, by certified mail, return receipt requested, asking such agency to show cause, within thirty days, why such authority should not be revoked. A copy of the show cause notice shall be sent to the chief executive officer of the municipality that authorized the agency and to any water company owning or operating a public water supply well within such municipality. Such water company may, through a representative, appear and be heard at any such hearing. The commissioner shall send a notice to the aquifer protection agency, by certified mail, return receipt requested, stating the reasons for the revocation and the circumstances for reinstatement. Any municipality aggrieved by a decision of the commissioner under this section to revoke its authority under said sections 8 to 14, inclusive, may appeal therefrom in accordance with the provisions of section 4-183 of the general statutes. The commissioner shall have jurisdiction over aquifers in any municipality whose authority to regulate such aquifers has been revoked. Any costs incurred by the state in reviewing applications to conduct an activity within an aquifer protection area for such municipality shall be paid by the municipality. Any fees that would have been paid to such municipality if such authority had been retained shall be paid to the state.

(b) The commissioner shall cause to be published notice of the revocation or reinstatement of the authority of a municipality to regulate aquifers in a newspaper of general circulation in the area of such municipality.

(c) The commissioner shall adopt regulations in accordance with the provisions of chapter 54 of the general statutes establishing standards for the revocation and reinstatement of municipal authority to regulate aquifers pursuant to section 8 of this act.

Sec. 14. The commissioner of environmental protection and the commissioner of transportation, within available appropriations, shall study methods to prevent contamination of drinking water in aquifer protection areas through design, construction and maintenance of transportation routes. In conducting the study, said commissioners shall consider prohibiting the transportation of potential groundwater contaminants through aquifer protection areas, mandating containment molding and drainage control in the design and construction of roads located within aquifer protection areas and the feasibility of nonsalt-based deicing material for roads within aquifer protection areas. The commissioners shall submit a report of their findings and recommendations to the joint standing committee of the general assembly having cognizance of matters relating to the environment on or before February 1, 1990.

Sec. 15. (NEW) The commissioner of environmental protection shall develop an incentive program to provide public recognition of users of land located within aquifer protection areas who demonstrate successful and committed efforts to protect drinking water supplies by implementing innovative approaches to groundwater protection. Such program shall also promote groundwater protection through education of members of businesses and industry and the public.

Sec. 16. (NEW) The commissioner of environmental protection shall formulate courses in technical training for members and staff of municipal aquifer protection agencies. Such courses shall provide instruction in the regulations developed pursuant to section 3 of this act, potential options for monitoring and enforcement, and technical requirements for site plan review. The commissioner may designate any organization or educational institution to provide such instruction.

Sec. 17. (NEW) The commissioner of environmental protection, in consultation with the commissioner of health services and the chairperson of the department of public utilities control, shall prepare guidelines for acquisition of lands surrounding existing or proposed public water supply well fields. In preparing such guidelines the commissioner shall consider economic implications for mandating land acquisition including, but not limited to, the effect on land values and the ability of small water companies to absorb the cost of acquisition.

Sec. 18. (NEW) (a) The commissioner of environmental protection, in consultation with the commissioner of health services and water companies, shall provide, within available appropriations, technical, coordinating and research services to promote the effective administration of this act at the federal, state and local levels.

(b) The commissioner shall have the overall responsibility for general supervision of the implementation of this act and shall monitor and evaluate the activities of federal and state agencies and the activities of municipalities to assure continuing, effective, coordinated and consistent administration of the requirements and purposes of this act.

(c) The commissioner shall prepare and submit to the general assembly and the governor, on or before December first of each year, a written report summarizing the activities of the department concerning the development and implementation of this act during the previous year. Such report shall include, but not be limited to: (1) The department's accomplishments and actions in achieving the goals and policies of this act including, but not limited to, coordination with other state, regional, federal and municipal programs established to achieve the purposes of this act; (2) recommendations for any statutory or regulatory amendments necessary to achieve such purposes; (3) a summary of municipal and federal programs and actions which affect aquifer protection areas; (4) recommendations for any programs or plans to achieve such purposes; (5) any aspects of the program or the act which are proving difficult to accomplish, suggested reasons for such difficulties, and proposed solutions to such difficulties; (6) a summary of the expenditure of federal and state funds under this act and (7) a request for an appropriation of funds necessary to match federal funds and provide continuing financial support for the program. Such report shall comply with the provisions of section 46a-78 of the general statutes.

Sec. 19. (NEW) Each water company serving ten thousand or more customers with wells in stratified drift aquifers shall prepare a municipal assistance program, which includes recommendations for site plan reviews, evaluation of risks and advice on procedures for dealing with hazardous waste spills in aquifers. Such program shall be made available to any municipality in which wells owned by the water company are located.

Sec. 20. (NEW) On or before the second Wednesday after the convening of each regular session of the general assembly, the commissioner of health services shall submit a report to the joint standing committee of the general assembly having cognizance of matters relating to the environment, which describes the status of, for the year ending the preceding June thirtieth, the water planning process established under sections 25-33g to 25-33j, inclusive, of the general statutes, as amended by this act, and efforts to expedite the process.

Sec. 21. Section 25-32d of the general statutes is repealed and the following is substituted in lieu thereof:

(a) Each water company as defined in section 25-32a and supplying water to one thousand or more persons or two hundred fifty or more consumers and any other water company as defined in said section requested by the commissioner of health services shall submit a water supply plan to the commissioner of health services for approval with the concurrence of the commissioner of environmental protection. The concurrence of the public utilities control authority shall be required for approval of a plan submitted by a water company regulated by the authority. The commissioner of health services shall consider the comments of the public utilities control authority on any plan which may impact any water company regulated by the authority. The commissioner of health services shall distribute a copy of the plan to the commissioner of environmental protection and the public utilities control authority. A copy of the plan shall be sent to the secretary of the office of policy and management for information and comment. A plan shall be revised at such time as the water company filing the plan or the commissioner of health services determines or at intervals of not less than three years nor more than five years after the date of initial approval.

(b) Any water supply plan submitted pursuant to this section shall evaluate the water supply needs in the service area of the water company submitting the plan and propose a strategy to meet such needs. The plan shall include, but not be limited to: (1) A description of existing water supply systems; (2) an analysis of future water supply demands; (3) an assessment of alternative water supply sources which may include sources receiving sewage AND SOURCES LOCATED ON STATE LAND; (4) contingency procedures for public drinking water supply emergencies, including emergencies concerning the contamination of water, the failure of a water supply system or the shortage of water; (5) a recommendation for new water system development; (6) such other information as the commissioner of health services, the commissioner of environmental protection or the public utilities control authority deems necessary; [and] (7) a forecast of future land sales; AND (8) PROVISIONS FOR STRATEGIC GROUNDWATER MONITORING.

(c) The commissioner of health services, in consultation with the commissioner of environmental protection and the public utilities control authority, shall adopt regulations in accordance with the provisions of chapter 54. Such regulations shall include, but not be limited to, a process for approval, modification or rejection of plans submitted pursuant to this section and a schedule for submission of the plans.

Sec. 22. Section 22a-354c of the general statutes is repealed and the following is substituted in lieu thereof:

(a) On or before July 1, 1990, each public or private water company serving one thousand or more persons shall map at level B all AREAS OF CONTRIBUTION AND RECHARGE AREAS FOR its existing [well fields located] WELLS LOCATED IN STRATIFIED DRIFT AQUIFERS THAT ARE within its water supply service area. On or before July 1, 1992, each public and private water company serving ten thousand or more persons shall map at level A all AREAS OF CONTRIBUTION AND RECHARGE AREAS FOR its existing [well fields located] WELLS LOCATED IN STRATIFIED DRIFT AQUIFERS THAT ARE within its water supply service area. The commissioner of environmental protection may map at level B all existing [well fields located] WELLS LOCATED IN STRATIFIED DRIFT AQUIFERS THAT ARE within the water supply service area of any public or private water company serving less than one thousand persons.

(b) Each public or private water company serving ten thousand or more persons shall map all [potential well fields] AREAS OF CONTRIBUTION AND RECHARGE AREAS FOR POTENTIAL WELLS that are located within stratified drift aquifers identified as future sources of water supply to meet their needs in accordance with the plan submitted pursuant to section 25-33h, AS AMENDED BY SECTION 24 OF THIS ACT, (1) at level B two years after approval of such plan and (2) at level A four years after approval of such plan. The commissioner of environmental protection shall identify and make recommendations for mapping all remaining significant [well fields] WELLS LOCATED IN STRATIFIED DRIFT AQUIFERS not identified by a public or private water company as a potential source of water supply within the region of an approved plan. Mapping of ANY OTHER AREA OF CONTRIBUTION AND RECHARGE AREAS FOR potential [well fields] WELLS LOCATED IN STRATIFIED DRIFT AQUIFERS by the commissioner shall be completed at a time determined by the commissioner.

Sec. 23. (NEW) (a) On or before July 1, 1995, each public or private water company serving at least one thousand persons but not more than ten thousand persons shall map areas of contribution and recharge areas at level A for each existing stratified drift wells located within its water supply area.

(b) Each public or private water supply company serving at least one thousand but not more than ten thousand persons shall map areas of contribution and recharge areas for all of the potential wells located in stratified drift aquifers identified as future sources of water supply in accordance with the plan submitted to section 25-33h of the general statutes, as amended by section 24 of this act, at level B not more than two years after approval of the plan and at level A not more than five years after approval.

Sec. 24. Section 25-33h of the general statutes is repealed and the following is substituted in lieu thereof:

(a) Each water utility coordinating committee shall prepare a coordinated water system plan in the public water supply management area. Such plan shall be submitted to the commissioner of health services for his approval not more than two years after the first meeting of the committee. The plan shall promote cooperation among public water systems and include, but not be limited to, provisions for (1) integration of public water systems, consistent with the protection and enhancement of public health and well-being; (2) integration of water company plans; (3) exclusive service areas; (4) joint management or ownership of services; (5) satellite management services; (6) interconnections between public water systems; (7) integration of land use and water system plans; (8) minimum design standards; [and] (9) the impact on other uses of water resources; AND (10) ACQUISITION OF LAND SURROUNDING WELLS PROPOSED TO BE LOCATED IN STRATIFIED DRIFTS.

(b) The plan shall be adopted in accordance with the provisions of this section. The committee shall prepare a draft of the plan and solicit comments thereon from the commissioners of health services and environmental protection, the department of public utility control, the secretary of the office of policy and management and any municipality, regional planning agency or other interested party within the management area. The municipalities and regional planning agencies shall comment on, but shall not be limited to commenting on, the consistency of the plan with local and regional land use plans and policies. The department of public utility control shall comment on, but shall not be limited to commenting on, the cost-effectiveness of the plan. The secretary of the office of policy and management shall comment on, but shall not be limited to commenting on, the consistency of the plan with state policies. The commissioner of environmental protection shall comment on, but shall not be limited to commenting on, the availability of water for any proposed diversion. The commissioner of health services shall comment on, but shall not be limited to commenting on, the availability of pure and adequate water supplies, potential conflicts over the use of such supplies, and consistency with the goals of sections 25-33c to 25-33j, inclusive, AS AMENDED BY THIS ACT.

(c) The commissioner of health services shall adopt regulations in accordance with the provisions of chapter 54 establishing the contents of a plan and a procedure for approval.

Sec. 25. (NEW) The commissioner of environmental protection, in consultation with the commissioner of health services, water companies, and business and industry shall develop a strategic groundwater monitoring plan to be implemented in aquifer protection areas not more than one year after completion of level A mapping pursuant to sections 22a-354b to 22a-354d, inclusive, of the general statutes, as amended by this act.

Sec. 26. Section 19a-37 of the general statutes is repealed and the following is substituted in lieu thereof:

The commissioner of health services may adopt regulations in the public health code [pertaining to protection and location of new water supply wells or springs for residential construction or for public or semipublic use] for the preservation of the public health PERTAINING TO (1) PROTECTION AND LOCATION OF NEW WATER SUPPLY WELLS OR SPRINGS FOR RESIDENTIAL CONSTRUCTION OR FOR PUBLIC OR SEMIPUBLIC USE, AND (2) INSPECTION FOR COMPLIANCE WITH THE PROVISIONS OF MUNICIPAL REGULATIONS ADOPTED PURSUANT TO SECTION 9 OF THIS ACT.

Sec. 27. Section 22a-354e of the general statutes is repealed and the following is substituted in lieu thereof:

Not later than three months after approval of the commissioner of environmental protection of mapping of aquifers at level B, each [municipality in which such aquifers are located, acting through its legislative body, shall authorize any board or commission, or shall establish a new board or commission to] MUNICIPAL AQUIFER PROTECTION AGENCY AUTHORIZED PURSUANT TO SECTION 8 OF THIS ACT SHALL inventory land uses overlying the mapped zone of contribution and recharge areas of such aquifers in accordance with guidelines established by the commissioner pursuant to section 22a-354f. SUCH INVENTORY SHALL BE COMPLETED NOT MORE THAN ONE YEAR AFTER AUTHORIZATION OF THE AGENCY.

Sec. 28. Section 22-6c of the general statutes is repealed and the following is substituted in lieu thereof:

The commissioner of agriculture may reimburse any farmer for part of the cost of the completion of a component of a farm waste management system, provided such component has been certified by the Federal Agricultural Stabilization and Conservation Service, and the cost is in accordance with said certification. The total federal and state grant available to a farmer shall not be more than seventy-five per cent of such cost. IN MAKING GRANTS UNDER THIS SECTION THE COMMISSIONER SHALL GIVE PRIORITY TO CAPITAL IMPROVEMENTS MADE IN ACCORDANCE WITH A FARM RESOURCES PLAN PREPARED PURSUANT TO SECTION 6 OF THIS ACT.

Sec. 29. Subsection (a) of section 25-84 of the general statutes is repealed and the following is substituted in lieu thereof:

(a) Any municipality may, by vote of its legislative body, adopt the provisions of this section and sections 25-85 to 25-94, inclusive, and exercise through a flood and erosion control board the powers granted thereunder. In each town, except as otherwise provided by special act, the flood and erosion control board shall consist of not less than five nor more than seven members, who shall be electors of such town and whose method of selection and terms of office shall be determined by local ordinance, except that in towns having a population of less than [twenty-five] FIFTY thousand the selectmen may be empowered by such ordinance to act as such flood and erosion control board. In each city or borough, except as otherwise provided by special act, the board of aldermen, council or other board or authority having power to adopt ordinances for the government of such city or borough may act as such board. The flood and erosion control board of any town shall have jurisdiction over that part of the town outside any city or borough contained therein.

Sec. 30. (NEW) Not more than two months after approval by the commissioner of environmental protection of mapping at level B pursuant to section 22a-354d of the general statutes, the commissioner, in consultation with the commissioner of agriculture, the cooperative extension service at The University of Connecticut and any other person or agency the commissioner of environmental protection deems necessary, shall inventory agricultural land uses overlaying the mapped area. Such inventory shall include, but not be limited to, the type and size of any agricultural operation and existing farm resource management practices. Any such inventory shall be completed not more than four months after commencement and shall be made available to technical teams established pursuant to subsection (b) of section 4 of this act.

Sec. 31. (NEW) State regulations for aquifer protection areas adopted by the commissioner of environmental protection pursuant to section 3 of this act shall be consistent with regulations adopted by said commissioner for farm resources management plans pursuant to section 6 of this act.

Sec. 32. This act shall take effect from its passage, except that sections 1 to 13, inclusive, and sections 15 to 28, inclusive, shall take effect July 1, 1989.

Certified as correct by

____
Legislative Commissioner.

____
Clerk of the Senate.

____
Clerk of the House.

Approved ______________________, 1989

____
Governor, State of Connecticut.

Eric J. Brown
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Mr. Brown received his B.S. degree in geology from the University of Rhode Island in 1980. After serving as a geological assistant for Mobil Corporation, he entered Boston College where he worked as a geophysical analyst at the school's Weston Observatory and received his M.S. degree in 1985. Mr. Brown taught science for five years at Greens Farms Academy in Westport, Connecticut before leaving to become executive director of the Connecticut General Assembly's Aquifer Protection Task Force. He is presently employed by the Hartford/New Haven law firm of Murtha, Cullina, Richter and Pinney as an environmental analyst and is attending Western New England College School of Law.

ABSTRACT

PROTECTING GROUND WATER FROM THE BOTTOM UP: LOCAL RESPONSES TO WELL-HEAD PROTECTION

WALPOLE BOARD OF HEALTH: GROUNDWATER PROTECTION PROGRAM IMPLEMENTATION

By Robin Chapell, R.S.
Health Agent

Walpole Board of Health

The Walpole Board of Health has instituted and regulated many programs to protect its water from contamination. Walpole has been designated as a sole source aquifer district so it is imperative that its water not be polluted. The Board has adopted Underground Storage Regulations, Toxic and Hazardous Materials Regulations, Private Well Regulations and Mandatory Sewer Connection Regulations. The Board is also responsible for implementing several monitoring programs in town to make certain, that particular landfills and industries in sensitive areas are not contaminating our aquifer. The Health Department has organized Household Hazardous Waste Collection Days to help alleviate a certain amount of illegal dumping. The department has been responsible for removal or testing of many residential underground tanks. Just recently the Board of Health strengthened Title V by requiring a bigger set back to wetlands.

"Walpole Board of Health: Groundwater Protection Program Implementation"

By Robin Chapell, R.S.

Health Agent
Walpole Board of Health

Towns and cities need to protect themselves from environmental degradation at its local level. This should be its first line of defense. Towns and cities should not wait til state and federal agencies do the work for them. After all, pollution and degradation of the environment will first be felt by the residents in the community. Its the residents that have the most at stake if something happens. Each town has its own special problems, history and geography that can be more easily recognized at the local level rather than by a state or federal agency. Day to day situations can be more easily monitored locally on a routine basis. This in no way implies that well needed protection should not occur at the state or federal level, but that it simply cannot replace local involvement.

One of the best governing bodies to protect the local environment are the local Boards of Health. They are charged with protecting the public health of their community under Massachusetts General Laws Chapter III Section 31. The Walpole Board of Health has taken its importance seriously and has instituted many varied programs and regulations to protect its groundwater from contamination as will be discussed later.

The Town of Walpole is located 19 miles south of Boston and 26 miles north of Providence. Over 19,000 residents reside in town. Walpole is an old mill town but now most of its residents work in Boston.

The Town of Walpole relies heavily on its aquifer for its drinking source. In fact, the town petitioned to be designated a sole source aquifer district and in 1988, EPA, so did so. This means that Walpole has only one main source for its drinking water. If this source is contaminated, all of Walpole's drinking water will be in jeopardy. Being a sole source aquifer district means certain state and federal projects in this area can be closely scrutinized if it is felt they can be detrimental to the town's water. Long before Walpole was designated a sole source aquifer district, the town saw the need to delineate certain sensitive areas in town where certain activities could influence the quality of the town's water. The town hired IEP Consultant Engineers to map out Water Resource Protection Districts in the town.

This map has been very useful to the Board of Health. When the Board of Health reviews any preliminary plan, definitive plan, board of appeals case, or notice of intent, the first question that is asked, is in what protection district is it in? If it lies in the protection districts, they ask how can the activity affect the aquifer? In certain instances in town, the Board has restricted uses, turned down plans, and/or set up monitoring programs. The monitoring programs help the Board keep up on present and future sources of contamination. At least four monitoring programs have been initiated within the town. They monitor either private landfills or industrial parks. Each program, reports in writing, four times a year to the health agent, and in turn is reported to the Board. Many times, the health agent is present during the gathering of samples. The programs are continually updated. The Board looks for the presence of VOCs, heavy metals, ph, conductivity, and ground-water levels. If something shows up, more samples need to be taken to explain its presence. If levels of an unwanted substance are too high, rise or monitoring ceases that would be reason enough to close the activity down. These monitoring programs are written in covenants and go with the land, not the owner, to insure long term participation of these mandatory programs.

The Board of Health also regulates all underground storage tanks. The Board promulgated regulations on its registration, usage and testing of the tanks. In the town's most sensitive water protection districts, no new tanks can go in. All commercial tanks, at age 20 must be removed. Residents have the option to biyearly test their tanks for leaks if they choose not to remove them. Town owned tanks are also being removed and replaced. All new underground tanks must be approved by the fire department and placement of these tanks must be approved by both the Water and Sewer Commission and the Board of Health. In 1988 the health department negotiated for the residents with a tank testing company to come to town and test residential tanks at a very reduced rate. About 16 tanks were tested. Other residents chose to remove their tanks and replace them with basement heaters or some switched to gas. At age 15, all tanks, commercial and residential must be put on a tank tightness monitoring program. Results are forwarded to the Health Department. All underground storage tanks in town must register with the Board of Health. All the information is computerized. Information can easily be retrieved in regards to the age, type, location, and water protection district of the tank. Since the beginning of this program many unused tanks have been ordered to be removed from Walpole. All tanks that are removed are inspected by the fire department and the health agent. If the integrity of the tanks that are being removed are in question, all surrounding soils will be treated as hazardous materials.

The Board of Health also regulates toxic and hazardous materials used in industries using 25 pounds or 50 gallons of hazardous materials stored on their premises at one time. This information has also been computerized and shared by the fire department. Each initial registration is followed by a site visit by the health agent. All new companies in town must comply with these Board of Health regulations before the town will issue them an occupancy permit. The health agent requires proper storage of all toxic and hazardous materials. The Board of Health is also sent all Material Safety Data Sheets, from companies dealing with hazardous materials.

The Board of Health also regulates the town bylaw for Mandatory Sewer Hook Up. Every residence, in all Water Protection Districts, must hook up to sewer if sewer is available. The time allowed for compliance for this relatively new by law depends on what water protection district they are in. Recently, the health department, had to take a few residents to court because they have decided not to hook up. Fortunately, as of this writing, the town has to contend with only one remaining stand out.

Private Well Regulations have recently been implemented by the Board. All new drinking water wells must be tested for VOCs, heavy metals, coliform, bacteria, water depth, and pump rate. If the wells do not meet federal standards for drinking water they cannot be used. Certain standards, such as manganese, can be met with the aid of a filter. All new dwellings, if on private wells, will not get their occupancy permit until the Health Department okays their well. Old well owners are continually encouraged to register their wells, but the health department knows its information is not nearly complete. The location of wells is very helpful in knowing how best to protect certain areas, which areas need to be protected, and what activities should be restricted where. there are certain flaws with the Board's well regulations. The biggest flaw is that only an initial test is required. The Health Department educates as many well owners as possible to the importance of regular testing for their drinking waters. The town tests its drinking water monthly. Hopefully, this year the Board will be reexamining these regulations and will be making them stricter where applicable.

The Board recognizes the problem of illegal dumping of hazardous materials and sometimes the legal improper disposal of these materials. In 1986 the Board of Health started implementing a yearly Household Hazardous Waste Day. Each year this event has become bigger and more costly to the town due to the increasing participation of the residents.

The Board of Health in Walpole is committed to continuing with this program in addition to exploring other ways to solve these problems. The Health Department, through school visits, articles in town papers, and talking to residents are trying to educate the citizens in using alternative safer household products, reducing quantities, and recycling.

Very recently the Board of Health examined Title V and its own septic system regulations to see if it met the town's needs. The Board, after months of deliberation, decided to strengthen the regulations by requiring a 100 foot set back from the septic tank and 150 foot set back from the leaching field to wetlands. The Board discussed distances bacteria and viruses could travel and came up with setbacks they felt more comfortable with for the Town of Walpole.

The Board of Health in Walpole follows up on leads about illegal dumping, business practices that might eventually harm the environment and any accidental spills in town. This way they can routinely press for clean up, monitor its progress, and hopefully prevent disasters.

The community has been very receptive and appreciative to the Board of Health in protecting the environment. Other departments have worked hand in hand implementing these programs. With little desention, the residents and businesses have complied and taken an active role in voicing their concerns and coming up with suggestions to protect Walpole's groundwater.

BIOGRAPHICAL SKETCH

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Case Study of Regional Effort: Wellhead Delineation as a Tool for Fostering Regional Cooperation

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ABSTRACT

Case Study of Regional Effort: Wellhead Delineation as a Tool for Fostering Regional Cooperation

The presentation proposed is based on current efforts to achieve regional cooperation in pursuit of groundwater protection. The regional setting is the Hunt Aquifer in Rhode Island, an aquifer with the capacity to deliver eight million gallons of water per day. The waters of the Hunt Aquifer are distributed to a population of over 50,000 by three different water suppliers, the North Kingstown Water Department, the Kent County Water Authority, and the Rhode Island Port Authority. Five public supply wells lie within 1000 feet of one another. The primary reservoir area is located at the boundary confluence of three municipalities, each with distinct political and land use control.

Wellhead delineation has become the vehicle for fostering a regional cooperative effort. The water suppliers have recognized that the results of a wellhead delineation study are a tool for determining future acquisition to protect wellheads; for assigning locations for monitoring potential contamination sites; and for providing information and direction to the three municipalities for land use regulation purposes. Additionally, it was recognized that the proximity of the wells and the likely pumping interaction necessitated a joint effort. To this end the three water suppliers have committed funding available in July, 1989, to contract for consulting services to conduct the wellhead delineation study.

Since November 1988, an ad-hoc committee composed of representatives of the water suppliers and the municipalities has been meeting to discuss issues related to groundwater protection as well as institutional constraints to regional cooperation. Dissimilar municipal zoning, subdivision, and other regulations are being reviewed. To expand the current information base available for the wellhead study, the water suppliers have authorized a cooperative water quality sampling program for their wells. The municipalities have inventoried land uses with potential for contamination: respective fire departments have focussed on the well area for MSDS inventorying. Formalization of committee efforts is anticipated.

In summary, wellhead delineation became a tool for fostering a regional cooperative effort for protecting the groundwaters of the Hunt Aquifer. This effort has led to involvement of water suppliers and municipalities in expanding the land use data base and pursuing techniques that address long-term groundwater protection.

Case Study of Regional Effort: Wellhead Delineation as a Tool for Fostering Regional Cooperation

Introduction

Background and Setting

This discussion is based on efforts to achieve regional cooperation in pursuit of groundwater protection for the Hunt Aquifer in Rhode Island. The waters of the Hunt Aquifer are distributed to a population of over 50,000 people by three different water suppliers: -the Town of North Kingstown Water Department, the Kent County Water Authority, and the Rhode Island Port Authority. Five of the seven public water supply wells in the Hunt Aquifer and belonging to the three water suppliers lie within 1000 feet of one another. The primary reservoir area, and the site of the five wells, is located at the confluence of three municipalities: the Towns of East Greenwich and North Kingstown and the City of Warwick.

No models existed in Rhode Island upon which to base the regional effort for groundwater protection. Peculiar to Rhode Island is the fact that there are no recognized regional planning agencies. Additionally, the 39 cities and towns that comprise the Rhode Island communities historically have operated independently of one another. Only a few examples exist of intercommunity cooperation.

In the idealized world a community draws its water resources from within its own boundaries and, thus, would be able to control the land use activities that could contribute to the quality of the drinking water. A board of health would exist to monitor water quality and advise the community on protection of its resources. Unlike other New England states, no board of health exists at the local level in Rhode Island to monitor water quality. The Rhode Island Department of Health (RIDOH) does monitor water quality but because its responsibility includes the entire state, it is unable to focus on individual systems and land use. The responsibility of assuring water quality rests with the water supplier, an agency or department that is rarely staffed with environmental or planning capacity. Moreover, in the case at hand groundwater crosses municipal boundaries such that, except for a portion of the Hunt Aquifer lying within the Town of North Kingstown, none of the three water suppliers is able to control the land use around their respective water supply wells.

Hydrologic setting

The setting for this discussion is the Hunt Aquifer located in Rhode Island along the west passage of Narragansett Bay. Figure 1 shows the location of the Hunt Aquifer (Number 11). The Hunt Aquifer is in the Potowomut River sub-basin drained by the Hunt, Maskerchugg, and Potowomut Rivers. The Hunt River flows northeastward and eventually discharges into Potowomut Pond. The Hunt Aquifer is a sand and gravel aquifer whose transmissivities range from 1000 to more than 4000 gallons per day per foot. The saturated thickness of the aquifer ranges from less than 20 feet to more than 100 feet. A groundwater reservoir where transmissivity is greatest is located generally along the Hunt River basin. All of the wells are located adjacent to the Hunt River.

The groundwater quality is considered to be generally good. Some chemical and volatile organic compound contamination has become evident. The aquifer system is vulnerable to contamination due to high permeability of stratified drift, the absence of a confining layer of soil, and in some areas, a relatively high water table. All of these conditions offer little resistance to the attentuation of pollutants.

Drinking Water Supply and Demand

The North Kingstown Water Department (NKWD), the Kent County Water Authority (KCWA), and the Rhode Island Port Authority (RIPA) share the Hunt Aquifer which has an estimated potential yield of 8 million gallons per day. This yield can be withdrawn using the existing pumping facilities. The KCWA has the capacity to withdraw 1.0 mgd from its one well; the RIPA has the capacity to withdraw 4.30 mgd from three wells; and the NKWD has the capacity to withdraw 3.67 mgd from three wells located in the Hunt Aquifer groundwater reservoir. Projections for the area served by the Hunt Aquifer indicate that the total resources available will be necessary in order to adequately serve new growth. A lack of alternative drinking water resources was documented in the Sole Source Aquifer petition for the Hunt Aquifer.

Kent County Water Authority is a public benefit corporation that supplies public water to all or a part of the Rhode Island cities of Cranston and Warwick and the Towns of Scituate, West Warwick, Coventry, East Greenwich, and West Greenwich from the Scituate Reservoir. The available 1.0 mgd from the Authority's well in the Hunt Aquifer is distributed to residents and businesses in the eastern portion of the Town of East Greenwich and the Potowomut area of the City of Warwick to approximately 8000

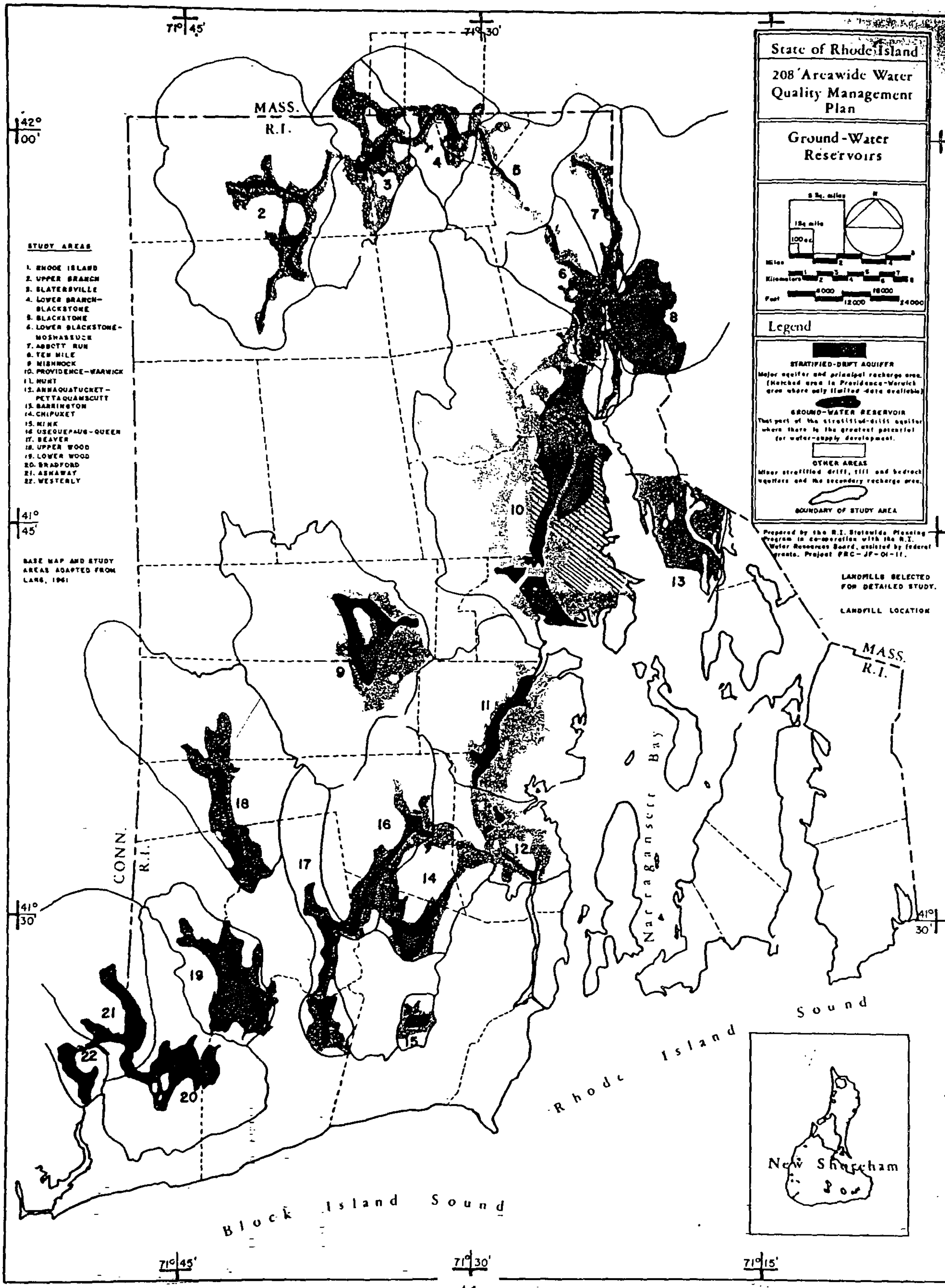
State of Rhode Island
208 Areawide Water Quality Management Plan
Ground-Water Reservoirs
Legend
STRATIFIED-DRIFT AQUIFER
Major aquifer and principal recharge area. (Hatched area in Providence-Warwick area where only limited data available)
GROUND-WATER RESERVOIR
That part of the stratified-drift aquifer where there is the greatest potential for water-supply development.
OTHER AREAS
Minor stratified drift, till and bedrock aquifers and the secondary recharge area.
BOUNDARY OF STUDY AREA
Prepared by the R.I. Statewide Planning Program in co-operation with the R.I. Water Resources Board, assisted by federal grants. Project PRC-JP-01-11.
LANDFILLS SELECTED FOR DETAILED STUDY.
LANDFILL LOCATION
STUDY AREAS
1. RHODE ISLAND
2. UPPER BRANCH
3. SLATERSVILLE
4. LOWER BRANCH-BLACKSTONE
5. BLACKSTONE
6. LOWER BLACKSTONE-MOSHASSUCK
7. ABBOTT RUN
8. TEN MILE
9. MISHNOCK
10. PROVIDENCE-WARWICK
11. HUNT
12. ANNAQUATUCKET-PETTAQUAMSCUTT
13. BARRINGTON
14. CHIPUXET
15. MINK
16. USEQUEPAUG-QUEEN
17. BEAVER
18. UPPER WOOD
19. LOWER WOOD
20. BRADFORD
21. ASHAWAY
22. WESTERLY
BASE MAP AND STUDY AREAS ADAPTED FROM LANG, 1961
MASS.
R.I.
CONN.
Narragansett Bay
Rhode Island Sound
Block Island Sound
New Shoreham
71°45'
71°30'
71°15'
42° 00'
41° 45'
41° 30'

Figure 1

services in total. During peak periods the Authority draws the maximum capacity from the well to supplement the supply drawn from the Scituate Reservoir.

The Rhode Island Port Authority, a state agency and subset of the State Department of Economic Development, is the governing body for over 1500 acres of industrial land located within the Town of North Kingstown. This land is known as the Quonset Point/Davisville Industrial Park and was acquired by the State from the Federal government following the withdrawal and closure in 1973 of most of the Navy facilities once located at Quonset Point and Davisville. The Port Authority also acquired the water supply wells that provided public water to the Navy base. One of those wells is located in East Greenwich and two are located in Warwick. Figure 2 shows the location of the wells in the confluence of the three municipal boundaries. The Port Authority has available to it in its three wells 4.30 mgd; in 1988 the average daily use was only 0.80 mgd. The Port Authority expects to reach its pumping capacity in several years as expansion continues at the Park with additional industrial development. Several industrial firms with large water demands have recently made commitments to locate at Quonset Point.

The Town of North Kingstown had an estimated 1985 population of 25,100. Ninety percent of the homes in the Town are serviced by the public water supply system. It is anticipated that the majority of new development will be connected to public water. The Town at present is wholly dependent on the use of individual septic disposal systems for the treatment of domestic sewage. North Kingstown still has extensive potential for additional growth due to the availability of land for suburban development. The North Kingstown Planning Commission has granted final approval for in excess of 600 lots over the last two years and approximately 550 lots exist in the review pipeline. Projections based on build-out growth scenarios indicate all water resources now available to the Town would be required to serve the potential development. In addition to its wells in the Hunt Aquifer, the Town draws groundwater from two other aquifers--the Annaquatucket and the Pettaquamscutt Aquifers--which are hydrogeologically connected to the Hunt and were part of the Sole Source Aquifer designation. The Annaquatucket has a potential yield of 3 6 mgd and the Pettaquamscutt a potential yield of 1.8 mgd. The two aquifers combined would not provide sufficient yield to deliver the peak demand of 7.38 mgd (July, 1988) required by the Town. Unlike the Hunt, both the Annaquatucket and the Pettaquamscutt Aquifers lie within the Town bounds.

Land Use Setting

Six wells are proposed for the wellhead delineation study. Five of these wells lie within 1000 feet of one another near the intersection of Frenchtown and Post Roads (see identified area in Figure 2); the sixth well lies approximately 3500 feet west of the Frenchtown and Post Road intersection.

Post Road is U.S. Route 1 and has been a primary transportation route since the founding of the colonies. Today this area is densely developed with residential, commercial, and industrial land use. None of the area around the wells is sewered. Yet residential development densities range from two-acre lots to 7000 square foot parcels. Industrial development is not as extensive as the commercial development activities. A large tool and die manufacturer has a private sewer treatment system that discharges to the Hunt River approximately 1200 feet from the location of three of the wells. Commercial development is varied but includes automobile repair and service facilities, several hair salons, and several shopping plazas including one that pre-dates current zoning and septic disposal regulations.

II. Impetus for Wellhead Delineation Study

The Town of North Kingstown took the initiative to use wellhead delineation to protect groundwater. The Town has had a history of groundwater protection beginning in 1974 with the adoption of groundwater reservoir and recharge overlay districts within its zoning ordinance. By late 1987, however, there was evidence to suggest the need to review and refine the mapping upon which the zoning was based and the effectiveness of the existing regulations. Whatever new mapping or regulations might be adopted, it was apparent that in the Hunt Aquifer, unlike the other Town aquifer systems, a regional approach to protection would be needed.

At least three factors led to a decision by the North Kingstown Town Council to authorize undertaking wellhead delineation studies for the four wellfield areas in which the Town's ten public water supply wells lie. First, there existed a heightened consciousness among Town officials and residents about groundwater protection as the Town undertook efforts to halt the expansion of an existing demolition debris landfill located within the drainage basin of the Annaquatucket Aquifer.

Secondly, a growing awareness of the vulnerability of local groundwater reserves, as well as a recognition of limited alternatives, was one product of research conducted by the Towns of East Greenwich and North Kingstown

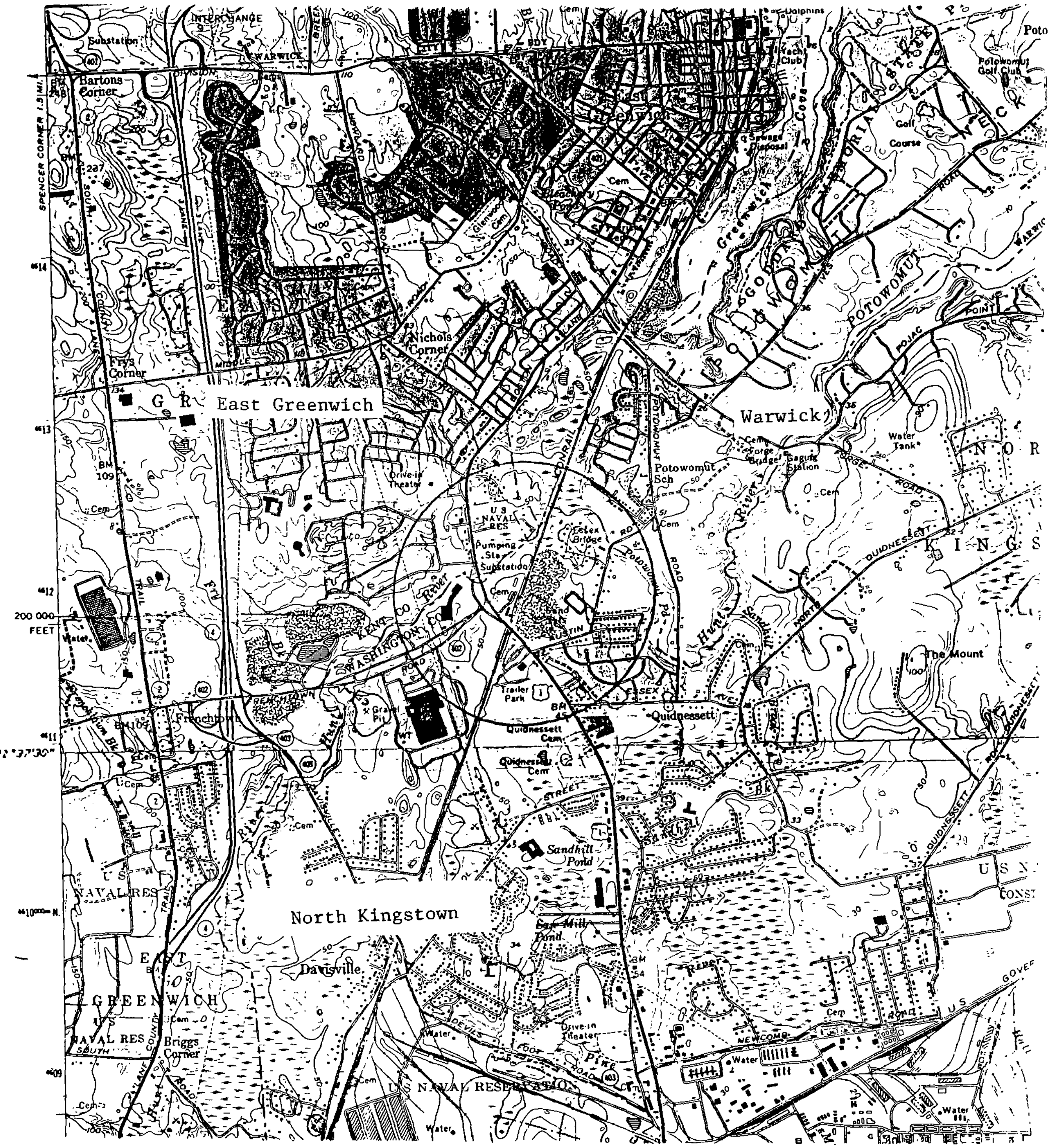

Figure 2: Boundary Line Confluence

in the preparation of a joint petition to the United States Environmental Protection Agency (USEPA) for Sole Source Aquifer status. This petition was prepared in the Fall of 1987. The aquifer system was designated a sole source aquifer in May, 1988 by USEPA.

Additionally, North Kingstown Planning and Public Works Department staff had attended area wellhead delineation conferences where the mandate of the federal legislation and the underlying concepts of wellhead delineation were explained. What was made perfectly clear was the fact that wellhead delineation would be required in the future. But more importantly, it was evident that wellhead delineation was a technique that could be used to refine aquifer mapping and allow for the determination of the zones of contribution to existing and future public water supply wells. In turn, the delineation could provide the basis for decisions in: assigning appropriate land use; identifying parcels for acquisition in pursuit of groundwater protection; and identifying sites of potential contamination and establishing monitoring programs. Town staff conveyed the conference messages to Town officials and the Planning Commission who pressed the Town Council for funds to accomplish wellhead delineation studies.

III. The need for a regional effort

At the request of the North Kingstown Planning Commission, the Town Council approved the creation of a Town Groundwater Committee to undertake necessary wellhead studies to insure Town planning and development activities were in concert with protection of the drinking water. The newly formed Groundwater Committee established a prioritization of the wells and wellfields based on quantity and quality of the supply. With their ability to each deliver 1.5 million gallons per day, the Town's two Hunt Aquifer wells located in East Greenwich and Warwick were given the highest priority. Planning Department to proceed with the necessary steps to accomplish a delineation of these wells. USEPA Office of Groundwater Protection representatives provided the delineation examples that led to the important recognition of interrelationships among proximate wells. For the first time, the Committee understood that what had been anticipated as a projected study of ten wells would actually be one of four wellfields.

IV. Getting underway with regional efforts

In November, 1988, the Town of North Kingstown hosted a meeting to which representatives of the three Hunt water suppliers and the communities that underlie the Hunt Aquifer were invited. Also invited to the meeting were representatives of state agencies whose purview includes the protection of the state's drinking water resources: the

Rhode Island Department of Health; the Rhode Island Water Resources Board; the State Division of Planning; and the Rhode Island Department of Environmental Management. The primary purpose of the meeting was to bring together those parties with vested interest in assuring the continued quality of the Hunt Aquifer. From the Town's perspective it was clear already that a wellhead delineation study must be accomplished. A secondary purpose was to explore the assistance, both financial and technical, that would be available from state agencies for assisting in protection efforts.

State representatives outlined their respective jurisdictions and the few financial assistance programs available but no state office offerred to play key roles in assisting what could and would become a regional effort. The only resolution agreed upon was that the three water suppliers and the three communities should continue to meet. From the discussion it was evident that of far more consequence immediately than studies of future quality was concern about finding ways to address present quality and the levels of VOC's that were evident in the wells. Uppermost was the recognition that it would be difficult to replace the 8 mgd should contamination force their abandonment. Impressive also was the presentation by the Department of Health of the proposed National Primary Drinking Water Regulations both future standards and required water sampling analyses that were to be adopted and mandated.

V. Obstacles to Achieving a Regional Effort

Over the months that followed the water suppliers and the municipalities continued to meet on at least a monthly basis. One difficulty was overcoming the differing contexts from which each participant came. The municipal planning officials tended to view the task in protection terms while the KCWA and RIPA focused on the current quality of the water. Both water supply agencies expressed skepticism about working cooperatively with the same municipalities whose land use decisions were viewed as the reason for declining water quality.

Over the last fifteen years both the KCWA and the RIPA had protested and, even filed suit, over municipal development approvals near their wells. None of the three municipalities was without direct responsibility for the character of the development in the wellfield areas. Zone changes, subdivision approvals, and zoning board of review variances and special exceptions have created an area with little open space, extensive impervious area, and uses incompatible with the long-term protection of the groundwater quality.

Each meeting was a forum for consciousness raising about different aspects of groundwater protection as well as the state of the water quality. Two possible avenues of regional effort were most obvious: a wellhead delineation study for the wells lying together at the East Greenwich-Warwick-North Kingstown boundaries; and a program of regional planning that could use the results of the wellhead study for proper land use decision

Finding a common direction towards wellhead delineation was impossible until a number of issues had been addressed and all parties were convinced of the following assumptions: 1) a wellhead delineation study was in the best interest of each water supplier; 2) identifiying the sources of present contamination now evidenced in the wells would require some level of delineation; 3) such delineation would be required by the Federal and State governments; and 4) a joint initiative would be cost-effective. The latter assumption was the only one readily accepted based on the close proximity of the wells and intuitive in the general principles associated with cost savings.

Discussion of protecting groundwater that shows evidence of contamination first raised questions about whether protection should be considered at all. Should funds be directed at remediation instead? Could the water supply be counted on as a future resource? Was abandonment a likely outcome? Could protection now overcome the effects of decades of poor land use decisions? These questions were raised primarily by the water suppliers who had recognized that the funding of such a study would be their responsibility. Each of these questions needed a response prior to consideration of committing to a wellhead study.

VI. Obstacles to Accomplishing Delineation

Funding

Each participant in the ad hoc committee recognized that undertaking a wellhead delineation study would require significant funding resources. With no available state or regional planning grants, the municipalities viewed the water suppliers as the appropriate funding source as several options for funding would be available to them. First, the water suppliers could request rate increases to cover the costs within a capital budget item. Secondly, a one cent per hundred gallons surcharge was available to water supply systems to use for planning efforts (pers commun. Peter Calise, Rhode Island Water Resources Board).

Expertise

None of the representatives of the water supply systems or the municipalities had experience with conducting a wellhead delineation study. In the winter of 1989 when the committee initiated discussions about wellhead delineation even the State had not yet prepareds the Federally required Wellhead Protection (WHP) Program which would later be submitted to USEPA. The committee was armed only with USEPA manuals describing wellhead techniques.

VII. Accomplishments

The efforts of the ad hoc committee have not been without significant accomplishments. Over the last nine months jointly or independently the water suppliers and the municipalities have undertaken projects that directly support the wellhead delineation and future protection efforts.

Land Use Mapping of Potential Contamination Sources

In preparation for the wellhead delineation study and in an effort to support the study, all three municipalities undertook the mapping of land use within the Hunt Aquifer with potential for contamination. Commercial, industrial, and densely developed residential areas were plotted. Research was conducted during the summer of 1989 by an intern shared by North Kingstown and East Greenwich. The intern investigated RIDEM records regarding underground storage tanks, RCRA sites, and similar locations in order to map contamination sites for future monitoring programs. While the mapping was successfully accomplished for each community, the effort was impeded by the dissimilar scale of town maps. Time and financial constraints also contributed to the inability to map the Hunt Aquifer on one piece of paper.

Water Sampling

In response to the evidence of low levels of VOC contamination, the water suppliers undertook a joint program of water sampling analysis. This effort was also undertaken to supplement and confirm the results of the water sampling that is annually conducted by the Department of Health. The program developed by the water suppliers was designed to present a picture of the Hunt groundwater quality, particularly in the wellfield. The sampling was conducted once a month for five months. Each sampling round included a sample from five wells and each sample was drawn on the same day at proximate times to insure establishing a snapshot of impacts on the wells. The samples were analyzed by the University of Rhode Island's School of Oceanography. The sampling period spanned the Spring and early Summer months specifically to test for differences among seasons.

The sampling effort produced results that showed increasing levels of one VOC at one well site. Armed with the findings of the water sampling program and evidence of increasing contamination in a well with the ability to deliver over 1.0 mgd, a request for a contamination investigation by the State DEM was made. That study is now in progress. Without the supplemental sampling and without the mutual support of the water suppliers, it is likely that such a study would have been accomplished.

Inventory of Hazardous Materials

The North Kingstown and East Greenwich Fire Departments are participating in the regional effort to monitor and protect the groundwater in the wellfield area. To that end, the respective fire departments have earmarked the area around the wells for the first priority in inventorying hazardous substances handled by commercial and industrial uses. Each of the Departments is equipped with computer software that will allow an analysis and comparison of the materials identified at business establishments with the type of contamination evident in the Hunt wells. Because the Potowomut section of Warwick is non-continguous to the rest of the city but instead lies adjacent to East Greenwich, the East Greenwich Fire Department is responsible for the area within the Hunt Aquifer that lies in Warwick and East Greenwich.

VII. Other Issues

Land Use Regulation

Regional cooperation will always be constrained by the effects of dissimilar zoning, subdivision, and other municipal regulations. At present, North Kingstown and East Greenwich are preparing or modifying aquifer protection ordinances; Warwick is awaiting the results of a wellhead study to appropriately designate a protected area.

Staffing and Financial Resources

To date, the Town of North Kingstown has provided the ongoing staffing for the committee for preparation of agenda, etc. The Town has also agreed to provide the necessary staffing for developing and accomplishing the process of Requests for Qualifications and Proposals. Necessary to the long term maintenance of a regional organization will be the requisite staffing and appropriate funding to support that staff. The regional effort would benefit from additional funding resources. Groundwater resources are most likely to cross municipal boundaries and be shared by several water supply systems. From a public policy point of view and based on the experience of the Hunt Aquifer committee, regional efforts should be encouraged and supported with financial, legal, and technical assistance.

VII. Summary

In spite of what may seem like many obstacles, the three water suppliers whose wells lie within the Hunt Aquifer are preparing to undertake a wellhead delineation study. At writing time, an agreement formalizing an association of the three bodies for accomplishing the study was expected within weeks. The funding for the study will be entirely provided by the water suppliers in equal shares. No direct funding of the wellhead study will be provided by the municipalities.

The proposed regional wellhead delineation study is the first such effort to be undertaken in Rhode Island. Technical assistance has been available upon request from the State Department of Environmental Management and the USEPA. The lack of available trained professional staff dedicated entirely to the regional project will hinder the effectiveness of this effort. The coordination required among water suppliers to proceed with the wellhead effort provided lessons for the future.

The effectiveness of the wellhead delineation study will depend largely on the regulations and implementation of same by the three municipalities. There is a vast array of municipal programs and regulations that could be adopted towards groundwater protection. Land use restrictions, impervious surface limitations, stormwater managment, and a coordinated review of projects are just a few examples of programs that could be implemented on a regional basis. To that end, coordination should be sought among the communities for consistency and for maximum protection.

Beyond the regulation level of protection, there are additional programs that could be adopted that would serve the goals of groundwater protection. Land acquisition, monitoring programs, and the sewering of the delineated wellfield provide examples of joint programs that would protect the public's investment in the drinking water supply.

The goal of accomplishing a regional wellhead delineation study is close at hand. The delineation effort has been the tool for fostering regional cooperation and interest in protecting the Hunt Aquifer. Unknown at this time is whether the regional cooperation will continue following the completion of the wellhead delineation study. It would seem that to fail to continue and participate in joint programs would frustrate protection efforts. It would be easy to dismiss regional efforts by assigning the future of the Hunt Aquifer to the municipalities who control the land use. Protection efforts must include the involvement of the water suppliers who have the capacity to provide leadership, program funding, and public policy initiative in furtherance of drinking water supply protection.

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MODEL FOR RURAL COMMUNITIES

TO ASSESS THREATS TO GROUND WATER QUALITY

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ABSTRACT

Rural communities which rely exclusively on private water supplies, and which rely on volunteer town boards with no professional staff, often face more difficulty in identifying threats to their ground water quality than do communities which have access to professional assistance and public funding for protection of their water supplies. The key reason for the frequent inability of rural communities to assess the threats to their ground water is a lack of financial resources to hire professionals to conduct the evaluation. What we learned through a year long effort in the town of Conway, Massachusetts is that it is possible for a volunteer effort to produce an in-depth and valuable ground water risk assessment.

This project was funded through the EPA 205J program and was designed to conduct a ground water risk assessment in a rural setting, using only volunteer effort and little or no funding. Conway was a guinea pig. The town's goal was a ground water risk assessment; the 205J program goal was a model for conducting a ground water risk assessment in a rural setting, with no public water supply, and no hired consultants.

Conway is a rural hilltown community in Western Massachusetts with a population of 1300 people and an area of 40 square miles. It relies entirely on private wells for its drinking supply and has no professional staff supporting town government. Businesses in town are primarily agriculture, a heavy equipment supplier, food processing, and small scale auto repair. It is a community of well educated, environmentally concerned citizens that are worried about the health and safety of their water supply.

Included in the volunteer effort were a town wide survey, door-to-door interviews, mapping, historic records review, geologic examination, public meetings and presentations, and a final report and recommendations. The intent of the survey was to locate all wells, septic systems, underground storage tanks, abandoned wells, and land uses. The one-on-one interviews were critical for gathering information as well as public outreach and participation. Existing documents were used for identifying the geology and hydrology of the community.

After identifying their aquifers and potential threats to ground water quality, final recommendations were developed for future action by the town. These recommendations included a program of water quality testing and amendments to board of health regulations and zoning.

Without staff, money, or expertise, how is a rural community expected to find out what threats may exist to the quality of its ground water? Why even bother to delve into the question in the face of such obstacles? In Franklin County, Massachusetts half of the towns rely exclusively on private wells for their water supply. There are only three towns in the county which have any surface water drinking supplies. Ground water quality is a pressing issue in such a setting, but a lack of funding on the local or state level makes professional studies out of the question, and thus the towns are left to wonder about what risks may exist to their sole source of drinking water.

This is ironic because the threats to ground water quality in a rural setting are usually a less complex and more controllable set of variables than exist in urban settings. The key reason for the frequent inability of rural communities to assess the threats to their ground water is a lack of financial resources to hire professionals to conduct the evaluation. This model is designed to provide a basic framework for a rural community to define threats to their ground water in the absence of professional assistance.

What is a "threat to ground water?" As used here, ground water quality is at risk if a land use presents the capacity to leach contaminants into a ground water supply which is used for drinking water, and that the contaminants are of sufficient quantity and type to present the potential for adverse health impacts. In other words, contamination into ground water which is not used for drinking does not present a threat because there would not be the potential for health consequences. Similarly, just because a land use MAY contaminate ground water does not necessarily mean that there is a threat to public health. The contamination may be in quantities small enough that no adverse health consequences would result. In other words, we are not determining that there is or will be contamination, but rather that under the right circumstances there could be a problem.

Step One -- Community Participation

Without the financial resources to hire a hydrologist, engineer, or other qualified water professional, the town must rely on volunteer community efforts to conduct the risk assessment. This is central to the success of the project. Representation from all town boards is essential, as well as the highway superintendent, the fire chief, and other concerned citizens.

While broad representation will help the process along, the most important members of the risk assessment committee will be volunteers with backgrounds in geology, planning, and engineering. Without some in-house expertise in geology and ground water dynamics, the committees efforts will be significantly more difficult. Often, local colleges and universities can provide students that may assist the community effort in return for academic credit. In this way, the necessary technical support can be supplied without significant financial commitment.

Once the committee is formed, a "leader" needs to be identified. Most likely, it will be a representative from the board which was the catalyst for the ground water risk assessment effort. It is also possible that this leader could be from outside the community. Assistance may be able to be obtained from the Regional Planning Agency, local colleges, or the local Conservation District. Leadership is important to provide direction, coordinate efforts, and do such mundane chores as organize meetings, do mailings, and keep the community informed of the ongoing efforts.

The committee should plan on meeting as a group at least once a month, with substantive work being done between meetings. While this is a volunteer effort, it will not be cost free. The town should appropriate enough money for the committee to do a town-wide survey mailing, mail meeting reminders and press releases, xeroxing, purchasing office supplies, mapping supplies, and copying of their report. Ideally, there will also be funding for water quality testing. A budget of anywhere from $1,000 to $5,000 could be sufficient.

Step Two -- Collecting Existing Data

The town probably already has access to a surprising amount of information concerning the town's geology, hydrology, water supplies, and risks to water supplies. Once the committee is formed their first task will be to start collecting this information. Their base goals will be to:

understand the geology of the town,

gather information on aquifer(s),

identify ground water research already done in the community,

locate and learn about wells in town,

locate underground storage tanks,

locate septic systems,

locate businesses which may present threats to ground water quality,

learn what town regulations and by-laws are already in place, and

identify town and state public works practices.

This information can be gathered from a variety of sources. Below is a list of sources to consult for this information:

USGS Surficial Geology map for your town,

USGS Ground-Water Availability map,

USGS -- ask whether there are any ground water or geology studies pertaining to your community,

Soil Conservation Service (SCS) Soils Maps,

DEP Water Supply Atlas Sheet for the town,

Colleges and Universities -- check geology departments and college libraries for theses addressing geology or ground water in the town, Contact consulting engineering firms in the area and ask whether they have any information on ground water or geology in the community. If they do, they may indicate who the work was done for and, therefore, who has possession of the report,

Other towns -- If the town is in the watershed or aquifer of a neighboring community with a public water supply, that town may have pertinent hydrogeologic information,

Town Hall -- look for Open Space and Recreation Plan (the local Conservation District will also have a copy of this),

Town Hall -- the Board of Health should have records on all private wells constructed in the past ten years. If the records are incomplete, the state Department of Environmental Management (DEM), Water Resources Division, can provide copies of the well logs. Well logs include information on the depth of the well, type of construction, depth of water table, yield of well, and materials passed through during construction,

Town Hall -- the Board of Health should have records on all septic systems. The DEP, Division of Water Pollution Control, may have copies as well,

Town Hall -- the Town Clerk should have permits for all businesses in town,

Fire Department -- The Fire Department should have permits for all underground storage tanks in town,

Town Hall -- Collect copies of all town by-laws, zoning by-laws, and Board of Health regulations,

Local Highway Department -- Interview about road salt application practices and storage,

State Department of Public Works -- If there are state roads in town, the same questions should be asked of the state,

Town Right to Know Coordinator -- May have information on businesses in town which are using hazardous materials. DEP will have this information if it is not available locally,

Town Hazardous Waste Coordinator -- May have information on businesses in town which produce hazardous waste. The DEP, Division of Hazardous Waste, also has listings of registered generators of hazardous waste by community,

DEP -- Water Pollution Control Division may have data on any streams in town concerning water quality,

DEP -- If the town abuts the Connecticut River, there is a study that was done pertaining to pesticides and ground water contamination which may be of use,

Regional Planning Agency -- May have information about the community use, or may be able to indicate where else to look, Old Town Maps -- can be important for historic land use information. Interviewing senior members of the community and reading books on town history can also be important for learning about past land uses which could have left behind potential sources of contamination,

CCAMP -- Is a multi-agency ground water protection project which has produced an excellent handbook on contamination sources for wellhead protection. It includes detailed information on types of threats to ground water; including descriptions of contaminants, their fate in soils and water, and description of land use categories. Their matrix of land uses which present threats to ground water quality is attached as appendix 2, and,

Massachusetts Audubon Society -- Has an excellent series of flyers on ground water protection, including basic information hydrogeology and town strategies for protecting ground water resources.

Step Three -- Filling in the Data Gaps

Despite the reams of valuable information which can be accumulated from the sources listed above, it is unlikely that this process will have provided all of the information needed to know about threats to a particular community's ground water. At this juncture, a town-wide survey is very important. The goal of the survey is to learn as much about specific sites as possible in order to determine what risks to ground water quality which may exist. For example, the survey will try to identify patterns of land use, relative siting of wells, underground storage tanks, and septic systems, proximity to roads to wells, location of abandoned wells, and more. In this way, a detailed picture of the town will begin to develop, as opposed to the generally broader sweep of information provided by gathering existing data. A sample survey is attached in appendix 1.

Conducting the survey will present several problems. In our experience there is tremendous community resistance to providing information about private property to anyone-- especially the town. The fear is that the information will somehow "be used against them." Because of this, it is important that there be adequate publicity about the survey, the reasons for it, and assurances that the information is not intended to be used as a basis for action against any individual. Assurances should also appear on the survey itself.

The survey should be mailed to each address in town. Be sure to include town owned buildings in the survey. Return postage should be provided, as well as a convenient location in town for people to drop off their completed surveys. For example, the library or town hall could have a box out to accept surveys. A name and phone number for questions should be included on the survey. Publicity containing reminders to complete the surveys, their importance, and, again, assurances about their use as part of a study and not as a way of "checking up" on people should be highlighted. A deadline for returning surveys should be included.

After about two months have gone by and less than the whole community has responded, it is time to go door-to-door. This is hard work, but very important. Speaking with individuals serves two important roles: 1) it helps diffuse community suspicion and concern about what you are "up to," and 2) provides a more complete survey response.

On the other hand, door-to-door may not be a feasible approach. One possible strategy would be to focus on certain key areas of town which are the most likely sources of contaminants, and restrict the door-to-door canvasing to that area. Also, if there is a similar pattern of development throughout town, then detailed information town-wide may not be necessary. Or, it may be that there are two distinct geologic settings in town and having a core of good data in each is adequate to determine levels of potential threat to ground water. If you have enough time and volunteer energy to cover the entire community, this is always preferable, but obviously not always realistic.

While the surveys are circulating, committee members should start conducting a windshield survey of the town to locate activities and businesses not previously identified which may present risks to ground water. Interviewing the owners of these facilities is a good idea. It helps to develop support for the risk assessment process, and can provide important information. It also helps prevent people from feeling that they are being singled out for attack. A listing of enterprises which may present risks to ground water quality is attached in appendix 2.

What is going to be done with the town-wide and windshield survey results, and well logs? Plot them on maps. This is not as difficult as it may sound. A good "base map" will be necessary from which to work. USGS topographic maps are excellent for this. If there are areas of dense development in town, the scale of the USGS map will probably be too small. In this case, enlarging the base map to a scale of perhaps 1:200 would help. This provides plenty of room for plotting of detailed information. Using a town road map as the base map can also work quite well. Again, changing the scale may make it more useable. The Regional Planning Agency in your area can help to arrange the production of a base map and, if necessary, can teach a member of the risk assessment committee how to plot the information on the overlays. By using sheets of transparent mylar over the base map layers of information can be developed.

Mapping all the information accumulated through the process described above would be difficult and not necessarily helpful. Key pieces of information to plot on the overlays are:

1) sand and gravel deposits identified on USGS surficial geology map,

2) locations and depths of private wells,

3) locations and identification of land uses which present threats to ground water quality,

4) locations of underground storage tanks,

5) septic system locations,

6) wells within 100 ft. of a septic system, and

7) wells within 20 ft. of a roadway.

These overlays are a critical first step in determining what threats to ground water quality may exist in town. Through the use of the overlays it is possible to begin to see the relationship between activities and wells, and can highlight areas of critical concern in a clear and simple way.

Step Four -- Which Land Uses Constitute A Threat to Ground Water Quality?

Not all threats to ground water quality are of equal significance. Some land uses, while appearing on a list of enterprises which present risks for ground water contamination, present a low risk. This determination is based upon the type of contaminants, how they interact with the environment, how they degrade in soil and water, how fast they move, and how dangerous they are to human health. It is important in the analysis of threats to ground water that the specific characteristics of the community are taken into consideration. Many types of activities will be identified on the attached lists which do not occur in a specific town. Therefore, it is an important step is to identify which land uses with potential risk to ground water do occur in a given community and to determine the level of risk which they present according to the charts given in appendix 1. In addition, identifying any other types of activities that there is reason to be concerned about which have not appeared on the list should be included.

Do not rely on the level of risk identified on the charts. For example, if there is a textile dying enterprise in town it is considered to present a slight risk to ground water. But, in a particular town the business has been illegally dumping its waste for years, or has a failing septic system, or has five shallow wells within thirty (30) feet of the site, or any other possible combination of circumstances that could make this a potentially severe risk for this community. Using common sense and knowledge of a specific setting to make determinations about what constitutes a threat to ground water is the key to a complete ground water risk assessment.

Step Five -- Learning From What Has Been Collected

There should now be enough information gathered to critically assess the potential for ground water contamination in town. It will be important to study the geologic maps, location of sand and gravel deposits, clay layers, and depths of wells to determine general patterns of ground water use in town. It is in this step that the assistance of someone with geologic and hydrogeologic expertise is critical. That person will be able to study the well logs, geologic maps, survey results, and DEP and USGS studies to describe the hydrogeologic setting of the town. Once this is understood the types of land use and risks that they may present can be analyzed by using the attached charts in combination with a detailed understanding of the specific site. For example, some land uses present great risks to shallow wells, but may present little to no risk to bed rock/deep wells. There may also be settings were septic system failures are more likely due to hydrogeologic settings, and this can be analyzed by the expert in geology.

Once the hydrogeologic setting is defined and understood, the land uses can be carefully examined to determine what risks they may present and to whom. For example, the town may store its winter sand and salt pile out of doors. This may present a ground water contamination threat to shallow wells in the vicinity. By knowing that there are shallow wells nearby, rational judgements can be made about water testing programs and appropriate town response to protect against contamination.

Step Six -- Now What

By studying the proximity of various land uses with private wells, the depth of those wells, and the degree of risk presented by the land use, decisions can be made about what to do next. At this point it should be apparent what activities in town may have already contaminated ground water, or which may in the future. If there is reason to believe that ground water may already be contaminated, the community should immediately implement a water quality testing program.

The water quality testing program should be designed to test for the contaminants which are believed to be present. For example, if the study indicated that septic system failure may have occurred in proximity to shallow wells, the tests would be looking for nitrates and coliform contamination. If the threat is presented by road salt, saline concentration would be highlighted. On the other hand, perhaps the threat is seen to be from agriculture. It will be necessary to identify the types of pesticides believed to have been used in order to test for them in the ground water. An annual community water testing program will help monitor long term and changing ground water conditions.

It is a good idea for the town to sponsor and pay for the water quality testing program. First, it helps ensure community cooperation with the testing program. Second, it ensures that copies of the test results come to the town. If the town does not pay for the test, then homeowner permission for copies of the test results to go to the town will have to be obtained. Third, by conducting a community program, the cost can be negotiated down below that charged for individual tests. If contamination is found, be sure to immediately notify DEP, Division of Water Pollution Control. They can often provide technical support for solving or remediating the situation.

Without water quality testing it will not be possible to know if there is an existing problem with ground water quality. If there is a problem, it is important to take remedial action to protect the health of the water users. If there is no contamination, then it is important to take steps to ensure against future contamination. Town regulations and by-laws, as well as public education can be key in safeguarding future water quality. Examples of town regulations and by-laws which can work to protect ground water quality include: aquifer protection zoning, private well regulations, hazardous materials and underground storage tank regulations, required septic tank pumping regulations, unregistered motor vehicle by-laws, and, wetlands protection by-laws. The Regional Planning Agency should be able to provide more information about these strategies. Other town actions can include: covering of salt piles, decreasing use of road salt, land acquisition and protection activities, town supported water quality testing, public education efforts, hiring of professional health agent and planning staff, and, cooperation in regional efforts to protect ground water.

Step Seven -- Finally

It is key that the results of the volunteer risk assessment be well publicized and presented to the community. Public education and support for the effort are essential if behavior is to be changed and town regulations and by-laws passed. Copies of your report should be distributed around town and made generally available. Be sure to send copies to the Regional Planning Agency and Conservation District.

Unless the town takes affirmative steps as a result of the study about threats to ground water quality, it is inviting contamination to occur. Perhaps the most important result of this study will be to educate the town officials about the threats to public safety which exist in town and the actions which they can take to protect the public.

APPENDICES

1. Sample survey.
2. Lists of Land Uses Which Present Risks to Ground Water.

APPENDIX 1.

Sample Survey

APPENDIX 1

SURVEY OF PRIVATE WELLS AND SEPTIC SYSTEMS FOR GROUNDWATER RISK ASSESSMENT STUDY

The Town Boards are conducting a study to determine potential threats to the quality of our drinking water. We need your help. Please provide the information requested below to the best of your ability. THIS INFORMATION WILL NOT BE USED BY ANY GOVERNMENTAL ENTITY AS A BASIS FOR ACTION AGAINST YOU. IT IS SOLELY FOR RESEARCH PURPOSES.

In order to determine what could potentially harm your drinking water, we need to know where your well is, your septic system, and other land use features. In this way we will be able to accurately map threats to ground water supplies, and just how close they are to private drinking supplies.

Please take a few moments to draw a diagram of your property, including: house, well, septic system, abandoned wells, underground storage tanks, railroad tracks, power lines, and other structures. We would also appreciate any information you have about your well: type, depth, water table level, how far it is from the road, septic system, and underground storage tanks. If you have a business on the site, please describe the type of enterprise. If you have any questions, please call ______________, at ____________.

Return postage has been provided. Please complete this form and return no later than _________. Surveys can also be dropped off at the library. Thank you very much for your assistance.

PLEASE DRAW RELATIVE LOCATIONS OF HOUSE, WELL, SEPTIC SYSTEM, UNDERGROUND STORAGE TANK, HIGH POWER LINES, RAILROAD TRACKS, AND OTHER STRUCTURES, AND SHOW DISTANCES BETWEEN (or guess at distances).

YOUR NAME:
STREET: ADDRESS:
PHONE NUMBER:
COMMENTS:

APPENDIX 2.

Lists of Land Uses Which Present Risks to Ground Water.

APPENDIX 2.

Lists of Land Uses Which Present Risks to Ground Water.

GROUNDWATER

RELATIVE LEVELS OF RISK

Taking into Consideration Volume, Likelihood of Release, Toxicity of Contaminants, and Mobility

Compiled and Analyzed by Vermont Department of Health, 1988

SEVERE -

Dry Cleaners
Gas Station
Car Wash with Gas Station
Service Station -- full or minor repairs
Painting and Rust Proofing
Junk Yards
Highway Deicing -- application and storage
Right of Way Maintenance
Dust Inhibitors
Parking Lot Runoff
Commercial Size Fuel Tanks
Underground Storage Tanks
Injection Wells: automobile service station disposal wells; industrial process water and waste disposal wells
Hazardous Waste Disposal
Land Fills
Salt Stock Piles

SEVERE TO MODERATE -

Machine Shops: metal working; electroplating; machining; etc
Chemical and Allied Products
Industrial Lagoons and Pits
Septic Tanks, Cesspools, and Privies
Septic Cleaners
Septage
Household Cleaning Supplies
Commercial Size Septic Systems
Chemical Stock Piles
Clandestine Dumping

MODERATE -

Carpet and Upholstery Cleaners
Printing and Publishing
Photography and X-Ray Labs
Funeral Homes
Pest Control
Oil Distributors
Paving and Roofing
Electrical Component Industry
Fertilizers and Pesticides
Paint Products
Automotive Products
Home Heating Oil Tanks Greenhouses and Nurseries

Golf Courses
Landscaping
Above Ground Fuel Tanks
Agricultural Drainage Wells
Raw Sewage Disposal Wells Abandoned Drinking Wells

<u>MODERATE</u> <u>TO</u> <u>SLIGHT</u> -

Water Softeners
Research Laboratories
Above Ground Manure Tanks
Storm Water and Industrial Drainage Wells
Stump Dumps
Construction

<u>SLIGHT</u> -

Beauty Salons
Car Wash
Taxidermists
Dying/Finishing of Textiles
Paper and Allied Products
Tanneries
Rubber and Misc. Plastic Products
Stone, Class, Clay, and Concrete Products
Soft Drink Bottlers
Animal Feedlots, Stables, and Kennels
Animal Burial
Dairy Waste
Poultry and Egg Processing
Railroad Tracks, Yards, and Maintenance Stations
Electrical Power Generation Plants, and Powerline Corridors
Mining of Domestic Stone
Meat Packing, Rendering, and Poultry Plants
Open Burning and Detonation Sites
Aquifer Recharge Wells
Electric Power and Direct Heat Reinjection Wells
Domestic Wastewater Treatment Plant and Effluent Disposal Wells
Radioactive Waste

LAND USE/PUBLIC-SUPPLY WELL POLLUTION POTENTIAL MATRIX

Land Use Considerations / Potential Contaminants	Acids	Bases	Chloride	Fluoride	Iron/Manganese (Fe/Mn)	Metals (except Fe & Mn)	Nitrate[1]	Pathogens (Virus/Bacteria)	Pesticides/Herbicides	Petroleum Products	Phenols	Radioactivity	Sodium	Solvents	Sulfate	Surfactants (Detergents)	Overall Threat to Public Water Supply[3]
Overall Threat to Public Health	L-M	L-M	L	L	L	H	M	L	H	H	H	H	L	H	L	L	
Mobility	M	L	H	H	M	L H	H	L	L H	M	M	L-H	H	H	H	H	
Natural Background	■		■	■	■	■						■	■		■		
Land Use Categories																	
Agriculture/Golf Courses							■		■								M
Airports						■			■	■				■		■	M-H
Asphalt Plants										■							L-M
Beauty Parlors		■				■								■		■	L[2]
Boat Yards/Builders						■				■	■			■			L
Car Washes			■			■				■			■	■		■	L
Cemeteries									■								L
Chemical Manufacture	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	H
Clandestine Dumping	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		H
Dry Cleaning														■			H
Furniture Stripping and Painting	■	■				■								■			M
Hazardous Materials Storage and Transfer	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	H
Industrial Lagoons and Pits	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	H
Jewelry and Metal Plating	■	■		■	■	■				■			■	■		■	M
Junkyards	■				■	■				■				■	■		L
Landfills	■		■		■	■	■	■	■	■	■	■	■	■	■		H
Laundromats								■						■		■	L-M
Machine Shops/Metal Working	■	■				■				■				■		■	H
Municipal Wastewater/Sewer Lines					■	■	■	■					■	■		■	H
Photography Labs/Printers	■	■				■								■		■	L-M
Railroad Tracks and Yards Maintenance Stations	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	M
Research Labs/Universities/Hospitals	■	■		■	■	■	■	■	■	■	■	■		■		■	L-M
Road and Maintenance Depots			■						■	■			■	■			M
Sand and Gravel Mining/Washing										■				■			L
Septage Lagoons and Sludge			■		■	■	■	■					■	■		■	H
Septic Systems, Cesspools and Water Softeners			■		■	■	■	■	■				■	■		■	H
Stables, Feedlots, Kennels, Piggeries, Manure Pits							■	■					■				M-H
Stormwater Drains/Retention Basins			■			■		■	■	■			■	■			L-M
Stump Dumps					■	■	■				■		■				L
Underground Storage Tanks									■	■				■			H
Vehicular Services						■				■				■		■	H
Wood Preserving						■				■	■			■	■	■	L

■ The contaminant(s) released from this land-use category *may render* groundwater at a public-supply well undrinkable in accordance with federal and state maximum contaminant levels.

☐ This land use category is not generally associated with the release of the particular contaminant in quantities that would render the groundwater at a public-supply well undrinkable. However, the contaminant may be associated with a particular activity.

L = Low Threat M = Medium Threat H = High Threat

This Matrix is based on a literature review and the combined field experience of the Cape Cod Aquifer Management Project (CCAMP). **THIS MATRIX SHOULD BE USED AS A GUIDE AND HANDY REFERENCE.** It is not a substitute for looking at a particular land use in detail. There will always be the potential for a business to use an unusual process using chemicals not normally associated with that business. The land-use categories included in the Matrix and *Guide to Contamination Sources for Wellhead Protection* are those that might be found in the primary recharge area of a public-supply well in Massachusetts. This Matrix may be misleading or erroneous if applied to low-yield private wells.

1. Nitrate has a cumulative impact on groundwater quality. No one category is responsible for the release of nitrate. A variety of land use categories release nitrate. These include animal feedlots, landfills, septic systems, septage lagoons, municipal wastewater and agricultural activities including turf maintenance.

2. There are no known instances of beauty parlors contaminating well water in Massachusetts. More research is needed to determine the severity of a threat to groundwater from this land use category.

3. Refer to *Guide to Contamination Sources for Wellhead Protection*, pp. 1 2

BIOGRAPHICAL SKETCH

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THE FOX(BOROUGH) GUARDING THE AQUIFER COOP: LOCAL CONTROL AT WORK

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Abstract

Both the elected officials and citizens of the Town of Foxborough, Massachusetts have made a serious commitment to groundwater quality protection and management of potential contamination sources. Foxborough's wellhead protection strategy is not a product of a federal or state mandated program, rather, it evolved over a five year period in response to local needs.

Due to the nature of the groundwater resource, it must be identified and protected at the local level. Unlike hazardous waste and leaking underground storage tanks which can be regulated by federal or state legislation regardless of location, occurrence, or quantity, the identification of aquifers and the development of wellhead protection strategies is a site-specific process.

The delineation of a wellhead protection area depends upon the hydrogeologic characteristics of the aquifer, the pumping rate and number of wells, and the amount of recharge the aquifer receives from precipitation and induced infiltration from surface water bodies. In Massachusetts, for example, a wellhead protection area in a buried river valley aquifer will have a different configuration than one in a glacial outwash plain aquifer. Foxborough recognized the importance of local resource-based groundwater protection five years ago when it delineated its wellhead protection areas and adopted a Water Resource Protection District bylaw in 1984.

Recently, over 40 Massachusetts communities have lost major municipal groundwater supplies to contamination or have experienced severe water shortages. The plight of neighboring communities prompted Foxborough officials to engage S E A Consultants Inc. to update the 1984 bylaw and redefine the wellhead protection areas to conform with recently adopted state guidelines for delineating primary (Zone II) and secondary (Zone III) aquifer recharge areas. The goal of the town was to have a technically defensible wellhead protection strategy.

Several carefully tailored approaches were used to delineate the Zone II and Zone III areas for Foxborough's 11 existing wells and 6 proven well sites. Monitoring wells were installed and performance tests conducted at each of the town's pumping stations

using an automated data gathering and processing system. This data logger supplied aquifer property data collected under uniform ambient conditions for use in a detailed town-wide aquifer simulation model which delineated the Zone II and Zone III areas for the 17 wells. Existing pumping test data was re-evaluated using current computer programs and incorporated into the town-wide model where necessary.

A mass balance analytical nitrate loading model was also used to determine the nitrate loading in the Zone II areas under maximum build-out conditions. A new Water Resource Protection District bylaw was written to protect both the Zone II and Zone III areas. The bylaw includes a comprehensive list of prohibited uses and uses allowed by special permit that are subject to stringent performance standards. Minimum lot sizes for various uses were also included to ensure that nitrate concentrations at the wellhead do not exceed drinking water standards. To further strengthen the town's wellhead protection strategy, S E A wrote a new Toxic and Hazardous Materials bylaw, recommended changes to subdivision rules and Board of Health regulations, and designed a groundwater monitoring program.

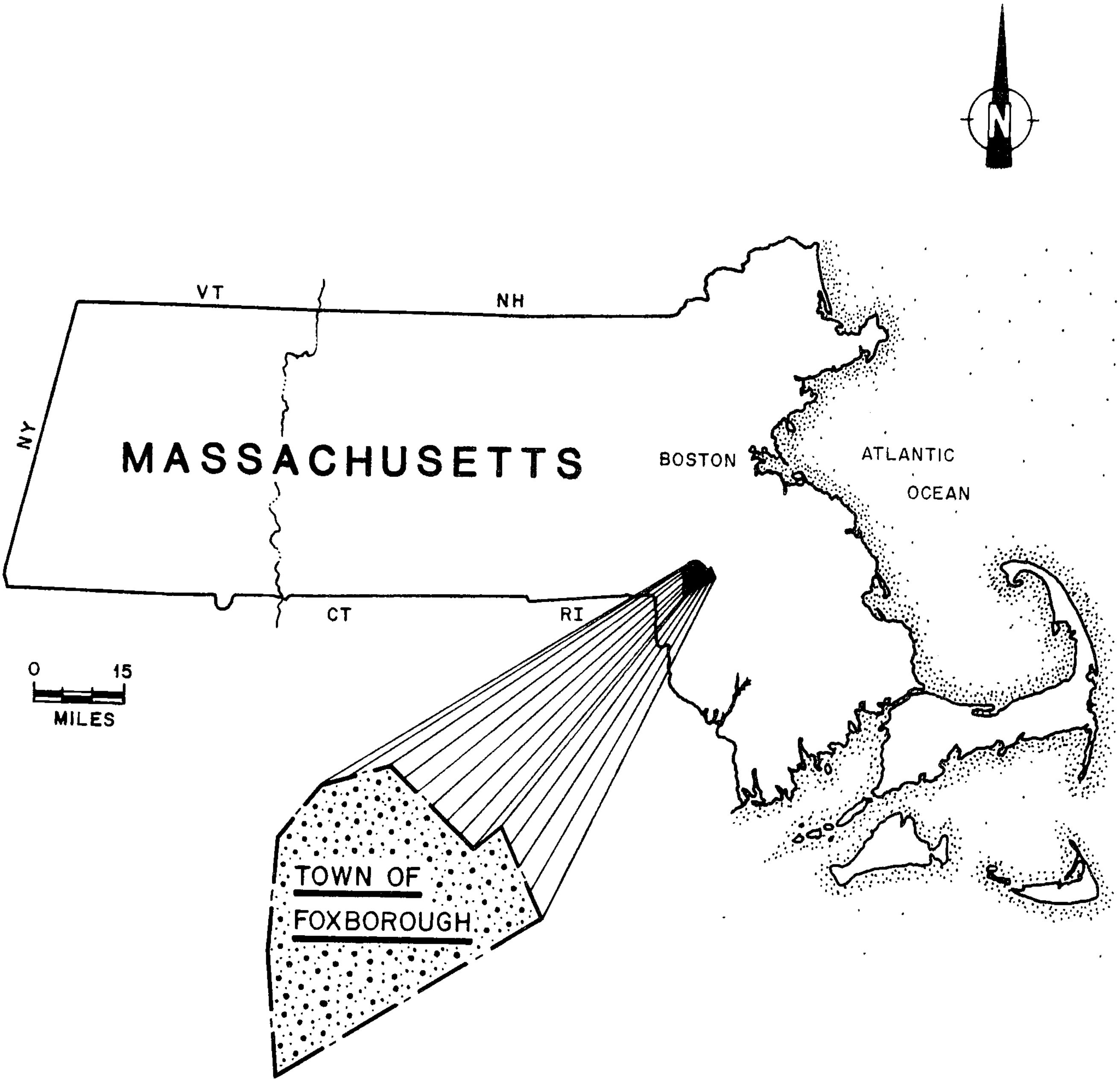
Introduction

Over forty municipalities in Massachusetts have lost all or part of their municipal groundwater supplies to chemical and bacterial contamination due to the siting of inappropriate land uses in the primary recharge areas of their public supply wells. All across the state, increasing development pressures threaten the supply of clean, abundant water; the very resource that enables the economy of a town to flourish.

The primary responsibility for groundwater protection lies not with the federal and state governments but with local boards and citizens. Although the tracking and disposal of hazardous waste and leaking underground storage tanks are managed by federal and state legislation, many other point and nonpoint potential contamination sources are more effectively controlled by municipal regulations.

The federal Wellhead Protection Program, authorized by the Safe Drinking Water Act Amendments of 1986, authorized Congress to distribute grants and technical assistance to states that develop wellhead protection programs. Massachusetts recently submitted a wellhead protection program to meet federal guidelines. Existing programs at the state level offer grants for land acquisition in sensitive recharge areas and technical assistance in delineating wellhead protection areas and drafting protective legislation. The philosophy at both the state and federal level is that wellhead protection strategies should be resource-based and thus are inextricably linked to municipal governments.

Comprehensive local groundwater protection strategies begin with an accurate, scientifically-based delineation of primary and secondary aquifer recharge areas. Historically, the use of land in the vicinity of public supply wells, excluding the 400 foot protective radius required by the state, was not stringently controlled. This occurred for two reasons: (1) the threats to the groundwater resource were not completely understood, and (2) the aquifers and well recharge areas were not accurately delineated. Now, however, several tools are available to communities to enable them to identify, define, and protect existing and potential groundwater supplies, including: sophisticated three-dimensional numerical computer models that simulate groundwater flow; innovative zoning and general bylaws; subdivision regulations; and Board of Health regulations. Conscious land use decisions must be made by citizens and local boards in order to protect groundwater supplies from contamination. An



Town Location Map
Foxborough, Massachusetts

exceptional example of a town that has taken substantial steps toward developing a comprehensive groundwater protection strategy is Foxborough, Massachusetts.

The Town of Foxborough, Massachusetts is located in Norfolk County, approximately 25 miles southwest of Boston. The town comprises approximately 21 square miles and its entire population of over 15,000 people is served by groundwater from 11 wells. The wells are between 30 and 40 feet deep and are screened in the unconsolidated glacial deposits of four buried river valley aquifers. These four aquifers, the Wading River Aquifer, Neponset Reservoir Aquifer, Billings Brook/Rumford River Aquifer, and the Canoe River Aquifer, derive a significant amount of recharge by induced infiltration from nearby surface water bodies. The combined safe yield of the town's 11 wells is approximately four (4) million gallons per day. Foxborough also has six proven well sites that will supplement the current system when needed.

Hydrogeology

Foxborough is located in the Eastern Plateau physiographic province of Massachusetts. In this area, the bedrock forms a flat, well-dissected plateau that gently slopes to the east. According to the U.S. Geological Survey Bedrock Geologic Map of Massachusetts (Zen, et al., 1983), four northeast/southwest trending bedrock units underlie Foxborough. They are, in order of occurrence from north to south, the Sharon Syenite, the Dedham Granite, the Wamsutta Formation, and the Rhode Island Formation.

During the Pleistocene Epoch, New England was glaciated several times. The glacier plucked and scoured the bedrock, entraining sediments that ranged in size from huge boulders (glacial erratics) to cobbles, pebbles, sand, silt, clay and rock flour. As the glacier advanced and retreated, it deposited some of its entrained debris, called till, directly on the ground. Till is a poorly sorted, heterogeneous mixture of sand, silt, clay and angular rocks of various sizes. The glacier smeared till over bedrock knobs and along the walls of bedrock valleys and deposited it in elongated till hills (drumlins). In some cases, till flowed or slumped off the surface of the melting ice. This "flow till" can sometimes be observed within sand and gravel deposits.

Over time, the climate changed and the earth experienced a gradual warming trend that continues to this day. As a result, the glacial ice began to melt. Along the irregular margin of wasting ice, meltwater streams poured from subglacial tunnels or through valleys carved in the ice. In the openings between the wasting ice and till-covered bedrock knobs, these streams sorted and deposited sediments in their channels (glaciofluvial deposits) as well as in ice-marginal lakes and ponds (glaciolacustrine deposits). These unconsolidated deposits are called stratified drift.

Meltwater streams transported, sorted and deposited glacially entrained sediments according to grain size. High velocity meltwater streams deposited cobbles, gravel, sand and minor amounts of silt and clay in major outwash plains and valley trains. The bulk of the fine grained sediments (silt and clay) was held in suspension and eventually deposited by slow flowing streams in glacial lakes. In Foxborough, the glacial meltwater streams filled the ancient north/south trending bedrock valleys with varying thicknesses of interbedded gravel, sand, silt and clay. Thus, the Town's buried river valley aquifers were created.

Aquifer Delineation and Mapping

In order to identify the extent of Foxborough's aquifers, locate sites favorable for future groundwater exploration and designate groundwater protection areas, it was necessary to delineate areas underlain predominantly by coarse-grained stratified drift. Unfortunately, detailed surficial geologic maps were not available for Foxborough. In the absence of such maps, soil survey maps provided much useful information. Although soils maps are a reflection of only the top two to three feet of soil, this top layer is generally indicative of subsurface materials. Soil maps and an Interim Soil Survey Report for Norfolk and Suffolk Counties are available for Foxborough from the U.S. Department of Agriculture, Soil Conservation Service. Certain soils, such as those of the Charlton-Hollis Association, are typical of glacial till. Because till does not readily transmit water, areas underlain by glacial till soils are considered to be non-aquifer areas. Other types of soils are more typical of stratified drift, which are more uniform sands and gravels generally capable of transmitting large quantities of water. Areas underlain by stratified drift-derived soils such as the Hinckley or Merrimac series are considered to be aquifer areas.

Topographic features were also used in mapping glacial deposits. Flat-topped terraces surrounded by steep slopes are typical of stratified drift, for example, whereas uniform slopes are generally characteristic of glacial till. Field verification was an important adjunct to reconnaissance mapping based upon topography and soils. Bedrock outcrops were noted, as were natural exposures of soil and man-made excavations. The "micro-topography" of the land, the number, size, and shape of boulders, drainage, and other factors were also utilized in mapping surficial deposits.

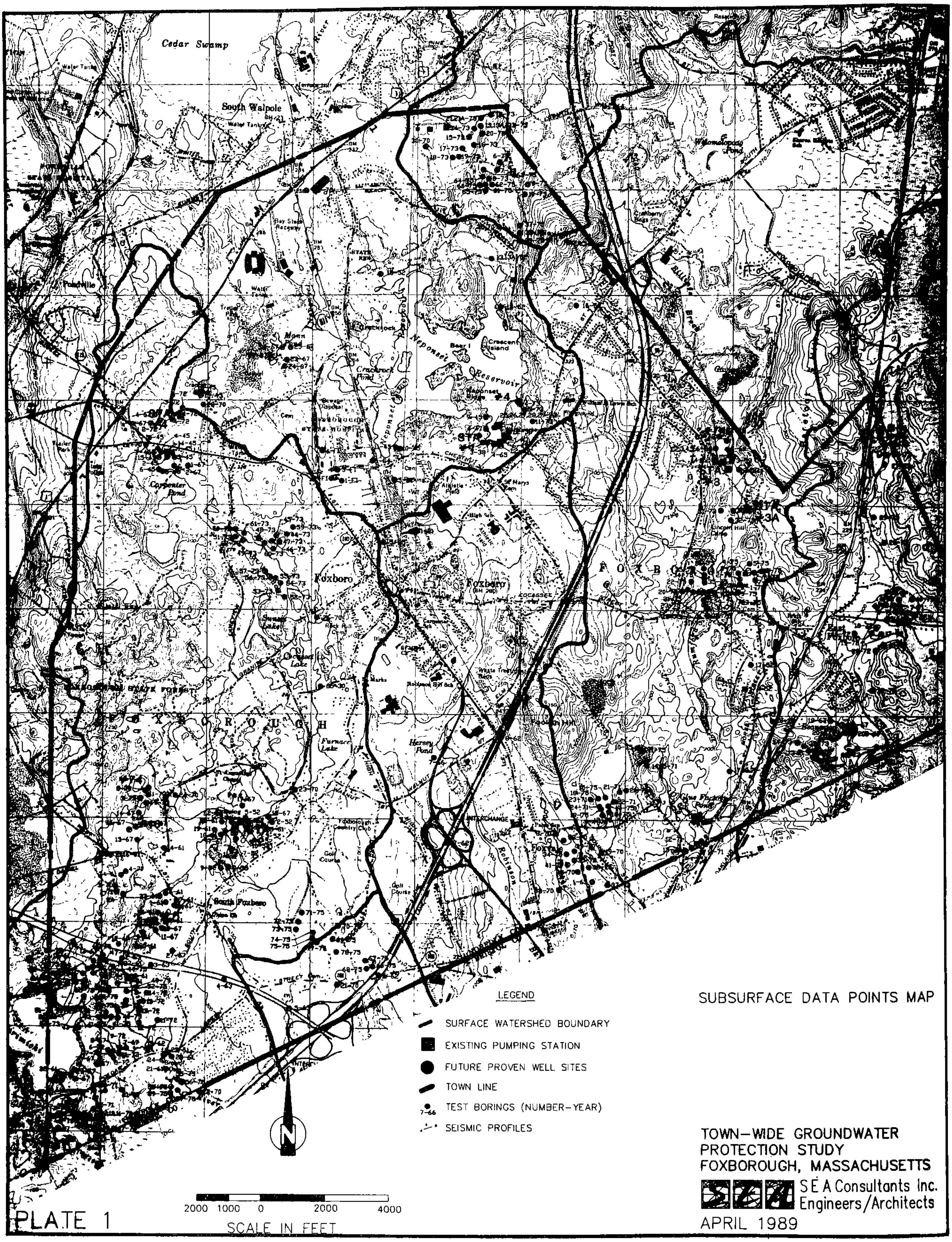
Well and boring data from over 300 locations in Foxborough were also used to delineate the unconsolidated aquifers (see Plate 1). The surficial geologic units shown on Plate 2 are divided into the two distinct types already discussed: glacial till and stratified drift. The limits of the non-aquifer glacial till areas are delineated on Plate 2 by the diagonal hatched areas and are labeled as "Qt". The limits of the remaining aquifer areas, the stratified drift deposits, are labeled as "Qsg".

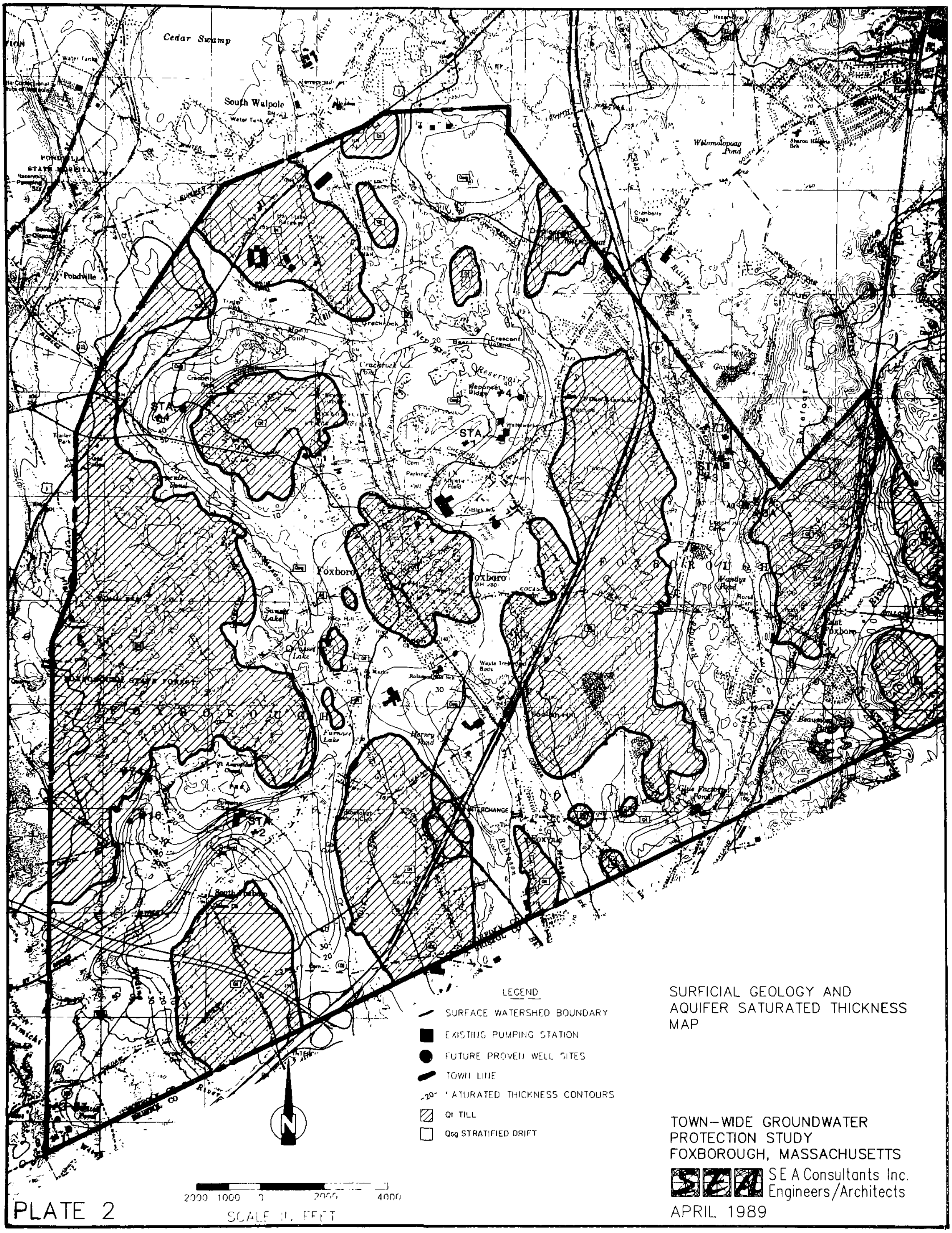
Aquifer Saturated Thickness

Within the stratified drift aquifer areas shown on Plate 2, the characteristics of the aquifer were further evaluated by determining the aquifer saturated thickness. The saturated thickness, or vertical thickness of the aquifer, is a measure of the size of the groundwater reservoir. The aquifer saturated thickness is calculated from boring and well log data by subtracting the top of aquifer (water table surface) from the bottom of aquifer (till or bedrock surface). Areas of highest saturated thickness (over 30 feet) are generally the most favorable for high yield well development.

The Wading River Aquifer is the most extensive aquifer in Foxborough, with a saturated thickness exceeding 50 feet in the vicinity of Lake Mirimichi. The Neponset Reservoir Aquifer appears, based upon existing data, to have a high favorability area limited to a northeast-southwest trending trough extending from the H.C. Morse proposed well site to the Foxboro Company. The vertical extent of the groundwater aquifer at Well Pumping Station No. 4, off of Route 1, is also limited in extent.

The northern portion of the Billings Brook/Rumford River Aquifer in Foxborough has been extensively explored and developed and is considered to be close to its safe yield. S E A recommended no further well development beyond the existing and proven well sites. There is, however, the potential for future well development in the southern


Cedar Swamp
South Walpole
Foxboro
Foxborough
Neponset Reservoir
Furnace Lake
South Foxboro
LEGEND
SURFACE WATERSHED BOUNDARY
EXISTING PUMPING STATION
FUTURE PROVEN WELL SITES
TOWN LINE
TEST BORINGS (NUMBER-YEAR)
SEISMIC PROFILES
SUBSURFACE DATA POINTS MAP
TOWN-WIDE GROUNDWATER
PROTECTION STUDY
FOXBOROUGH, MASSACHUSETTS
SEA Consultants Inc.
Engineers/Architects
APRIL 1989
PLATE 1
2000 1000 0 2000 4000
SCALE IN FEET
N


Cedar Swamp
South Walpole
Pondville
Foxboro
Reservoir
STA
LEGEND
SURFACE WATERSHED BOUNDARY
EXISTING PUMPING STATION
FUTURE PROVEN WELL SITES
TOWN LINE
SATURATED THICKNESS CONTOURS
Qt TILL
Qsg STRATIFIED DRIFT
SURFICIAL GEOLOGY AND
AQUIFER SATURATED THICKNESS
MAP
TOWN-WIDE GROUNDWATER
PROTECTION STUDY
FOXBOROUGH, MASSACHUSETTS
S E A Consultants Inc.
Engineers/Architects
APRIL 1989
PLATE 2
2000 1000 0 2000 4000
SCALE IN FEET

portion of the Rumford River Aquifer south of Route 140 (Cocasset Street) and east of Morse Street. The Canoe River Aquifer is the only known aquifer in Town which is not currently being utilized as a source of water supply. S E A recommended additional exploration in this aquifer east of East Street and southwest of Beaumont Pond to better define the favorability of this aquifer.

Aquifer Transmissivity

In addition to the aquifer saturated thickness map, a map of Aquifer Transmissivity (Plate 3) was prepared. Aquifer transmissivity is a better indicator of potential well yields than saturated thickness alone. Aquifer transmissivity is equal to the saturated thickness of the aquifer multiplied by the hydraulic conductivity (permeability).

Hydraulic conductivity is a quantitative description of the water-transmitting characteristics of the soil materials comprising the aquifer. It is defined as the volume of water at the existing kinematic viscosity (field conditions) which will move in unit time under a unit hydraulic gradient through a unit area normal to the direction of flow. For this study, the pumping test analyses and previous reports describing the aquifer in terms of geology and hydraulic conductivity were reviewed.

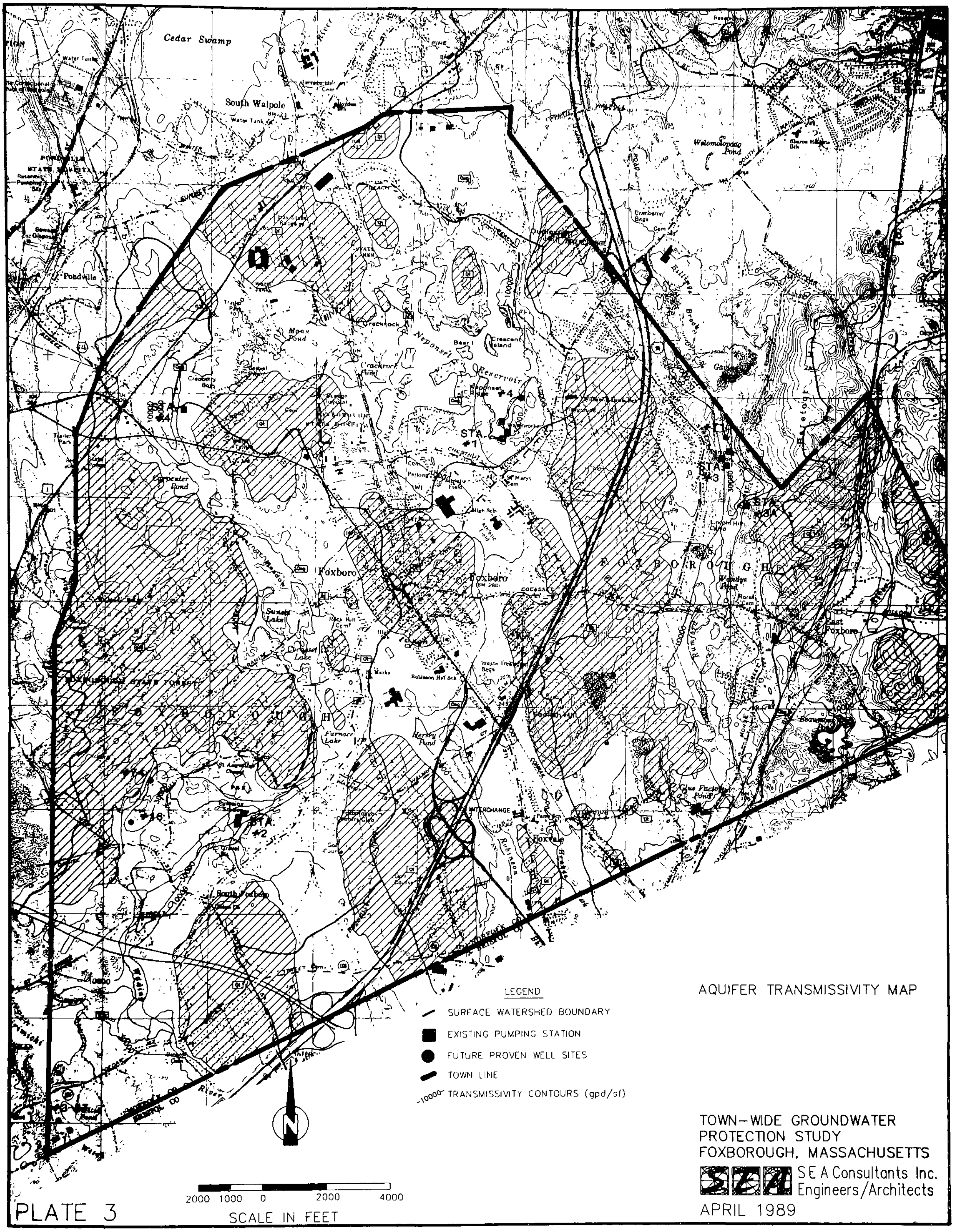
Available pumping tests were evaluated using computer pumping test analysis programs (Hall Groundwater Consultants, Inc., 1986) for time versus drawdown and distance versus drawdown. The transmissivity of individual test well locations was also calculated using the boring log descriptions and assigning average hydraulic conductivities to the various grain size distributions (sand, gravel, silt, clay) which were reported.

Field Exploration Program and Prolonged Pumping Tests

S E A designed a field exploration program and conducted four pumping tests to expand the aquifer property data base and calibrate the zone of contribution groundwater flow model. Based upon the data compilation and review, and the aquifer hydrogeologic maps, specific areas were identified adjacent to the existing pumping stations where additional data was needed to determine aquifer stratigraphy and the following properties: saturated thickness, hydraulic conductivity, transmissivity and storativity. Following site inspections at each pumping station, a field exploration program was designed consisting of observation well installation, water table elevation surveying, and completion of a prolonged pump test.

A total of 13 new observation wells were constructed using the drive-and-wash method. The wells consist of 2.5 inch steel casing with five feet of screen set at either the bottom of aquifer (deep wells) or just below the surface organic sediment deposits (shallow wells). Clustered wells, consisting of a shallow and deep well at the same location, were utilized at Stations No. 1, No. 2 and No. 4 to evaluate the induced infiltration from adjacent surface water bodies and allow for a more accurate calculation of aquifer properties.

Four pumping tests were conducted at each of the four existing pumping station locations (Nos. 1-4) during January 1989. The 13 new observation wells and 10 existing observation wells were used to monitor water table drawdown in the vicinity of each pumping station. Each pumping station was shut down for a minimum of two days prior to commencing the three day pump test to allow the water table to recover to (or close to) its static elevation. The pumping test itself was conducted for approximately


LEGEND
SURFACE WATERSHED BOUNDARY
EXISTING PUMPING STATION
FUTURE PROVEN WELL SITES
TOWN LINE
10000 TRANSMISSIVITY CONTOURS (gpd/sf)
AQUIFER TRANSMISSIVITY MAP
TOWN-WIDE GROUNDWATER
PROTECTION STUDY
FOXBOROUGH, MASSACHUSETTS
S E A Consultants Inc.
Engineers/Architects
APRIL 1989
PLATE 3
2000 1000 0 2000 4000
SCALE IN FEET
Cedar Swamp
South Walpole
Pondville
Foxboro
East Foxboro
South Foxboro
Foxvale
STA. #1
STA. #2
STA. #3
STA. #4
INTERCHANGE

three days followed by two days of recovery readings. The actual duration of well shutdown prior to the test, length of the pump test, and recovery after the test, were performed as the normal operation of the water supply distribution system allowed.

In order to obtain water level measurements simultaneously from four observation wells during the pump tests, an automated computer storage and retrieval system consisting of pressure transducers linked to a data logger was used for both the pumping and recovery phases of the test.

Water level sampling interval times were programmed into the data logger to correspond to the Massachusetts Department of Environmental Protection Water Supply guidelines (DEP, 1989): 10 readings taken at six second intervals, followed by 10 readings taken at one minute intervals, followed by 10 readings taken at ten minute intervals, followed by one reading taken each hour for the duration of the pump test. Recovery sampling intervals were identical to the pump test drawdown intervals.

Zone of Contribution Modeling

A three-dimensional finite difference groundwater flow model was used to delineate the zone of contribution recharge areas for Foxborough's 11 existing wells and 6 proven future well sites. S E A chose the U.S. Geological Survey's MODFLOW computer model (McDonald and Harbaugh, 1984) to simulate groundwater flow in the heterogeneous aquifer system. MODFLOW simulates groundwater flow in both steady state and transient conditions. The program code for the Foxborough model was adapted to run on a Digital Microvax II computer which allowed the simulation of anisotropic, nonhomogeneous aquifers under varying pumping scenarios. In Foxborough, induced infiltration from surface waters provides a significant amount of recharge to the public supply wells. Therefore, the model also simulated the exchange of water between surface waters and groundwater.

The primary objective of the numerical computer model was to provide a sound technical basis for delineating water supply protection zones in accordance with Massachusetts Department of Environmental Protection (DEP) definitions, which are given below:

Zone I: The 400-foot wellhead radius designated by DEP for the protection of the supply which is owned or controlled by the water supplier.

Zone II: The area of an aquifer which contributes water to a well under the most severe recharge and pumping conditions that can be realistically anticipated (180 days with no recharge and continuous pumping at the maximum rated "safe yield" capacities of the pumping stations). It is bounded by the groundwater divides which result from pumping the well(s), and by the contact of the edge of the aquifer with less permeable materials such as till and bedrock. At some locations, streams and lakes may form recharge boundaries.

Zone III: That land area beyond the area of Zone II from which surface water and groundwater drain into Zone II. The surface drainage area as determined by topography is commonly coincident with the groundwater drainage area and will be used to delineate Zone III. In some locations, where surface and groundwater drainage are not coincident, Zone III shall consist of both the surface drainage and the groundwater drainage areas.

Zone I is defined here for the sake of completeness; all land within Zone I is currently owned by the Town of Foxborough. Zone II is the primary zone of interest in this investigation, and the aquifer modeling discussed below was performed specifically to meet the requirements of defining Zone II. Zone III is integrally connected to Zone II via surface runoff and surface water bodies which form recharge boundaries.

Mathematical Model

MODFLOW's aquifer simulation program calculates the hydraulic head in an aquifer under various recharge and pumping conditions. This is achieved by solving the following partial differential equation governing the two-dimensional flow of groundwater in an aquifer:

$$\partial/\partial x(T\partial h/\partial x) + \partial/\partial y(T\partial h/\partial y) = S\ \partial h/\partial t + Q$$

Where:			
	T	=	transmissivity of the aquifer
	h	=	head
	x,y	=	rectangular coordinates
	S	=	storage coefficient of the aquifer
	t	=	time
	Q	=	net groundwater withdrawal/recharge rate per unit surface area

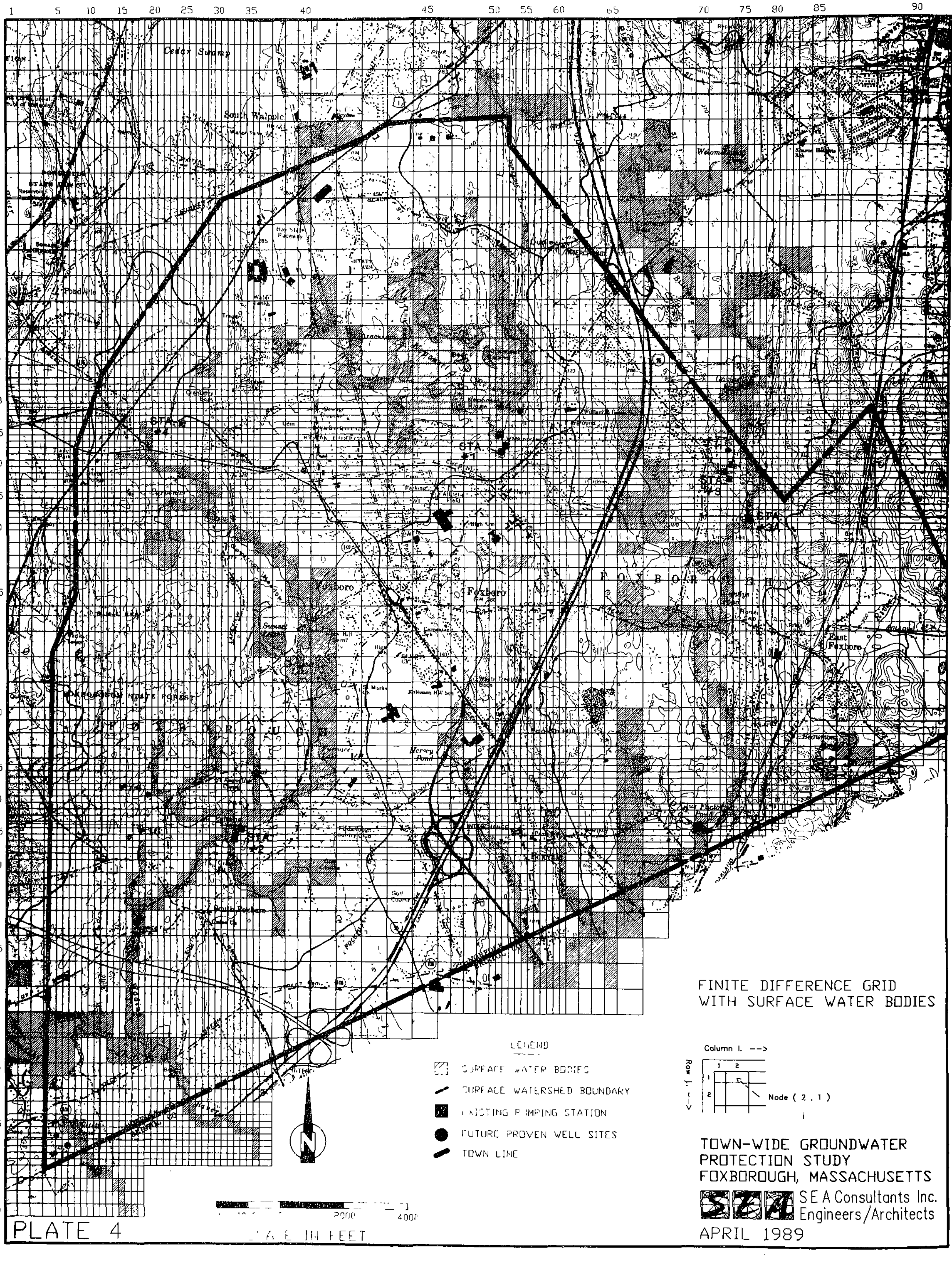
MODFLOW calculates the solution to this equation by solving each node equation of a column of the model while all the terms in the other columns are held constant. Column by column and then row by row, the process continues until a convergence is achieved.

Aquifer Hydraulic Properties

The hydraulic properties of the aquifers, including recharge, hydraulic conductivity, storativity, initial water table elevation, and bottom of aquifer elevation were entered into MODFLOW by superimposing a variable spaced grid system over maps of the aquifer properties and then interpolating values at each grid node. Plate 4 illustrates the finite difference grid which was developed to assemble the model data base. The variably spaced grid consists of a 91 column by 96 row grid superimposed over the entire Town of Foxborough and the upgradient Billings Brook Aquifer in the neighboring Town of Sharon. Grid size ranges in size from 200 by 200 feet to 800 by 800 feet. The smallest grid spacing was used over existing and proven well sites to provide greater resolution and calibration of the model in areas where water table drawdown during pumping is greatest. Output from the model consists of calculated water table elevations at each node.

The estimated average annual recharge to the aquifer within the study area from rainfall and snowmelt, based on U.S. Geological Survey Hydrologic Atlas data and rainfall data, was assumed to be 15 inches per year for stratified drift aquifer areas and 6 inches per year for glacial till (nonaquifer) areas.

Hydraulic conductivity at individual nodes within the stratified drift areas was calculated from pumping tests and boring logs. Each hydraulic conductivity value was plotted onto the base map and interpolated between data points to define the value at each node. A value of 1 foot per day was used for all nodes within the glacial till areas.


FINITE DIFFERENCE GRID
WITH SURFACE WATER BODIES
LEGEND
SURFACE WATER BODIES
SURFACE WATERSHED BOUNDARY
EXISTING PUMPING STATION
FUTURE PROVEN WELL SITES
TOWN LINE
Column I. -->
Row J. -->
Node (2 , 1)
TOWN-WIDE GROUNDWATER
PROTECTION STUDY
FOXBOROUGH, MASSACHUSETTS
S E A Consultants Inc.
Engineers/Architects
APRIL 1989
PLATE 4
2000
4000
Cedar Swamp
South Walpole
Foxboro
Foxboro
East Foxboro
FOXBOROUGH
STA

The initial, non-pumping water table elevation was determined using surveyed water levels from prolonged pumping tests, evaluation of static water levels recorded on boring logs, and interpretation of surface water elevations from the topographic base map. Plate 5 is a map illustrating the simulated steady state, or long-term average, water table elevation.

The aquifer bottom, or bedrock, elevation was calculated by subtracting the saturated thickness value for each node from the water table elevation for each node. The surficial geologic map and field investigations were also incorporated into the bedrock elevation data base.

The storativity (or storage coefficient) of an aquifer is defined as the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of hydraulic head normal to that surface. For unconfined aquifers, like those in Foxborough, the principal source of water is from gravity drainage, the volume of water derived from expansion of the water and compression of the aquifer being negligible. Thus, in the case of unconfined aquifers, the storativity is virtually equal to the specific yield. The specific yield of an aquifer is defined as the ratio of the volume of water which the saturated portion of an aquifer will yield by gravity drainage to the volume which is subject to such drainage.

Storativity values were calculated from available pumping tests by the following formula:

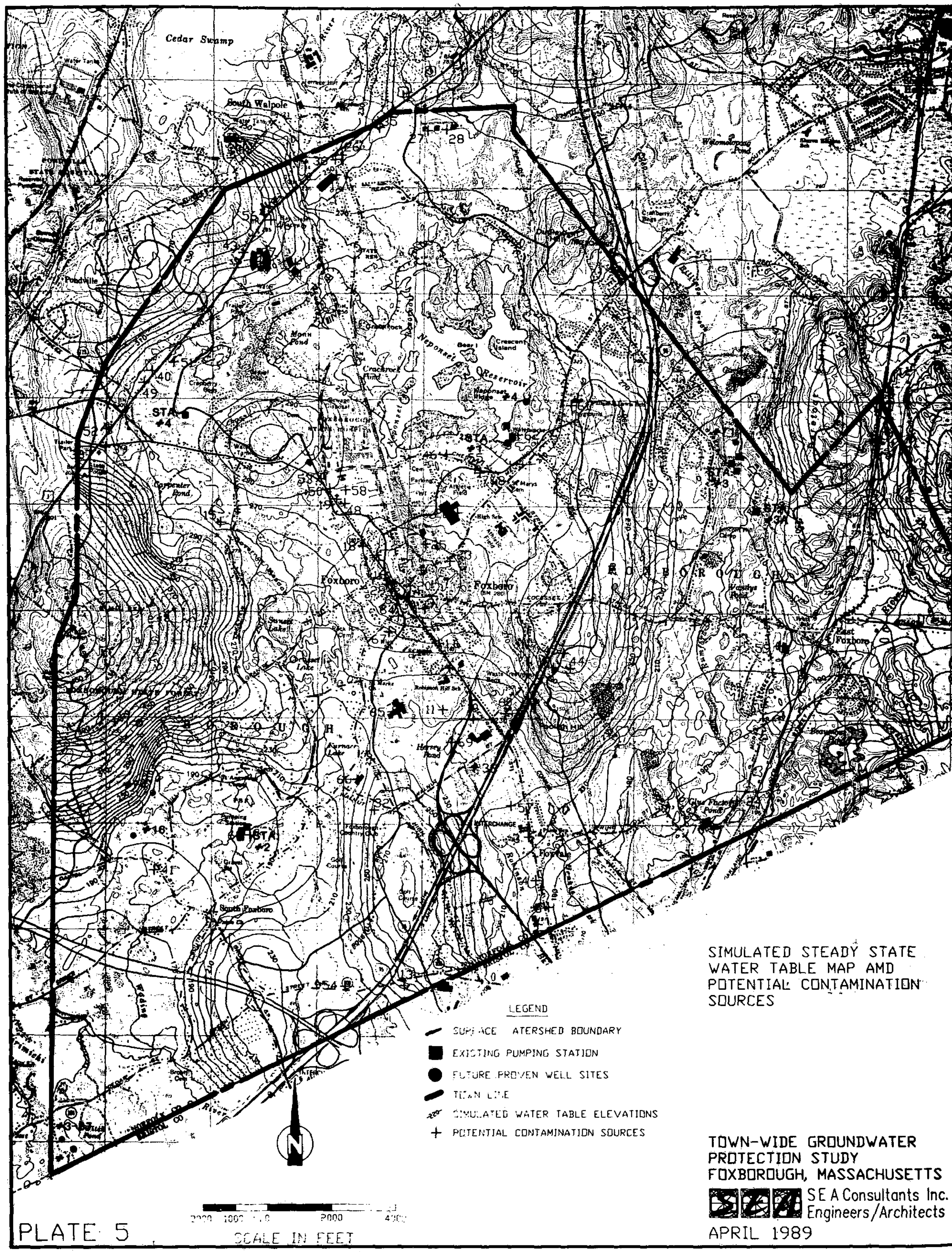
$$S = \frac{0.3\,Tt}{r_o^2}$$

Where
- S = Storativity (dimensionless)
- T = Transmissivity (gpd/ft)
- t = Time since pumping started (days)
- r_o = Intercept at zero drawdown of extended straight line of distance-drawdown graph (feet)

The calculated storativity values range from 0.03 to 0.50 indicating unconfined aquifer conditions and, at the higher end of the range, significant amounts of induced infiltration from surface waters. Storativity values were also calculated by comparing soil logs to values reported in the literature for specific yield. These analyses suggest that a value of 0.20 for Foxborough's sand and gravel aquifers is appropriate. Storativity was considered to be a constant throughout the modeled stratified drift aquifer area.

Boundary Conditions

The numerical simulation model extends beyond the Foxborough town line and includes the entire upgradient watershed area for each aquifer and, most importantly, the Town of Sharon wells which are within the Billings Brook Aquifer. The surface watershed boundaries along the edge of the model were simulated as no-flow boundaries. This was necessary in order to depict the physical system as accurately as possible. The southern limits of the model, south of the Foxborough town line, were simulated as constant head boundaries; the water table elevation was held constant. The direction of groundwater flow along the southern town line is to the south, or out of town.


SIMULATED STEADY STATE
WATER TABLE MAP AMD
POTENTIAL CONTAMINATION
SOURCES
LEGEND
EXISTING PUMPING STATION
FUTURE PROVEN WELL SITES
SIMULATED WATER TABLE ELEVATIONS
POTENTIAL CONTAMINATION SOURCES
TOWN-WIDE GROUNDWATER
PROTECTION STUDY
FOXBOROUGH, MASSACHUSETTS
S E A Consultants Inc.
Engineers/Architects
APRIL 1989
PLATE 5
SCALE IN FEET
Cedar Swamp
South Walpole
Foxboro
East Foxboro
South Foxboro

Thus, the constant head water table elevations along this boundary are lower than elsewhere in town and the model effectively "drains" water out of the aquifer in this area.

The MODFLOW "river package" was used to simulate the significant effect that surface water bodies (streams, rivers, ponds, wetlands and lakes) have on recharging the groundwater aquifer when the wells are being pumped. Plate 4 illustrates the nodes which were designated as induced infiltration, or river nodes. The surface water elevations at each river node were set equal to the input static water table elevation. Bottom sediment hydraulic conductivities were varied from 0.7 ft/day to 2.0 ft/day depending upon the substrate observed along the individual induced infiltration areas during the field investigations.

Model Calibration

The purpose of model calibration is to confirm that the model simulates observed field conditions. The initial step of model calibration involved development of a steady state static water table map. The final calibration procedure involved comparing computer-generated water table elevations and drawdowns with those measured during the field pumping tests.

Contouring of the static water table was initially performed manually and was then supplemented by water levels measured during the four pump tests. The static steady state water table map generated by the computer simulation model as a result of the boundary conditions, starting head distribution, aquifer properties, and recharge values discussed above is presented as Plate 5. Comparison of the two maps provided documented verification of the reliability of the model to accurately represent the behavior of the actual system under the given conditions.

Water table contours illustrating groundwater discharge into the surface drainage system are evident in both the regional contouring and the model runs. The water table contours from the program runs, however, do not have the sharp distinction of the manually prepared map. This dampening of groundwater contours occurs because the surface water is modeled as a node-centered system, and is averaged over the entire grid area. The effect of the rivers cannot be modeled as sharply as actual field conditions would indicate. However, the overall correspondence between the observed field conditions and the model-generated contours is quite good with simulated water levels being within one to two feet of the surveyed water levels and water levels indicated on the topographic base for the various ponds and streams. Comparison of drawdowns observed during the pump tests performed by S E A and simulated by the model for the same duration and pumping rate were also quite good with a residual difference of one foot or less.

Delineation of Water Resource Protection Zones

Following calibration, MODFLOW was used to simulate the worst-case Zone II scenario by pumping all existing and proven future wells at their maximum-rated capacities for 180 days with no recharge to the aquifers. This simulation included the Town of Sharon's existing and proven wells within the Billings Brook Aquifer upgradient of Foxborough's Station No. 3 and No. 3A. The pumping rates used in the Zone II simulation are listed in Table 1.1.

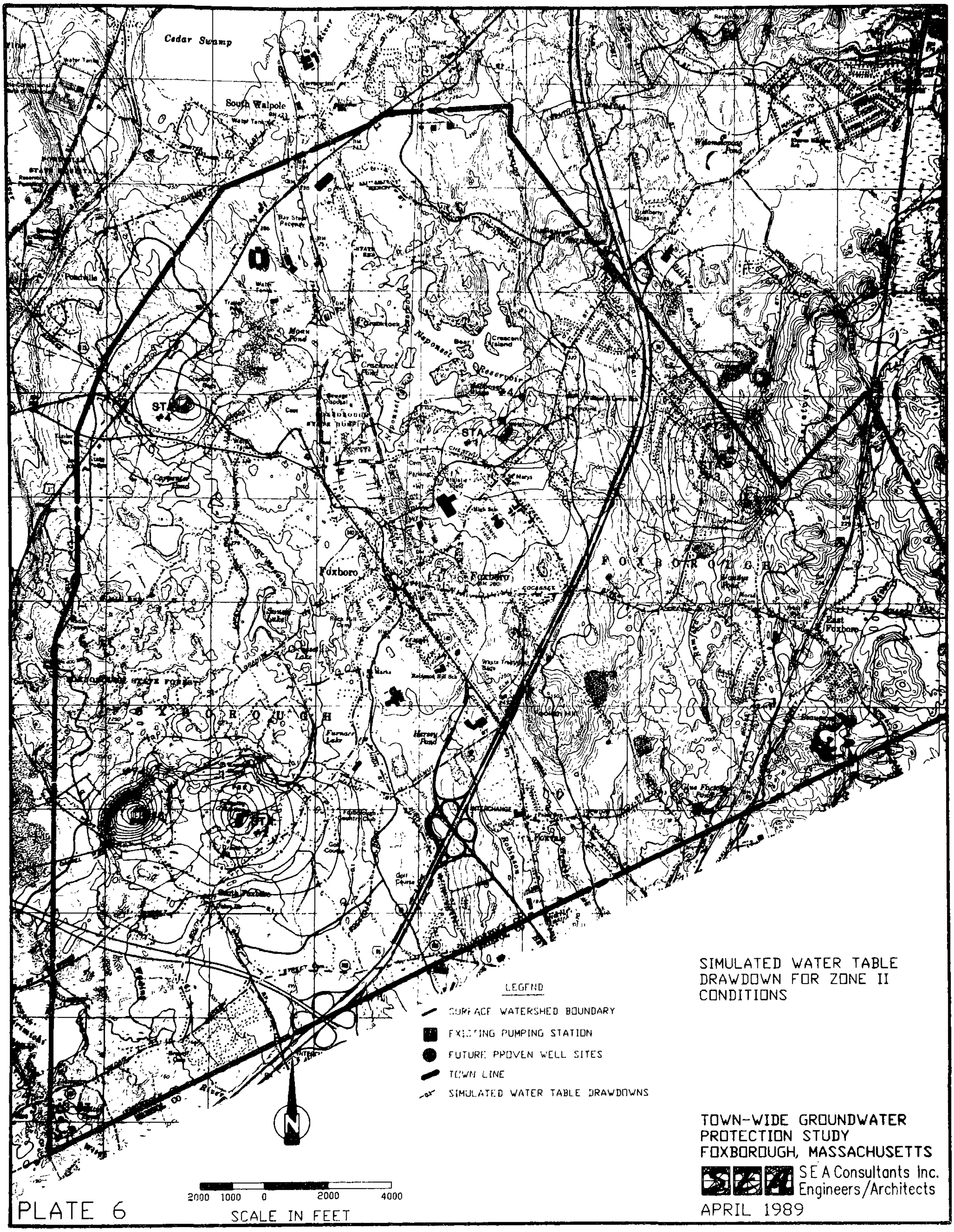
Table 1.1
Well Pumping Rates for Zone II Simulation

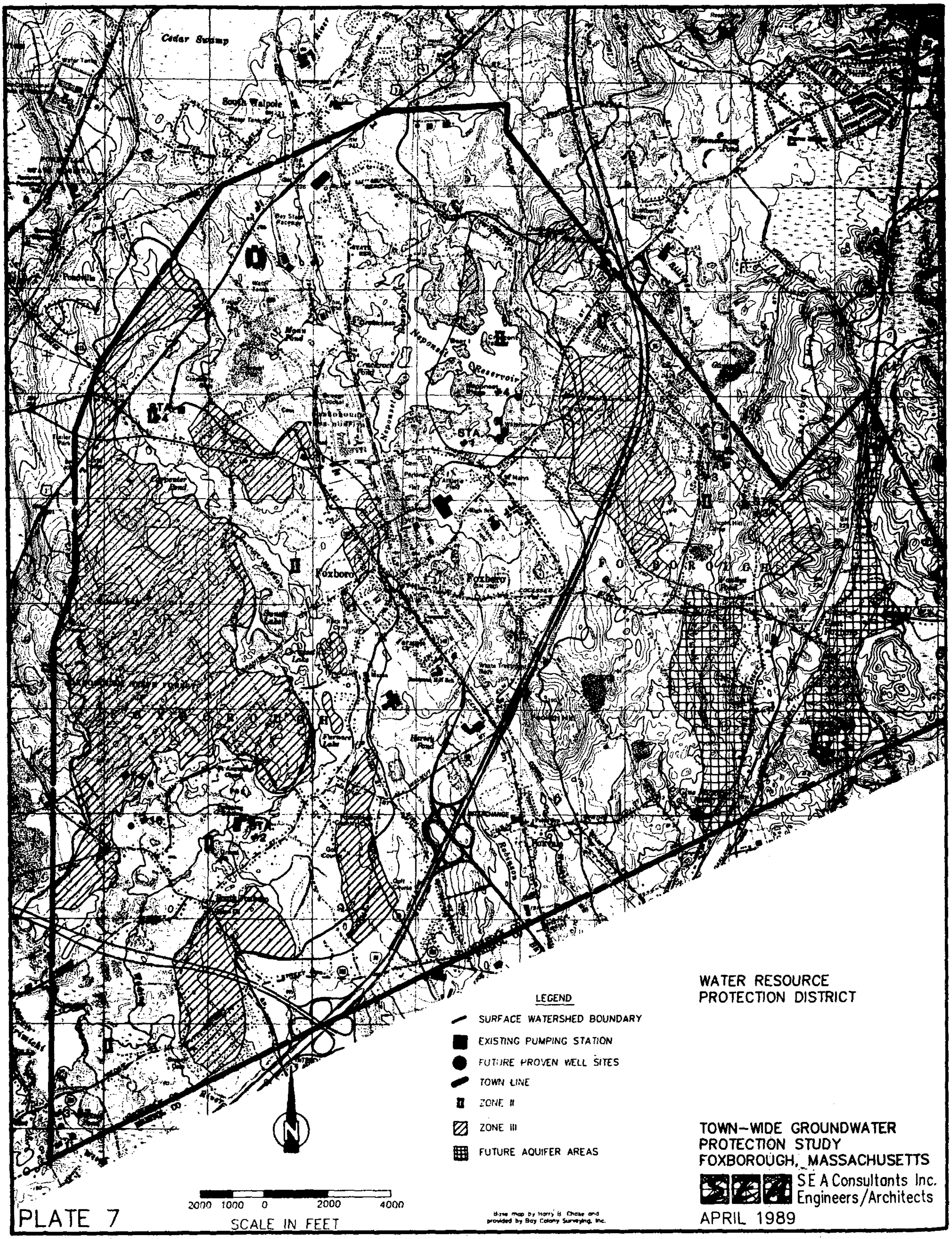
Town	Well No.	Pumping Rate
Foxborough	Sta. #1, Well #1	400
	Well #2A	350
	Sta. #2, Well #4	400
	Well #5	400
	Well #6	400
	Sta. #3, Well #7	250
	Well #8	150
	Well #9	400
	Sta. #3A, Well #10	500
	Sta. #4, Well #12	325
	Lamson Road #71	350
	Mill Street #74	300
	Witch Pond #3-87	500
	Witch Pond #1	700
	H.C. Morse #4	350
	West Street #16	500
Sharon	Sta. #5	300
	Sta. #7	350
	Wolomolopoag Pond	280

Plate 6 is a map of the Simulated Water Table Drawdown for Zone II Conditions and illustrates water table drawdown after 180 days of pumping with no recharge. Water table drawdown was calculated by subtracting the water table elevations simulated after 180 days of pumping with no recharge from a second simulation performed for 180 days with no recharge and no pumping. The difference between the two simulations is the water table drawdown due solely from well pumping.

The groundwater divides resulting from pumping form the downgradient limits of Zone II for both the Witch Pond proposed wells and the Billings Brook/Rumford River wells (Station No. 3 and 3A). The lateral limits of Zone II are the contacts between the stratified drift aquifer deposits and the glacial till (Zone III) deposits. The upgradient limits of Zone II were delineated by extending the simulated water table drawdowns upgradient to the prevailing hydrogeologic boundary, which for the three Zone II areas, is the groundwater divide forming the limit of the sand and gravel aquifer. Following the delineation of Zone II, the Zone III areas were determined by delineating the surface watersheds which contribute recharge into Zone II. Plate 7 is a map of the Water Resource Protection District calculated for Foxborough's aquifers and illustrates the extent of the Zone II and Zone III areas.

Future Potential Aquifer Areas were also delineated on Plate 7 and are included within the Water Resource Protection District. These areas, including the Canoe River Aquifer and the southern portion of the Rumford River Aquifer, were delineated to include the stratified drift aquifer deposits with a saturated thickness greater than 10 feet. These areas may, upon further test well exploration, prove suitable for the development of high-yield water supply wells.


Cedar Swamp
South Walpole
Foxboro
FOXBOROUGH
East Foxboro
Neponset Reservoir
LEGEND
SURFACE WATERSHED BOUNDARY
EXISTING PUMPING STATION
FUTURE PROVEN WELL SITES
TOWN LINE
SIMULATED WATER TABLE DRAWDOWNS
SIMULATED WATER TABLE DRAWDOWN FOR ZONE II CONDITIONS
TOWN-WIDE GROUNDWATER PROTECTION STUDY
FOXBOROUGH, MASSACHUSETTS
S E A Consultants Inc.
Engineers/Architects
APRIL 1989
PLATE 6
2000 1000 0 2000 4000
SCALE IN FEET


Cedar Swamp
South Walpole
Foxboro
Neponset Reservoir
LEGEND
SURFACE WATERSHED BOUNDARY
EXISTING PUMPING STATION
FUTURE PROVEN WELL SITES
TOWN LINE
ZONE II
ZONE III
FUTURE AQUIFER AREAS
2000 1000 0 2000 4000
SCALE IN FEET
Base map by Harry B. Chase and provided by Bay Colony Surveying, Inc.
WATER RESOURCE PROTECTION DISTRICT
TOWN-WIDE GROUNDWATER PROTECTION STUDY
FOXBOROUGH, MASSACHUSETTS
SE A Consultants Inc.
Engineers/Architects
APRIL 1989
PLATE 7

Potential Sources of Contamination

Foxborough is a relatively urbanized town that contains single and multi-family residential developments and typical service-oriented commercial businesses. The Foxboro Company, which has several locations throughout the town, is Foxborough's primary industrial business.

Stratified drift aquifers are highly susceptible to contamination by a wide variety of land uses. Contaminants may enter the groundwater as leachate from historic industrial sites and associated waste disposal areas, illegal dumping sites, accidental spills, or agricultural areas. However, contamination is much more commonly associated with heavily developed commercial or industrial areas, solid waste landfills, industrial and commercial wastewater disposal, septic system effluent, and septage disposal facilities.

Working with town officials, S E A targeted for investigation three categories of potential contamination sources, underground storage tanks and the storage of toxic and hazardous materials, road salt storage and application, and septic system effluent. Best Management Practices (BMPs) designed to mitigate the threat to groundwater quality posed by these potential contamination sources appear in the bylaws, revised regulations, and recommendations prepared by S E A.

Underground Storage Tanks and Toxic and Hazardous Materials Storage

Most commercial and industrial facilities store fuel and/or hazardous materials in underground storage tank systems, above ground tanks or drums. Accidents involving these storage facilities can and will occur. In the absence of an adequate containment structure for drums or above ground tank storage areas, secondary containment for underground storage tanks (including piping), and a spill response contingency plan, spills or leaks from these facilities pose a serious threat to groundwater quality.

Underground storage tank systems (USTs) are also a serious threat to groundwater quality. Many types of commercial and industrial facilities store gasoline, diesel fuel, waste oil, heating oil, solvents and other hazardous materials in USTs. Highway departments, trucking companies, and service stations may have several different tanks of varying capacities for the storage of gasoline, diesel fuel and waste oil. Municipal facilities and public or private institutions such as hospitals, schools, libraries, and households store heating oil in USTs.

In Foxborough, tank capacity for USTs varies from 275 gallons to 50,000 gallons. Each underground tank is a potential threat to local public water supplies. Defects in tank materials, improper installation, corrosion or mechanical failure of the pipes and fittings may result in leaking USTs. Most early underground tanks were inadequately designed and manufactured from bare carbon steel. The corrosion of these bare steel tanks is by far the most common cause of leaking USTs. Although the installation of bare steel tanks is now illegal, many of the bare steel tanks still in use in Foxborough have exceeded their life expectancy (commonly 15 years) and have little or no protection against the corrosive action of the soil and water. Moreover, the exact age, condition and location of many existing tanks may not be known, making it extremely difficult to predict or prevent leaks.

A complete inventory and mapping of the location of each residential, commercial and industrial underground storage tank was beyond the scope of S E A's investigation. However, a preliminary list of 94 commercial and industrial tanks and 17 municipal tanks (with capacities greater than 250 gallons) registered with the Foxborough Board of Selectmen and Fire Department was compiled. Eighteen of the 111 commercial and industrial underground storage tanks are located in Zone II areas or the Future Potential Aquifer areas. The age of only seven of these eighteen tanks is known. At least one of these tanks has exceeded its 15-year life expectancy. It is likely that the remaining 11 tanks are at or near their life expectancy. The remaining 93 tanks are located over till and bedrock in secondary aquifer recharge areas or in sections of town outside the proposed Water Resource Protection District.

Road Salt Storage and Application

Both the storage and excessive application of road salt in sensitive aquifer recharge areas are potential sources of groundwater contamination. Several of Foxborough's existing wells have come close to, or have periodically exceeded, the secondary drinking water standard for sodium which is 20 milligrams per liter (mg/l).

The amount of salt (sodium chloride, NaCl) used to keep streets and highways clear of snow and ice has steadily increased since the mid-1940's. Salt is an abundant, affordable and very effective de-icing agent. Motorists in many states expect "bare pavement" road conditions throughout the year, regardless of seasonal or climatic conditions. As a consequence, state and local highway officials in New England bear the responsibility of providing the highest level of vehicular mobility possible, some to the point of using straight salt instead of a sand and salt mixture.

Sodium chloride is composed of approximately 40 percent sodium ions and 60 percent chloride ions by molecular weight. When salt comes in contact with water, the sodium and chloride ions disassociate and move with the surface water or groundwater. The degree to which road salt will impact aquifers and public water supplies depends upon several factors including: the amount and method of salt applied to roadways, the amount and method of salt storage, soil types, the distance between the source of salt and the water supply, and groundwater movement.

Both the Massachusetts Department of Public Works facility, located on Route 140 and the Foxborough Department of Public Works facility located on Elm Street, maintain large road salt stockpiles in Foxborough. However, because both facilities are located outside the boundaries of the proposed Water Resource Protection District and both facilities store their road salt in enclosed sheds, the risk of groundwater contamination is relatively low.

The Massachusetts Department of Public Works applies a mixture of 4 parts salt and 1 part calcium chloride (4:1) on state highways and Interstate roadways. The Town of Foxborough applies a 3:1 sand to salt mixture to town roads. To mitigate the impact of road salting within the proposed Water Resource Protection District, S E A recommended that the Foxborough Board of Water and Sewer Commissioners work with the town Public Works Department to implement the following Best Management Practices (DEQE, 1981):

- All road crews should be aware of the location of sensitive aquifer areas.

- Reduced application rates should be developed for roads within the Water Resource Protection District.

- o Levels of service should be determined prior to the winter season. Depending upon road type, weather conditions and traffic volumes, these levels of service can range from no salt use, to mainly plowing and using sand, to straight salt application on heavily traveled road sections and critical intersections.

- o Various mixtures of salt, calcium chloride and sand should be used in the Water Resource Protection District. The State of Connecticut recommends that a 7:2 sand-premix mixture should be used in sensitive aquifer areas. Premix is 3 parts sodium chloride and 1 part calcium chloride by weight.

Septic System Effluent and Nitrate Loading Analysis

In Foxborough, septic systems provide for disposal of household sanitary wastes and sanitary wastewater from a variety of commercial and industrial operations. The 20,000 square foot lots in the center of town are served by a sanitary sewer system. Although the town has developed a long range sewering plan, most of the sanitary waste in the community is currently disposed of via septic systems.

The most common contaminant identified in groundwater is dissolved nitrogen in the form of nitrate (Freeze and Cherry, 1979). A nitrate nitrogen loading analysis was performed in order to evaluate the future potential impact, at 100 percent buildout under current zoning, that septic system effluent, fertilizers, and roadway runoff might have on groundwater quality. The goal of the nitrate loading analysis was to determine, for each Zone II area, the maximum nitrate loading which can be allowed to occur while maintaining an acceptable margin of safety below the drinking water standard. As a result of the nitrate loading analysis, the sewage disposal density and minimum lot size requirements in the Water Resource Protection District bylaw were developed.

The current federal and state drinking water standard for nitrate nitrogen in drinking water is 10 mg/l. To allow for an acceptable margin of safety, S E A recommended that a management guideline of 5 mg/l be adopted for the following reasons:

- o to statistically ensure that actual concentrations which are likely to fluctuate due to analytical variability, changes in aquifer recharge, and inherent sampling error, are maintained below 10 mg/l at least 90% of the time (Cape Cod Planning and Economic Development Commission, 1979);

- o to allow for plumes of higher concentration which could result from periods of high nitrate loading and low groundwater recharge; and

- o to allow for localized plumes of higher concentration resulting from a continuous point source in a uniform flow field; and

- o to be consistent with the findings of several studies performed on Long Island.

The Long Island studies statistically evaluated nitrate concentrations measured in numerous groundwater samples and concluded that when the mean concentration was 5.8 mg/l, 10 percent of the samples had concentrations exceeding 10 mg/l. In order to achieve better than 90 percent compliance with the 10 mg/l regulation, an average concentration of less than 6 mg/l would be required, thus the recommended management guideline of 5 mg/l.

Nitrate nitrogen concentrations are typically calculated using a mass-balance approach over a unit area to determine the appropriate housing density (sewage disposal volume and minimum lot size). Nitrate levels are thus evaluated on an individual lot basis. The basic concept of this approach is that the water quality beneath a lot will be the result of mixing nitrates from sewage, fertilizers, and road runoff with the recharge from precipitation and septic system effluent.

The basic procedure for determining the future buildout (saturation density) nitrate concentration was as follows:

1. Calculate total recharge from precipitation and sewage disposal within each Zone II;
2. Calculate total nitrate loading from sewage, fertilizers and road runoff;
3. Calculate nitrate concentration by diluting the total loading with the total recharge.

As described earlier, the average recharge rate within Zone II was determined to be 15 inches per year. For the purposes of this analysis, it was assumed that water pumped from individual wells is recycled back into the same aquifer such that there is no net gain or loss of water to the aquifer.

The buildout analysis conducted for the Town of Foxborough by the Metropolitan Area Planning Council (MAPC) and dated May, 1988 was used as the data base for calculating the total number of buildable lots within each of zone of contribution. The individual assessors' sheets were used to determine which of the lots listed by MAPC were within each respective Zone II.

Nitrate loadings were estimated for individual residential lots using the loading rates specified in the Water Resource Protection District bylaw as follows:

- 4 persons per dwelling unit
- 7 pounds per person per year
- 2 pounds nitrate per 1000 square feet per year from fertilizer (assumed 6,000 square feet of lawn per lot)
- 69.35 pounds nitrogen per lane mile per year

It was estimated that 7 percent of Zone II consists of roadways and other impervious areas. The total number of equivalent lane miles was then calculated. The results of the nitrate loading analysis are presented in Table 1.2.

Table 1.2
Results of Nitrate Loading Analysis

	Wading River Aquifer	Neponset/Rumford River Aquifer
Zone II Area (sq. miles)	3.89	1.85
Total Recharge (liters/year)	3.8×10^9	1.8×10^9
Total Nitrate Loading (mg/yr)	21.4×10^9	12.7×10^9
Nitrate Concentration (mg/l)	5.6	7.0

Because the projected saturation development nitrate concentration (under current zoning) exceeds the recommended management guideline of 5 mg/l, S E A recommended that the minimum residential lot size within the Water Resource Protection District be 60,000 square feet. With this minimum residential lot size, the saturation development nitrate loading will be below the guideline of 5 mg/l.

Groundwater Protection Strategy

Unlike some towns which have their entire water supply at one location, the Town of Foxborough is fortunate to have an existing water supply system consisting of eleven wells which tap four separate aquifer systems throughout town. The Town also has six proven future well sites for which the required 400 foot protective radius has already been acquired. Four of the proven future wells will be located in areas (two at Witch Pond and two at Daniels Street/Mill Street) where the groundwater aquifer is not currently being tapped. This spatial diversity provides an added degree of protection from potential groundwater contamination and loss of a majority of the water supply from a single contamination incident.

Having wells located in several areas throughout town, does, however, have significant implications in terms of groundwater protection. Instead of concentrating on a small area for aquifer protection, local officials must realize that a significant portion of the town is within a water supply well zone of contribution. Foxborough's groundwater protection strategy must be flexible, innovative, and be applicable throughout the town. S E A, working closely with the Foxborough Board of Water and Sewer Commissioners and the Planning Board, developed a groundwater protection strategy that included a new Water Resource Protection District bylaw and Toxic and Hazardous Materials bylaw, revisions to the Planning Board's subdivision rules and additions to the Board of Health regulations. S E A also developed a groundwater monitoring program to provide the town with an early warning system and a tool to better identify sources of contamination.

Water Resource Protection District Bylaw

Zoning has long been used as a means for municipalities to control growth. Massachusetts General Laws (M.G.L.) Ch. 40A and its 1975 amendment, which is known as the Zoning Act, list conservation of natural resources as one of the purposes of zoning. Communities have the authority to enact zoning restrictions to protect groundwater and often do so by regulating the density of development, allowable uses, exemptions, and uses allowed by special permit.

The most common zoning technique used to protect groundwater supplies is an Aquifer Protection or Water Resource Protection District bylaw. These bylaws are "overlay districts," areas superimposed on the existing zoning map. The rules of the underlying district continue to be in effect, except where the overlay district imposes more stringent requirements. These overlay district bylaws are designed to prevent contaminants from entering the groundwater by regulating land uses in the Zone II and Zone III areas of public supply wells. Where induced infiltration supplies a significant source of recharge to a well, surface water bodies are also protected. Generally, the regulation of various types of land use is divided into four categories: prohibited uses, restricted uses, permitted uses, and uses allowed by special permit.

Foxborough adopted a Water Resource Protection District bylaw in 1984, four years prior to hiring S E A. This overlay district bylaw defined three protected areas: Area 1A - the cone of depression generated by a municipal well after 7 days of continuous pumping at its rated capacity or a 600-foot protective radius, whichever is greater; Area 1B - 600-foot protective radius around test wells designated as future municipal wells; and Area 2A the surface of the land lying above the aquifer and designated recharge areas and a 250-foot protective strip around surface water bodies. The aquifer and aquifer recharge areas in Area 2A were delineated based upon data obtained from the U.S. Geological Survey's Hydrologic Atlases and an estimated travel time for certain contaminants.

The bylaw listed permitted uses, prohibited uses, and special permit uses. Overall, the bylaw was fairly comprehensive and included, under the special permit process, requirements for wastewater quality standards and limits on the volume of wastewater discharged to a lot. Minimum residential lot size in Area 2A was 60,000 square feet. Oil and grease traps and sediment traps were required before stormwater can be recharged to the groundwater. Uses allowed in Area 1A and Area 1B were limited to conservation of soil and water, non-intensive agricultural uses, outlook recreation, hunting, fishing, boating, and foot or bicycle paths. All other uses were prohibited. Prohibited uses in Area 2A included the disposal of solid waste, hazardous waste, liquid or leachable wastes, process wastewater, and the storage of petroleum or hazardous wastes.

Although the list of activities regulated under the bylaw was comprehensive, the method used to delineate the wellhead protection areas and aquifer recharge areas did not accurately determine the extent of the town's four buried river valley aquifer systems, nor did it consider the effect of different pumping and recharge scenarios. Consequently, the land area protected under the bylaw was much smaller than the actual area in the town that serves as primary and secondary aquifer recharge areas to the 11 existing wells and 6 proven future well sites. S E A drafted a new Water Resource Protection District bylaw specifically designed to protect the extensive primary (Zone II) and secondary (Zone III) aquifer recharge areas that had been delineated using

MODFLOW. The bylaw regulates Zone II and Zone III areas, Future Potential Aquifer Areas, and Body of Water 250-foot Setback Areas. On May 11, 1989, the new bylaw was passed at the Foxborough Town Meeting.

The new bylaw contains an expanded list of prohibited uses which enables the Town to control the siting of a host of businesses that store hazardous materials or generate hazardous wastes or wastewater. For example, dry cleaning businesses, painting or wood preserving businesses, and printing or photocopying establishments, store many different types of hazardous chemicals on-site and generate contaminated process wastewater. The disposal of this wastewater into on-site septic systems could pose a serious threat to groundwater quality.

Based upon the results of the nitrate loading analysis, the bylaw requires that the minimum lot size for any single or two-family residential lot be 60,000 square feet (sf) with a minimum of 30,000 sf of upland area. For Zone II areas, the design sewage flow for new development cannot exceed 165 gallons per day (gpd) per 10,000 square feet of upland lot area. In Zone III, design sewage flow cannot exceed 165 gpd per 10,000 sf of total lot area. The bylaw also limits the amount of impervious surface area for each type of lot in the Water Resource Protection District.

The Planning Board, as Special Permit Granting Authority (SPGA), has final authority over the special permit provisions of the bylaw. Special permits are required for certain types of new development and the expansion of existing non-residential and multi-family residential development. Provisions for review by other town agencies and for public hearings exist within the bylaw. The bylaw also encourages the use of BMPs for the management of toxic and hazardous materials by specifying the types of materials which must be submitted to the SPGA by the applicant. These materials include:

- a complete list of all chemicals, pesticides, fuels, and other potentially toxic or hazardous materials to be used, generated, stored, or disposed of on the premises;

- a description of proposed measures to protect hazardous materials storage areas from vandalism, corrosion and leakage;

- a description of proposed methods to recharge site runoff which must pass through oil and grease traps before it is discharged to the ground;

- an erosion and sedimentation control plan; and

- projections of nitrogen concentrations and other relevant solutes in the groundwater at the downgradient property boundary using the standards listed in the bylaw. The projections may also be required for down-gradient drinking-water wells.

Toxic and Hazardous Materials Bylaw

Foxborough also has the authority to pass local bylaws it considers necessary for the protection of the health and welfare of its residents. A commonly adopted general bylaw is a Toxic and Hazardous Materials bylaw. The purpose of this regulatory tool is to require certain safeguards for handling and storing toxic and hazardous materials rather than to regulate specific land uses. A general bylaw differs from a zoning bylaw in that pre-existing uses can be regulated by a general bylaw while they are protected (grandfathered) as non-conforming uses under zoning bylaws. In addition, unlike the new Water Resource Protection District adopted by Foxborough, a general bylaw regulates specific practices throughout the town. Many existing small businesses that use toxic and hazardous materials would not be regulated under the Water Resource Protection District bylaw including:

- Dry cleaners
- Motor vehicle service and repair shops
- Photographic processing or printing businesses
- Electroplating/metal working shops
- Furniture stripping/woodworking shops

A Toxic and Hazardous Materials bylaw serves a dual purpose: it protects the town's water resources and ensures the safety of people who work with the chemicals and those who respond to spills, leaks or other emergencies. Many communities in Massachusetts have adopted general bylaws that control materials such as pesticides, petroleum products and toxic or hazardous chemicals.

The residents of Foxborough, recognizing the importance of controlling the storage and use of hazardous materials by small businesses and industries, had adopted a Hazardous Materials bylaw several years before this study was undertaken. S E A recommended that the town strengthen and expand its existing control over toxic and hazardous materials. The new Toxic and Hazardous Materials bylaw proposed by S E A included the following important BMPs:

- the development of spill control and countermeasure plans
- requirements for areas where hazardous materials are pumped or transferred
- guidelines for air emissions of solvents
- expanded requirements for registration of toxic and hazardous materials
- expanded requirements for the above ground and underground storage of toxic and hazardous materials
- registration requirements for existing underground storage tanks
- notification requirements for the application of herbicides or pesticides

The Board of Health is designated to enforce the bylaw and issue permits. To aid in the enforcement of a Toxic and Hazardous Materials bylaw, S E A also recommended that a local hazardous waste coordinator be appointed to periodically update both the list and the map of potential contamination sources prepared by S E A.

Subdivision Rules and Regulations

Under M.G.L. Chapter 41, sections 81A-81J, known as the Subdivision Control Law, Planning Boards are given the power and duty to adopt regulations that govern the design and construction of ways, drainage, and utilities within proposed subdivisions. With the appropriate regulations, the Foxborough Planning Board can be effective in protecting the water resources of the Town.

Toward this end, S E A proposed revisions to the existing regulations that included additional requirements under the subdivision design standards and expanding the Board of Health's role in the review of subdivision plans. The existing regulations gave the Planning Board discretion to require the developer to pay for the services of an independent consultant to evaluate the environmental impact of the proposed development. Under the existing regulations, any report would have to assess the impacts to:

- o surface water quality, level, and runoff;
- o groundwater quality and level;
- o surface and subsurface soils;
- o traffic;
- o town services;
- o physical environment;
- o human environment; and
- o entire town.

Additionally, the report should include a detailed statement of:

- o any adverse effects which cannot be avoided if the plan is implemented;
- o possible measures to mitigate the impact; and
- o alternatives to the proposed plan.

S E A recommended that the report also include an assessment of the impact of the proposed project on the town's water supply, and any proposed water conservation measures.

Foxborough's subdivision rules and regulations contain detailed design standards for streets, curbs, sidewalks, storm drainage, utilities, signs and easements. S E A recommended the addition of the following design standards that focus on groundwater protection.

Design and construction shall reduce, to the extent possible, the following:

- o encroachment within any wetland or floodplain;
- o volume of cut and fill;
- o area over which existing vegetation will be disturbed, especially if within 200 feet of a river, wetland or waterbody or in areas having a slope of more than 15 percent;
- o number of trees removed having a diameter at breast height (dbh) of over 12-inches;
- o extent of waterways altered or relocated; and
- o dimensions of paved areas (including streets) except as necessary to safety and convenience, especially in aquifer recharge areas.

In order to reduce erosion accompanying the installation of ways, utilities, and drainage, and the resultant pollution of streams, wetlands and natural drainage areas, S E A proposed that the Planning Board require the applicant to submit a sediment control plan, including control methods such as berms, dikes, detention ponds, mulching, and temporary sodding. S E A also recommended that the Planning Board limit the use of de-icing chemicals on ways located within the Water Resource Protection District.

The Foxborough Board of Health has a very important role in the subdivision review process (M.G.L. ch. 14, Section 81U). The Board may approve or disapprove definitive plans based upon deficiencies in drainage, sewer lines, on-site sewage disposal or the potential contamination of municipal wells, or any other area within their jurisdiction.

The Planning Board's current subdivision rules and regulations contained no specific review guidelines for the Board of Health. Instead, the Board of Health approves or disapproves definitive plans based upon a determination as to whether any of the land in the proposed subdivision can be used as building sites without injury to the public health. In order to provide for a more thorough review of subdivisions proposed for location within the Water Resource Protection District and supplement the powers of the Planning Board, S E A recommended that the Subdivision Rules and Regulations be strengthened to reflect the Board of Health's broad scope of jurisdiction and authority.

S E A revised the regulations to give the Board of Health specific criteria by which to review Definitive Plans for subdivisions within the Water Resource Protection District.

When reviewing subdivision plans within the Water Resource Protection District, the Board of Health would be required to evaluate the following issues:

- o The geologic characteristics and percolation of each lot,
- o Downgradient surface water impacts due to the migration of sewage-derived contaminants. To assist them with their evaluation, the Board of Health may require the project proponent to submit relevant hydrogeologic information pertaining to the proposed subdivision that includes:
    - a geologic description of the parcel that includes the location and depth of confining layers (silt and clay)
    - approximate aquifer thickness throughout the parcel,
    - groundwater flow directions,
    - determination of downgradient surface water features and wetlands (on and off-site)
    - the projection of nitrogen concentrations downgradient of the subdivision,
    - the impact of nitrogen, phosphorous, and other contaminants on downgradient wetlands, ponds, streams and rivers.

Board of Health Regulations

The Town of Foxborough Board of Health Regulations were updated during 1988. The update focused primarily on increasing setback distances required between septic system components and wetlands, and revising sewage flow estimates. In general, the regulations are very comprehensive. S E A proposed two important additions to the Board of Health regulations to provide a greater degree of groundwater protection. They were:

1. Increase the vertical separation distance between the maximum seasonal high water table and the bottom of leaching trench (pit, galley, etc.) from 4 feet to 5 feet. This will provide a greater degree of filtering and nutrient attenuation and reduce the potential for septic system failure due to excessive water table mounding which would flood the system.

2. Establish a permanent monitor well network (using existing wells outside areas of pumping well influence) and monitor the wells monthly for groundwater level. The groundwater levels should be compared to the statewide monitoring performed by the U.S. Geological Survey and a procedure established for applying correction factors to water level data submitted from septic system deep test holes. The purpose of this established correction factor is to ensure that septic systems are designed using maximum historical water table elevation, and not a single, uncorrected value recorded during a below normal, or dry, springtime.

Groundwater Monitoring Program

Another component of Foxborough's groundwater protection strategy is the groundwater monitoring program developed by S E A. In the past, water quality has been monitored at the wellhead as required by the Massachusetts DEP. Currently, water from the Town's 11 public supply wells is treated for corrosivity. Contaminants of concern from nonpoint sources include sodium from road salt application and nitrates from subsurface sewage disposal. However, the major nonpoint source of contamination is the effluent from the on-site systems which serve various residential, commercial and industrial uses in the Town. Underground storage tanks and hazardous industrial and commercial land uses are significant point source threats to groundwater quality. Contaminants of concern from these point sources include solvents, petroleum products, metals, and compounds with an extremely high or low pH. S E A's recommended groundwater monitoring program will provide the Town with an early warning system as well as a tool to better identify sources of contamination.

The monitoring well locations, upgradient of the wellhead protection areas delineated by S E A as well as around certain surface water bodies, were chosen based on existing land use and development patterns and hydrogeologic conditions. For example, induced infiltration of surface water provides a significant source of recharge to several of the Town's wells, while the types and amounts of toxic and hazardous materials stored on-site and the wastes generated by several identified potential sources of contamination dictated the placement of certain monitoring wells.

The new monitoring wells will be screened at various depths depending upon site-specified parameters. After the implementation of the monitoring program, Foxborough can, with minimal cost, strengthen its early warning system by expanding the proposed monitoring well network to include wells installed by private sector businesses, industries and residential developments. S E A recommended that the Town incorporate into their monitoring well network the monitoring wells required for the installation of new underground storage tanks and the wells required under the new Toxic and Hazardous Materials bylaw. Foxborough's recently adopted Water Resource Protection District bylaw requires special use permits for many land uses within the district. S E A recommended that the town require permanent on-site monitoring wells for every special permit use within the district boundaries. These wells could then be incorporated into the well network.

For the first several years, S E A recommended that water quality samples should be collected from the monitoring wells two times each year in order to establish baseline water quality data and spot any significant trends. After that, samples can be collected on an annual basis. At a minimum, the water should be tested for volatile organic compounds (U.S. EPA Method 524), synthetic organic compounds (U.S. EPA Method

504), sodium, nitrates, pH, and specific conductance. The Town should also test for the parameters for which the DEP has established primary and secondary drinking water standards.

Conclusions

While many other towns have experienced severe water shortages and lost all or part of their municipal water supply to contamination, Foxborough has hired consultants who have identified six proven future well sites, delineated the primary and secondary recharge areas to the 11 existing wells and 6 future well sites, and written new groundwater protection bylaws and regulations. In addition to the work performed by its consultants, Foxborough has conducted household hazardous waste collection days and aggressively acquired conservation land to protect open space and critical aquifer recharge areas.

In Foxborough, it is clear that the local response to wellhead protection has been diligent, creative, and successful. The protection of groundwater resources requires a strong, unified local commitment to developing comprehensive groundwater strategies. The residents of Foxborough know that in order to ensure the future viability of their community, they must manage growth at the local level. Foxborough, through its development of an innovative groundwater protection strategy, will be better equipped to maintain the delicate balance between the ability of the groundwater resource to support growth and its ability to assimilate the resulting wastes.

Acknowledgements

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Biographical Sketch

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Kimberly D. Noake is a hydrogeologist with S E A were she is responsible for projects related to aquifer identification and protection. Prior to joining S E A, Ms. Noake was employed by the CEIP Fund, Inc. as the Principal Investigator for a hydrogeologic and land use study of Silver Lake, the water supply for Brockton, Massachusetts. While employed by the Massachusetts Department of Environmental Quality Engineering, she participated in the Cape Cod Aquifer Management Project (CCAMP) and authored the Guide to Contamination Sources for Wellhead Protection. Town-wide aquifer identification and protection studies and working with local communities to develop and implement comprehensive groundwater protection programs are among Ms. Noake's foremost professional interests. Ms. Noake received her M.A. degree in Environmental Studies from Boston University and B.A. degree in Geology from Smith College.

ABSTRACT

GROUNDWATER PROTECTION EVOLUTION: ACTON'S EXPERIENCE

The Town of Acton, Massachusetts is located 25 miles west of Boston and is totally dependent on groundwater resources to supply a population of approximately 18,000 people. In 1979 the Town lost approximately 50 percent of the developed water supply well capacity to volatile organics contamination.

Over the next decade the various Town Boards and Committees worked with both volunteer resources and professional consultants to study the aquifer systems of the community, existing potential contamination sources, and possible problems from future development under existing zoning. A Groundwater Protection Committee was formed with representatives of each of the Boards in Town with the authority to implement some aspect of a groundwater protection program. This paper will review the sequence of steps, successes and failures, undertaken by the Town to develop and implement a multi-faceted program. The authors are a resident who was formerly the Chairman of the Groundwater Protection Committee during the development and passage of the first set of groundwater protection zones articles (1985) and the current Town Planner who was instrumental in the development of the revised zoning articles adopted in 1989. The first author worked as a consultant to the Town during a recent study to technically define aquifer protection zones prior to the revised zoning. The community's attitude and approach toward groundwater management has evolved over the decade with each new effort building upon the experience of the prior effort.

If you would like a copy of this paper, please contact the author
at (617) 969-0050

Biographical Sketch: Duncan W. Wood

Proposed Speaker: "Groundwater Protection Evolution: Acton's Experience"

Education:	Dartmouth College	- AB: Engineering Sciences
	Thayer School of Engineering	- BE: Environmental Engineering
	Massachusetts Institute of Technology	- MSCE: Water Resources
	Northeastern University	- MBA

Professional Experience:

Mr. Wood has 13 years of consulting experience in the water resources field. Assignments have ranged from flood control planning to permitting for new water supply wells. Mr. Wood has been an active user and developer of computer modelling applications for both groundwater and surface water studies. Mr. Wood is an Associate of the firm of Goldberg-Zoino & Associates and had overall responsibility for the most recent geohydrologic modelling study to establish groundwater protection zones for the Town of Acton.

Community Experience:

Mr. Wood served as a member of the Acton Planning Board from 1982 to 1985. He represented the Planning Board on the Town's Groundwater Protection Committee and served as Chairman of that Committee. He was the presenter of the first set of aquifer protection zoning by-laws adopted by the Town meeting in 1985.

Biographical Sketch: Roland H. Bartl

Co-Author: "Groundwater Protection Evolution: Acton's Experience"

Education:	Universitat Hohenheim, Stuttgart, Federal Republic of Germany.	- Master's Degree, Environmental Sciences & Agriculture.

Professional Experience:

Mr. Bartl has been a professional planner with the Town of Acton since August 1987. He has been instrumental in formulating and coordinating Acton's Groundwater Protection District and Zoning Bylaw, adopted by Town Meeting in April 1989. As planning director, Mr. Bartl is in charge of reviewing all land development plans and he coordinates Acton's comprehensive growth management plan. Prior to his Acton experience, Mr. Bartl researched the effects of land development and agriculture on endangered wetland species. He also spent 5 years as a farm manager and teacher.

EASTON'S EXPERIENCE AND THE CANOE RIVER AQUIFER ADVISORY COMMITTEE

Wayne P. Southworth

Superintendent
Water Division
Town of Easton
Easton, MA

We all take water for granted. We use it and abuse it, never really thinking how it got to the faucet or if and when it will be there in the future.

The citizens of the Town of Easton, like many communities, are very concerned and dedicated towards protecting its groundwater and water supply.

The Easton Conservation Commission has been actively acquiring land for many years, presently having control of 1,364 acres. The State Department of Environmental Management controls the Boderland State Park which comprises 594 acres in Easton. They have also bought 1,089 acres in the Hockomock Swamp for conservation purposes.

The Easton Water Division owns 240 acres surrounding its 5 pumping stations, 26 acres of which were recently purchased with a $500,000 Aquifer Land Aquisition Grant from the State Department of Environmental Protection. There is now over 22% of the property in Easton under state and local government control.

In 1973 a new Zoning Groundwater Protection District Overlay was established which consisted of an 800 foot and a 1,600 foot radius around our existing municipal well sites. Any proposed development within this area had to seek approval from the Board of Appeals. Construction of an on-site sewage disposal system within 800 feet of the well site was prohibited.

In 1986 the Town hired I.E.P. Inc. of Northboro, Massachusetts to do an Aquifer Protection Study, the purpose of which was to develop a comprehensive groundwater protection program for the community, including the delineation of critical aquifer recharge areas and evaluating water quality threats within these areas. Recommendations would then be made to establish an aquifer protection bylaw.

The study was completed in early 1987 and a model bylaw was proposed at the Annual Town Meeting in the Spring. The local Planning Board had a few problems with our proposal, so it was decided to postpone action until we had their full support.

The Water Division worked with them during the year and held several public meetings.

At the Annual Town Meeting in May of 1988 the Planning and Zoning Board proposed the new Aquifer Protection Districts and Bylaw themselves and it passed unanimously.

The new overlay covers over one-third of the town. Residential dwellings are permitted on one acre lots and all other uses must request a special permit from the Zoning Board of Appeals. A few of the prohibited uses are:

1. Sales or storage of fuels
2. Junk yards
3. Packaged sewage treatment plants
4. Car washes
5. Dry cleaning establishments
6. Metal plating establishments

In applying for a special permit the applicant must supply a list of all chemicals, pesticides, fuels and other toxic materials that are to be manufactured, stored or used on the premises. Projections of downgradient concentrations of nitrogen and other relevant chemicals at the property boundaries. Appropriate groundwater models and nitrogen loading calculations must also be provided.

The Water Division sponsored the first Household Hazardous Waste Collection Day in the town in 1984. This effort was to educate the public as to the needs of protecting the community's groundwater through the proper use and disposal of household chemicals. A permanent waste oil collection site was established at the Landfill at that time, Since then we have worked on a regional Collection Day with the city of Brockton. As of September 1989 we will have conducted seven collection days with the most recent including the city of Brockton, the towns of Avon, East Bridgewater, Easton and West Bridgewater. These events have been very successful exemplifying how communities can cooperatie with one another.

The Canoe River Aquifer Advisory Committee (CRAAC)

The Canoe River Aquifer Advisory Committee was formed in February 1987 after years of discussion among the Water Superintendents of Easton, Norton and Mansfield regarding the protection of the aquifer that supplied a good portion of water to each community. The adjoining town of Foxborough joined with us in May of 1987.

State Representative William Vernon worked with the committee to draft and file legislation which was approved by the State Legislature on October 22, 1987. This legislation has been regarded as a model for the state. This act gave us legitimacy specifying that each community shall appoint three members and advise the Boards of Selectmen, Planning Boards and other committees of the member towns relative to development, conservation and zoning within the Canoe River Aquifer.

The committee has authority to review all plans of development of land within the aquifer and report its findings to the appropriate agency.

The committee must inform and educate the public about water conservation and the condition of the Canoe River Aquifer. An annual report shall be prepared and provided to the Board of Selectmen of each member town.

The Legislation was amended to allow the Town of Sharon to join the committee in May of 1988.

The committee meets on the first Thursday of each month in one of the member communities between 1:00 - 3:00 p.m. The fifteen members, for the most part, are all public officials from Selectmen, Planning Board members, Conservation Committee members, Board of Health, Water Commissioners and Water Superintendents.

Members of CRAAC have been very active since its initial formation. On October 1, 1987, the Executive Office of Communities and Development awarded the committee a $40,000 strategic planning grant. I.E.P. Inc. was selected as the consultant to develop a surficial geology map of the aquifer and provide us with a report including a developable lot study, nutrient loading analysis, a town by town analysis comparing the major characteristics of land use regulations for each town, recommendations as to the future actions of the committee and to provide public workshops as to its findings.

In May of 1987, CRAAC joined the Adopt-A-Stream Program supported by the Massachusetts Department of Fisheries, Wildlife and Environmental Law Enforcement and adopted the entire Canoe River. Since then, there have been sections of the river adopted by other groups for specific reasons.

On May 7, 1988, the committee conducted its first annual spring Canoe River Awareness Day at the Mansfield Fish and Game Club. This event was very successful with over fifty in attendance. Presentations by state officials and committee members were followed by a canoe trip. We received tremendous press and cable coverage which helped to alert the public as to the needs of protecting this aquifer.

A winter Awareness Day was held at Wheaton College in Norton on February 12, 1989. Over fifty residents and public officials attended from the five communities.

Some of our accomplishments have been the installation of signs indicating the Canoe River at all road crossings, the education of Highway departments as to proper road salting practices and the elimination of road salt in sensitive areas around the well sites. The Towns of Easton and Norton worked together to close an uninhabited road between the two communities which had become a dumping ground since the closing of area landfills. This area was next to the wells of both communities.

CRAAC held its second annual Canoe River Awareness Day on Saturday, May 6, 1989, again at the Mansfield Fish and Game Club, which included a river clean-up in all five towns, presentations by the D.E.Q.E., State Senators and Representatives, a canoe trip and picnic.

The committee applied for and received a $2,000 grant from the Department of Fisheries, Wildlife and Environmental Law Enforcement to create a composite assessor's map of the aquifer. This map has been completed by I.E.P. and is now being used to develop a list of land owners within the aquifer.

The committee is working with the Natural Resources Trusts of Easton, Norton, and Mansfield to develop a land use conference during the winter of 1990. We will invite land owners within the aquifer who have parcels that are prone to development.

The activities and accomplishments of this committee demonstrate again how communities can work together to help protect our most vital natural resource.

Wayne P. Southworth
Easton Water Division
417 Bay Road
South Easton, MA 02375

Wayne P. Southworth is Superintendent of the Town of Easton Water Division. A twenty year employee of the Town of Easton, he has served as Superintendent since 1980. He has a Massachusetts grade 4 certification as a Drinking Water Supply Facilities Operator.

He has been chairman of the Canoe River Aquifer Advisory Committee since its formation in 1987. He serves on the Governors Hazardous Waste Advisory Committee and is the First Trustee of the Massachusetts Water Works Association.

In 1988 the Massachusetts Municipal Association named him Outstanding Municipal Employee of the Year.

ABSTRACT

WELLHEAD PROTECTION FOR THE CHAFFIN POND WELLS IN NORTH WINDHAM, MAINE

by W. Dana Perkins, Jr.
Director of Quality Control
Portland Water District - Portland, Maine

The Portland Water District delivers water to approximately 46,000 services, providing water to over 160,000 people in the Greater Portland Area. Most of the water comes from Sebago Lake, but the supply is also supplemented by wells in North Windham and Cumberland. The North Windham system consists of 2 gravel packed wells approximately 75 feet deep with a total short term pumping capacity of 1000 gpm.

In 1978 the limits of the aquifer were defined using surface watershed delineation and geologic inference on the nature of the subsurface. Because Windham is a fast growing community, it was desirable to better delineate the aquifer recharge area so as to not unnecessarily restrict development within the outer boundary of the recharge area. Bey doing a computerized ground water model of the aquifer it was possible to separate the recharge area into 3 zones, each with different land use restrictions to accommodate the appropriate level of protection to the well.

A hydrogeologist was hired to construct a three dimensional computer model of the recharge area and to present recommendations for implementation of an aquifer protection ordinance. This report outlines the advantages gained by use of a 3 dimensional computer model over a 2 dimensional model and describes the recommendation and implementation of an aquifer protection ordinance.

Mr. Dana Perkins, Jr., the director of quality control of the Portland Water Dist., Portland, ME., has been with the district since 1981. Prior to this position, he was chief chemist of the South Portland Wastewater Treatment plant. Mr. Perkins has also authored and co-authored several papers related to water and wastewater treatment in the northeastern area.

BRIDGEPORT HYDRAULIC COMPANY
AQUIFER PROTECTION PROGRAM

MARK L. JOHNSON, P.E.

VICE PRESIDENT - ENGINEERING
BRIDGEPORT HYDRAULIC COMPANY
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Abstract

Bridgeport Hydraulic Company (BHC) is the tenth largest investor-owned water utility in the nation serving a population of approximately 360,000 in 17 towns in Fairfield, New Haven and Litchfield counties in Connecticut. BHC has always had an active source protection program for both its watershed and aquifer areas. Certain ground water pollution threats to its wellfields in the mid to late 1980's required BHC to take a more proactive stance in the area of aquifer protection. BHC initiated a three stage aquifer protection program which consists of an aquifer protection plan, aquifer protection workshops, and a public awareness program. BHC's aquifer protection program has already shown great benefits in helping to protect these valuable supplies and developing better relationships with the communities in which these wellfields are located. The program has gained recognition from both federal and state regulatory agencies.

I. Introduction/Background

Bridgeport Hydraulic Company (BHC) is the tenth largest investor-owned water utility in the nation serving a population of approximately 360,000 in 17 towns in Fairfield, New Haven and Litchfield counties in Connecticut. BHC has 15 wellfields located in 11 of these communities. These ground water supplies range in capacity from 0.02 mgd to 16 mgd safe yield capacity. BHC's ground water sources provide a total safe yield of approximately 30 mgd or 30% of the company's total 90 mgd safe yield capacity.

Beginning in 1984, BHC began to experience a series of pollution threats to several of its wellfields. A summary of these contamination events is summarized below:

1. Lakeville Wellfield, Salisbury, CT - During a pump test operation, BHC detected hydrocarbon in the production water of its Lakeville Wellfield. A consultant was immediately retained to assist BHC in determining the source and rectifying the problem. The potential source(s) were located and an intercepter well was installed and the pollution plume was diverted away from the well head. After two years of aquifer monitoring, the wellfield was placed back in service at a reduced pumping rate. BHC has experienced a total cost to date of approximately $200,000 in monitoring well installation and sampling/laboratory costs. The well head remains clean but the contamination threat is still unresolved.

2. Salisbury Wellfield, Salisbury, CT - In 1984 BHC experienced the detection of low levels of tetrachlorethylene (PCE) at its Salisbury wellfield. Again, BHC immediately retained the services of a ground water consultant to identify and hopefully remediate the situation. Monitoring well installation and laboratory analysis indicates the potential source of pollution as a former dry cleaning establishment. The owners of the dry cleaning establishment have long since left the area and the existing owners of the property have virtually no assets. BHC is forced to treat the production water via air stripping. Total costs spent to date on this project are approximately $200,000 and future design and treatment costs are expected to approach $150,000.

3. Oxford Wellfield, Oxford, CT - In late 1987, BHC experienced a solvent pollution contamination in close proximity to its Oxford Wellfield. The solvent pollution was discovered as part of the construction of a small shopping center. The owner of the shopping center has cooperated with the company and the Department of Environmental Protection (DEP) in removing contaminated soils. However, contaminated ground water still exists at a distance of approximately 800′ from one of the well heads. BHC continues to monitor the water quality in the aquifer through its own monitoring wells and wells installed by the owner. Recent heavy rainfall patterns in Connecticut have assisted in mobilizing the ground water contamination and BHC is finding the solvents traveling towards the well head. BHC has spent a total of approximately $50,000 to date on monitoring and sampling/laboratory costs.

4. Hamill Wellfield, Litchfield, CT - BHC has experienced a number of contamination events near this particular wellfield. Sodium contamination has been identified as coming from a local salt storage facility. In addition, a Department of Transportation (DOT) garage facility, although remote, has been linked to an isolated salt contamination problem and hydrocarbon spill. In the first 6 months of

1989, BHC has experienced 4 hydrocarbon spills/threats around the perimeter of the zone of influence of the Hammill Wellfield.

BHC has always had an active source protection program for both its watershed and aquifer areas. However, the events documented above made it clear to management that a more proactive stance in the area of aquifer protection was required. In response to this need BHC initiated a 3 stage aquifer protection program. The first stage included the preparation of BHC's aquifer protection plan. A major task in the plan was to model each of the 15 wellfields using a two dimensional ground water flow computer program. Once the aquifers were modeled and the safe yield of each supply was determined, the zone of influence of each wellfield was plotted on a map of the aquifer area. Within each zone of influence, a survey was undertaken to determine the location of potential sources of groundwater contamination. With the potential sources plotted on the aquifer maps, certain monitoring well locations were developed to provide an early warning program for potential pollutants traveling towards the wells. The plan also suggested aquifer protection ordinances for those wellfield influence areas, emergency response programs for contamination events and a list of the key chemicals to analyze at each monitoring well. The second stage involved presentation of the plan and a review of ground water protection techniques with the towns. Finally, the third stage of the program consists of a general public awareness program on aquifer protection.

II. Aquifer Protection Plan

BHC solicited the services of YWC, Inc. of Monroe, CT to assist in the preparation of BHC's aquifer protection plan. YWC's first task was to model each of BHC's 15 wellfields using a two dimensional radial flow ground water computer program. YWC actually used 2 ground water models--Aquifer and Plasm. BHC supplied YWC with all available well drillers' logs, observation well construction logs, pump test data, drawdown data, production records, and other historical information to assist in preparing the ground water models. YWC then took that information along with information gathered from existing geological survey data from each aquifer area, and field geological interpretation and developed the ground water models with their appropriate cell configurations and boundary conditions. As part of the modeling process, BHC was deeply interested in a more accurate determination of the safe yield of each wellfield and instructed YWC to calculate the safe yield utilizing the ground water flow models. The criteria used for developing the safe yield was 180 days of pumping, with no vertical recharge, keeping the water levels 5' above the screens at all times. Utilizing this conservative methodology for safe yield, the critical zone of influence is that area outside the well head which had a drawdown of 1' under that drought condition.

With the zones of influence of each wellfield determined and plotted on an appropriate scale map, YWC then conducted field and historical pollution inventories of these areas. Of specific interest were former gas stations, dry cleaning establishments, land fills, businesses, hazardous materials storage areas, etc. In addition to actually surveying the entire area, YWC contacted local officials and townspeople with historical knowledge of the area for leads to possible contamination spots not visibly noticed. Upon completion of this inventory of potential contamination spots, BHC and YWC selected strategic locations for early warning monitoring well installations. The installation of the 15 monitoring wells were scheduled for a two year program. Water quality sampling from these monitoring wells will accent BHC's regular water quality sampling program so that any pollution activities in the aquifer will be immediately noticed and early remediation plans could be put into effect. The aquifer protection plan document contains specific water quality parameters for each monitoring well that BHC's laboratory will analyze. In addition, as most wellfields were located near a surface water feature, stream sampling is also included as part of the early warning system.

The aquifer protection plan also includes sections in the document relating to emergency response techniques in the event of an aquifer pollution contamination event, and suggested aquifer protection ordinances for those towns affected. The emergency response portion was developed to assist BHC in the event of a contamination event which requires swift action. Included are emergency phone numbers and response techniques. Emergency response includes not only notification of appropriate state and local officials but also includes a list of suppliers of portable treatment facilities that could be utilized to treat the pollution event. Other remediation activities identified for each wellfield include such things as intercepter wells and alternate sources of supply. BHC also presented two aquifer protection ordinances that were developed for the town of Salisbury and the town of Wilton, CT as suggestions to the other communities for adoption. These ordinances include the restriction of certain activities such as gasoline stations, dry cleaning establishments within the zones of influence of these wellfields and also include hazardous waste storage regulations.

III. Aquifer Protection Workshops

BHC determined in the early stages that communication of its aquifer protection plan at the local level was a necessity. BHC did not want this document to become placid and sit on the shelves of local planning agencies. The plan pertaining to each community was forwarded to its First Selectman and five copies were provided for the various agencies in town. BHC engaged the services of the Housatonic Valley Association (HVA), a non-profit conservation group with experience in ground water protection, to assist in making presentations to the towns' chief elected officials, commission members and interested citizens. Throughout the fall of 1988, BHC visited all 11 communities with the HVA and presented the aquifer protection workshops. The workshops included, (1) a slide show on the basics of ground water protection and pollution, (2) a slide presentation on BHC's contamination experiences, (3) a review of existing federal, state and local regulations pertaining to aquifer protection and potential future legislation, (4) a review of the specifics of BHC's aquifer protection plan for the wellfield in each community, and (5) a review of the regulatory and non-regulatory actions each community could take to help protect not only BHC's supplies but ground water in general.

The response to the workshops was tremendous with BHC being able to get the message out to over 200 chief elected officials and commission members. Although geared towards public officials, most workshops were attended by many interested citizens. Any aquifer protection program must include a workshop at the local level for public officials.

IV. Public Awareness Program

The third stage of BHC's Aquifer Protection Plan program includes a public awareness program. It is essential to include the general public in aquifer protection issues because not all citizens are actively involved with local government. BHC began an active media program in 1988 during the initiation of the local workshop program. As mentioned previously, many interested citizens did attend the workshops. Once the word got out on the workshop program, several local associations asked BHC to provide the workshop to their groups. BHC has conducted the workshop for three towns in which BHC does not have public water supply wells and civic organizations such as the Audubon Society, etc. In addition, BHC has prepared press releases for all activities concerning monitoring well installation, workshop announcements, BHC's coordination during spill events with the DEP and local officials, and general interest topics on aquifer protection. Finally, BHC has prepared an aquifer protection pamphlet which will be available to all BHC customers and will be distributed at aquifer protection workshops and other presentations.

BHC plans future media contact with the general public. Such items will include newspaper advertisements on the hazards of aquifer contamination and video presentations in conjunction with conservation groups on aquifer protection.

V. Conclusions

BHC's aquifer protection program has already shown great benefits not only helping to protect these valuable supplies but in developing better relationships with the communities in which these wellfields are located. The aquifer protection plan has been referred to on numerous occasion by BHC's internal source protection task force in regards to review of building development proposals, highway projects, open space issues, etc. Some examples of the effectiveness of the plan include:

1. Oxford Wellfield - restrictive covenants with a local bank constructing a branch office within the zone of influence. Restrictions in their deed include such things as (1) no use of salt on driveways, (2) no underground storage of any hydrocarbons, (3) treatment of all parking lot runoff, (4) no hazardous chemical storage, and (5) a complete monitoring system surrounding their proposed septic system.

2. Cornwall Springs - BHC commented on a proposed residential pond construction within the zone of influence. The proposed pond construction could affect local ground water hydrology. If it is not properly constructed, it could be a source of contamination during construction. Also, most ponds are chemically treated at some point in their life and could affect ground water quality.

3. Westport Wellfield - The town of Westport immediately adopted aquifer protection ordinances as a result of BHC's aquifer protection plan.

4. All Wellfields - BHC began its own program of reviewing underground storage facilities at its wellfield stations. All underground tanks have now been removed and replaced with either interior tanks or switched to propane.

5. Salisbury Wellfield and Lakefield Wellfield - BHC's engineering department coordinated with the town of Salisbury in preparing a design and specifications for an underground storage vault for underground storage tanks.

These are just a few of the positive affects of BHC's aquifer protection plan. The plan has gained recognition from the Federal Environmental Protection Agency and the State Department of Environmental Protection. Development of a plan and implementation of a program such as the one presented can only benefit other utilities as a tremendous protection and public relations tool.

MARK L. JOHNSON, P.E.

BIOGRAPHICAL SKETCH

EDUCATION

BS Civil Engineering	Worcester Polytechnic Institute 1976
MS Environmental Engineering	University of Maine - 1977 (Phi Kappa Phi Honor Society)
	University of Bridgeport - MBA Program - 21 Credit Hours

EMPLOYMENT

1987 - Present	Bridgeport Hydraulic Company - Vice President of Engineering
1983 - 1987	Bridgeport Hydraulic Company - Director of Engineering
1979 - 1983	Bridgeport Hydraulic Company - Superintendent of System Operations
1978 - 1979	Bridgeport Hydraulic Company - Engineer and Assistant Project Manager - Trap Falls Project

PROFESSIONAL AFFILIATIONS

Geotelec, Inc., Norwalk, CT - Director
American Academy of Environmental Engineers - Diplomate
American Water Works Association - Member
Connecticut Water Works Association - Member
New England Water Works Association - Member
American Society of Civil Engineers - Member

CERTIFICATION

Registered Professional Engineer - Connecticut
Water Treatment Plant Operator - Class IV - Connecticut
Water Distribution Plant Operator - Class III - Connecticut

PAPERS

"Bridgeport Hydraulic Company's Aquifer Protection Program" - Wellhead/Aquifer Protection Conference (CWWA/YWC/IWR) - October, 1988.

"Utility Interconnection - The Southwest Regional Pipeline Experience" - Connecticut Water Works Association - May, 1986.

"Designing and Constructing the Trap Falls Water Treatment Plant" - American Water Works Journal - March, 1983.

"The Use of Lamellae Settlers" - New York Water Works Association - 1983.

"The Transition Problem in Pumped Wells" - American Geophysical Union - 1978.

ABSTRACT

"AQUIFER PROTECTION THROUGH LARGE SCALE COMPUTER MODELLING"

by David F. Edson, P.E.
Senior Project Manager
Dufresne-Henry, Inc., Westford, MA

The Barnes Aquifer, one of the largest in central and western Massachusetts, extends over the eastern portion of the City of Westfield, Massachusetts. The City has developed six wells in this aquifer, each producing between 1,400 and 1,600 gpm, representing 90 percent of its total water supply capability.

In 1985, the City enacted a set of aquifer protection bylaws and developed a wellhead protection district map based upon surficial geology and topography. In 1989, a more detailed and thorough delineation of wellhead protection areas was completed by use of large scale hydrogeologic computer modelling.

Wellhead protection areas were detailed using MODFLOW, a three-dimensional finite difference groundwater flow model developed by the U.S. Geologic Survey. The area modelled was 14,000 feet by 32,000 feet, represented by a 33 by 70 division grid system yielding 2,310 data nodes. Node spacing varied between 400 and 900 feet. Aquifer characteristics and hydrogeologic features incorporated into the model included:

- aquifer permeability, saturated thickness and storativity
- initial head distribution, i.e., static water table condition
- induced infiltration from surface water bodies
- till barrier boundaries
- pumping well withdrawal and interferences

Aquifer characteristics and hydrogeologic features were primarily obtained from:

1. Analyses of City well testing records such as well logs and pumping test results, and

2. A USGS water resource investigation of the area which at the time was completed but not published.

Wellhead protection districts were developed based on criteria contained in Massachusetts state guidelines for "Zone II" which includes 180 days of continuous well pumping with no recharge from precipitation. Described are methods of data analyses, our modelling approach, sensitivity analyses and results. The advantages and disadvantages of the large scale modelling approach to aquifer protection are discussed along with suggested guidelines for its use in other communities.

Professional Profile

DAVID F. EDSON, P.E.

SENIOR PROJECT MANAGER

<u>Specialized Professional Competence</u>

Ground Water Evaluation
Water Facility Design
Utility Management

<u>Representative Assignments</u>

Project Engineer or Manager:

Ground water exploration and supply development. Zone of contribution delineation and aquifer protection and management.

Ground water quality evaluations, contamination investigations, discharge permitting, and remediation projects.

Water facility evaluation and design of: wells, pumping systems, distribution and storage.

Water quality assessments and design of water treatment facilities.

Capital planning and economic feasibility studies.

<u>Professional Background</u>

Registered Professional Engineer in Massachusetts, Maine, and Connecticut.

Graduate engineering courses, Nottheastern University
M.B.A., State University of New York at Buffalo
B.S. in Civil Engineering, State University of New York at Buffalo

Entered Profession in 1976, joined Dufresne-Henry, Inc. in 1986

Member: American Water Works Association
Member Ground Water Committee
New England Water Works Association
Chairman, Ground Water Committee
Member, Committee on Management Development
National Water Well Association

Publications and Presentations

Edson, D.F., "Re-emergence of the Wellfield", Journal of the New England Water Works Association, Vol. 102, No. 4, December, 1988.

Edson, D.F., "Well Design", presented at Municipal Ground Water Supply Seminar, sponsored by Resource Education Institute, Inc., Westborough, MA., September, 1986.

Edson, D.F., "Microcomputer Billing for the Small Water Utility", Journal of the New England Water Works Association, Vol. 96, No. 4, December, 1982.

DETERMINING THE AREA OF CONTRIBUTION TO A WELL FIELD: A CASE STUDY AND METHODOLOGY FOR WELLHEAD PROTECTION

by

W. James Griswold and John J. Donohue, IV
BCI Geonetics, Inc.
Laconia, New Hampshire

ABSTRACT

This paper presents a case study of an hydrogeological evaluation for wellhead protection conducted in an alluvial valley-fill aquifer in central Massachusetts. The criteria for wellhead protection in Massachusetts are set by the Department of Environmental Quality Engineering (DEQE) and are among the most technically detailed and sophisticated in the nation. DEQE defines its wellhead protection areas as the zone of contribution to a well or wellfield under the most severe pumping conditions that could be reasonably expected, i.e., 180 days of continuous pumping with no areal recharge. This report presents a practical, technically defensible, step-by-step method which ground water professionals can employ to produce a product to address the spirit and letter of the law aimed at wellhead protection.

The evaluation begins with the development of an initial conceptual model of the area, evaluating such key elements as surficial and bedrock geology, associated contributions to ground water flow, recharge potential and induced infiltration from streams. The conceptual model is tested and revised through the installation of monitoring wells. Detailed measurements of ambient conditions both of ground water and surface water flows are taken to isolate the effects of the well(s) from the natural variations in the overall flow regime. The aquifer is then subjected to the stress of a required 120-hour pumping test. The results of analysis of the pumping test and ambient conditions are used in a numerical model to extrapolate from the 120-hour test to the 180-day, no-recharge conditions dictated by DEQE regulations. Finally, the modelled 180-day drawdown results are subtracted from a potentiometric surface map reflecting average non-pumping conditions. The area of contribution is delineated from a flownet constructed on the resultant potentiometric surface.

INTRODUCTION

This paper presents a practical means of delineating wellhead protection zones using a case study conducted in an alluvial valley-fill aquifer system in central Massachusetts. This approach addresses the particular legal requirements of the State of Massachusetts' Zone II, defined as the area that contributes recharge to a well or wellfield under the most severe pumping conditions that could reasonably be expected, i.e., 180 days of continuous pumping with no areal recharge. Although the wellhead protection requirements for the State of Massachusetts are among the most technically detailed and sophisticated in the nation, several other states (e.g., New Hampshire) do employ or are in the process of adopting regulations that incorporate many of the procedures demanded by Massachusetts. Thus, the methods described can be modified for other states that have related statutory requirements.

The objective of the case study was to determine the zone of contribution for the Bondsville Fire and Water District wellfield in central Massachusetts. The Bondsville wellfield consists of three production wells constructed in glacial outwash sand and gravel. Two wells functioned reasonably well, pumping a combined 225 gallons per minute. The third well had seen its yield decline significantly from its original rated capacity of 125 gpm and had not responded to redevelopment efforts. A new well had been drilled to serve as its replacement. To receive approval as a new source in accordance with Massachusetts Department of Environmental Quality Engineering (DEQE) Safe Drinking Water Guidelines, the water district had to delineate the 180-day, no-recharge zone of contribution to the wellfield.

This paper is divided into three sections. The first, relatively brief section summarizes the salient requirements of the Massachusetts Department of Environmental Quality Engineering (DEQE). These requirements form the basis for the implementation of the hydrogeological program to determine the zone of contribution. The second and third sections examine the approach used in the case study to fulfill the DEQE requirements. Section Two concentrates on the steps taken to formulate an initial conceptual model of the area, to test and update that model from field investigation data. Section Three deals with the actual delineation of the zone of contribution to the wellfield, tracking the process of moving from a conceptual to a quantitative model.

SECTION 1: REGULATORY REQUIREMENTS

The commonwealth of Massachusetts Department of Environmental Quality Engineering (DEQE) - Division of Water Supply regulates the development and operation of all public water supplies. The functional documentation of this regulatory process is entitled the "Safe Drinking Water Guidelines and Policies," 1989 edition.

Within these guidelines, the development of a public ground water resource is governed by the New Source Approval process. The process is a step-by-step exploratory and development procedure that culminates in the DEQE Division of Water Supply Approval of a Public System. The process is broken into eight major steps, the emphasis of which is the determination of zones 1, 2, and 3 (wellhead protection areas) which are evaluated in relation to existing and future land use activities, as they impact the long-term integrity of quantity and quality of the wells being developed. The core of these requirements involves a quantitative hydrogeological evaluation to determine Zone 2, defined as that area of an aquifer, which supplies recharge to a pumping well under the most severe recharge and pumping conditions which can be realistically anticipated. These requirements set forth a well-structured, long-term process intended to provide the necessary background information for the long-term management of ground water resources. In order to appropriately address the spirit of these requirements within the limits of realistic budgetary constraints, creative hydrogeological techniques must be employed to ensure that theoretical and technical considerations are not compromised.

SECTION 2: CONCEPTUAL MODEL DEVELOPMENT

2.1 General Considerations

The development of a conceptual hydrogeologic model begins with a compilation and thorough evaluation of material already available about the study area. This secondary data source material may take the form of available hydrogeologic and geologic reports, mapping efforts by the USGS and State Geological Surveys, published papers, university theses and dissertations, well logs and water quality analyses. A great deal of information can often be derived from conversations with local drillers, many of whom keep files on work they have done. As trivial or as obvious as this step appears, its importance is frequently overlooked, and it is often given short shrift, both from a monetary and time standpoint in the overall project plan. However, it takes only a couple of instances of drilling and logging an expensive monitoring well only to find that the USGS or the Army Corps of Engineers has excellent records of a well they drilled in the very same area some thirty or forty years before to realize the savings that can occur from a thorough perusal of existing data.

There are a number of ways that secondary source data can be compiled for analysis. One particularly useful means of obtaining a synoptic view of the study area is using map overlays and cross sections. We have found that at least two scales of map are necessary in a wellhead protection program study, one small scale map that provides a more regional perspective, incorporating most, if not all, of the drainage basin, and a large scale map to show a more detailed view of the wellfield and its immediate hydrogeologic environment. With properly sized base maps, a series of overlay maps can be derived to display and correlate various types of data. In general, we employ a minimum of three separate overlays, including a well location map with a regional potentiometric surface indicated, a surficial geologic/geomorphic map and a bedrock/structural geologic map. Other maps are frequently needed, e.g., an isohyetal map, if precipitation shows significant areal variation, a water main distribution map, and a tax or property ownership map. These maps can take as simple a form as a mylar overlay on top of a blowup of a standard USGS quadrangle or it can be input into a more sophisticated mode of storage and retrieval, such as a computerized geographic information system. In either case, the objective is the same: to provide first a regional and then a detailed perspective of a variety of data at a glance.

A second means of analysis is with geologic cross-sections. Constructing a series of cross-sections forces the hydrogeologist to incorporate a number of different data sets leading to an overall model of the region. Data inconsistencies such as a pronounced head difference across an area that ostensibly shows little geologic variation point to areas in need of further investigation. Additionally, cross-section construction focuses attention on the key problem of boundary conditions to the hydrogeologic system. Ultimately, the question of whether the situation can be analyzed accurately as a one, two or three dimensional problem must be addressed. Drawing a number of cross-sections and incorporating various data (surficial and bedrock geology, ground water conditions) into those sections offers a good first step in qualitatively and quantitatively addressing those issues.

The methods of analysis described above should be synthesized to create a formal conceptual model. It is important to make this step a written document. It forces the hydrogeologist to sift through, think about, and organize the ideas and data that have been collected. Putting the conceptual model in print often reveals data gaps and grey areas of information that might otherwise have been overlooked. It provides a means by which the project team may quickly examine the state of the project and contribute to the overall effort by offering constructive technical input. The initial model will change as the project proceeds, sometimes radically, but the written conceptual model focuses on the salient issues of the hydrogeologic environment being studied.

2.2 Bondsville Conceptual Model: Methods

In constructing the initial conceptual model for the Bondsville wellfield, the process described above was followed. The objective was to obtain the best information possible on the prevailing hydrogeologic conditions within time and budgetary limitations. Surficial geology was transferred to the base maps, with particular emphasis on hydraulic properties and attention to recharge potential to the valley fill aquifer. Well logs from local drillers, the USGS, DEQE and other state agencies were compiled on two base maps scaled 1:960 and 1:6000. A potentiometric surface map was drafted based on the available water level data. Investigations into precipitation data and possible impacts from regulated flows were made. Aerial photography was examined for the possibility of significant bedrock structures that might represent zones of enhanced permeability. Additionally, low-level aerials were used to better examine the surficial geology and glacial geomorphology. A field reconnaissance of the area was made, ground truthing questions raised during the process of establishing the data base. In particular, staff gauges were installed on Jabish Brook, given the potential for induced infiltration. Several geologic cross-sections and an aquifer thickness map at a 1:6000 scale completed the efforts prior to writing the initial conceptual model.

2.3 Bondsville Conceptual Model: Written Description

The Bondsville Fire and Water District wellfield is located within the watershed of Jabish Brook, a tributary of the Swift River in Palmer, Massachusetts. The wellfield lies approximately 1800 feet above the confluence of Jabish Brook and the Swift River. There are presently three wells in the wellfield, two on the west side of Jabish Brook and one on the east side. Well No. 3, on the east side, is in the process of being replaced with an adjacent, newly constructed production well (Well No. 4).

The Jabish Brook watershed is underlain by the Devonian Belchertown quartz monzodiorite covered with approximately 15-20 feet of compact glacial till. The aquifer which supplies the production wells is composed of glacially-derived stratified sand and gravel deposits approximately 50 feet thick in the vicinity of the production wells. The axis of Jabish Brook Valley trends north-south and includes areas where the sand and gravel is over 100 feet thick. Several feet of stream terrace deposits composed of sands, silts and gravels overlay the glacial outwash near Jabish Brook.

There are several key hydrogeological factors that influence the size and shape of the zone of contribution to this wellfield: leakage from Jabish Brook, the thickness and hydraulic conductivity of aquifer materials, the behavior of the low permeability boundaries of the aquifer, areal recharge and the rate and duration of pumping at the wellfield.

From the geologic setting, previous pumping test information, and field observations, it appears that Jabish Brook acts as a significant source of recharge to the Bondsville Well Field. Induced infiltration from Jabish Brook will slow the expansion of the cone of influence acting as a line source of recharge. It is unknown whether this source of recharge will be continuously available to the well. If the stream goes dry from excessive pumping and/or seasonal variations in ground water levels, the stream will cease to act as a recharge source.

The stratified sand and gravel deposits that comprise the Jabish Brook Valley aquifer are thickest along the central axis of the valley and grade into the lateral, north-south trending till and bedrock boundaries. When the Bondsville wells are pumped, the cone of influence will expand preferentially along the axis of the valley within the aquifer materials with the highest transmissivities. These aquifer and boundary conditions will affect the cone of influence into an elliptical shape with the long axis trending in a north-south direction.

2.4 Conceptual Model Revision: Analytical Modelling

Following its initial development, the conceptual model is subjected to testing. Questions and hypotheses based on the model are developed and tested to improve the overall understanding of the hydrogeologic environment. In general, this usually entails monitoring well installation. However, in order to provide additional guidance in the placement of observation wells, particularly for those designed for the long term pumping test, analytical modelling should be performed. In this case, reasonably good control had been achieved on the type, extent and hydraulic character of the aquifer from previous pumping tests and from well logs. Boundary conditions had been established, based primarily on surficial geologic mapping. The regional gradient was estimated from the potentiometric surface map. Using this database, a preliminary Zone II boundary was calculated using a uniform flow model and the superposition of radial and one-dimensional flow fields to determine the area of contribution (Todd, 1980).

The calculations resulted in a downgradient stagnation point distance of 2280 feet and a capture width of 7000 feet on either side of the wellfield. The 0-foot isopach for saturated sand and gravel bordered by relatively impermeable till and bedrock was used to delimit the lateral extent of the estimated zone. To estimate the upgradient boundary, we determined the amount of land needed to produce the estimated 525 gpm pumped by the wellfield with a recharge rate of 17 inches/year, an appropriate estimate for the climatic conditions and stratified drift deposits found in Bondsville. 600 acres of stratified drift was enclosed in the initial Zone II estimate.

2.5 Conceptual Model Revision: Monitoring Well Installation

To further refine the model, monitoring wells are installed. Monitoring wells serve several purposes, functioning as a means to better understand the subsurface distribution and hydraulic character of materials, as measuring points with which to revise the potentiometric surface map and, later, as monitoring points for pumping test evaluation.

Well drilling in Bondsville consisted of hollow-stem augering of the hole with split-spoon sampling at 5 foot intervals. Construction involved the installation of 2-inch, schedule 40 PVC riser, 2-inch PVC 10-slot screen, sand pack along the screened section, backfilling with well cuttings, a bentonite plug below a cement grout and a locking cap. Each well was developed with a suction pump and response tested to ensure proper hydraulic connection to the aquifer. Well locations and elevations were determined by survey to ensure water level measurements to within 0.01 feet (Figure 1).

2.6 Conceptual Model Revision: Formal Presentation

Following the installation of monitoring wells and the completion of regional and local testing of the conceptual model, it is vital to revise the conceptual model to incorporate the new findings. This stage of the program also entails committing to writing the data and analysis gathered since the early stages of the project. At this point, maps, overlays, well logs and cross-sections will play an increasingly important role and should form a portion of the overall written effort. In essence, this is the point at which the entire project pauses and takes stock of its position. Whether this revision takes the form of an in-house presentation, a submission to State authorities or to the client, it should have the status of an formal report in a usable format for easy future reference.

The conceptual model in the Bondsville study was revised principally based on accurate geologic logs created from the drilling of each well and updated water level measurements. The logs revealed the original model in need of only minor revisions of some contours of the aquifer thickness map. Of greater importance to the model revision process was the result of the revisions to the potentiometric surface map. With the more detailed information provided by water level measurements in the monitoring wells, the area of influence resulting from the two operating production wells was clearly visible. Jabish Brook did not function as a constant head boundary, but did contribute water to the wells as the area of influence from the existing pumping wells reached beneath and beyond the stream. Furthermore, the flow in Jabish Brook had decreased from a measured 27 cfs in March, 1988 to 2 cfs in June 1988. The potentiometric map contours were redrawn to indicate that Jabish Brook was losing water to the aquifer (Figure 1).

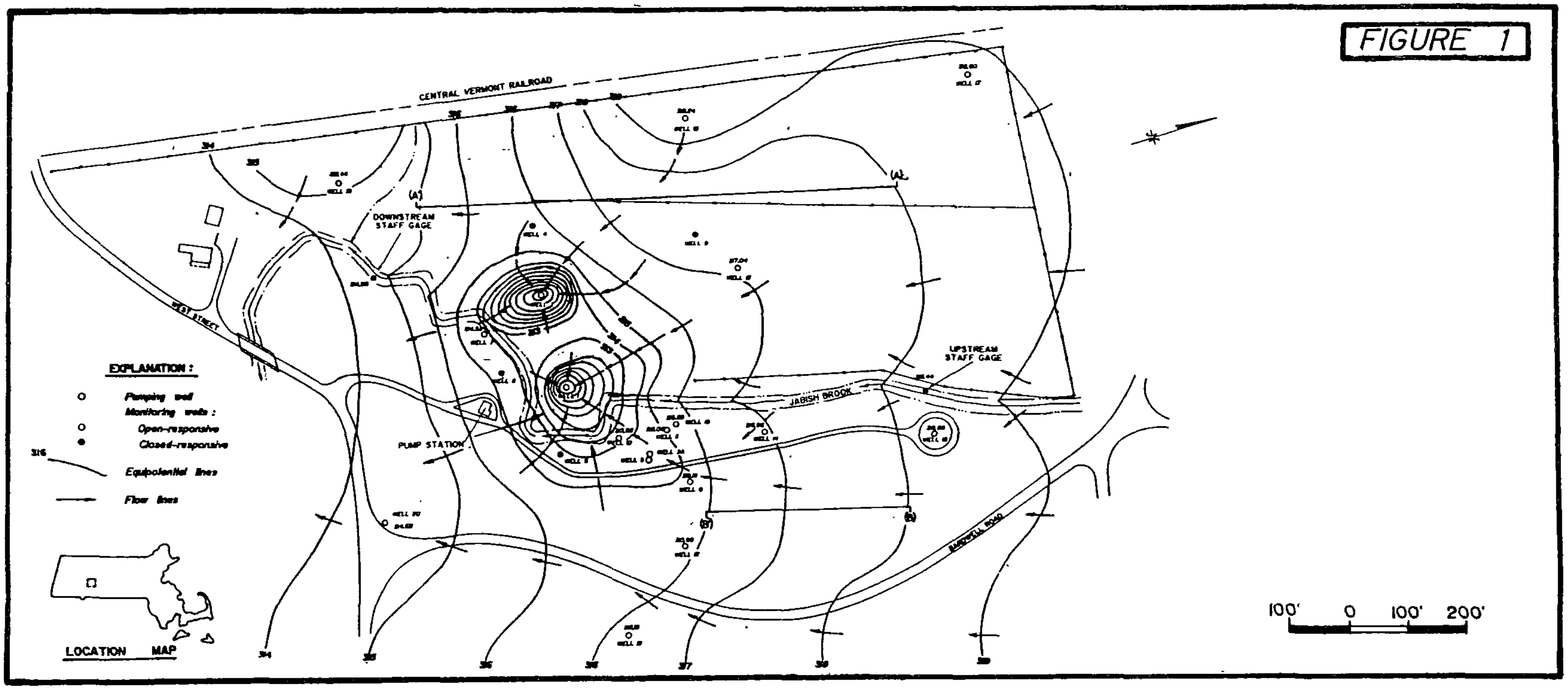

CENTRAL VERMONT RAILROAD
DOWNSTREAM STAFF GAGE
UPSTREAM STAFF GAGE
JABISH BROOK
PUMP STATION
WEST STREET
BARDWELL ROAD
EXPLANATION :
Pumping well
Monitoring wells :
Open-responsive
Closed-responsive
Equipotential lines
Flow lines
LOCATION MAP
100' 0 100' 200'

FIGURE 1

SECTION 3: ZONE II DELINEATION

Once the conceptual model has been updated and revised, the initial steps to move to a more quantitative approach were taken. A critical step in the development of an accurate quantitative model to determine the zone of contribution is the performance of a long term pumping test. Both a step test and a constant rate test were performed. The wellfield is the district's sole source of water and could not be shut down for the duration of the test. Consequently, Wells No. 1 and 2 would pump continuously throughout all tests at their normal capacities (170 and 80 gpm) to establish a quasi-steady state condition. Additionally, the Bondsville storage tank was to be filled prior to all test pumping with a full day's average demand in storage at all times to ensure adequate water supplies.

3.1 Ambient Condition Measurement

Two weeks before the beginning of the constant rate pumping test, five observations wells (MW's 12, 13, 14, 15, and 19) were equipped with automatic recorders to measure water levels at hourly intervals. The information from the data plots would be used to correct drawdown data from the constant rate test for ambient conditions. At the beginning of the constant rate test, the general trend was downward (Figure 2). Only the change in head with time for the final section of each curve was used to modify the results of the drawdown measurements in the monitored wells, adjusting the measured drawdowns for the downward trend.

Two staff gauges had been installed on Jabish Brook several months prior to test pumping, one upstream and one downstream of the Bondsville wellfield. These were monitored periodically to acquire some sense of the stream discharge with time. On two occasions rough estimates of the stream's discharge were made using measured cross sections of the stream and the speed by which floating objects passed. One measurement followed heavy rains and was approximately 27 cfs. Several months later, another measurement was made at the same cross section, with only about 2.5 cfs flowing. Using readings from the staff gauges on those days produced an equation used to determine a general sense of the magnitude of the stream discharge, e.g., whether the stream was flowing at 5, 15 or 50 cfs. The record of staff gauge readings just prior to the start of the constant rate test showed the brook was dropping in level.

3.2 Constant Rate Test

The constant rate pumping test lasted for five days. The pumping rate of 200 gpm was measured with a flowmeter and with an orifice weir at the end of the discharge line. Water from the pumped well was discharged into Jabish Brook below the downstream gauge, several hundred feet from the nearest monitoring well to minimize any problem of recharging the aquifer. Six observation wells were monitored automatically with automatic data loggers (MW's 12, 13, 14, 15, 16, and 19) while all others and the pumping well were monitored by electronic hand probes.

Staff gauges on Jabish Brook were monitored during the first day of the test. Unfortunately, temperatures dropped substantially during the second day and large portions of the stream's water froze, negating the accuracy and utility of staff gauge readings.

A series of water quality samples were taken on Days 1, 3 and 5 of the test, in accordance with DEQE requirements. In addition, pH, CO_2, specific conductance, and temperature were monitored both for the pumping well and Jabish Brook. Following pumping, recovery was monitored for three days, the amount of time needed for the well to recover to within 2 percent of the maximum drawdown.

FIGURE 2
MONITORING WELL #13: PRE-PUMPING

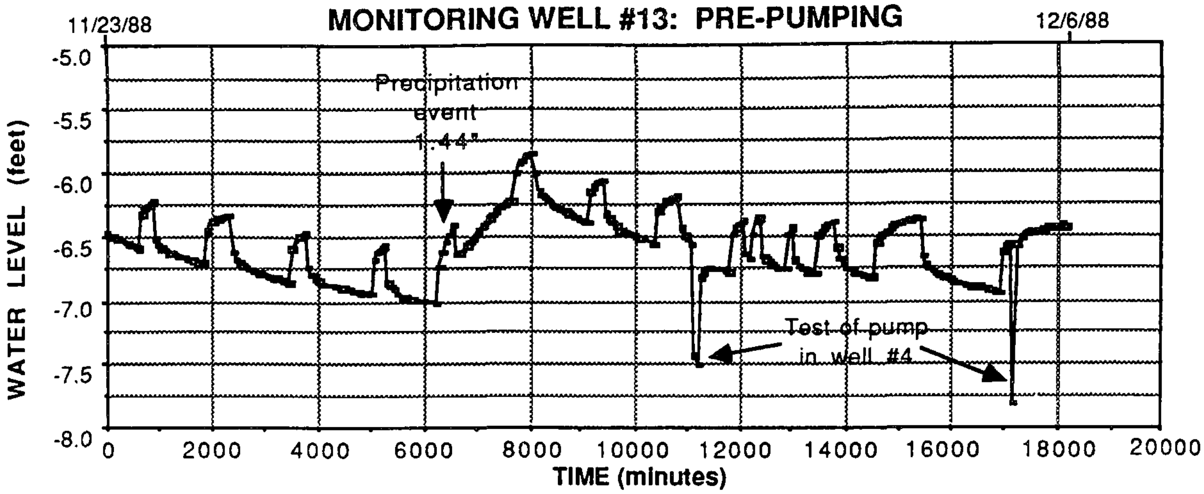


FIGURE 3: OBSERVATION WELL MW 13

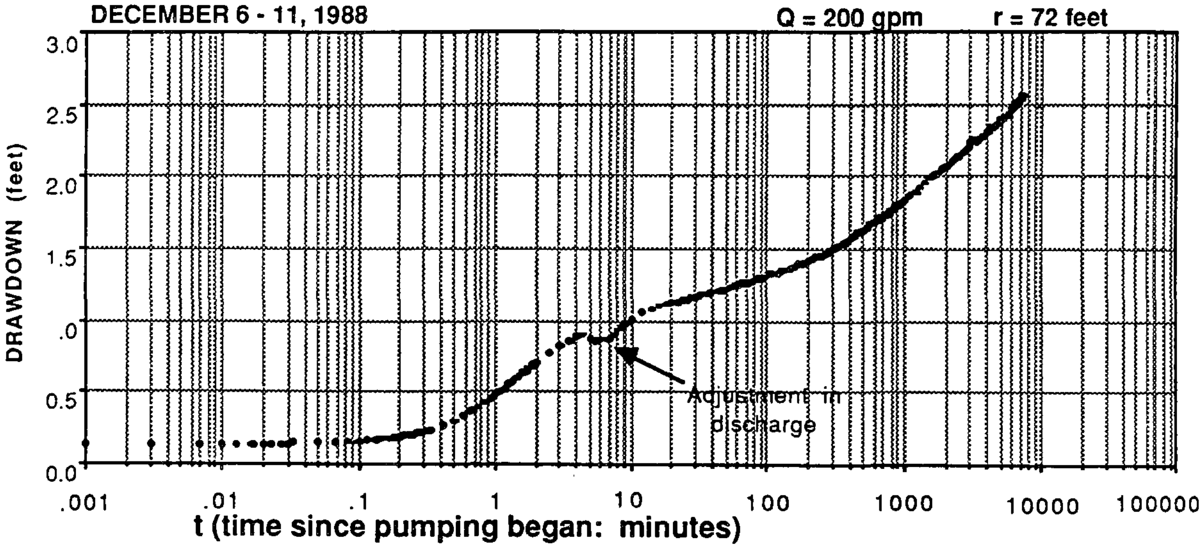
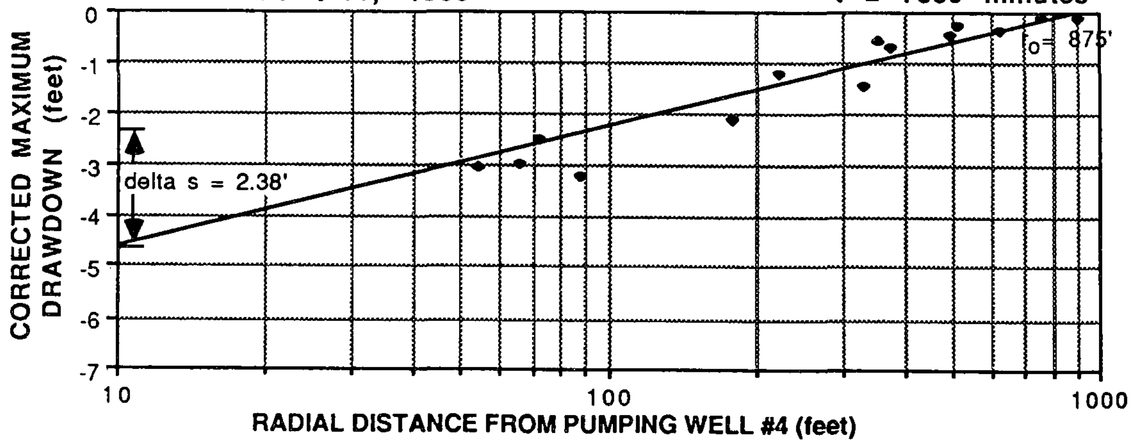


FIGURE 4: DISTANCE/DRAWDOWN PLOT (All monitoring wells)



The pumping well essentially stabilized 20 minutes into the test with 98 percent of the maximum drawdown of 31.6 feet occurring by that time. The time-drawdown curves of near observation wells indicate that the pumping well began to draw upon water from Jabish Brook quite early in the test (Figure 3).

Analysis of ambient conditions indicated water levels were generally moving downward in the period of time prior to the pumping test, and no precipitation occurred during the test which would alter that trend. Consequently, the drawdowns in those observation wells monitored prior to the constant rate test were corrected to true drawdowns, that is, drawdowns plus or minus the amount of change that would have occurred regardless of pumping. That procedure resulted in an adjusted distance-drawdown plot of corrected monitoring wells which was used to calculate a transmissivity of 44,000 gpd/ft and a storage coefficient of 0.09 (Figure 4). These values are consistent with the results of the well log analysis and overall conceptual model derived for this hydrogeologic environment. Analysis of recovery curves confirmed the estimates of transmissivity obtained using the distance-drawdown curves.

3.3 Revisions to Conceptual Model

The results of pumping test analysis provided an additional opportunity to fine-tune the conceptual model in preparation for a more quantitative approach to the problem, particularly with regard to the impact of Jabish Brook. The aquifer appears remarkably homogeneous and isotropic in character. Observation wells with widely differing locations and orientations from the pumping well showed a close clustering along the distance-drawdown plot (Figure 4). Preferential drawdowns along a general east-west orientation can be explained by two factors. First, Wells No. 1 and 2 are fairly close to one another, along a rough east-west strike. Interference leads to more drawdown along that trend. With the addition of Well No. 4, that trend of drawdowns is somewhat enhanced. Second, the presence of boundary conditions represented by the gradation of thinning aquifer materials into glacial till uplands, particularly those to the east where till constricts the Jabish Brook valley to a fairly narrow zone, adds to the apparent anisotropy.

The reaction of water levels in wells monitored prior to the constant rate test to a rainfall event (Figure 2) and the evidence of a partial recharge boundary on the time-drawdown curves (Figure 3) suggest a fairly significant effect from the stream on the aquifer. To calculate the amount of water actually contributed from the stream during the pumping test, the distance-drawdown curve was used to calculate the volume of aquifer affected by the pumping well. The volume was multiplied by a storage factor to determine the amount of water actually removed. That figure was then compared to the measured discharge of 200 gpm times the number of minutes pumped. The key element in this calculation scheme is the storage coefficient. Based on the conditions dictated by the distance-drawdown curve and the 200 gpm pumping rate, the stream would contribute nothing with $S = 0.14$, forming an upper bound to the problem. A lower bound might be $S = 0.02$, which would entail approximately 85 percent of the discharge. Physical observation of the streambed materials suggests that the 85 percent figure is unlikely. Noting that the calculated storage coefficient from the distance-drawdown plots was 0.09, using a storage coefficient of 0.10 results in a stream contribution of approximately 26 percent, while a storage of 0.08 has the stream contributing 41 percent of the total discharge. The amount contributed changes with stream stage. This is an expected response in this kind of stream system, since the base of the stream tends to be armoured and hydraulically "tight" while the bank sides are sandy and much more permeable. During periods of low flow, contribution to the aquifer by stream leakage is relatively small due to the less permeable nature of the stream bottom. When the stage rises, however, water flows easily into the aquifer through the banks, prompting a rise in the water table. During this test pumping, more water came from the stream early in the test before the stream froze. Less came afterwards since available water decreased due to the decline in stage. About 30-40 percent of the water discharged under these particular meteorological and hydrogeological conditions came from infiltrated stream water.

3.4 Quantitative Model Development

To achieve a more accurate delineation of Zone II and to better understand the impact of the third pumping well in the Bondsville wellfield, we elected to employ a numerical approach to the problem using the USGS Three-Dimensional Modular Finite Difference Model (MODFLOW), calibrating the model with the results from the five day pumping test. The problem is two-dimensional (no confining layers and no flux from underlying till or bedrock), and a single layer model was constructed.

The Jabish Brook valley was discritized into a variably spaced grid covering 3.77 square miles (7000' x 15000'). The area of the wellfield was closely gridded to reflect the better data base and the need for head distribution resolution. The glacial till uplands that flank the valley were modeled as no-flow boundaries. Geological investigation, both surficial mapping and test drilling, had revealed that the till in the region is quite "tight"; its water releasing capacity is low, particularly relative to the transmissivities of the sands and gravels of the valley proper. The Swift River to the south was modeled as a constant head boundary while the top (north) of the model was represented as a combination of no-flow boundaries (in the areas of glacial till hills) and constant head boundaries (in the stream valleys). The map of saturated sand and gravel produced for the initial conceptual model was employed to provide initial values of aquifer saturated thickness. To determine a value for hydraulic conductivity, we used the calculated transmissivity from the pumping test (44,000 gpd/ft) divided by the average saturated thickness (40 feet), resulting in a value of 146 ft/day. Hydraulic conductivity undoubtedly does vary in other portions of the Jabish Brook valley, but because we had no direct data to that effect, we decided not to alter the K value elsewhere in the model. Because saturated thickness varied, transmissivity varied in the model as well. Specific yield was initially placed at 0.09.

Jabish Brook is a regulated stream. The entire flow is usually diverted upstream of the Bondsville wellfield to the Springfield City Water System. Because of this situation, the stream can exhibit significant variation in flow over time subject to the diversion, rainfall events, and groundwater interflow below the diversion point. Accordingly, Jabish Brook experiences a period of seasonal low flow in the vicinity of the wellfield. Jabish Brook did contribute water to the Bondsville wellfield during this test pumping, but we felt that the most stringent pumping conditions that could be anticipated under a 180-day, no-recharge scenario would be to have no stream contribution to the wells. Consequently, the stream was not modeled.

The water table elevation was set uniformly at an arbitrary level and calibrated from that initial condition. We did not have enough data to calibrate to ambient water level conditions, so the model was employed in a "quasi-numerical" sense to generate drawdowns based on a flat water table reflecting the varying boundary and aquifer conditions.

The model was run and calibrated using two stress periods to reflect the actual conditions of the test pumping. The initial stress period consisted of two wells (1 and 2) pumping continuously at rates of 170 and 80 gpm, respectively. This stress period lasted 30 days, reflecting the fact that Bondsville's two existing wells pumped continuously prior to, during, and after the pumping test. The second stress period was five days long, modeling the five day pumping test. It used the head distribution from the first stress period as an initial condition and consisted of all three wells (wells 1, 2 and 4) pumping at 170, 80, and 200 gpm. The output from that model run was compared with actual drawdown values obtained in the field at the end of the five day test pumping. Calibration involved modifying saturated thickness (using detailed well logs from the test drilling phase of the project) and uniformly varying specific yield throughout the modeled wellfield area. The result was a set of modeled drawdowns that compared acceptably with the actual drawdowns.

The calibrated model was re-run using first the 30-day, 2-well stress period followed by a 180 day run with all three wells pumping, modeling the 180-day, no-recharge scenario.

3.5 Zone II Determination

To delimit the zone of contribution (as opposed to the zone of influence) to the wellfield involved superimposing the 180-day modelled drawdown map onto the potentiometric surface map. To manipulate these two data sets, the water table map was digitized and gridded with a random data gridder from Geosoft®. The gridded file was filtered using two passes from a 9-point Hanning filter, and the result was a computerized water table map that matched the hand-contoured product. The drawdown output file from the 180-day run of the numerical model was also gridded. The two gridded files were then subtracted, creating a new grid that when contoured, represented a map of the water table reflecting the impact of 180 days of no recharge pumping at the wellfield. A flow net was constructed to determine where the zone of contribution occurred. From the results of the flow net analysis, the zone of contribution corresponding to Zone II conditions was established. This resulted in a Zone II of approximately 0.5 square miles (Figure 5). The zone is bounded to the east and west by till and bedrock uplands; to the north of a locus of points representative of a groundwater divide between the portion of the aquifer where groundwater would discharge to the stream rather than be diverted to the wellfield; and to the south by a locus of points representative of the downgradient stagnation points. Zone III, defined as the area topographically directly upgradient of Zone II was developed utilizing the Zone II and geologic and topographic maps. It encompasses an area of till and bedrock uplands of approximately 1.2 square miles.

3.6 Additional Protection Zones

With the establishment of Zones II and III, the steps required by DEQE for a new source approval are completed. However, the spirit of the law is concerned with the overall protection of the aquifer. Recognition of the stream, aquifer, and wellfield interrelationships is a very important consideration in the formulation of a groundwater protection strategy for this wellfield. Given the definition of Zone II being "that area of an aquifer which supplies recharge to a well(s) under the most severe recharge and pumping conditions that can be realistically anticipated," eliminating the recharge contribution from Jabish Brook is appropriate. However, much of the time this wellfield will be obtaining a recharge contribution (at times greater than 40 percent) from Jabish Brook. Under these conditions, the quality of the water in the brook will have an impact on the quality of the water produced in the wellfield. In summary, it means that contaminant threats outside of the Zone II and III, but contributory to Jabish Brook may be significant to the long-term management of this water resource.

CONCLUSIONS

The process of wellhead protection zone delineation to meet Massachusetts DEQE regulations begins with the development and refinement of a conceptual model of the hydrogeologic environment. This iterative approach relies heavily on secondary source material in its initial stages, taking full advantage of published and unpublished material about the hydrogeology of the area. Later, field checks to ground truth the gathered data, analytical modelling to point out data gaps and monitoring well installation to better characterize subsurface conditions contribute to the updating and revision of the model. Once the formal conceptual model is completed, it is possible to move to a more quantitative approach to the problem. Designing and conducting a long term pumping test results in the production of data that can be used to calibrate a numerical model of the area. Running the calibrated model to the requisite 180 days with no areal recharge provides a map of drawdowns that can be superimposed on an average ambient potentiometric surface map, revealing, through construction of a flow net, the zone of contribution (not just influence) to the

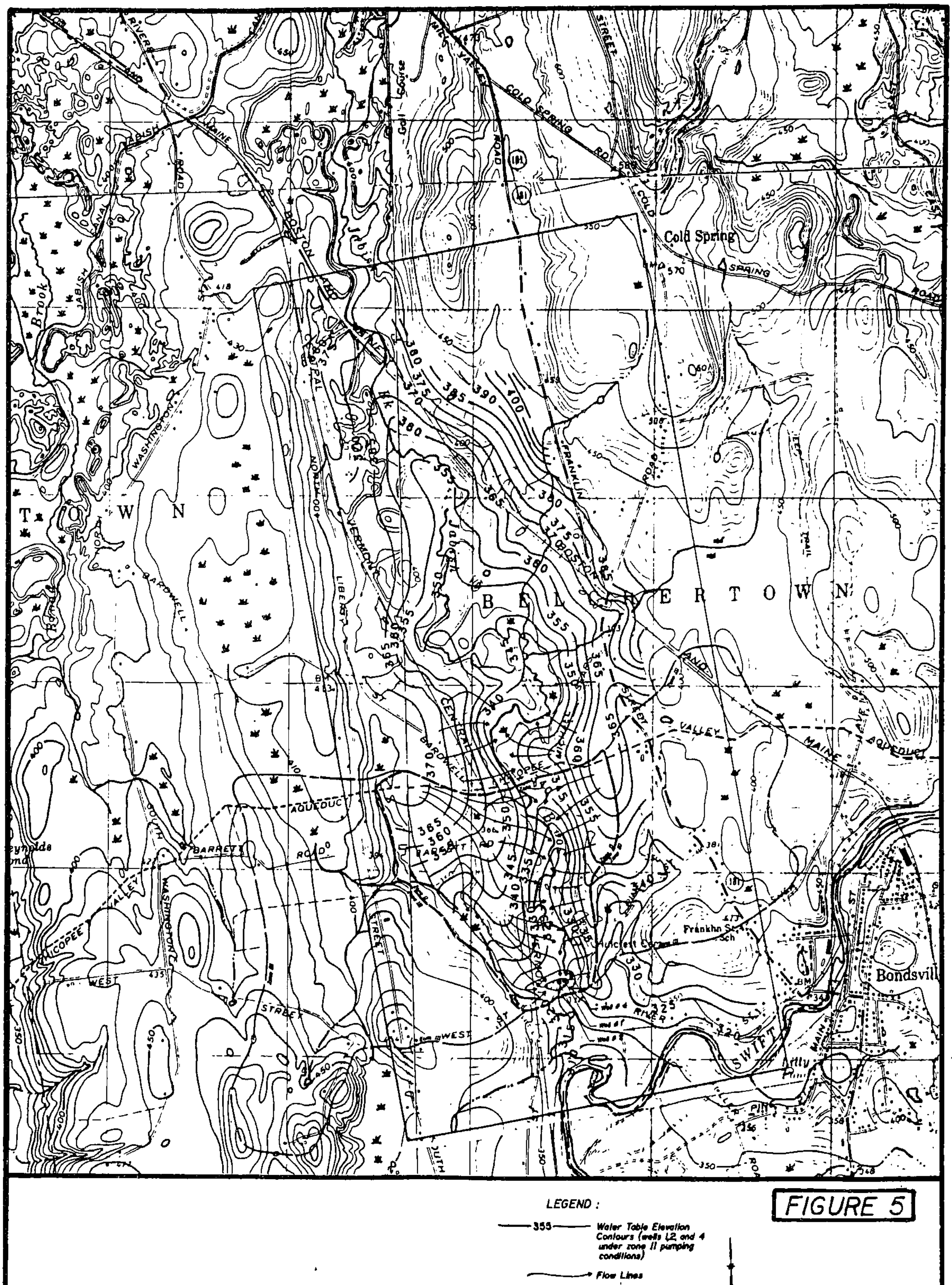

LEGEND :
355 Water Table Elevation Contours (wells 1,2, and 4 under zone II pumping conditions)
Flow Lines
Zone II Boundary
Zone III Boundary
Cold Spring
Bondsville
T O W N
AQUEDUCT
BARRETT
SWIFT RIVER
Franklin St Sch

FIGURE 5

well or wellfield. That 180 day zone of contribution is Zone II; Zone III is the area upgradient of Zone II to the extent of the nearest topographic divide. Delineation of Zones II and III complete the legal requirements set out by the DEQE, but it must be recognized, particularly in cases of induced infiltration from streams, that contaminant threats outside the established protection zones must be considered for responsible, long-term aquifer management.

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FIGURES

The Use of Time of Travel in Zone of Contribution Delineation and Aquifer Contamination Warning

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Determination of the Zone of Contribution for water supply aquifers traditionally depends on the use of drawdown information under specified conditions. In part, this has been due to the availability of computer models which produce this information.

Recent advances in computer modelling make possible determination of travel time as well as drawdown. This alternative tool has advantages in determination of the zone of contribution as well as having proved useful in determining where monitoring efforts should be located to provide known degrees of protection in terms of warning time.

This paper discusses some of the principle advantages of the use of time of travel rather than drawdown, such as:

1. Freedom from the influence of significantly sloping piezometric surfaces.
2. Proper accounting for the effects of high-permeability strata in the aquifer.
3. Proper inclusion of recharge from nearby low-permeability areas.
4. Clear delineation of where monitoring should occur for definite warning times.

This paper also discusses the use of computer models for travel time determination, including:

1. Required input data.
2. Conversion of conventional (e.g. PLASM, MacDonald-Harbaugh) format models to be used with travel time models.
3. Problems with the use of transmissivity or averaged permeability based models for the determination of travel times.

The Zone of Contribution to an aquifer supplying a water supply well is of considerable interest. Not only are there practical reasons for this, such as determining what threats may be present to a given water supply source, but there are now various State and Federal programs requiring delineation of the Zone and specifying certain activities which may or may not take place within the Zone. Increasingly, these delineations are being incorporated into legal documents, such as planning and zoning regulations, and thus the need for accuracy and defendability is great.

The traditional approach to determining the Zone of Contribution to a water supply aquifer takes one of two forms. The first is a specific radius around the production well(s), determined either by de jure means (thou shalt protect 400 feet) or by various approaches which incorporate some flexibility for the geology, such as Connecticut's Level B mapping, which sets the radius as a function of well yield and measured or estimated aquifer transmissivity. This approach, whether de jure or flexible, does not take into account the real geology of the area in anything more than a cursory fashion. The second approach has been based on observing (or modelling) the drawdown caused by the production wells under certain specified conditions and drawing the boundary at a specific value of drawdown. The conditions and the value of drawdown to be used may be based on the best judgement of the investigators, or may be written into regulations. Obviously, field observation would be the best approach; equally obviously, it is not generally practical, as the conditions are intentionally extreme and there is usually a lack of data. All of this leads to the use of computer models to predict the performance of an aquifer, based on a calibrated mathematical simulation of the performance of the aquifer.

The first question, however, is: is drawdown a satisfactory measure of the Zone of Contribution in the first place? If not, why is it used and specified?

One's initial reaction to this question is why not? At first glance, it seems reasonable to suppose that if the water level in an aquifer is drawn down by pumping a well, then the water which was lost must have been removed by the well. This is exactly true only for an aquifer in which there was no initial movement of the groundwater. In such an aquifer, any drawdown must have come from pumping the production well. The supposition is not true for an aquifer in which there was some initial slope and thus some initial ground water flow. In that situation, some of the drawdown down gradient from the production well is not due to withdrawals by the production well, but to a reduction in the total quantity of through flowing water due to the activity of the pumping well. There is a point at some distance down gradient from the production well, at which the drawdown may be large, but where the slope of the piezometric surface changes from towards the well to away from the well. Water farther away from the well than this point does not reach the production well, even though the drawdown is significant. Further, upgradient from the well, water will reach the well (in some unspecified time), even though the drawdown may be insignificant, as there is still a slope of the piezometric surface towards the production well. At what initial slope of the piezometric surface does this effect become significant? That is, at what initial slope will the results from using drawdown instead of consideration of actual ground water slopes under drawdown conditions become sufficiently different to warrant defense of the later and rejection of the former? There can be no single answer to that question, as it depends on the nature of the land use, possible contamination problems, and land values. Clearly in an area of low land values with no contamination problems, it is not important. Conversely, in an area where land values are high and a proposed use of high value may be located within the zone defined by one approach, but not the other, even small differences may become important.

It would be possible to define the Zone of Contribution to a well as the entire ground water shed of the well under specified conditions (corresponding, presumably, to those now used for drawdown). That is, it would be the entire area from which water flows towards the well under those conditions. However, this does not seem to me to be a particularly practical approach, particularly for wells located in large watersheds (e.g. one I worked on recently in the lower Housatonic valley) as it would include vast areas of land from which water would, theoretically, reach the well--assuming the conditions held constant--but with time spans measured in decades or centuries.

It seems to me that a more practical approach would be to define the Zone of Contribution--or, better, several zones of varying stringency of protection--based on travel time to the well. As a first pass at this, I suggest that the innermost zone, perhaps corresponding to the State of Massachusetts Zone I, be defined as the area around the well within which the travel time is so short as to make a change to an alternative supply and/or provision of treatment, in the event of contamination being discovered within the zone, prohibitively difficult: in other words, within which there is a clear risk of a contamination spill reaching the public water supply system without a chance for correction. The next zone (Zone II?) would be the zone within which there is sufficient time to provide emergency treatment for the water, but which is sufficiently close to the well to be clearly connected with it over a water year: in fact, I suggest that this boundary be set at a travel time of one year. The outermost zone most logically would be set at a distance corresponding more or less to the expected useful (or economic) life of the well; perhaps 10 years would be reasonable.

A second set of reasons for the use of time of travel as a criterion rather than drawdown or pure slope is the influence of the local geology on the imminence of a hazard. Consider the case in which an otherwise uniform aquifer of, let us suppose, medium sand, contains within it a rather thin, but very elongated and narrow, stringer of very coarse sands and gravels with a permeability three orders of magnitude greater than the general sand. This is not an unusual phenomenon in New England, and could represent a periglacial stream channel in a more generalized valley fill (for instance). The presence of the small amount of high permeability material in thickness will not change the overall transmissivity significantly and thus the ground water slopes will not be significantly affected--but the travel time along the path of the coarse stringer will be three orders of magnitude less than from some other point, not in the vicinity of the lens but at the same distance (discounting the influence of vertical motion to the depth of the lens). Thus the imminence of hazard from contamination from a source along this stringer will be much greater. This will be properly accounted for on a travel time model, but not on a model giving only slope or drawdown information. It is of some practical interest, however, particularly since we often try to site wells to take advantage of such stingers. Another situation is the one in which a well is close to a till/outwash boundary. It is common practice to assume that the Zone of Contribution to a well in outwash ends at the till contact. In fact, many ground water models which I have had the opportunity to examine as a consultant also end at the boundary, on the assumption that till is "impermeable" (which, of course, it is not, although the permeability is rather low in general). A properly constructed model producing head (and drawdown) distributions, which takes into account the influence of bedrock permeability as well as the influence of till, may show that there is significant drawdown in these areas. But is this drawdown area to be considered part of the Zone of Contribution and, if it is, which zone? Again, it is not possible to answer this question unequivocally from slope considerations alone, but it can be answered directly from time of travel modelling. (From experience with a number of different aquifers, the answer turns out to be maybe sometimes.)

The last area which I wish to mention regarding the benefits of the use of time of travel modelling is in siting monitoring wells, the purpose of which is presumably to give timely warning of approaching contamination so that alternative measures can be undertaken. Time of travel siting makes it possible to use a completely rational approach to siting these wells: the object is to site the well at such a distance that it will sample a significant fraction of the water (observe the relative concentration of flow lines, which is another output from the time of travel mapping) and, more important, that the time of travel from the monitor to the production well is adequate. Fortunately, it is very easy to define "adequate": it is simply the sum of the sampling interval at the monitoring well, plus the time it takes to analyze the sample, plus the time it takes to set up an alternative scheme. In fact, it becomes possible to perform a cost/benefit analysis on various monitoring schemes (within limits), based on the numbers of wells required and their locations vs. the sampling interval at each well.

Time of travel modelling is not particularly difficult. There is at least one computer program available to do it which is based directly on, and requires no additional data than, the underlying head distribution model. However, it does require that both the underlying head distribution model be created properly and that adequate geologic information is provided. Since more information is being retrieved from the model, more information is required going into the model.

Specifically, it is absolutely essential that the model adequately represent, at each node, all of the significant strata and their permeabilities, including the bedrock. (Significant strata being those that differ by an order of magnitude from some sort of average permeability--in most cases, it is appropriate to model them all, but in some cases, depending very much on the judgement of the modeller, some can be lumped together). In addition, their depths must be accurately represented as much as possible, as a high-permeability stratum which dries during the pumping does not contribute to time of travel while it is dry, but does when it is wet. It is conceivable to have very different travel times depending on pumping schedule with the same overall gallonage pumped, if a high permeability stratum is being alternately dewatered and flooded under one schedule, but permanently wet (or dry) under another.

The model should be constructed so that the grid (finite difference or finite element) covers the entire watershed of the aquifer, if at all possible. The use of constant head nodes should be minimal (a properly constructed and calibrated model should not require any at all), although constant flow nodes may be required at some border locations either if the model does not cover the entire aquifer (for input from areas beyond the model) or to account for exports from areas outside the watershed being studied. The stratigraphy at each node must be analyzed and used as input. Ideally, of course, one would take a core at each node. This is, clearly, impractical! A completely satisfactory alternative, however, is to use available stratigraphic information in combination with a thorough analysis of the geomorphology, stratigraphy, and historical geology of the area to interpolate intermediate stratigraphy from the available information.

The model, of course, must be able to accept this information. The traditional PLASM model and, indeed, any strict two dimensional model whether it is finite element or finite difference, cannot do so, as they use either a bulk permeability at the node, converted to transmissivity by multiplying by saturated thickness, or, in the case of confined models, the bulk transmissivity. There simply is no way to allow for the effect of high-permeability stringers in these models. Three dimensional models can, in principle, allow for these by means of using multiple layers and can also incorporate bedrock characteristics properly. There are some real problems with these models in areas of steeply dipping or heterogeneous topography and geology, however, in that a large number of layers may be required. This may not be feasible without the use of very large computers. Models do exist, however, which are fundamentally two dimensional as regards head field output, but which accept the stratigraphy at each node. If possible, these should be used as the foundation for time of travel modelling except in the rare instances where information on vertical flow rates and head differences is required.

Calibration of models to be used for time of travel outputs must be done with a great deal of care. As noted earlier, constant head nodes are discouraged, as they can distort the head field in their vicinity. Constant flow nodes are usable, provided they are real (that is, there really is a constant flow of some sort in the area). Streams and lakes must be accounted for by a scheme which allows for recharge or discharge, depending on the relative heads. Actual infiltration rates for each node must also be estimated closely, taking into account soil materials and slopes of the ground surface. Aquifer recharge from interflow at points where valley walls descend onto more level areas can be significant. Calibration is often accomplished by adjustments in bulk permeability or transmissivity. All that is required is to adjust the bulk permeability (or transmissivity) at each node of the model to adequately reflect the influence of the high or low permeability strata. Not only will this make time of travel calculations invalid, more subtly, it may make the range of the model very limited: if the bulk permeability is influenced by a high-permeability stratum rather high in the section, the model may calibrate perfectly under normal conditions (and with all available calibration data) and yet fail miserably under more extreme conditions when the high permeability stratum is dewatered by pumping.

Instead, calibration must be accomplished by carefully keeping in mind the real geology in the area. Permeability (which directly affects time of travel) should be adjusted for calibration only to the extent that is consistent with the materials and the geologic interpretation of the area. Stratigraphy (in particular stratum top and bottom elevations) must be altered only to the extent that the result is geologically plausible. Substitution of one formation type for another at a particular elevation at a node, or insertion of a new stratum, is subject to the same constraint. It is my experience that, if the geology is well thought out and reasonably correctly interpreted, very little adjustment of either stratigraphic thicknesses or formation permeabilities will be required to complete calibration. Difficulties in calibration often indicate errors in geologic interpretation, which can and should be resolved with further field investigation (it is rarely necessary to do subsurface work). It may be necessary to seek consultation from an experienced glacial geomorphologist in some instances.

Calibration should be checked against all available aquifer information. Wetlands which are not perched water table situations should be reflected accurately, and are a convenient check in areas with few (or no) ground water observations. A properly calibrated model should simulate with reasonable accuracy any pump test that has been performed, as well as the actual operating records if they are available. Perhaps it is worth noting, in passing, that many models do not report the actual level in the pumping well, but rather the head at the node in which the well is located. If this is the case, calibration is impossible. Correction must be made to reflect the performance of the aquifer in the immediate vicinity of the well and the well itself. The model referred to above does this automatically.

The summary for calibration is that the geology must be correct first; any geologic approximations can cause large errors, although approximations are acceptable provided the consequences are carefully thought out and will not affect the validity or usability of the model. I cannot emphasize this point enough!

Conversion of PLASM and other models, including three dimensional models which do not include adequate resolution to show significant, but thin layers, to suitable forms for time of travel modelling is extremely difficult. I do not recommend this, except in situations in which it is impossible for one reason or another to create the model in the first place with adequate vertical resolution, either by use of a model with allows full stratigraphy at each node or use of an adequate number of layers in a three dimensional model (typically ten or more). It is usually cheaper (and quicker) to remodel the area in question on a model which can handle the required information.

In summary, I would like to emphasize that time of travel modelling has several advantages, among which are proper accounting for the influence of initial aquifer slope, high-permeability strata, and bedrock, and allowing a rational method for siting observation wells; secondly, that computer models are available to perform time of travel modelling; third, that considerably more input information about the local geology is required to construct and calibrate these models, but that the information is readily developed by qualified geologists; fourth, that conventional models with inadequate vertical resolution cannot be used as input for time of travel modelling and; fifth, that conventional models with inadequate vertical resolution may give misleading results for head fields under extreme conditions.

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DELINEATION OF CONTRIBUTING AREAS TO PUBLIC SUPPLY WELLS IN STRATIFIED GLACIAL-DRIFT AQUIFERS

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Abstract

Several analytical and numerical methods are available for delineating contributing areas to public supply wells. These methods employ variable levels of computational complexity and require differing levels of data specification. A recent advance in the ability to analyze contributing areas quantitatively has been the coupling of particle-tracking algorithms to numerical ground-water-flow models. A demonstration of the use of this method for delineating contributing areas to hypothetical public supply wells pumping from a stratified glacial-drift aquifer on Cape Cod, Massachusetts, has shown that (1) the location of a well with respect to areas of recharge and discharge for the aquifer will have a significant effect on the shape of a well's contributing area, (2) the recharge rate to an aquifer and the pumping rate of a well will have a significant effect on the size of the well's contributing area, (3) multiple pumping wells within an aquifer must be considered simultaneously in the determination of a well's contributing area, and (4) the lithology of the aquifer in the vicinity of the well must be well defined.

The study also has shown that contributing areas determined using analytical modeling were similar to those determined using numerical modeling coupled with particle tracking for wells pumping from a thin, single-layer, uniform aquifer with simple boundary conditions, and that the use of numerical models for the delineation of contributing areas for wells in such an aquifer may not be warranted. However, numerical modeling and particle tracking provide a better quantitative tool than do analytical models for conditions normally encountered in the field, such as thick, heterogeneous aquifers with complicated boundary conditions in which several wells are pumping simultaneously. Under these conditions, analytical models are not capable of providing sufficient detail to predict accurately the land area which contributes water to a well.

Introduction

The delineation of contributing areas to public supply wells is an important component of State and Federal strategies for the protection of ground-water quality. The delineation of contributing areas requires first, a conceptual, and second, a quantitative understanding of the ground-water flow system from which the well is pumping. Many quantitative methods are available for analyzing ground-water-flow systems and, in particular, the delineation of contributing areas to supply wells. However, many of the methods used to delineate contributing areas to large-capacity supply wells are not capable of integrating the several hydrologic and well-design factors that may affect the size and shape of a well's contributing area. Consequently, the accuracy of a contributing area delineated for a supply well may be directly dependent on the method of analysis chosen.

A recent advance in the ability to analyze ground-water-flow systems quantitatively has been the coupling of particle-tracking algorithms that trace particle pathlines within a ground-water-flow system to numerical ground-water-flow models. The coupling of these methods provides a powerful tool for the analysis of the factors that affect the response of an aquifer to the pumping of a large-capacity supply well, and should improve the delineation of a well's contributing area. The U.S. Geological Survey is conducting a project to demonstrate the use, and assess the effectiveness and limitations, of numerical modeling and particle tracking for the delineation of contributing areas to public supply wells that tap stratified glacial-drift aquifers under selected conditions of aquifer heterogeneity and well configuration. The results of the method are being compared to contributing areas delineated using analytical models to gain an understanding of the conditions under which the different analyses are most appropriate. The study is being conducted in cooperation with the Massachusetts Department of Environmental Protection, the Massachusetts Department of Environmental Management, and Barnstable County, Massachusetts.

Purpose and scope

This report outlines two methods for delineating contributing areas to public supply wells and presents some of the results of an ongoing study to demonstrate the use, and evaluate the strengths and limitations, of these methods for wells located in multilayered stratified glacial-drift aquifers. The methods of analysis evaluated are analytical modeling and numerical modeling coupled with particle tracking. A brief description of the sources of water to wells pumping from stratified glacial-drift aquifers is presented as background to the methods of analysis.

Sources of water to a well pumping from a stratified glacial-drift aquifer

Perhaps the first step in the delineation of a contributing area to a public supply well is the identification within the hydrogeologic environment of probable sources of water to that well. The identification of these sources aids (1) development of a conceptual model of the ground-water-flow system, and (2) selection of a method of analysis for the delineation of the well's contributing area. In general, ground water at a well that taps a stratified glacial-drift aquifer has four sources: (1) recharge from precipitation which falls directly on the stratified drift; (2) recharge from adjacent aquitards, such as silt, clay, till and bedrock; (3) recharge from induced infiltration of surface water, such as a nearby stream, river, lake or pond; and (4) removal from ground-water storage. Sources (1) and (2) constitute water that is "captured" by a well that otherwise would discharge at the natural discharge areas of the ground-water system; these sources are referred to here as captured ground-water discharge.

The volume of water contributed by each source to the total volume of water withdrawn by a well will change as a function of time. Morrissey (1987) used a numerical flow model to investigate the transient response of a hypothetical stratified-drift, river-valley aquifer to the pumping of a large-capacity supply well located 200 feet from a river. Sources of water to the hypothetical well are (1) water removed from storage, (2) water from induced infiltration of streamflow, and (3) captured ground-water discharge. His results, reproduced here in figure 1, indicate that, during the first few hours of pumping, the well is sustained almost entirely by water removed from ground-water storage. After approximately 1 year, water removed from storage ceases and the well is sustained entirely from captured ground-water discharge and induced infiltration of streamflow. The length of time that a supply well will remove water from ground-water storage will depend on the aquifer in which the well is located and the screened interval of the well. Wells that are screened near the bottom of a thick aquifer may remove water from storage for a much longer time than is shown in figure 1.

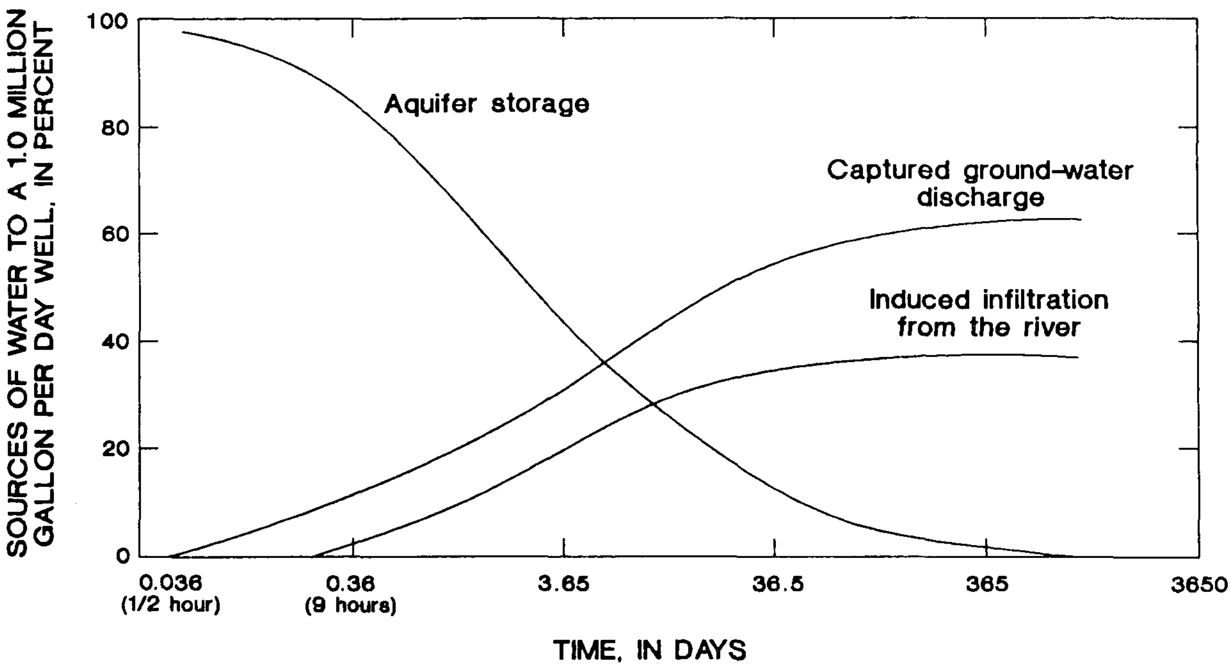


Figure 1. Graph showing sources of water pumped from a well as a function of time (modified from Morrissey, 1987, figure 27).

Although Morrissey's results indicate that the sources of water to a well may change over time, only steady-state (or equilibrium) conditions were investigated for this report. Steady state implies that there is no removal of water from storage. The contributing area determined for steady-state conditions is the largest area that would be anticipated for a given average recharge rate to the aquifer and average discharge rate of a well because the land (contributing) area needed to sustain the discharge rate of the well decreases proportionately with contributions from ground-water storage.

The area of stratified drift necessary to supply a well with water may be determined from the discharge rate of the well and the recharge rate to the aquifer, if recharge from precipitation is the only source of water to the well. The discharge rate of the well (Q) is equal to the recharge area of the well (A) multiplied by the recharge rate to the aquifer (r). Therefore, the area necessary to recharge the well at its steady-state pumping rate is Q/r. This relation provides a simple means of determining if the recharge area delineated for a well is large enough to sustain its withdrawal rate.

Methods for delineating contributing areas

Analytical modeling

Several analytical models can be used to delineate contributing areas to public supply wells. These models require that simplifying assumptions be made about the ground-water system from which a well is pumping and the geometry of the well itself. These assumptions include simplifications or idealizations of aquifer boundary conditions, homogeneity of aquifer properties (such as hydraulic conductivity), and simplification of well design (such as a fully penetrating well screen). Several of these models are discussed by U.S. Environmental Protection Agency (1987), Morrissey (1987), van der Heijde and Biljin (1988), and Newsom and Wilson (1988) and need not be reviewed here.

The aquifer chosen for study is located in Eastham and the southern part of Wellfleet, Cape Cod, Massachusetts. The aquifer consists of stratified glacial outwash approximately 100 feet thick underlain by lacustrine silt and clay approximately 400 feet thick. These deposits are underlain by granitic bedrock. Precipitation which falls on the outwash is the only source of recharge to the aquifer; recharge has been estimated to be 17.4 in/yr (inches per year) (LeBlanc et al, 1986). Several ponds in the study area are in hydraulic connection with the aquifer and may be sources of water to wells located near them. A map of water-table altitudes for the aquifer (figure 2) indicates that ground-water flows from the central area of Eastham toward Town Cove, Cape Cod Bay, Blackfish Creek, and the Atlantic Ocean.

Contributing areas to two hypothetical supply wells completed in the aquifer underlying Eastham were delineated by superimposing (or subtracting) steady-state drawdowns determined using the Theim-Dupuit method (Kruseman and de Ridder, 1983) onto a map of prepumping water-table altitudes. The Theim-Dupuit equation is used to determine steady-state drawdowns in the vicinity of a fully penetrating well pumping from an unconfined aquifer. The Theim-Dupuit method of analysis was chosen for this study because the aquifer is unconfined and because

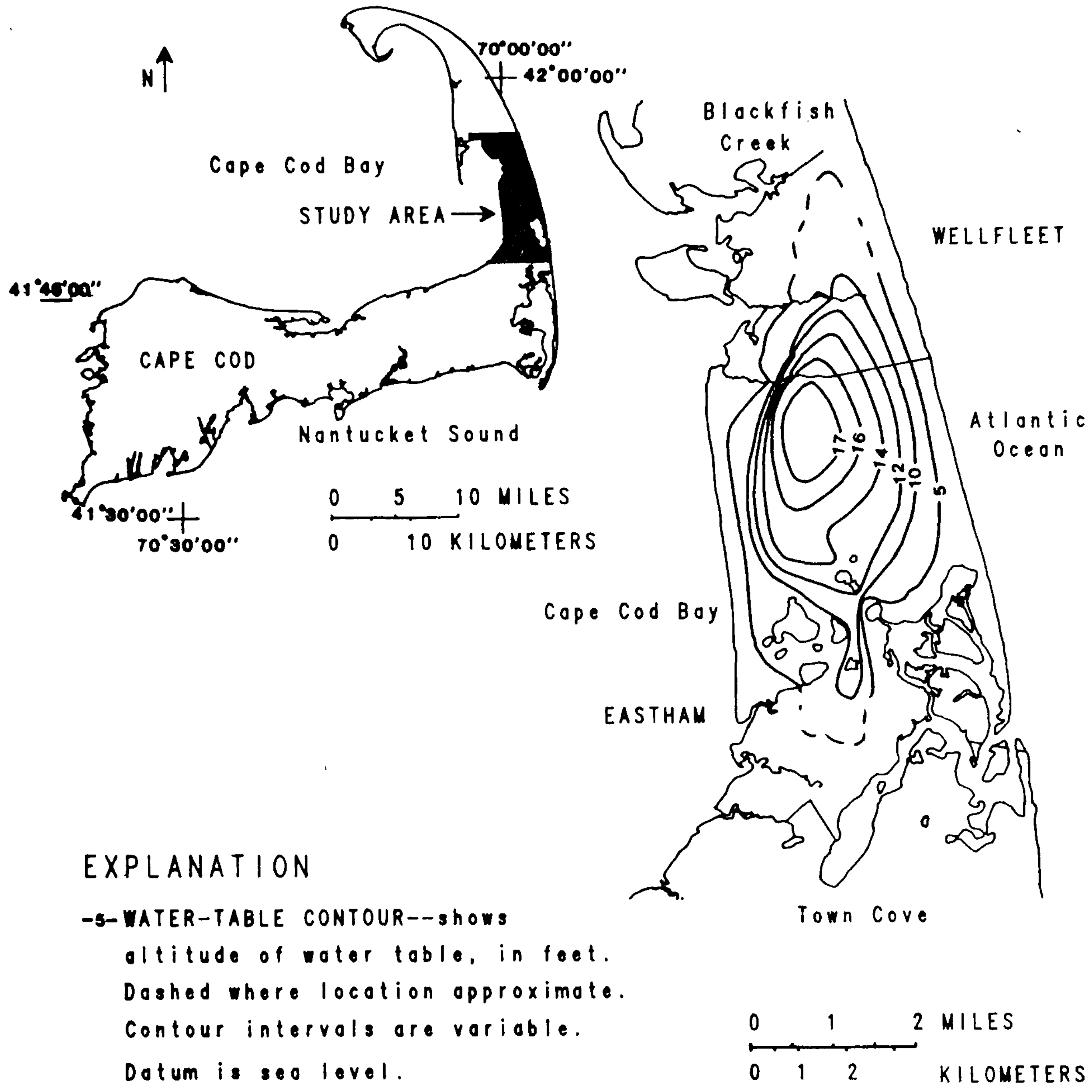


Figure 2. Location of study area and average water-table altitudes for the stratified glacial-drift aquifer of Eastham and south Wellfleet, Massachusetts.

there are no impermeable or surface-water boundaries that might influence the distribution of drawdowns in the vicinity of the wells. It was assumed that the pumping rate of well B would not cause a landward encroachment of the saltwater/freshwater boundary at the shore of the Atlantic Ocean, located 2,500 feet downgradient from the well, because the drawdowns were anticipated to be small for the simulated discharge rate of 0.5 Mgal/d (million gallons per day) and because a discharge rate of 0.5 Mgal/d is less than approximately four percent of the total discharge from the aquifer. The assumption that the saltwater/freshwater boundary is unaffected by pumping at well B might not be valid for increased discharge rates. Application of the Theim-Dupuit method to the determination of drawdowns produced by wells A and B requires that several assumptions be made. These are (Kruseman and de Ridder, 1983)--

(1) The aquifer is of infinite lateral extent, homogeneous, isotropic and of uniform thickness over the area influenced by the well;

(2) the water-table surface is nearly flat prior to pumping;

(3) the aquifer is pumped at a constant discharge rate;

(4) the well fully penetrates the aquifer and flow is horizontal and uniform everywhere in a vertical section through the axis of the well;

(5) the velocity of flow is proportional to the tangent of the hydraulic gradient;

(6) the aquifer is unconfined;

(7) flow to the well is in steady state; and

(8) a concentric boundary of constant head surrounds the well.

One further condition which must be specified in the Theim-Dupuit method is a radial distance from each pumping well at which drawdown is known. For this analysis, two distances were used at which drawdown was assumed to be equal to zero. The distances used were 2,300 feet and 11,500 feet. The first distance, 2,300 feet, was chosen because it is the distance required to intersect an area of stratified drift necessary to sustain the pumping rate of each well for the condition of a flat water-table surface prior to pumping, for a pumping rate of 0.5 Mgal/d and recharge rate to the aquifer of 17.4 in/yr. The second distance, 11,500 feet, which is five times the first distance, was chosen for comparison. It must be realized that the assumption of zero drawdown at these distances is simply a means to compute a rough approximation of drawdown within the cone of depression of each well, and is a limitation of the analytical model. In actuality, the cone of depression extends to the concentric boundary of constant head listed in assumption 8. Assuming a fictitious drawdown of zero at some distance from a supply well is an arbitrary assumption which might not be appropriate in many cases. The errors introduced by using this assumption should have a negligible effect on the pathlines used to delineate the contributing area for each well, for the assumption to be valid.

Drawdowns were calculated for several points in the vicinity of two hypothetical supply wells located in the aquifer. The well locations are shown in figure 3. Well A is near the crest of a natural recharge mound where the hydraulic gradients are very flat; well B is located between this ground-water mound crest and the discharge area of the Atlantic Ocean. Hydraulic characteristics used in the calculations of drawdown are given in Table 1. These characteristics were determined from well logs in the area of the hypothetical wells and from the results of aquifer tests that have been conducted in the stratified-drift deposits of Cape Cod, Massachusetts (Guswa and LeBlanc, 1986). Drawdowns were calculated at distances of 500; 750; 1,000; 1,250; 1,500; 1,750; and 2,000 feet from the pumped wells. Calculated drawdowns were subtracted from the map of prepumping water-table altitudes to produce new maps of water-table altitudes in the vicinity of each well (figure 3). Contributing areas were delineated by constructing a flow net near each supply well. Flow lines were drawn perpendicular to lines of equal water-table altitudes because the aquifer was assumed to be homogeneous and isotropic (Freeze and Cherry, 1979).

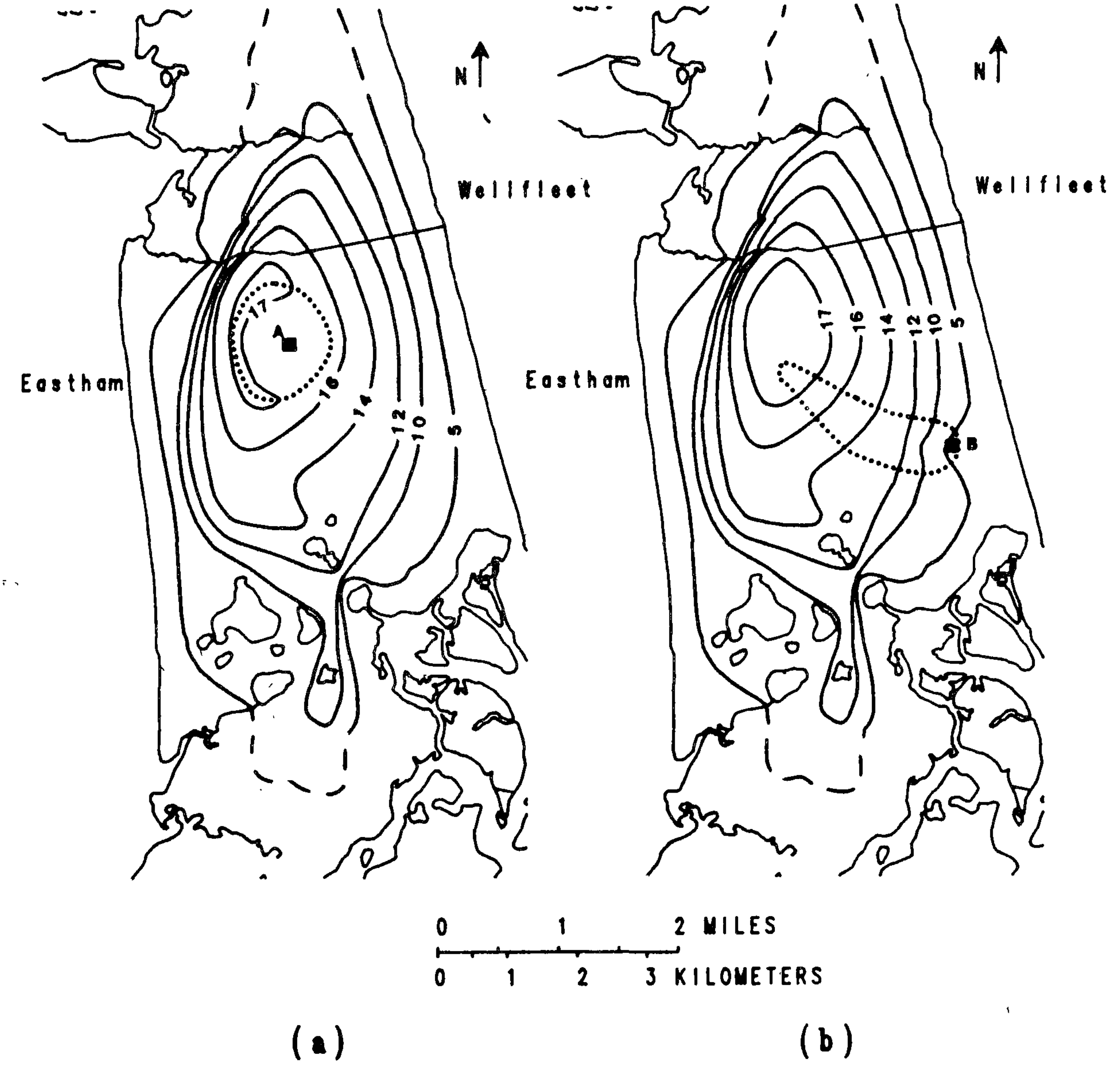
Table 1.--Parameters used in the determination of drawdown for wells A and B using the Theim-Dupuit method.

Hypothetical well	A	B
Horizontal hydraulic conductivity (ft/d)	150	170
Aquifer thickness (ft)	81	46
Transmissivity (ft^2/d)	12,150	7,820
Discharge rate at the well (Mgal/d)	0.5	0.5

Contributing areas for the two wells determined using the analytical model are shown in figure 3. The drawdowns computed using the two assumed distances to zero drawdown differed in each of the two hypothetical cases. However, the differences between the drawdown determined using each of the two assumed distances were not great and did not affect significantly the delineation of contributing areas to each well. The contributing areas determined using each of the assumed values did not differ significantly because the accuracy of the hand-generated pathlines was insensitive to the differences in these drawdowns. Figure 3 shows only the results for the radius of influence equal to 2,300 feet. The results indicate that the shape of the contributing areas are strongly dependent on the location of the well in the aquifer. The contributing area delineated for well A, near the crest of the recharge mound, is ovoid-like in shape; water is captured about equally from all areas around the well. The contributing area delineated for well B, located between the crest of the ground-water mound and the discharge areas of the aquifer, is elongate in shape; water is captured primarily from areas which lie upgradient from the well.

Numerical modeling and particle tracking

Numerical ground-water flow models have been used extensively for the conceptual and quantitative analysis of ground-water flow, including the delineation of contributing areas to public supply wells. Numerical models are used to determine ground-water heads at specified locations within a simulated aquifer. Ground-water flow nets then are constructed from these computed heads to delineate a well's contributing area. The construction of a two-dimensional ground-water flow net for a three-dimensional flow problem is a time-consuming task that may yield inaccurate results because it is necessary to ignore flow in the third dimension.



EXPLANATION

—5— WATER-TABLE CONTOUR--shows altitude of water table, in feet. Dashed where location approximate. Contour intervals are variable. Datum is sea level.

········ Contributing area determined using analytical model.

■ Location of hypothetical supply well.

Figure 3. Water-table contours and contributing areas for hypothetical supply wells A and B, each pumped at 0.5 Mgal/d, determined using an analytical model.

Particle tracking offers a relatively simple yet quantitatively powerful alternative to the construction of ground-water flow nets. Particle tracking is the tracing of fluid particle pathlines through a ground-water-flow system over time (Pollock, 1988). The steps in the mathematical determination of pathlines are as follows: A numerical flow model is used to compute ground-water heads at individual cell nodes within a simulated aquifer. These nodal values of head are used to compute intercell flow rates by Darcy's Law; ground-water-velocity vectors derived from these flow rates may be computed for every point in the flow field. Pathlines are then determined from the ground-water-velocity vectors.

Particle-tracking algorithms differ in their method of determining ground-water-velocity vectors. Pollock (1988) has developed a semianalytical particle-tracking algorithm for use with block-centered, finite-difference, ground-water-flow models, and has written a computer program based on this algorithm for use with the modular ground-water-flow model of McDonald and Harbaugh (1988). The mathematics of the particle-tracking algorithm may be found in Pollock (1988).

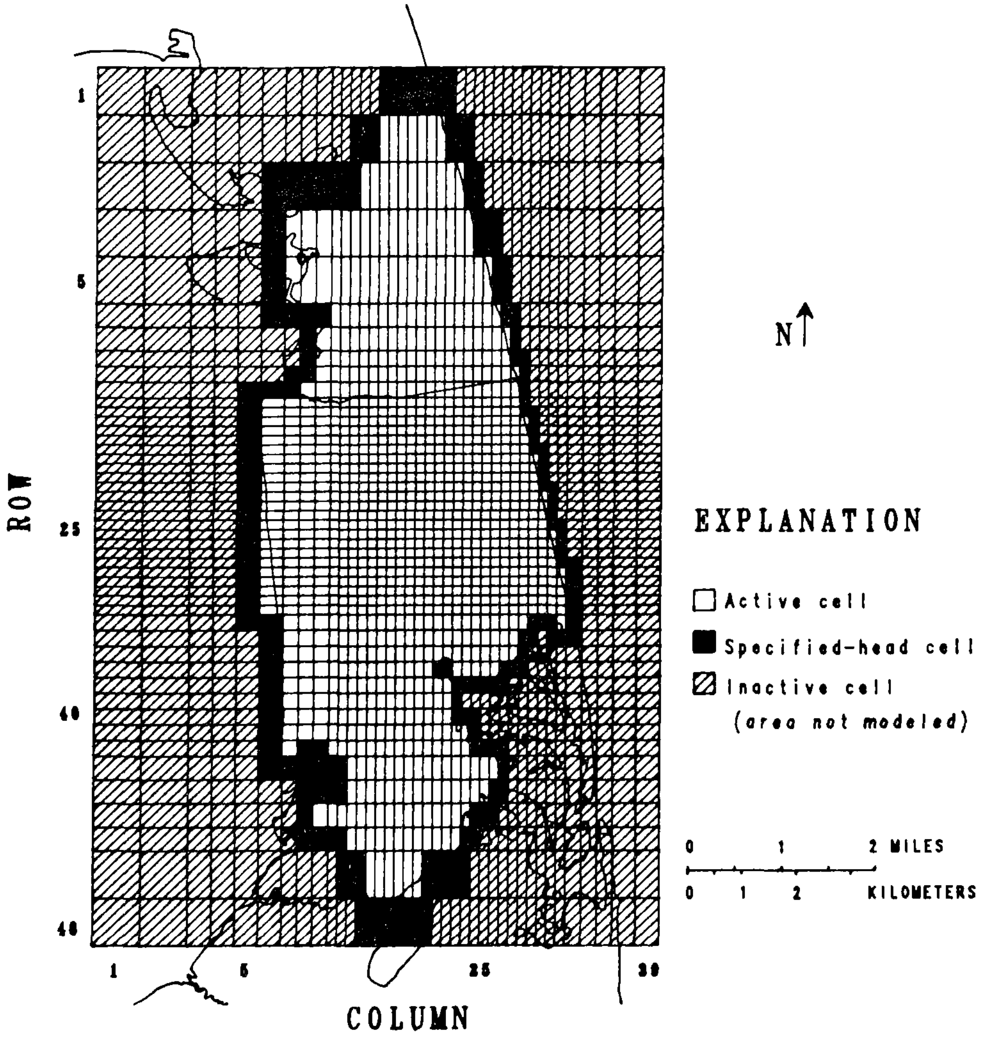
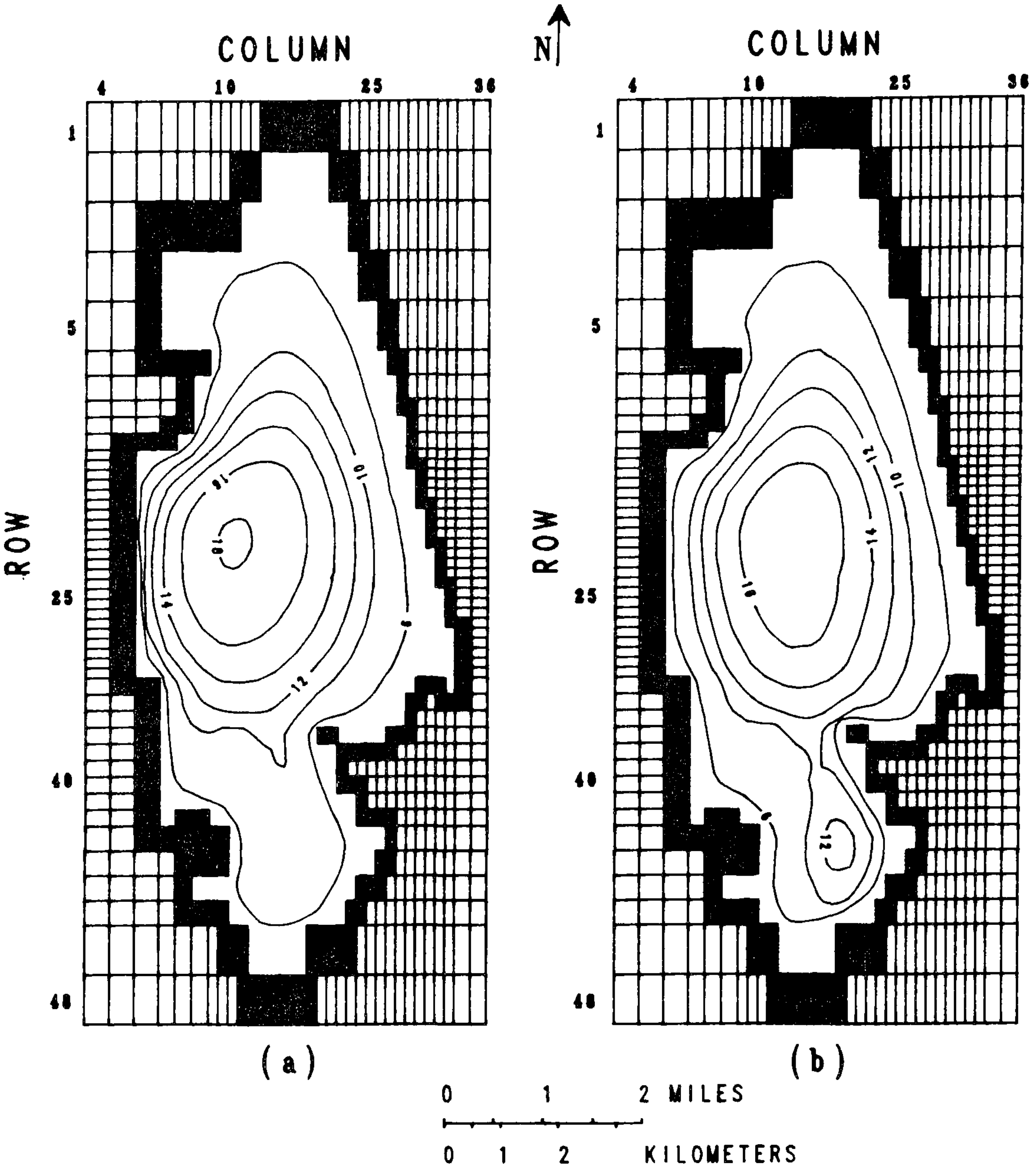


Figure 4. Grid and boundary conditions for the two-dimensional and top layer of the three-dimensional ground-water flow models.



EXPLANATION

—5— CALCULATED WATER-TABLE CONTOUR--Shows altitude of calculated water-table altitude, in feet. Datum is sea level.

■ Specified-head cell.

Figure 5. Calculated water-table altitudes for (a) two-dimensional model and (b) layer 1 of three-dimensional model.

Two-dimensional and three-dimensional ground-water flow models were developed for the unconfined aquifer of Eastham and south Wellfleet, Massachusetts (figure 4) to demonstrate the use of numerical modeling and particle tracking for the delineation of contributing areas to supply wells located in stratified glacial-drift aquifers, and for comparison to the analytical model results described previously. The three-dimensional flow model consists of 5 layers, with 48 rows and 39 columns of grid cells in each layer. The simulated aquifer is bounded laterally by specified-head cells in the top layer and by no-flow boundaries in the four lower layers; it is bounded on the bottom by a no-flow boundary. The two-dimensional flow model consists of a single layer, with 48 rows and 39 columns of grid cells. The single layer, two-dimensional model is bounded laterally by specified-head cells and vertically by a no-flow boundary. Each of the models is bounded on the top by a water table that receives a uniform rate of recharge from precipitation.

The models were calibrated using average ground-water altitudes measured in 16 observation wells and by 7 pond gages in the study area during 1963-88. Horizontal and vertical hydraulic conductivities were estimated from the lithologic logs of several test holes completed in the aquifer. Values of hydraulic conductivity were varied both horizontally and vertically within the simulated aquifer. Initial estimates of hydraulic conductivity and recharge to the aquifer were modified during calibration to obtain a root-mean-square error between observed and simulated ground-water altitudes of 0.8 feet for the two-dimensional model and 0.9 feet for the three-dimensional model. These mean errors are consistent with the accuracy of the map of water-table altitudes made for the study area and with the level of understanding of both the distribution of hydraulic conductivity within the aquifer and recharge rate to the aquifer; additional calibration could not be justified on the basis of available data. Ground-water altitudes determined for the top layer of each model are shown in figure 5. The similarity of these simulated water-table altitudes with those shown in figure 2 is clearly evident.

Contributing areas to two hypothetical supply wells, shown in figure 3, were delineated using the particle-tracking computer program for both the two-dimensional and three-dimensional ground-water flow models. Particles were placed at the water table of the simulated aquifer and their pathlines traced through the model. The area defined by the starting locations of particles that reach a particular supply well constitutes the well's contributing area. Several simulations were completed to demonstrate the value of the technique in the analysis of a multilayered stratified-drift aquifer with multiple pumped wells.

In the first six simulations, each well was pumped individually at three separate pumping rates, 0.25 Mgal/d, 0.50 Mgal/d, and 1.0 Mgal/d (figure 6). The results of the particle-tracking analysis indicate that the size of a well's contributing area depends on the pumping rate at the well. Recharge from precipitation to the stratified drift is the only source of water to these wells; therefore, the area necessary to supply each well with water is equal to Q/r. This relation was verified for each simulation directly from the results of the particle-tracking program. The simulations also agree with the observation made from the results of the analytical model that the shape of a well's contributing area depends on the location of the well with respect to the recharge and discharge areas of the aquifer.

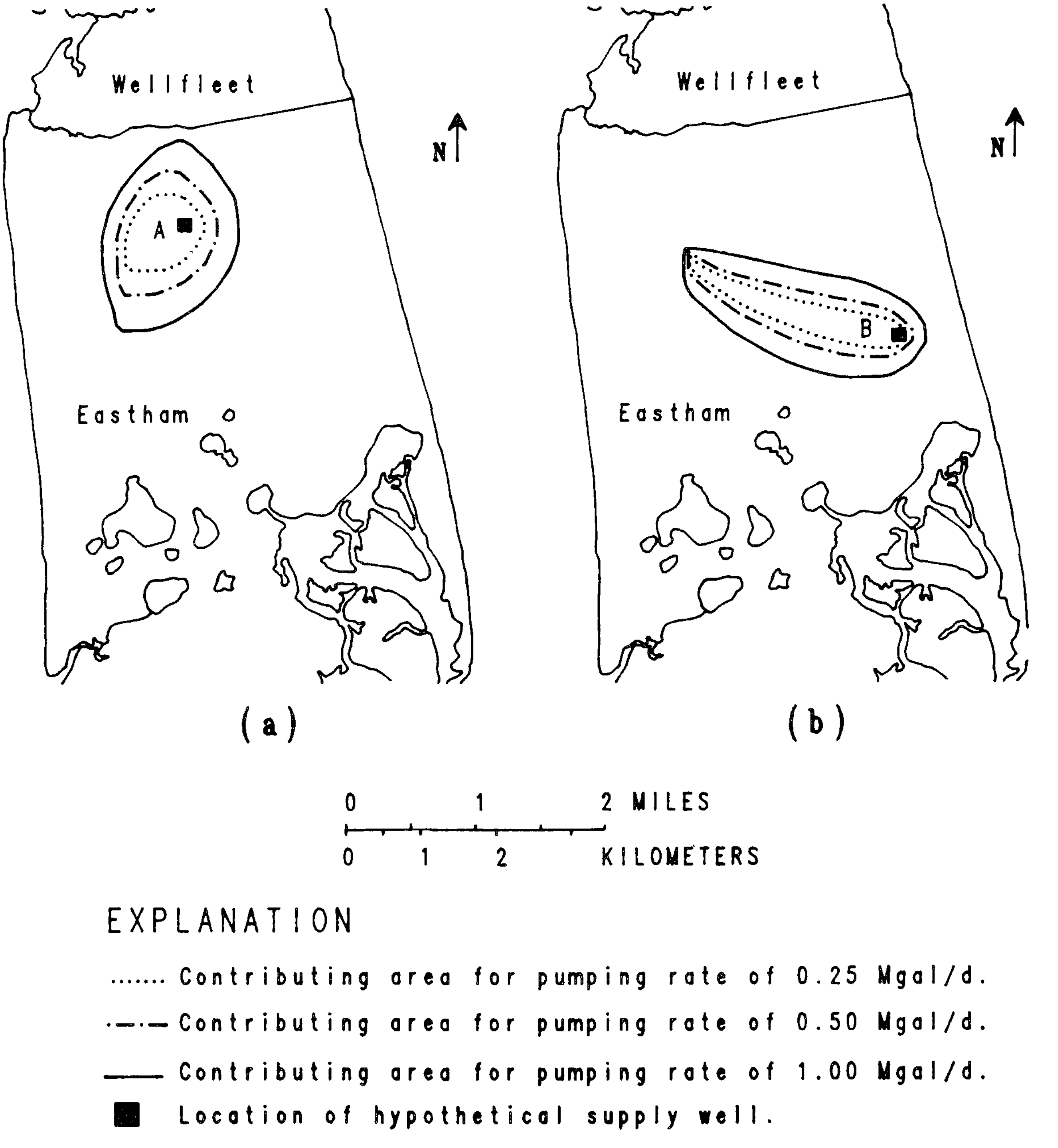


Figure 6. Contributing areas for pumping rates of 0.25 Mgal/d, 0.50 Mgal/d and 1.00 Mgal/d for (a) well A and (b) well B, determined using the two-dimensional ground-water-flow model.

The values of hydraulic conductivity and aquifer recharge used in the development of a ground-water-flow model commonly are only best estimates of the true field value. One way of evaluating the effects of uncertainties in the estimates of these properties to the delineation of contributing areas is to complete a series of simulations in which the value of each property is varied over what is felt to be a realistic range of values. As an example, three simulations were run using the two-dimensional numerical model in which the recharge rate to the aquifer was varied from 75 to 125 percent of the calibrated value (figure 7). Because recharge from precipitation is the only source of water to the well, the size of the well's contributing area is directly dependent on the value specified for recharge. Figure 7 indicates that the value of aquifer recharge specified in the model has a significant effect on the area that contributes water to the well.

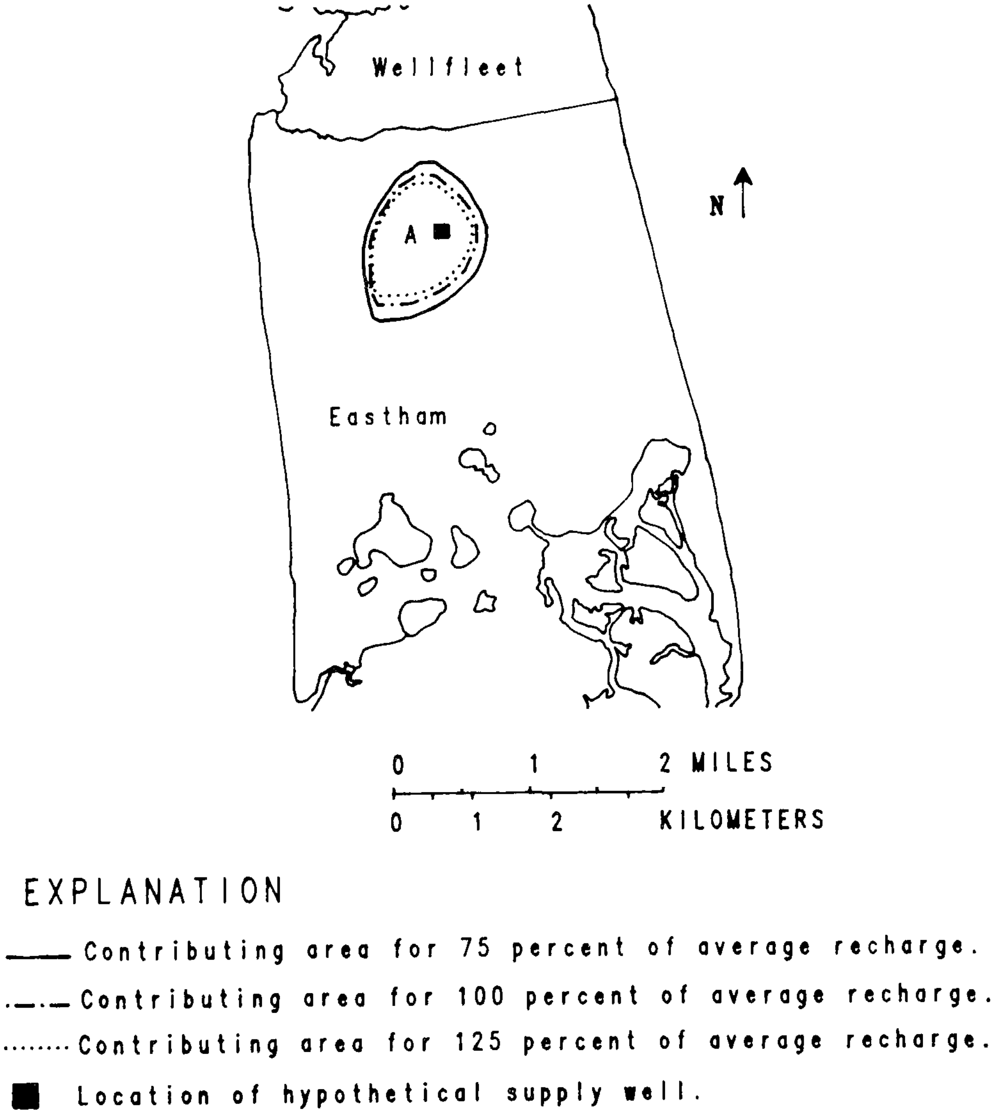


Figure 7. Contributing areas to well A for recharge rate to the aquifer equal to 75, 100, and 125 percent of calibrated model value, determined using the two-dimensional ground-water flow model.

In order to investigate the effects caused by multiple pumped wells to the delineation of recharge areas, a two-dimensional simulation was run in which both wells A and B pumped simultaneously at a rate of 0.5 Mgal/d. The results of the simulation are shown with the results of two simulations in which each well was pumped individually at a rate of 0.5 Mgal/d (figure 8). The results indicate the importance of considering simultaneously the effects of multiple wells on the delineation of contributing areas. Contributing areas to two or more supply wells can not overlap simultaneously because a particle of water that reaches the water table can flow either to one of the wells or to a natural discharge area of the system; it can not flow to more than one discharge point. The area of overlap in the contributing areas shown in figure 8a is not possible.

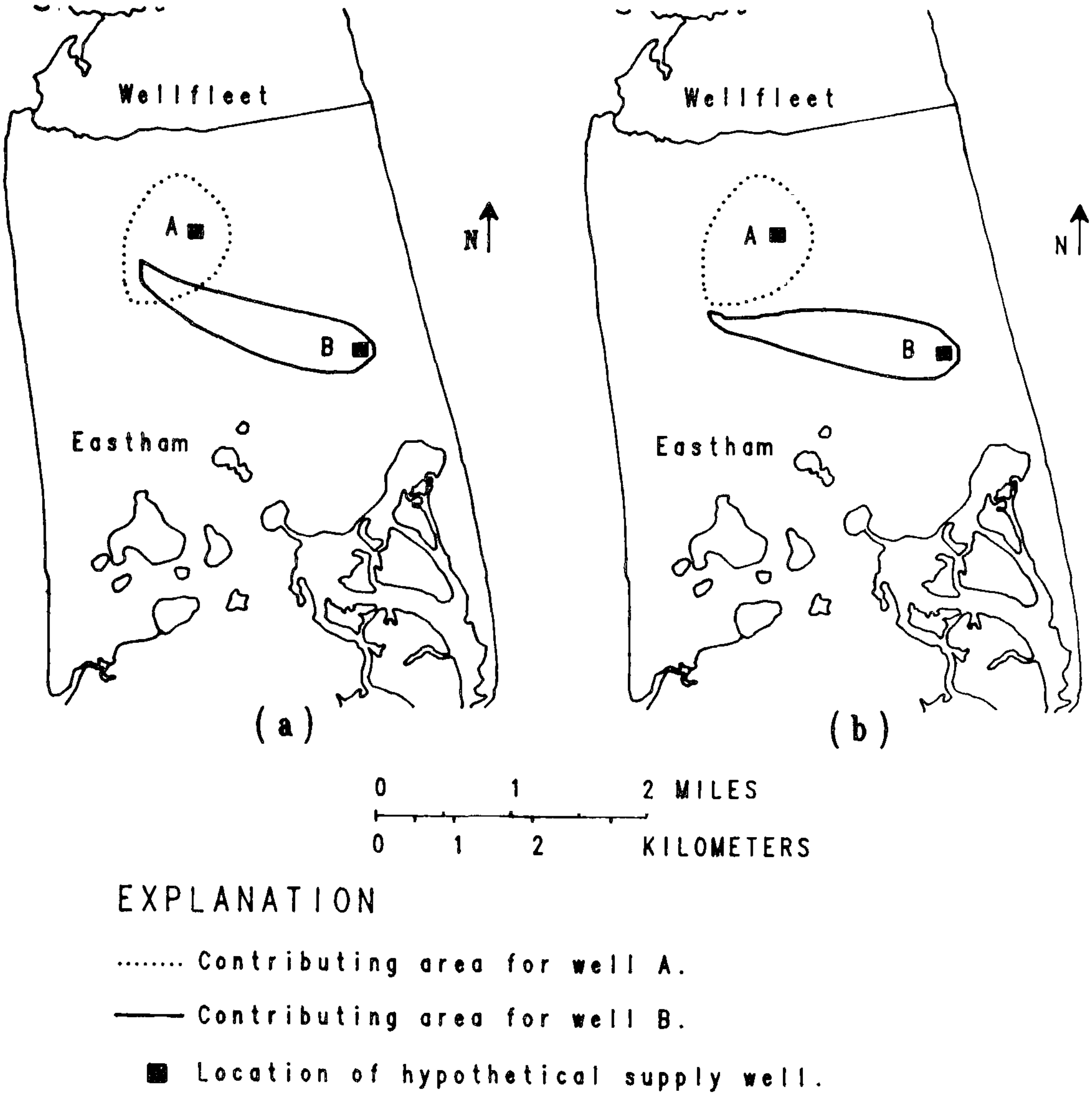


Figure 8. Contributing areas to wells A and B for (a) each well pumped independently at 0.5 Mgal/d and (b) both wells pumped simultaneously at 0.5 Mgal/d, determined using the two-dimensional ground-water flow model.

Vertical and horizontal heterogeneities in aquifer properties can have a significant effect on ground-water flow, and, therefore, would be expected to have an effect on the location and shape of a supply well's contributing area. The effect of aquifer heterogeneity to the delineation of contributing areas was investigated using the three-dimensional numerical model by introducing a discontinuous zone of material of low hydraulic conductivity, representative of clay, in the vicinity of well B (figure 9). The simulated layer of clay was placed in layer 2 of the model. The screened interval of the supply well was located in layer 3 of the model and the well was pumped at a rate of 0.5 Mgal/d.

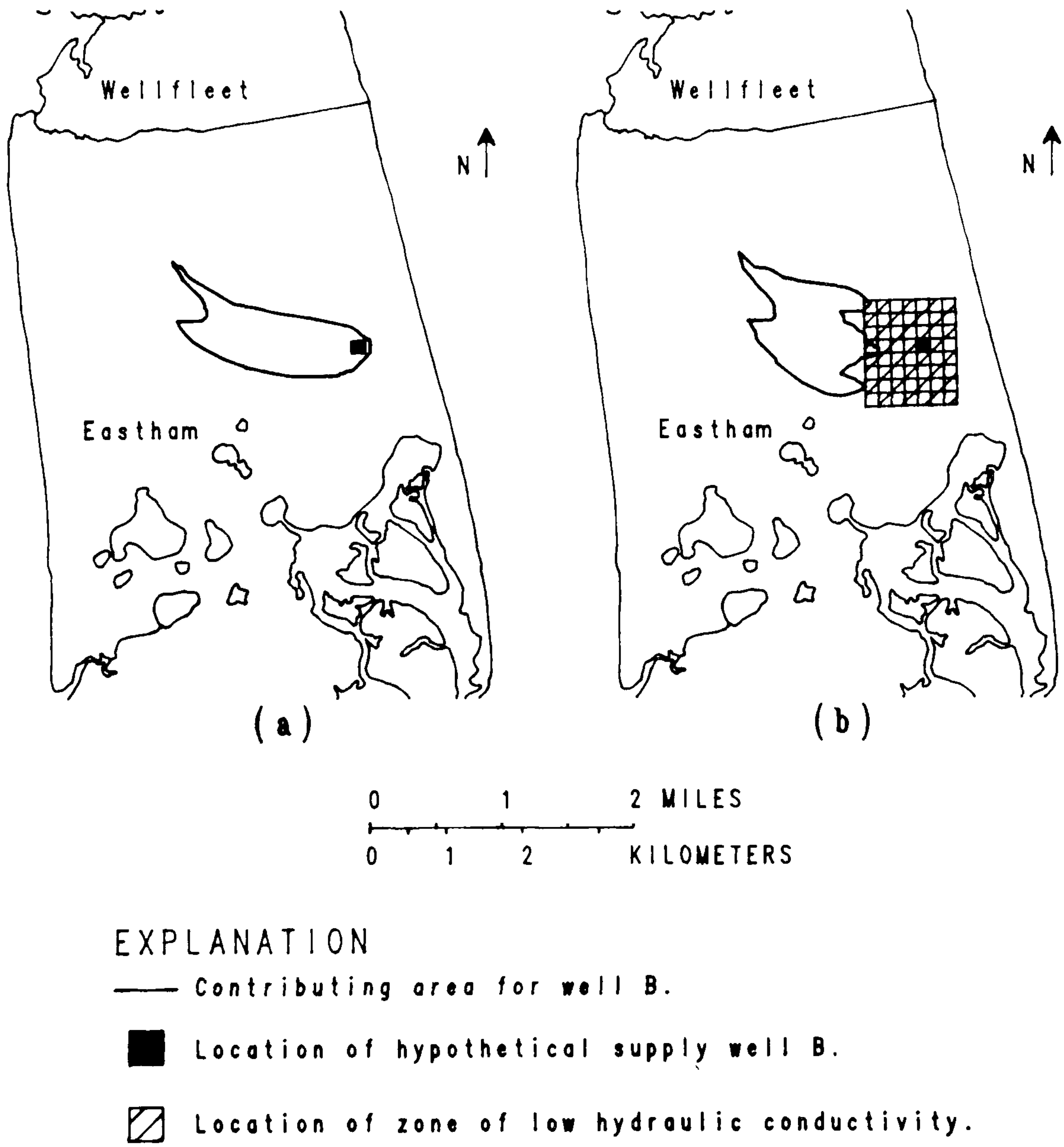


Figure 9. Contributing areas to well B, for (a) simulation of the natural system, and (b) simulation of a zone of clay in the vicinity of the well. Pumping rate is 0.5 Mgal/d.

The results of the simulation (figure 9) show that the surface layer contributing water to the well is greatly changed by the introduction of the discontinuous zone of clay, which diminishes the rate of vertical movement of water in the vicinity of the well. As can be seen in figure 9, the surface area that contributes water to well B does not surround the well. Water which reaches the water table in the vicinity of well B discharges to the natural boundary of the aquifer (the Atlantic Ocean) downgradient of the well. The bifurcation of the contributing areas shown in figure 9 is the result of spatial variations in both the horizontal and vertical hydraulic conductivities in the third and fourth layers of the model and the location of the eastern boundary of specified-head cells. Pathlines of particles initiated at the water table in the row of the model in which well B is located are also shown in cross section (figure 10). These pathlines indicate the vertical flow path that particles of water follow from the water table to discharge points at the well or the specified-head cells. The results of figures 9 and 10 point to the importance to the determination of a supply well's contributing area of defining accurately the lithology of an aquifer in the vicinity of the well.

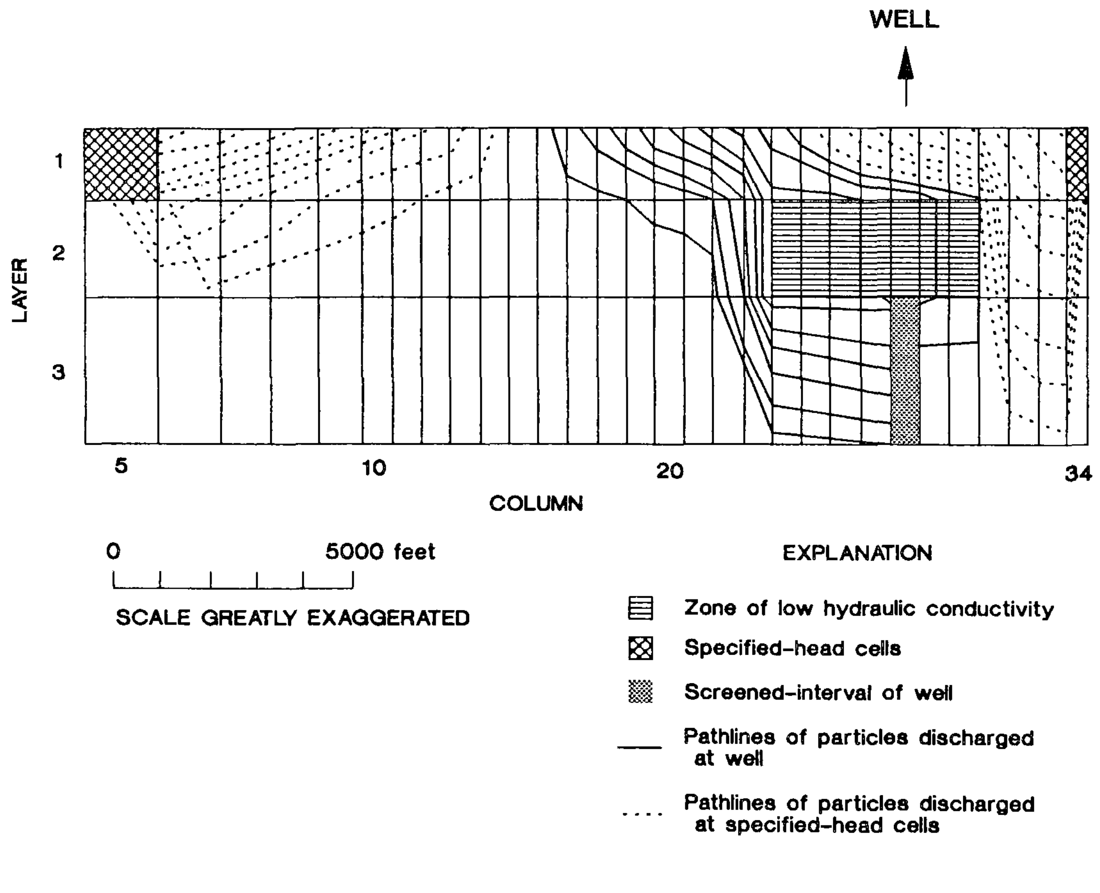


Figure 10. Cross-section of particle pathlines in row 28 for simulation in which a zone of low hydraulic conductivity overlies the screened-interval of well B. Pumping rate is 0.5 Mgal/d.

Evaluation of delineation methods

A comparison between the contributing areas delineated for the two hypothetical supply wells using the analytical model and the calibrated two- and three-dimensional numerical models coupled with particle tracking is shown in figure 11. The differences in the contributing areas delineated using the three models are greatest at points farthest from the wells. The uniformity in the horizontal and vertical hydraulic conductivities of the upper layers of this aquifer produces similar results for the three methods. Part of the difference in the recharge areas delineated using the three models is the result of differences in the distribution of ground-water heads in each of the model aquifers. The map of water-table altitudes used in the analytical model was constructed from field data on ground-water heads. The water-table altitudes represent the average response of the ground-water system to recharge, given the geologic framework and natural boundary conditions of the aquifer. The distribution of heads simulated by the numerical models are somewhat different than the field-derived map of water-table altitudes because the models do not replicate exactly the real ground-water system. Uncertainties in the understanding of the geologic framework of the aquifer, recharge to the aquifer, and the boundary conditions of the aquifer result in a distribution of ground-water heads that is only an approximation of the natural system.

The three methods of analysis presented in this report for the delineation of contributing areas to public supply wells completed in stratified glacial-drift aquifers represent three levels of computational complexity that require increasing levels of data specification. Each of the techniques has several advantages and disadvantages which should be considered in the selection of a method of analysis.

The primary advantage to using analytical models of ground-water flow is that the models generally are computationally simple and require less data than do numerical models. Data requirements for the analytical model discussed in this report are a map of water-table altitudes, an estimate of the thickness and hydraulic conductivity of the aquifer, and the discharge rate of the well. The primary disadvantage of using analytical models is that they are based on simplifying assumptions of the ground-water flow system. For instance, the analytical model used in this report assumes that the aquifer is of infinite areal extent, homogeneous and uniform in thickness. Additionally, simple boundary conditions must be assumed, such as an impermeable boundary, an infinite boundary, or a fully penetrating river boundary. In this report, it was necessary to assume a distance at which drawdown produced by each well was known. Simplifications of the hydrogeologic framework and boundaries of the ground-water system may result in poor predictions of the contributing area to wells located in aquifers which are arealy and vertically heterogeneous or contain complex natural boundaries. However, for single wells pumping from uniform aquifers with simple boundary conditions, the use of analytical models may be justified. Inspection of figure 11 indicates that the delineation of contributing areas to wells pumping from a thin, single-layer, uniform aquifer, such as the aquifer underlying Eastham and south Wellfleet, is not greatly enhanced by the use of the more complex numerical models and particle-tracking algorithm.

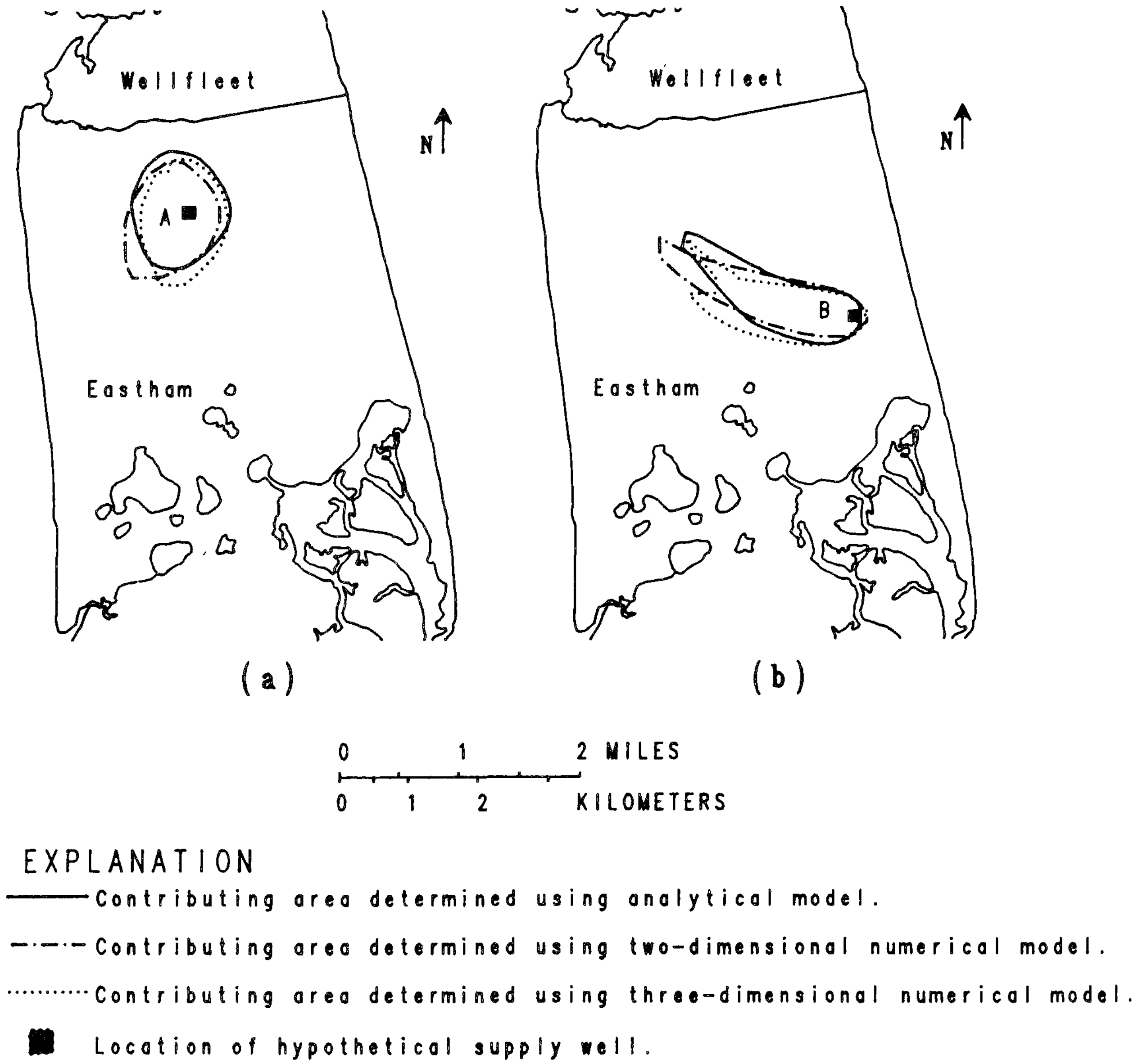


Figure 11. Comparison of contributing areas to (a) well A and (b) well B for pumping rates of 0.5 Mgal/d, determined using different modeling approaches.

Numerical ground-water flow models coupled with particle tracking offer a powerful computational tool for the analysis of supply-well contributing areas. The primary advantage of using numerical modeling and particle tracking is that these procedures provide a more detailed description than do analytical models of the factors that affect the location and shape of contributing areas for wells pumping from complex two- and three-dimensional aquifers. The disadvantage to the numerical methods is the large amount of data that must be specified. Data requirements include a map of ground-water altitudes for the aquifer, estimates of recharge rates and hydraulic parameters throughout the aquifer, the specification of aquifer boundary conditions, and the location and rate of withdrawal of supply wells. Furthermore, results of the numerical models are limited by the understanding of the hydrogeologic framework of the aquifer, the accuracy of the boundary conditions specified for the model, and the estimates of system properties. In effect, the numerical models determine an exact solution to a complex, yet ill-defined, two- or three-dimensional ground-water-flow problem. However, the numerical models are not limited by as many simplifying assumptions as are analytical models. The results of numerical models should improve an understanding of the aquifer under study, and, in particular, help to conceptualize the effect of a large-capacity supply well on ground-water flow. This study has shown that particle tracking is of considerable aid in the delineation of contributing areas in aquifers that are heterogeneous.

Summary

The delineation of contributing areas to public supply wells is an important component of State and Federal strategies for the protection of ground-water quality. The delineation of contributing areas requires first a conceptual and second a quantitative understanding of the ground-water flow system in which the well is located, so that predictions of the response of the system to the pumping of a large-capacity supply well can be made. The identification within the hydrogeologic environment of possible sources of water to a supply well is an important first step in the development of a conceptual model of ground-water flow in the study area and in the selection of a method of analysis for delineating a well's contributing area.

A recent advance in the ability to analyze quantitatively ground-water flow systems has been the coupling of particle-tracking algorithms to numerical ground-water flow models. A demonstration of the use of this method for the delineation of contributing areas to hypothetical supply wells pumping from a stratified glacial-drift aquifer of Cape Cod, Massachusetts, has shown that (1) the location of a well with respect to areas of recharge and discharge for the aquifer will have a significant effect on the shape of a well's contributing area, (2) the recharge rate to an aquifer and the pumping rate of a well will have a significant effect on the size of a well's contributing area, (3) multiple pumped wells within an aquifer must be considered simultaneously in the determination of a well's contributing area, and (4) the lithology of the aquifer in the vicinity of a well must be well defined.

The study also has shown that contributing areas determined using analytical modeling were similar to those determined using numerical modeling coupled with particle tracking for wells pumping from a thin, single-layer, uniform aquifer with simple boundary conditions, and that the use of numerical models for the delineation of contributing areas for wells in such an aquifer may not be warranted. However, numerical modeling and particle tracking provide a more powerful quantitative tool than do analtyical models for conditions normally encountered in the field, such as thick, heterogeneous aquifers with complicated boundary conditions in which several wells are pumped simultaneously. Under these conditions, analytical models are not capable of providing sufficient detail to predict accurately the land area that contributes water to a well.

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DEVELOPMENT OF AQUIFER PROTECTION ZONES AND EVALUATION OF CONTAMINATION POTENTIAL IN TOWN OF CHELMSFORD MUNICIPAL WELLS

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Abstract

The Town of Chelmsford, Massachusetts, obtains its entire municipal water supply from 22 groundwater wells. Periodic testing since 1979 has detected trace concentrations of volatile organic compounds in nearly all of the Town's municipal well fields, with concentrations in excess of 50 ppb (total volatile organics observed) in some wells. As a pilot study for protecting public water supplies in developed towns in the Commonwealth of Massachusetts, the Department of Environmental Protection (DEP) assigned Wehran Engineering the task of evaluating contamination that has been detected in Chelmsford water supply wells. The study focused on delineating aquifer protection zones around these wells, identifying potential past and present contamination sites in these areas, and prioritizing these sites with respect to their potential to impact the Town's water supply wells.

To provide a current assessment of the quality of Chelmsford's municipal water supply, all accessible wells (18 of 22) were sampled in June, 1987 and analyzed for volatile organic compounds. Analytical results at that time showed; a maximum of 15 ppb in one well, trace concentrations in two other wells, and either non-detectable, or below detection limit, concentrations of volatile organic compounds in the remaining wells.

Aquifer protection Zones I, II, and III were delineated for each of the municipal supply wells in conformance with Massachusetts Division of Water Supply Guidelines.

A records search was conducted to identify and locate potential past or present sources of contamination that might impact Chelmsford's municipal water supply wells. A total of 121 potential contamination sites were identified and located. Of these sites, none were located in Zone I areas, 81 were located in Zone II areas, and 40 in Zone III. An additional 69 sites were identified, but could not be located.

A ranking system was developed to prioritize sites in terms of their potential to contaminate municipal supply wells. The system is based on such factors as aquifer

protection zone designation, relative distance within a zone from a well, the types of chemicals potentially used, the volume of spills, and the ranking of watersheds according to the degree of contamination that has been detected in wells. The ranking system is designed to divide potential sites into groups, with each group assigned a priority ranking relative to one another.

The 121 potential contamination sites that could be located were prioritized using this ranking system. It was recommended that, in order to identify sources of contamination that are impacting Chelmsford's municipal supply wells, preliminary site assessments be conducted for potential sites in the highest priority groups. These assessments are likely to reveal that many of these sites can be reassigned to lower priority groups. Those sites, however, that are found to have a high potential for contamination will be recommended for additional site investigations.

The DEP has acted on these recommendations by completing preliminary assessments at over 15 of the highest priority sites. Based on the results of these assessments, the DEP is currently planning a site investigation (with the installation of monitoring wells and sampling of groundwater) at the highest priority site.

Introduction

Background

The Town of Chelmsford, Massachusetts, is an industrialized, suburban residential community that obtains all of its drinking water from groundwater. Periodic testing of groundwater in municipal supply wells since 1979 has detected trace concentrations of volatile organic compounds in nearly all of the Town's well fields. As a pilot study for protecting public water supplies in developed towns in Massachusetts, the Department of Environmental Protection (DEP) assigned Wehran Engineering the task of evaluating contamination that has been detected in Chelmsford water supply wells by delineating aquifer protection zones surrounding the Town's municipal supply wells, identifying potential past and present contamination sites in these areas, and prioritizing these sites with respect to their potential to impact the Town's water supply wells. Based on the results of this study, the DEP may conduct similar investigations in other Massachusetts Towns.

The Town of Chelmsford covers approximately 22.5 square miles in areal extent and is located in Middlesex County, Massachusetts. It is bordered to the north by the Towns of Lowell and Tyngsborough, to the west by Westford, to the south by Carlisle, and to the east by Billerica (Figure 1). In 1980, the population of Chelmsford was 31,174, and approximately 90 industrial building units were located in the Town.

Water in the Town is supplied by three privately owned water districts designated as; the East, North and Central Districts. All commercial and industrial users, as well as the majority of residents are supplied by these three districts. The remaining residents obtain water from private wells. Presently, the three Districts have a combined total of 22 supply wells (including one well (field) consisting of 49, 2-1/2 inch tubular wells). Of these 22 wells, the North District operates 4 wells, the East District operates 2 wells, and the Central District is responsible for the remaining 16 wells.

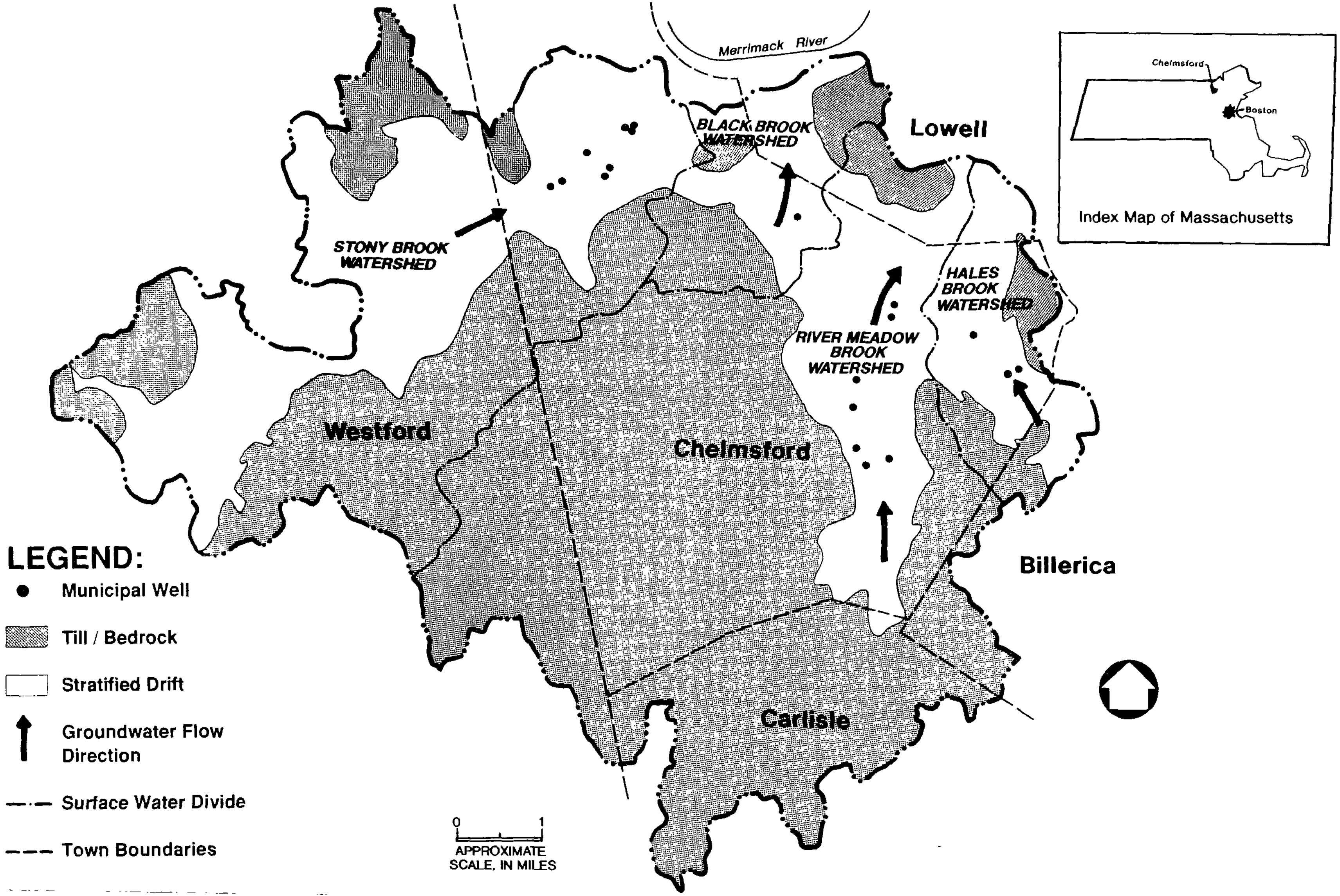

Figure 1. Site map showing Town of Chelmsford municipal water supply wells, associated watersheds, and distribution of stratified drift versus till/bedrock.

Laboratory analyses for volatile organic compounds in water collected from Chelmsford municipal supply wells have been performed since 1979. Volatile organic compounds (primarily chlorinated solvents) were detected in ten of the eleven well fields. The chemicals most commonly reported were trichloroethylene and tetrachloroethylene. In any given sampling round, volatile organic concentrations are typically on the order of one to two parts per billion (ppb), or none detected. In one well, however, a maximum of 340 ppb was detected.

Growth in the Town has been relatively uncontrolled with respect to allowing development in some of the more environmentally sensitive groundwater recharge areas. As a result, the contamination that is found in any one of the municipal supply wells could be attributed to a number of potential contamination sources.

Purpose and Scope

The purposes of this pilot study are to delineate aquifer protection Zones I, II, and III for each municipal supply well according to Massachusetts Division of Water Supply Guidelines, to perform a records search to identify and locate potential past and present sources of contamination in these zones, and to prioritize sites in terms of their potential impact on the Town's water supply wells. The scope of this investigation is limited to identifying contamination sources in only those areas that impact Chelmsford public water supplies. The identification of contamination sources is based solely on information obtained from the records search and does not include additional site investigation activities. Furthermore, the delineation of aquifer protection zones is based on available data only. Wehran identified significant hydrogeologic data gaps prior to initiating the investigation, however, Wehran and DEP agreed that it would not be cost- effective to acquire new data to fill these gaps. Rather, it was decided that Wehran would utilize existing data and make assumptions where necessary. These assumptions were made conservatively, so that the end result would be to increase the size of Zone II areas relative to Zone III.

Hydrogeologic Setting

The boundary of the study area is defined by the surface water divides surrounding the Town of Chelmsford's municipal wells/well fields, as obtained from drainage maps prepared by the U.S. Geological Survey (USGS) in Boston, Massachusetts, (Figure 1). This area covers approximately 45 square miles, and incorporates nearly the entire Town of Chelmsford, small portions of the Towns of Lowell, Billerica, and Carlisle, and a large portion of Westford. The study area is bordered to the north by the Merrimack River and is located entirely within the watershed of that river. Figure 1 shows the four major sub- basins, or watersheds, within the study area as defined by the USGS. The major streams within each watershed (from west to east across the study area) are Stony Brook, Black Brook, River Meadow Brook, and Hales Brook.

Groundwater in the study area occurs in three principle formations; 1) bedrock underlying the entire area, 2) till deposits which overlie bedrock throughout most of the area and which are exposed on hills and ridges (Baker, 1964), and 3) stratified-drift deposits which occur in valleys and on the lower slopes of hillsides.

Bedrock in the vicinity of Chelmsford is composed of a variety of Paleozoic igneous and metamorphic rocks. Because these rock types are relatively impermeable compared to the stratified-drift deposits, none of the Town's wells have been completed in bedrock. Individual wells completed in bedrock typically yield 2-10 gallons per minute (Brackley and Hansen, 1985).

Throughout most of the study area, bedrock is overlain by glacial till which has an average thickness of fifteen feet. Due to the poor sorting of the till, wells completed in these deposits generally yield less than 10 gallons per minute (Brackley and Hansen, 1985).

In terms of groundwater resource potential, the stratified- drift deposits are the most important stratigraphic unit in the Chelmsford area because they have much higher hydraulic conductivity than either the bedrock or till. All municipal supply wells in the Town of Chelmsford are screened in the stratified drift deposits. In addition, the majority of private wells in Chelmsford and surrounding towns are completed in this unit. Individual wells generally yield hundreds of gallons per minute (Brackley and Hansen, 1985). These deposits are generally sorted and stratified, and consist of sand and gravel with subordinate amounts of silt and some boulders. The stratified drift deposits occur in river valleys and range in thickness from less than one foot, where they pinch out against valley walls, to 140 feet in the pre-glacial channel of the Merrimack River.

The general direction of groundwater flow is from upland areas to the east, west, and south of the four major stream valleys towards the Merrimack River on the northern border of the study area (Figure 1). The altitude of the water table ranges from approximately 90 feet along the Merrimack River, to more than 250 feet at the western edge of the study area (Feldman, 1978). The depth to the water table is generally less than ten feet below land surface in low-lying areas and less than 30 feet below land surface in hilly areas (Baker, 1964).

According to the Water District Superintendents, safe yield for the wells/fields ranges from 250 to 700 gallons/minute and the average pumping rate for each well/field ranges from 250 to 850 gallons/minute. It should be noted that not all wells are continually pumping; in some cases a well is normally shut down while an adjacent well is pumping, and vice versa.

Available boring logs for 12 of the 22 wells indicate that all wells are water table wells, completed in an unconfined sand and gravel aquifer. Available pump test data in the vicinity of the wells indicate transmissivities ranging from approximately 3,350 to 15,000 squared feet/day, saturated thicknesses of 40 to 65 feet, and average hydraulic conductivities of 70 to 230 feet/day. The proximity of the wells to various streams suggests that, depending on their pumping rate, they may cause significant induced stream infiltration.

Current Groundwater Quality Assessment

One round of groundwater samples was collected from the Chelmsford municipal supply wells by Wehran personnel on June 1st and 3rd, 1987. The samples were analyzed for volatile organic compounds using USEPA Test Method 624.

The analytical results show that one well (the well with highest concentrations detected in the past) contains 15 ppb total volatile organics. Two other wells show trace levels (<10 ppb) of volatile organic compounds (defined as less than 10 times the detection limit), while the remaining wells contained either non-detectable, or below detection limit (1.0 ppb), levels of volatile organic contamination.

Delineation of Aquifer Protection Zones

The Massachusetts Division of Water Supply has established guidelines (1986) for the delineation of aquifer protection zones surrounding municipal supply wells, referred to as Zones I, II and III (Figure 2). Zone I areas are defined as those portions of aquifers which lie within a 400 foot radius of the wellbore. Because of their close proximity, contamination sites in these areas have the greatest potential impact on water quality in the wells.

Zone II is defined as "that area of an aquifer which contributes water to a well under the most severe recharge and pumping conditions that can be realistically anticipated. It is bounded by the groundwater divides which result from pumping the well and by the contact of the edge of the aquifer with less permeable materials such as till and bedrock. At some locations, streams and lakes may form recharge boundaries". The Guidelines specify the most severe recharge and pumping conditions as pumping at safe yield for 180 days without recharge. Under these conditions, the locus of 0.1 feet of drawdown is the predicted area of influence. These drawdowns are then subtracted from the pre-pumped water table configuration, and subsequent analysis of flow lines identifies the zone of contribution (Zone II area) for each well.

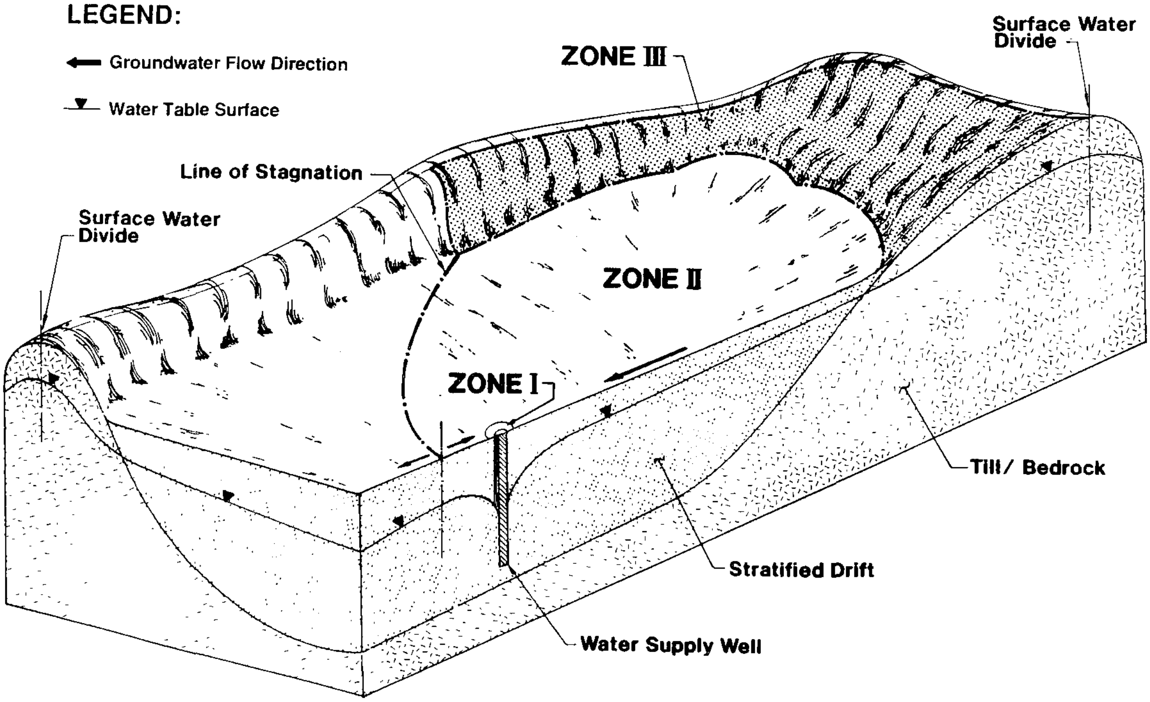

Figure 2. Conceptual block diagram of a stream valley illustrating Massachusetts aquifer protection zones I, II and III in relationship to a pumping well.

Zone III is defined as "that land area beyond the area of Zone II from which surface water and groundwater drain into Zone II. The surface drainage area as determined by topography is commonly coincident with the groundwater drainage area and will be used to delineate Zone III. In some locations, where surface and groundwater drainage are not coincident, Zone III shall consist of both the surface drainage and the groundwater drainage areas".

Using these definitions, the delineation of the outer boundaries of Zones I and II is relatively straight forward. After field verification of the well locations, a line drawn at a radius of 400 feet around each well defines the outer boundary of the Zone I area. The outer boundary of Zone III coincides with surface water divides for the tributary. This information was obtained from drainage maps prepared by the USGS.

The major effort associated with mapping aquifer protection zones is delineating the boundary between Zones II and III. Defining this boundary first requires locating the contact between the edge of the aquifer with less permeable materials (till/bedrock). This geologic contact was obtained from the Hydrogeologic Investigation Atlas of the study area (Brackley and Hansen, 1985) and is shown on Figure 1.

The identification of "that area of an aquifer which contributes water to a well under the most severe recharge and pumping conditions that can be realistically anticipated" requires an evaluation of groundwater flow to the well. Because numerous hydrogeologic variables affect groundwater flow, it is difficult to calculate this area manually. As a result, a digital computer model was developed to perform the calculations.

Two-dimensional groundwater flow models of the study area were designed and calibrated to compute hydraulic-head changes in the stratified-drift aquifer under natural and man-made stress conditions. For these models, Wehran utilized the USGS three-dimensional groundwater flow model (MODFLOW) developed by MacDonald and Harbaugh (1984).

The models use a finite-difference method in which differential equations that describe groundwater flow are solved numerically. The equations require definition of the geologic and hydrologic properties of the area modeled, the boundaries, and the pumping stresses.

The study area was divided into two regions to simplify the modeling effort. A finite-difference grid composed of equal size blocks (500 by 500 feet) was developed for all areas underlain by stratified drift deposits. The active modeled area covers approximately 14 square miles and includes over 1,500 active nodes.

Boring logs indicate that the stratified-drift deposits in both model areas are unconfined aquifers overlying much less permeable till and bedrock. As a result, although the computer model that was utilized has the capability of simulating a series of layers within the aquifer (i.e., a three-dimensional flow model), both areas were modeled as a two-dimensional single layer.

The groundwater flow models were calibrated under steady-state conditions. Calibration consisted of adjusting input hydrologic parameters to the model until differences in water table elevation between model simulations and a groundwater contour map of the area were within acceptable limits (i.e., within 10 feet over the majority of the modeled area). A sensitivity analysis of the steady-state models was then conducted to assess the limitations of the conceptual model and the uncertainty in the selection of input data values and boundary conditions.

After calibrating the models under steady-state conditions, several transient runs were made with each model to predict the areas of influence and zones of contribution for the wells as a result of a specific stress on the aquifers. This stress is defined by Division of Water Supply Guidelines as pumping at safe yield without recharge for 180 days. The computed steady- state heads for each model were used as starting heads for each transient run. All wells were pumped simultaneously, and at safe yield, to simulate worst-case conditions.

To evaluate the zones of contribution to the wells, the amount of drawdown caused by pumping the wells at safe yield (with no recharge) was subtracted from the observed heads, i.e., the average steady-state aquifer head distribution. On the downgradient side of the pumping wells, the creation of localized groundwater divides (lines of stagnation) where water flows back to the wells were predicted by the models. In these areas, the model predicts that pumping the wells will cause the natural gradient and direction of groundwater flow to be reversed causing groundwater to flow back towards the well, in a direction that is contrary to the "natural" regional flow (Figure 2). As a result, these local divides (lines of stagnation) form the downgradient margins of the zones of contribution (Zone II) where contaminated groundwater could potentially be directed towards the well. Analysis of flowlines was performed to extend the upgradient boundaries of these capture zones to the hydrogeologic contact between the stratified-drift deposits and till/bedrock. The zones of contribution (Zone II areas) are then defined as the areal extent of stratified-drift deposits upgradient of these boundaries. Inasmuch as the pumping stress was designed to simulate worst-case conditions (i.e., all wells pumping simultaneously) the zones of contribution were delineated for groups of wells as opposed to each individual well. Although this analysis produces larger zones of contribution than if each well were pumped separately, it provides a better simulation of aquifer protection as opposed to considering only wellhead protection.

The aquifer protection zones delineated in this study for the Town of Chelmsford's municipal water supply wells are shown on Figure 3. Zone I consists of the area within a 400 foot radius around each wellbore. Zone II areas begin at the outer margin of Zone I, and extend to the margin of the zone of contribution. The lines of stagnation defining the downgradient margin of the zones of contribution is shown on Figure 3 for various groups of wells. Zone III areas for each group of wells extends along flowlines from the outer boundary of Zone II (contact between stratified-drift with till/bedrock) to the watershed boundary. It should be noted that portions of Zones II and III overlap between the various groups of wells. Specifically, within a given watershed, the areas within Zones II and III for upgradient wells are included in the corresponding Zones of all downgradient wells. Therefore, moving downgradient within a given watershed, Zones II and III become successively larger as they incorporate the aquifer protection zones of all upgradient wells.

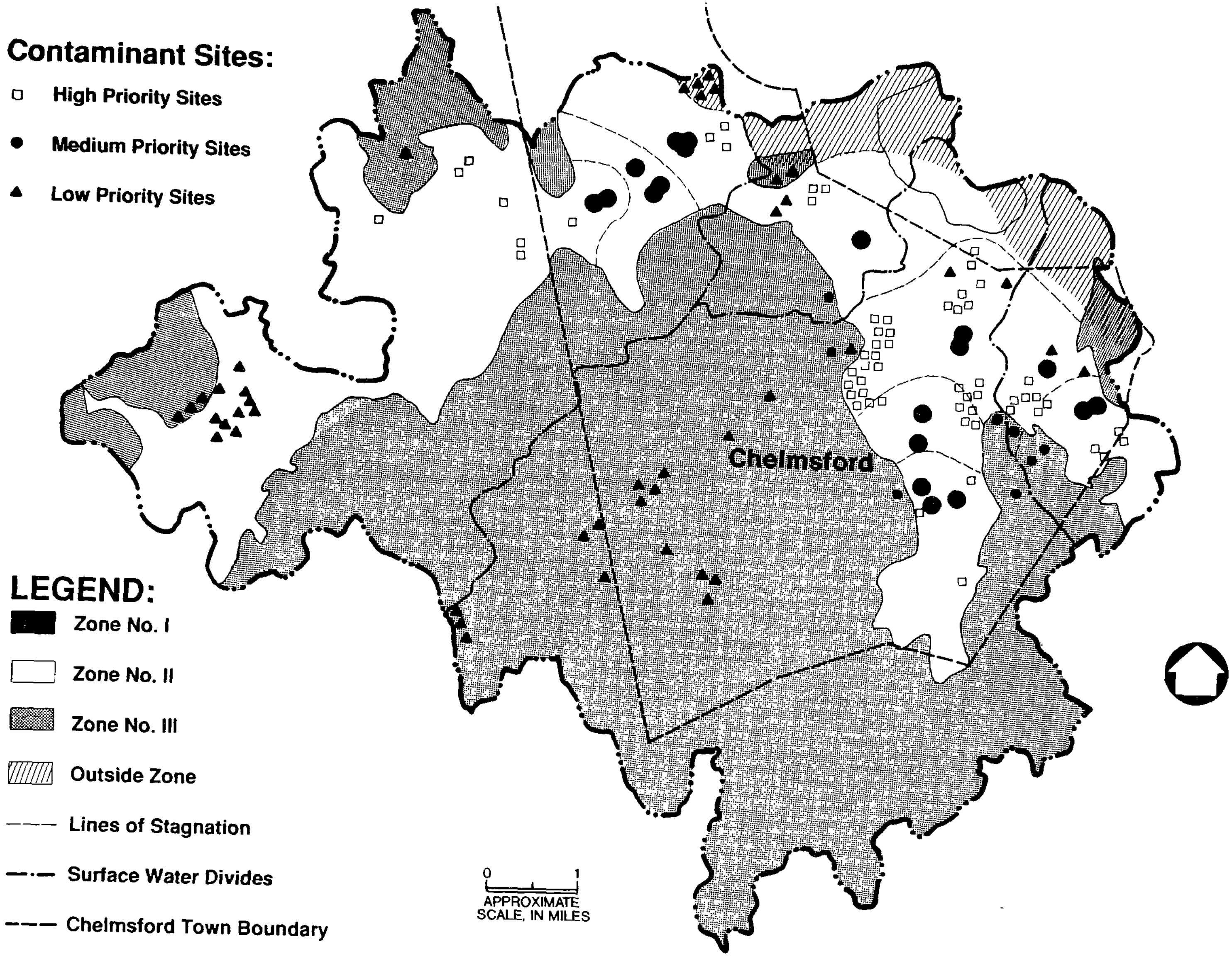

Figure 3. Site map showing potential contamination sites in relation to aquifer protection zones and associated lines of stagnation. For simplification, the 17 groups identified in the priority ranking system (Figure 4) have been assigned either a high, medium, or low priority as follows: high priority (Groups 1-7), medium priority (Groups 8-13), and low priority (Groups 14-17).

Identification of Potential Sources of Contamination

A records search was conducted to identify and locate past or present potential sources of groundwater contamination that may impact Chelmsford's municipal supply wells. This search addressed the area bounded by the watersheds of all the Town's municipal supply wells, which includes the majority of Chelmsford and portions of the Towns of Westford, Carlisle, and, Billerica.

The records search expanded upon a list that had been compiled by the DEP's Northeast Regional Office based on their files of hazardous waste violations/complaints. Wehran identified and located additional potential sites through interviews with Town employees, reviewing Federal, State and Town files, library searches, and a site reconnaissance survey. The site reconnaissance consisted of visual observations made while driving along various streets in the study area. It should be noted that no attempt was made to gain access to any potential sites that were identified.

A total of 121 potential contamination sites were identified and located. The majority of these sites fall into several broad categories; known spill sites, facilities with past hazardous waste violations, National Pollution Discharge Elimination System (NPDES) permit sites, landfills, industries or businesses that typically use hazardous chemicals (i.e., dry cleaners), and gas stations.

A table with brief descriptions of each potential contamination site was compiled; however, because the records search was based on available information, as opposed to site assessments, many site descriptions are incomplete. In particular, it often was not possible to identify the type of operation, the types of chemicals that were used and/or stored, or precisely when a facility was in operation.

A total of 69 potential contamination sites could not be located. The majority of these sites have gone out of business and documentation regarding their location was not readily available. An attempt was made to locate the more recent sites during the site reconnaissance survey.

It should be noted that because the organic compounds that have been detected in the water supply wells are chlorinated solvents, the records search placed less emphasis on types of operations that would utilize different types of chemicals. In particular, it was not considered cost-effective to attempt to identify the locations of all underground petroleum storage tanks in the study area.

Prioritization of Potential Contamination Sites

Priority Ranking System

The records search identified and located a total of 121 potential contamination sites which are distributed as follows; no sites in Zone I, 81 sites in Zone II, and 40 sites in Zone III. Because future site assessments may be conducted as a first step in eliminating these potential sources of contamination, a system has been developed to rank the sites in terms of their potential health impact on the Town's water supply wells. It should be noted that because chlorinated solvents are the types of compounds that have been detected in the water supply wells, the ranking system places higher priority on sites which may have potentially used chlorinated solvents. The system is designed to divide the sites into groups, with each group assigned a relative ranking, from highest (Group 1) to lowest priority (Group 17). The 69 additional potential contamination sites that were identified, but which could not be located were excluded from the priority ranking system.

Figure 4 is a flow chart which summarizes the ranking system. The first criteria used to rank the sites is the determination of whether they are located in Zones I, II, or III. Any site located in Zone I is assigned to the highest priority group (Group 1) because these sites are located within 400 feet of a well. In general, Zone II sites have the next highest priority, because they lie within the zone of contribution and there is a high potential for contaminants to flow into wells. However, as shown on Figure 4, several types of Zone II sites are considered to have lower priority than some Zone III sites. Such Zone II sites include those which are; 1) located more than 15,000 feet from any supply well because of the potential for substantial dilution and degradation of a contaminant release (Group 16), 2) highly unlikely to have used chlorinated solvents (Group 14), and 3) spill sites where very low volumes (less than 30 gallons) were released (Group 14).

The remaining Zone II sites are divided into Groups 2 through 7. These sites are first subdivided according to watershed, based on the amount of contamination that has been detected by laboratory analysis in water supply wells within a particular watershed. Past and present analytical data indicate that wells in the River Meadow Brook watershed have been more affected by contamination than wells in the other watersheds. Several wells in the Hales Brook and Stony Brook aquifers have shown minor contamination, therefore, Zone II sites in these watersheds have lower priority than Zone II sites in the River Meadow Brook watershed. Similarly, Zone II sites in the Black Brook watershed have lowest priority, because the one well in this watershed has shown only trace levels of contamination. Within each watershed, sites that are known to have used chlorinated solvents are assigned a higher priority than sites that have only the potential to have used these compounds. It should be noted that because of the limited nature of the data collected in the records search, for many sites it is not possible to rule out the potential for use of chlorinated solvents. For example, gas stations were included in these high priority groups because of the potential that chlorinated solvents were used in automotive repair work (degreasing, painting, etc.) Similarly, industries that use chlorinated solvents in the manufacture of certain products were included in high priority groups even though, in some cases, it is unknown whether the site was used for manufacturing, or purely retail purposes. A preliminary assessment that includes interviews with officials of various facilities may indicate that chlorinated solvents were never used at many sites, in which case those sites could be reassigned to a lower priority group.

Because of their location, some Zone III sites were given higher priority than the Zone II sites in Groups 14 and 16. The criteria used to select these Zone III sites was that they were located in close proximity to a Zone II boundary (less than 1000 feet), and within 10,000 feet of a water supply well. Within this category, those sites that were unlikely to have used chlorinated solvents, or which had spills of less than 30 gallons, were given a low priority ranking (Group 15). The remaining Zone III sites were then subdivided into Groups 8 through 13 using the same criteria that were applied to the Zone II sites.

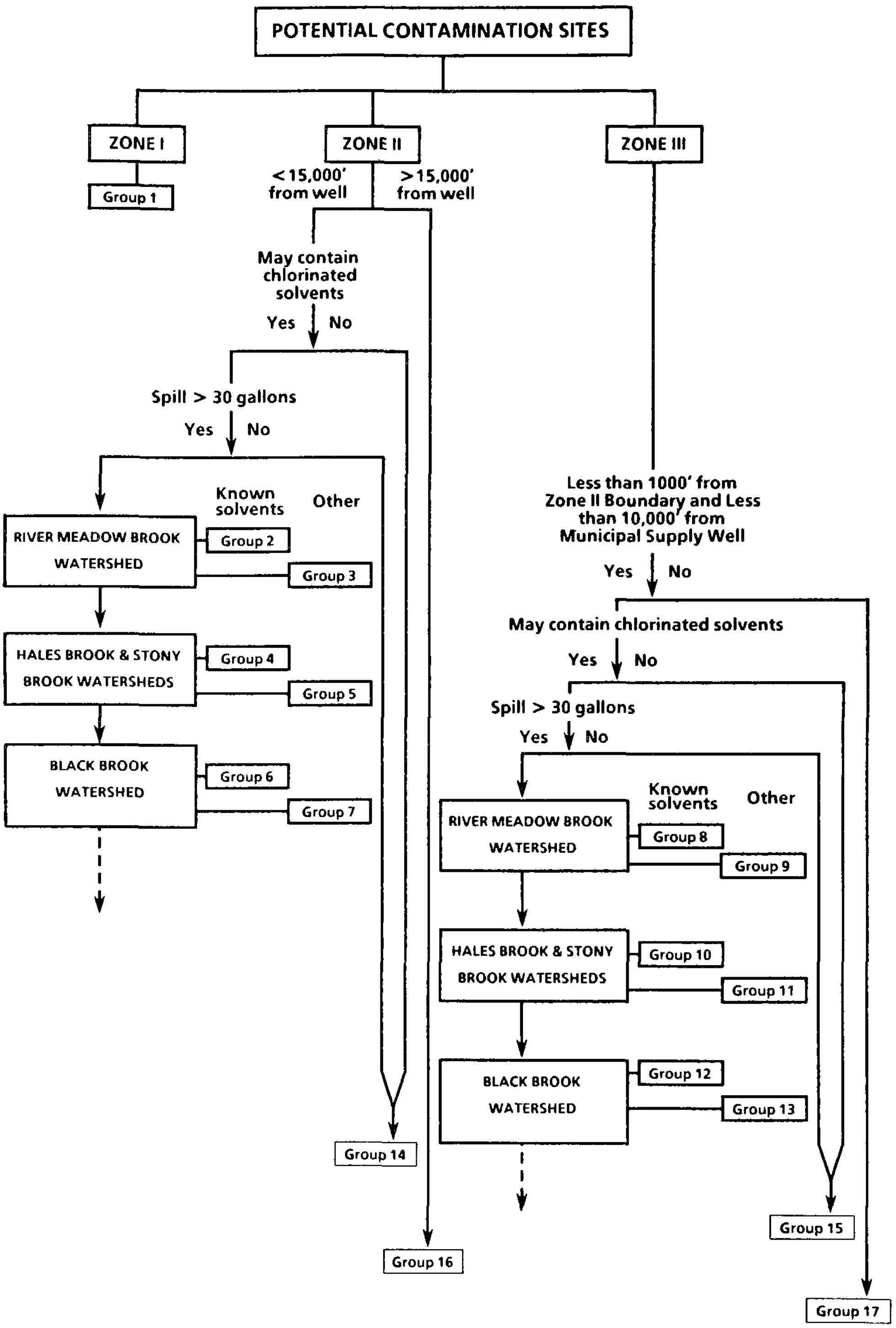

Figure 4. Flowchart of priority ranking system of potential contamination sites The system ranks respective sites from highest priority (Group 1) to lowest priority (Group 17).

Zone III sites located more than 1,000 feet from a Zone II boundary were assigned to the lowest priority group (17) because of their low potential to impact wells. In addition, Zone III sites located downgradient of lines of stagnation were assigned to the lowest priority group because groundwater in these areas will not flow toward the wells. These sites were included in the ranking, however, because they lie within the watershed and could impact future supply wells.

Results of Prioritization

The priority ranking of the 121 sites into the 17 groups was based solely on data obtained from the records search. Additional data which is subsequently obtained regarding a particular site may require an adjustment in the relative priority group to which a site has been assigned. Because of the limited nature of available data, a conservative approach was utilized in the ranking of sites so that in general, additional information will likely shift the priority ranking of many sites to a lower group.

To simplify the presentation of results, sites in the 17 priority ranking groups have been assigned either a high, medium, or low priority as follows: high priority (groups 1 through 7), medium priority (groups 8 through 13), and low priority (groups 14 though 17). As shown on Figure 3, all high priority sites are located in Zone II areas, however, some Zone II sites are ranked as low priority. In general, the majority of low priority sites are located in Zone III, or in a Zone II but many miles upgradient of municipal supply wells.

Summary and Conclusions

The objectives of this investigation were to evaluate contamination that has been detected in the Town of Chelmsford's municipal water supply wells by assessing the current quality of water in the wells, delineating aquifer protection zones around these wells, identifying potential past and present contamination sites in these areas, and prioritizing these sites with respect to their potential to impact the Town's water supply wells.

Eighteen of the Town of Chelmsford's twenty-two water supply wells were sampled and analyzed for volatile organic compounds. Analytical results showed that the highest levels of contamination were 15 ppm in one well, trace amounts of contamination in two wells, and the remaining wells contained either non-detectable, or below detection limit, levels of volatile organic contamination.

Aquifer protection Zones I, II, and III were delineated for the municipal supply wells (in conformance with Massachusetts Division of Water Supply Guidelines) using existing hydrogeologic data.

Well locations were field checked during collection of groundwater samples, to confirm the location of Zone I areas (400 foot radius around each wellbore). Zone II areas were delineated utilizing the USGS three dimensional groundwater flow model to predict the zones of contribution to the wells based on 180 days of continuous pumping with no recharge. Zone III areas were delineated through the use of the USGS Hydrologic Investigations Atlas of the area, USGS watershed boundary information, and the results of the Zone II analysis.

A records search was conducted to identify and locate potential past or present sources of contamination that might impact Chelmsford's municipal supply wells. A total of 121 potential contamination sites were identified and located. Of these sites, none were located in Zone I, 81 were located in Zone II, and 40 in Zone III. An additional 69 sites were identified, but could not be located.

A ranking system was developed to prioritize sites in terms of their potential to contaminate municipal supply wells. The system is based on such factors as aquifer protection zone designation, relative distance within a zone from a well, the types of chemicals potentially used, the volume of spills, and the ranking of watersheds according to the degree of contamination that has been detected in wells. The system is designed to divide potential sites into 17 groups, with each group assigned a priority ranking relative to one another. Using this system to rank the 121 potential contamination sites in Chelmsford indicated that some Zone II sites have lower priority than some Zone III sites.

Recommendations

Based on the results of this investigation, Wehran Engineering makes the following recommendations for additional work in the evaluation of the contamination potential of Chelmsford's municipal supply wells, and for the future protection of those wells and their associated aquifers.

1. To identify sources of contamination that are currently impacting Chelmsford's municipal water supply wells, preliminary assessments should be completed for all high priority sites. These assessments would consist of a records search, site visit, and possibly, interviews with officials of the facility. Because the ranking of sites was made conservatively using limited available data, it is anticipated that many of these high priority sites will be reassigned to lower priority groups based on the results of the preliminary assessments.

2. After conducting preliminary assessments, it is recommended that those sites that remain in high priority groups be further evaluated with site investigations. These investigations will include the compilation of a detailed site history with some sampling and analysis. The results of such an investigation will provide the data necessary to further evaluate whether a particular site is potentially impacting any of the Town's municipal supply wells and whether there will be a need for either monitoring or some form of remediation.

3. The Town of Chelmsford should utilize the aquifer protection zones that have been delineated in this study for future land use planning and water supply siting.

4. With regard to aquifer/wellhead protection, this pilot study should be expanded to include the following. First, there should be an educational program at the local level to explain the need for aquifer protection. Second, there should be coordination between various groups such as planners, lawyers, public health officials and water resource specialists in the development of groundwater protection strategies. These strategies would

typically involve modifying existing towns by- laws or creating new aquifer protection overlay districts. The intent of these by-laws would be to prohibit certain types of development or activities in the more sensitive groundwater recharge areas, or to place specific performance standards on those developments. Finally, this pilot program should be expanded to other industrial towns that are dependent upon groundwater resources. The same general approach used in this pilot study can be applied to other States that have different aquifer protection zoning systems, providing those systems are based on hydrologic principals.

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Biographical Sketches

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Donald W. Podsen is a senior geologist with Wehran Engineering Corporation in Methuen, Massachusetts, where he has been employed for four years. Before joining Wehran, Mr. Podsen worked in petroleum exploration with ARCO Alaska, for five years. He has a B.A. in geology (1977) from the University of Vermont and an M.S. in geology (1981) from the University of Colorado. Since working at Wehran, Mr. Podsen has been the project manager of numerous hydrogeological investigations of hazardous wastes. He is a Certified Professional Geologist with the American Institute of Professional Geologists.

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DETERMINING THE DEVELOPMENT POTENTIAL WITHIN WELLHEAD PROTECTION AREAS AND RESULTING IMPACTS FROM NITROGEN LOADING

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INTRODUCTION

Considerable progress has been made over the past decade concerning the delineation of wellhead protection areas (WHPA's). Protection zones based upon fixed radii have evolved into more accurate approximations of zones of contribution to pumping wellfields based upon sophisticated modelling approaches.

Protection strategies for WHPA's have included the development of overlay zoning districts within which specific potentially hazardous land uses are prohibited. Such uses may include landfills, industries or businesses using or producing hazardous materials, underground fuel storage tanks, sewage treatment plants, salt storage areas and so forth. Another common approach in protecting wellhead protection areas has been to require Environmental Impact Reports for large proposed development projects which exceed specific thresholds. Project proponents are usually required to evaluate potential impacts of such large-scale projects in excruciating detail.

Although these protection strategies are important, they do not address cumulative impacts of land development within wellhead protection areas over time. Ground water contamination from dispersed, non-point residential and agricultural uses can contaminate public water supplies as effectively as a poorly-sited landfill. A recent case study on Cape Cod, Massachusetts has documented a clear correlation between housing densities and nitrate-nitrogen concentrations in ground water (Nelson et al, 1988). See Figure 1.

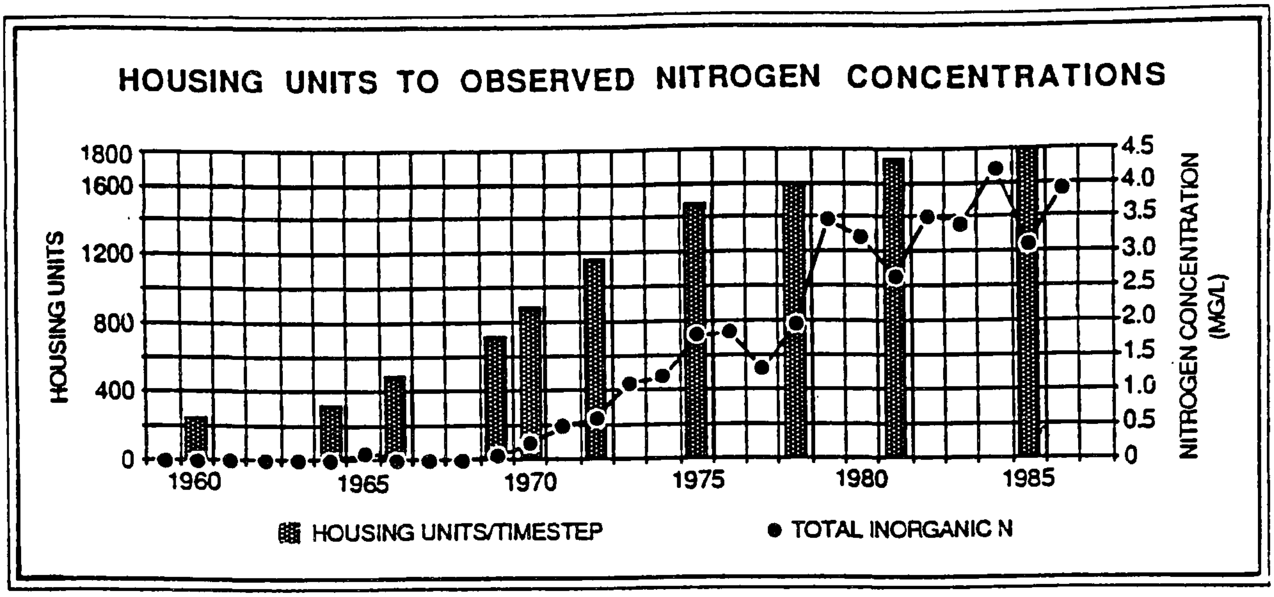


Figure 1

The approach which is outlined in this paper is a methodology for examining the cumulative effects of land development within WHPA's and is comprised of two principal steps: 1) determination of the development potential; and 2) prediction of the resulting nitrate-nitrogen concentrations.

DETERMINING THE DEVELOPMENT POTENTIAL

Clearly the first consideration in impact assessment within wellhead protection areas is the delineation of accurate wellhead protection area boundaries within which the analysis will be conducted. A variety of methods have been developed to accomplish this, ranging from drawing fixed radii around a wellfield, to mapping based on detailed hydrogeologic field investigations and modelling. An in depth discussion of appropriate delineation techniques is beyond the scope of this paper, however, the importance of an accurate delineation cannot be overemphasized. Delineation of wellhead protection areas based on fixed radii are not appropriate for assessing cumulative impacts; some site-specific hydrogeologic data are required for a meaningful analysis. In addition to existing public wellfields, potential water supplies and areas used extensively for private water supplies should also be considered in a comprehensive aquifer protection strategy.

Once an accurate understanding of the ground-water flow dynamics and the WHPA is developed an land use analysis must be undertaken. The land use analysis should first determine the type, intensity and distribution of existing land uses. This can best be accomplished utilizing assessors' tax maps, aerial photographs and field checking. This analysis is then supplemented by determining the development potential of all vacent parcels within the WHPA. This is done by evaluating the highest development potential of each parcel according to existing zoning, subdivision and other land use codes. Wetlands and soil limitations should be considered during this analysis. Certain parcels may have permanent conservation restrictions or easements as restricted open space and therefore should be considered undevelopable.

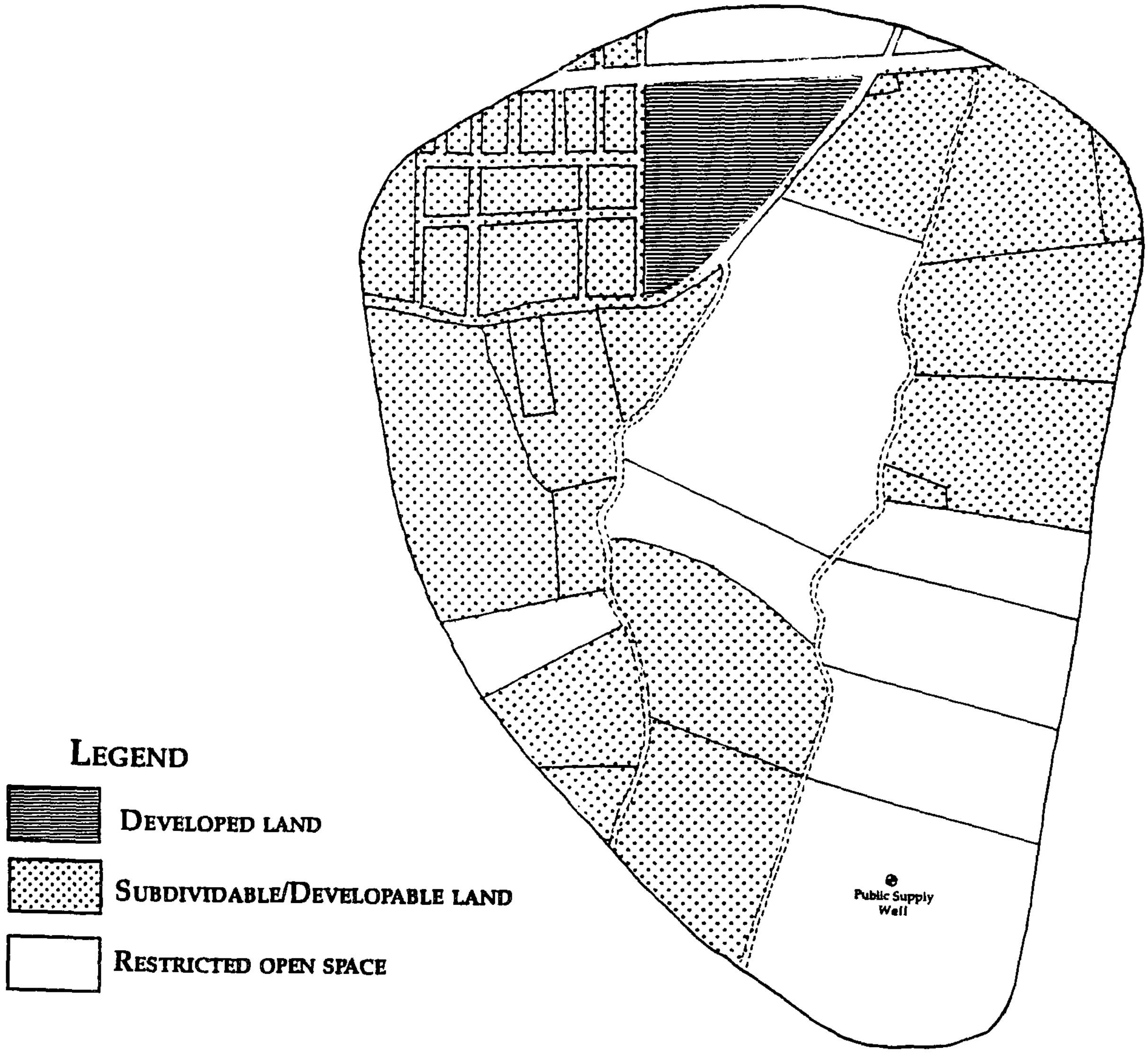
State land use enabling legislation throughout the country dictates that once a community programs itself through zoning and subdivision control, it is tied into a development "blueprint" which is difficult to alter. Unfortunately, this blueprint often allows for land development that exceeds the assimilative capacity of drinking water supplies with respect to a variety of contaminants, particularly nitrate-nitrogen.

A particularly difficult issue to resolve, in controlling land use within WHPAs is that of "grandfathered" lots. Most zoning bylaws and ordinances allow for significant protection of subdivided but still vacant land from proposed zoning changes. In Massachusetts, for example, once a preliminary subdivision plan has been filed with the local planning board, the property owner is protected from any new zoning changes for a period of 7 years. If during that time, individual lots are sold to different property owners, the right to build upon these lots may be protected indefinitely. Consequently, WHPAs may contain a significant number of small, vacant lots, which, if developed, could result in significant contamination of the water supply.

The total development potential of the WHPA is determined by summing existing development and future potential development. This calculation will result in a quanitification of the "saturation" development or "build-out" population. An illustration of this analysis is provided in Figure 2.

CALCULATING THE NITROGEN LOADING

Once the developable lot analysis has been completed all potential sources of nitrogen are assessed and tabulated. These sources typically include wastewater, residential and agricultural fertilizers, road run-off and precipitation. Several analytical models have recently been developed to predict nitrate-nitrogen concentrations in ground water using a mass balance approach (Nelson et al 1988; Frimpter et al, 1988). These models predict nitrate-nitrogen concentrations in ground water by dividing the annual nitrogen loading from the various sources by the annual dilution due to natural and artificial ground-water recharge. The primary source of error in these analytical methods has been in the assumed nitrogen loading and dilution values used in the model. To test and verify the conventional nitrogen loading



CATEGORY	ACRES	UNITS
Developed land	31	95
Subdividable/Developable Land	337	219
Restricted Open Space	243	-
Total	**611**	**314**

FIGURE 2. Developable Lot Analysis of a Wellhead Protection Area

variables typically used, the authors recently developed an analytical model which was calibrated using actual water quality data collected on Cape Cod, Massachusetts over a 25-year period (Nelson et al., 1988). This model was presented at the NWWA FOCUS Conference in 1988. The results of this nitrogen loading analysis, when applied to the WHPA depicted in Figure 2, are presented in Table 1. This analysis shows that under saturation development conditions a nitrate-nitrogen concentration is predicted.

The results of the nitrogen loading assessment are then compared to acceptable nitrate-nitrogen concentrations within ground water. The US EPA has established standard of 10 mg/L for nitrate-nitrogen concen-trations in drinking water; concentrations above this limit may cause health problems in infants. Using this standard as a planning guideline is not recommended however. A statistical analysis of drinking water samples collected on Long Island revealed that median nitrate-nitrogen concentrations of less than 5.4 mg/L are required to meet the 10 mg/L federal drinking water standard 90% of the time (Porter, 1978). Many communities in Massachusetts have therefore adopted a 5 mg/L nitrate-nitrogen standard as a conservative planning guideline.

TOOLS FOR CONTROLLING NITROGEN LOADING WITHIN WHPA'S

If the "programmed" development (existing development plus potential growth) within a WHPA exceeds the assimilative capacity of the water supply, a variety techniques can be used to mitigate for existing development and control future growth to achieve acceptable nitrate-nitrogen concentrations. These techniques can be grouped into three categories: regulatory, non-regulatory and legislative approaches (Coughanowr et al, 1989).

Regulatory techniques include zoning, subdivision control and sewage disposal regulations and are generally implemented at the local governemntal level. Examples include raising the minimum lots size or limiting the amount of sewage per lot area. These techniques are often highly effective in that they can be tailored to meet the physical and political needs of specific communities. However, grandfathering provisions within zoning codes limit their effectiveness as noted earlier in this paper.

Non-regulatory techniques include the aquisition of open space and and structural solutions such as sewering or construction of private sewage treatment plants. These approaches are often costly and may be more appropriately used where regulatory techniques are not sufficient to control growth or where existing development already exceeds the carrying capacity of the aquifer.

Legislative techniques refer to the establishment of special legislation where existing legal authority is inadequate. Examples include cases where wellhead protection areas or aquifer recharge zones cross jurisdictional boundaries. Special legislation may be required based upon a "hydroregional" approach

TABLE 1

NITROGEN LOADING CALCULATIONS UNDER SATURATION BUILD OUT CONDITIONS
Project: Sample Wellhead Protection Area
Date: 21 July, 1989

INPUT FACTORS

Sewage flow (gal/day)	103620
N-conc. in effluent (mg/l)	33.9
Lawn area (square feet)	3140000
Pavement (square feet)	1269629
Roof area (square feet)	628000
Natural area (square feet)	23147531
Recharge rate for pervious area (in/yr)	18
Recharge rate for impervious area (in/yr) *	40

INPUT	CALCULATIONS	RESULTS
Sewage (gal/day)		CALCULATED LOADING (LBS/YR)
103,620	x N-conc (mg/l) x 3.785 l/gal x 365 days/yr : 454000 mg/lb	10689
Lawn area (sq ft)		
3,140,000	x 0.0017 lb N/sq ft	5338
Pavement area (sq ft)		
1,269,629	x 0.00031 lb N/sq ft	394
Roof area (sq ft)		
628,000	x 0.00015 lb N/sq ft	94
Natural area (sq ft)		
23,147,531	x 0.000005 lb N/sq ft	116
	TOTAL NITROGEN LOADING (LBS/YR)	16631
		TOTAL RECHARGE (MG/YR)
Recharge from sewage (gal/day)		
103,620	x 365 days/yr : 1,000,000 gal/million gal	37.82
Total pervious area (sq ft)		
26,287,531	x 18 in/yr /12 in/ft x 7.48 gal/cu ft : 1,000,000 gal/million gal	294.95
Total impervious area (sq ft)		
1,897,629	x 40 in/yr /12 in/ft x 7.48 gal/cu ft : 1,000,000 gal/million gal	47.31
	TOTAL RECHARGE (MGAL/YR)	380.08
TOTAL NITROGEN LOAD/TOTAL RECHARGE X 454,000 MG/LB : 3,785,000 L/MGAL		
	=RECHARGE NITROGEN CONCENTRATION (mg/l or ppm)	5.25

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where a new management commission may be created to regulate land uses within the newly delineated area.

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Scott Horsley is Vice President of Horsley Witten Hegemann, Inc. where he provides expert consultation in water quality science and planning. He has prepared aquifer protection mapping and plans for over three dozen local governments, has assisted in the development of four sole source aquifer petitions and has served as an expert witness in several court cases involving critical water issues. He serves on National Water Well Association's Aquifer Protection Committee and was a former member of the Commonwealth of Massachusetts' Ground-Water Steering Committee. Scott has authored numerous publications on ground-water resource delineation and protection. Scott was employed under EPA-funding with the Cape Cod Planning and Economic Development Commission where he developed an analytical model and mapped critical zones of contribution to 130 public supply wells throughout Barnstable County, Cape Cod, Massachusetts. He holds a Master's degree from the University of Rhode Island and a Bachelor of Science degree from Southeastern Massachusetts University with academic training in geology, biology, planning and environmental law. Scott is an Adjunct Professor at Tufts University in Massachusetts.

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Christine A. Coughanowr is a hydrogeologist and partner with Horsley Witten Hegemann, Inc. where she provides consultation in ground water, wetlands, and coastal processes. She has recently developed a spread-sheet based methodology for assessing cumulative impacts of nitrogen loading to ground and surface water resources. Christine has a Bachelor of Science degree in geology from Duke University and a Master of Science degree in geology from the University of Delaware.

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Mark Nelson is a hydrogeologist with Horsley Witten Hegemann, Inc.. He has directed numerous projects delineating wellhead protection areas, as well as critical ground water resource areas surrounding lakes, coastal ponds, and estuaries. Together with Scott Horsley, Mark has recently developed an analytical nitrogen loading model used to determine land use impacts on ground water quality. Mark has a Bachelors degree in geology from Brown University and will receive a Masters degree in environmental science and engineering from the Oregon Graduate Center in the spring of 1990.

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Jon Witten is President of Horsley Witten Hegemann, Inc. where he directs the firm's land use planning program, and provides public and private sector consultation in land use planning strategies. he is currently assisting EPA's Office of Ground Water Protection to develop training programs for state and local officials. Jon has successfully authored several hundred local ordinances designed to protect ground-water resources and developed a unique regulatory approach for assessing the cumulative water quality impacts of land development in sensitive water resource protection areas utilizing a nutrient loading method. He has lectured nationally on appropriate strategies to mitigate the impact of land development on natural resources. Jon was the Planner and Administrative Director for the Town of Falmouth, Massachusetts for three years and has taught training courses on land planning and development in Boston for the past four years. He has a Master's degree in Regional Planning from Cornell University and is certified by the American Institute of Certified Planners. Jon is an adjunct assistant professor at Tufts University in Massachusetts.

EVALUATION OF LOCAL REGULATORY EFFORTS IN IDENTIFYING AND CONTROLLING THE THREAT OF UNDERGROUND FUEL STORAGE TANKS

Charlotte Stiefel and George Heufelder

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Abstract

For the past two years, the Barnstable County Health and Environmental Department, a regional advisory agency, has coordinated a county-wide effort to assist towns in formulating an overall underground storage tank (UST) management plan for groundwater protection. Certain key elements for initiating a residential UST program have been identified and include passage of a comprehensive regulation, support of regional and local agencies and public education initiatives. The level of regulation determines the overall reduction of threat to the groundwater, as evidenced by number of tank removals. When only registration of residential UST was required, up to 10% of the residential UST are removed annually. Passage of a comprehensive UST regulation which also includes testing and removal requirements resulted in up to 18% tank removal. Reduction in the number of residential UST can be greatly enhanced if the local municipality takes initiatives to reduce the removal costs, such as allowing disposal at the local landfill. Administration of an effective UST control program requires a significant time commitment; in Barnstable County this has been supplied at a regional level, with help from local fire and health departments.

Regarding commercial UST, despite comprehensive state regulations, over 20% of the tanks in the study area were not in compliance with testing requirements. Local initiatives in the form of a single notification letter resulted in an almost-immediate reduction of this figure to 11%.

Introduction

Leaking underground storage tanks (UST) constitute one of the most significant threats to groundwater quality in the United States. The increased awareness of this problem is demonstrated by the number of state and federal UST regulations which have been adopted in the last few years. A comprehensive wellhead protection program, however, should also include local efforts at UST control.

In Barnstable County, Massachusetts (which includes the fifteen towns comprising Cape Cod) the need for such regulation was underscored by the 1977 contamination of Provincetown's public water supply from leaking underground tank. Shaken by this catastrophe, many Cape towns adopted local health regulations on UST in the early 1980's. These regulations, like the present state/federal regulations, focused on "commercial" tanks leaving many tanks exempt from strict controls. In 1986, the Barnstable County Health and Environmental Department (BCHED), under funding from the US EPA Office of Underground Storage tanks, began to assist towns in developing a comprehensive UST management program which addresses not only the commercial installations but the remaining threat of on-site (mostly residential) heating oil tanks.

The role of the Barnstable County Health & Environmental Department is strictly advisory; we do not have the authority to mandate residential UST regulation. Therefore, our approach has been to encourage towns to adopt regulations and then assist them in implementing a comprehensive UST management program. As might be expected, our recommendations are followed to varying degrees among different towns. This paper evaluates which aspects of a UST program are the most effective and those factors to consider when instituting various components. Also included is an analysis of the efficacy of local efforts in the enforcement of the state/federal regulation of commercial tanks.

Residential UST Program

The BCHED program includes the development and presentation of a model Board of Health regulation, tank testing by soil-vapor analysis, public education, data management and enforcement assistance.

The model regulation, which is included in Appendix A, covers mandatory tank registration and tagging along with various installation, maintenance, testing, spill/leak reporting and removal requirements. Briefly, all heating oil UST are registered with the local health department and given a numbered tag to attach to the fill pipe. Oil distributors are then required to report unregistered tanks to the health department. New installations are required to be double-walled with interstitial space monitoring. Existing tanks must be tested at age 15 and annually after age 19 and removed at age 30. At this time, 11 of the 15 Cape towns have revised their original UST regulations in response to our recent efforts. As mentioned above, many towns have revised or adopted only parts of the model regulation.

Under the EPA grant, BCHED developed a UST testing program involving the use of soil-gas analysis as an easy and inexpensive method of testing heating oil tanks. The method and materials used are explained, in detail, in <u>REGULATION AND TESTING OF RESIDENTIAL UNDERGROUND FUEL STORAGE TANKS</u> (Stiefel & Heufelder, 1988). Using this method, a residential tank can be tested at a first year cost of under $200; testing in subsequent years would cost under $50. The existence of this testing program was a very important factor in the acceptance of a testing requirement on residential UST. Most Boards of Health would have been reticent to impose expensive restrictions on "innocent" homeowners. The inclusion of a testing requirement in a town's regulatory effort is an important factor in the overall success of the program.

The public education efforts of BCHED are another important, though unquantifiable, factor in the overall success of UST regulation in Barnstable County. Efforts to speak to appropriate groups and, especially, to members of the media are critical to the success of any effort. Foremost, personnel in the fire and health departments must be made aware of the threat, and, more importantly, be compelled to alleviate the threat. This is often a problem; Boards of Health and fire officials have so many responsibilities that they are sometimes unwilling, or actually unable, to take on another project. In Barnstable County, this problem was partially addressed by the assistance that BCHED could supply under the auspices of the grant. Regardless of the time spent, the philosophy of these departments is very important. Statements made by local officials as to the importance of tank testing and removal go a long way toward making it a reality.

Education of the general public is also essential. The average tankowner must be convinced that the costs involved with testing and/or removal of UST are outweighed by the protection these measures afford to the groundwater. This education process must also extend to oil dealers. Their first reaction, fear of losing customers, must be alleviated by convincing them that cooperation with these regulatory efforts is in the best interest of their customers. Since oil dealers have the most complete information on the locations of UST, obtaining their cooperation is essential. Many Cape oil dealers have agreed to send form letters to their customers notifying them of the regulations - this has proven to be the best way of getting the word out.

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Results and Discussion

To determine which of the towns' programs were the most effective at reducing the overall risk to groundwater and which components of the program lead most to its success, we partitioned the towns' actions into four "levels": registration, tagging and testing; registration and tagging only; registration only (no oil-dealer participation in the notification process); and those taking no action. The evaluation criteria used is the number of tanks taken out of service and is based on the assumption that a tank removed from service translates to a reduction in the overall threat to groundwater.

Figure 1 indicates the number of tanks taken out of service in each of five of the nine towns which have accepted the full regulation. These five towns were selected for analysis based on the ability to obtain reliable tank-removal information for both pre-regulation and regulation periods. The regulations in each of these towns were passed during 1987 and became effective in the latter part of that year. Therefore, 1988 is considered the first regulatory year in these towns. These data are compared with that of five towns (Figure 2) which have promulgated regulations requiring only registration of tanks (Dennis, Harwich and Sandwich) or towns having no regulation at all (Eastham and Yarmouth). These data show that there were greater increases in tank removal activity in towns having a complete regulation compared with towns which do not. Towns with a comprehensive regulation generally had a 4-60 fold increase in tank removals across pre-post regulatory years (Figure 1) and greater than 5% of the UST population taken out of service each year (Table 1). This compares with towns which do not have a comprehensive regulation and generally exhibit less than a 5-fold increase in activity across years 1986-1989 (Figure 2) and have less than 5 % of the UST population removed each year (Table 1).

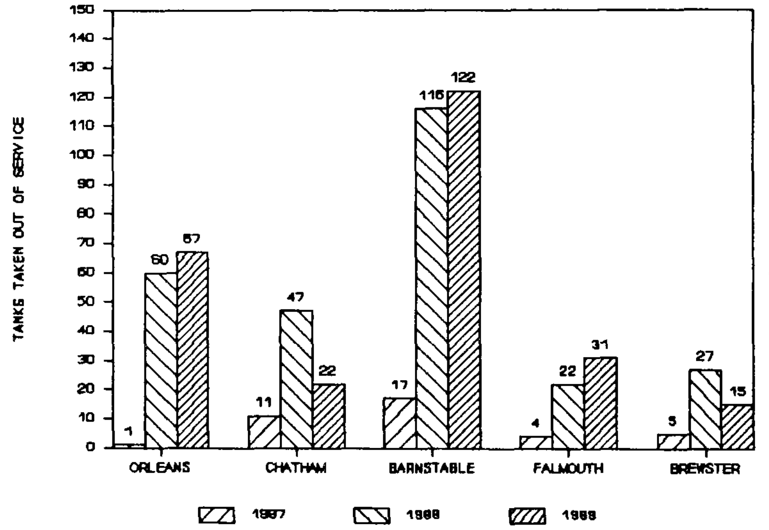

Figure 1 Numbers of residential UST taken out of service in selected towns having comprehensive UST regulations. Barnstable County, Massachusetts 1987-1989.

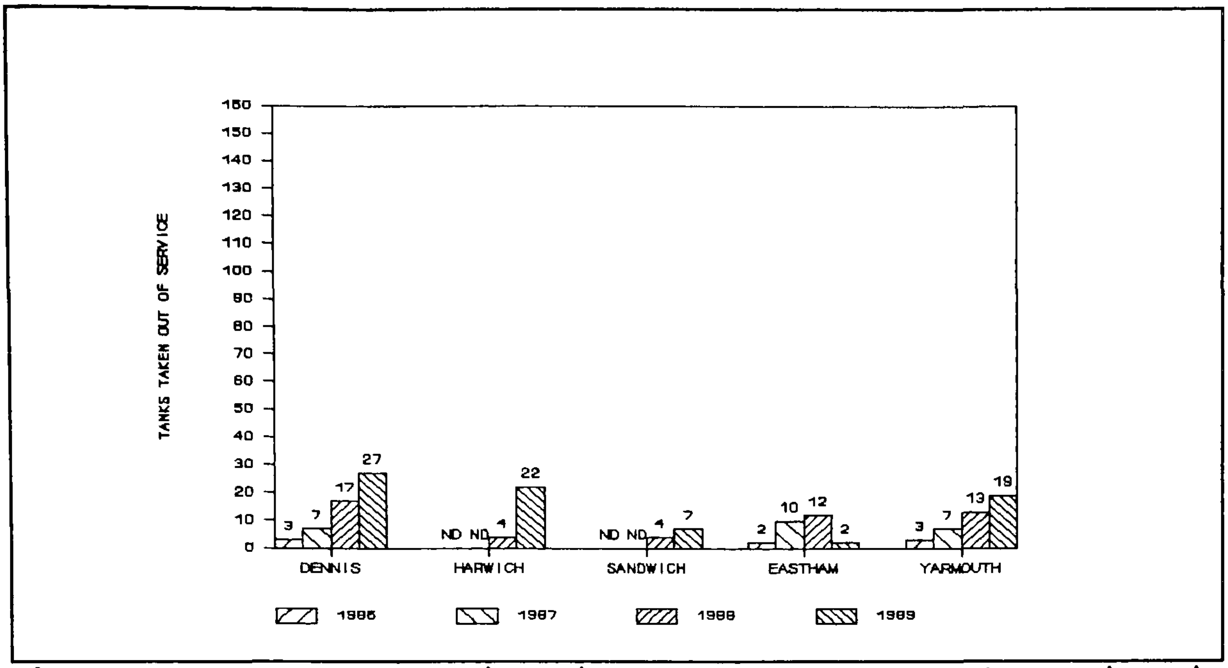

Figure 2 Numbers of residential UST taken out of service in selected towns without comprehensive UST regulations. Barnstable County, Massachusetts 1986-1989. ND= no data.

Table 1: Percentage of total residential underground tanks removed in the years 1986-1989. Numbers in parentheses represent the estimated number of USTs present in 1987.

Towns with comprehensive UST regulations

	Orleans (440)	Chatham (380)	Barnstable (900)	Falmouth (650)	Brewster (300)
1987	.2%	3%	2%	.6%	2%
1988	14%	13%	13%	3%	9%
1989	18%	7%	16%	5%	6%

Towns without comprehensive UST regulations

	Dennis (305)	Harwich (226)	Sandwich (350)	Eastham (325)	Yarmouth (600)
1986	1%	ND	ND	.6%	.5%
1987	2%	ND	ND	3%	1%
1988	6%	2%	1%	4%	2%
1989	10%	10%	2%	.7%	3%

Total number of tanks is estimated, numbers removed are from fire department records. ND= No data.

Among towns having a comprehensive regulation, there are differences in the success of the program as evidenced by the number of tanks taken out of service. Although it is difficult to totally isolate those factors which account for the success of residential UST programs, our experience in nine towns allows us to draw some conclusions.

The most successful programs exist in the towns of Orleans and Barnstable. Several factors contribute to the success in Orleans. Foremost, since they were the first town to adopt the regulation, they received maximum input from our department. Also, both the health and fire departments made strong commitments toward addressing the economic and regulatory issues associated with tank removal. In early 1987, while the costs of removing tanks were high due to the absence of Cape companies in this industry, officials in Orleans, following careful research of the regulations involved, established policies and procedures which minimized the costs to the average tankowner. In short, Orleans encouraged individuals to take advantage of a two-year abandonment period (following removal of product from the tank), which spreads the costs of tank removal and replacement over a broader period. In addition, this town allows the disposal of tanks at the local landfill (a practice not allowed in some other Cape towns), thus reducing the overall costs of removal.

The success of the program in Barnstable can largely be attributed to the commitment of the town in terms of personnel and effort. This town's hazardous waste specialist was designated the responsibility for overseeing the UST program and some of the five town fire departments are quite committed to the program. In addition, the health department aggressively solicited the participation of the oil dealers in the notification process. In the Town of Chatham, where there was an intermediate level of success between Orleans and Barnstable, the alternate was true. In this town, the fire department took the more aggressive role in the enforcement of the UST regulation. In addition to the supportive agencies in each of these three most-successful towns, another factor, that of the economic level of the community, may come into play in determining the overall number of UST removals. It is interesting to note that the Cape towns exhibiting the highest estimated per capita income levels are Orleans and Chatham (U. S. Bureau of the Census, 1985).

Among the Cape towns which opted to adopt only the registration requirement of the UST regulation or which opted not to update their UST regulation, there was, again, varying degrees of success in eliciting removals. In the towns of Dennis and Harwich which have mandatory UST registration (Dennis requiring oil-dealer participation in the notification process), it is projected that nearly 10% of the UST will be removed from service during 1989. When the Town of Harwich recently adopted a comprehensive regulation, the fire department immediately received numerous inquiries regarding tank removal. The experience in Dennis and Harwich contrasts with that of Sandwich, Eastham and Yarmouth which generally remove less than 5% of their tanks/year.

In summary, our experience indicates that a reduction in the threat to groundwater is related to the level of regulation adopted. When there was no residential UST regulation or public education program, we observed annual removal rates of 1% or less. The general public education which occurs when there is an aggressive regional program seemed to also benefit towns which did not adopt any regulation (1-4% annual removal). Towns actively registering tanks, but having no further regulation, had up to 10% of their UST removed annually. Adoption of a comprehensive UST regulation resulted in an annual removal rate as high as 18%. The most important factors in determining the success of the UST program in Barnstable County were the support of a regional agency, commitment of fire and health department personnel at the local level and a public education effort. The acceptance of the comprehensive regulation was significantly fostered by the development and use of inexpensive testing and removal methods.

Commercial UST Program

Existing Massachusetts regulations (527 CMR 9.00 Tanks and Containers) impose various restrictions on motor fuel UST. Part of BCHED's program is to assist the local fire departments with the enforcement of the sections which require these tanks to be registered and to be tested at certain ages. Our experience in the last two years has indicated that although compliance with the registration requirement is quite good (99.5%), many tanks are not being tested as they should.

In the summer of 1989, visits were made to 15 of the 19 Cape fire departments (at present, visits to remaining departments are being arranged). Records on approximately 770 tanks were reviewed, updated, and records of previous tightness tests were checked. Letters were then sent to tank owner/operators whose fire department files did not show appropriate tests. Of the 194 (25%) tanks in this category, 31 (16%) responded with records showing either that the tanks had previously been removed or that the required testing had been done. The reason for inaccurate fire department records in these 31 cases could be because the tank owner/operators were negligent in sending the information to the fire departments, or because the fire departments lost/misplaced the information. Of the remaining 163 tanks which still appear to have been out of compliance at the beginning of the summer, owner/operators of 76 (47%) have responded to our letter with schedules for testing and/or removal of the tanks. At the time of this writing, owner/operators of 87 tanks (53%) have yet to respond to our letter, however some notifications have only recently been issued.

In summary, the passage of comprehensive state commercial UST regulations does not mean, of itself, that the threat to groundwater has been alleviated. Indeed, over 20% of the active commercial UST in our area were out of compliance with state testing regulations prior to our efforts. However, with a fairly-minimal effort such as sending a reminder letter, a significant increase in compliance can be obtained.

References

Stiefel, C.L. and G.R. Heufelder. 1988. Journal of New England Water Works Association, Volume 102(4): 254-266.

Appendix

FUEL STORAGE SYSTEM REGULATIONS

Whereas, leaking fuel storage systems pose an immediate and serious threat to Cape Cod's sole source aquifer, and,

Whereas, the Town of (   ) does not have records to locate all such systems installed within the Town,

Therefore, under Chapter 111, Section 31, of the Massachusetts General Laws, the(   ) Board of Health hereby adopts the following regulation to protect the ground and surface waters from contamination with liquid toxic or hazardous materials.

DEFINITIONS: "Toxic or hazardous materials" shall be defined as all liquid hydrocarbon products including, but not limited to, gasoline, fuel and diesel oil, and any other toxic or corrosive chemicals, radioactive materials or other substance controlled as being toxic or hazardous by the Division of Hazardous Waste of the Commonwealth of Massachusetts, under the provisions of Massachusetts General Laws, Chapter 21C, Section 1, et. seq.

The following regulations apply to all toxic or hazardous material storage systems:

Section 1. Installation of Fuel Storage Tanks

1-1. Following the effective date of this regulation, the installation of all underground fuel, gasoline or other chemical storage tanks shall conform with the following criteria: In that the United States Environmental Protection Agency designated the Town of (   ) as overlying a sole source aquifer, secondary containment of tank and piping and an approved in-tank or interstitial space monitoring system shall be required for new or replacement tanks.

1-2. Following the effective date of this regulation, all tanks installed aboveground outside shall be of material approved for outside use.

Section 2. Tank Registration

The following regulations shall apply to A) all underground tanks containing toxic or hazardous materials as defined above which are not currently regulated under 527 CMR 9.26 - Tanks and Containers, to B) all tanks containing fuel oil, whose contents are used exclusively for consumption on the premises, and to C) farm and residential tanks of 1,100 gallon capacity, or less, used for storing motor fuel for non-commercial purposes.

2-1. Owners shall file with the Board of Health, on or before (   ) the size, type, age and location of each tank, and the type of fuel or chemical stored in them. Evidence of date of purchase and installation, including fire department permit, if any, shall be included along with a sketch map showing the location of such tanks on the property. Upon registering the tank with the Board of Health, the tank owner will receive a permanent metal or plastic tag, embossed with a registration number unique to that tank. This registration tag must be affixed to the fill pipe or in such a location as to be visible to any distributor when filling the tank and to any inspector authorized by the Town.

2-2. Effective ( ) every petroleum and other chemical distributor, when filling an underground storage tank, shall note on the invoice or bill for the product delivered, the registration number appearing on the tag affixed to the tank which was filled. Every petroleum and other chemical distributor shall notify the Board of Health of the existence and location of any unregistered or untagged tank which they are requested to fill. Such notification must be completed within two (2) working days of the time the distributor discovers that the tank registration tag is not present.

2-3. Prior to the sale of a property containing an underground storage tank, the fire department must receive from the current owner a change of ownership form for the registration of the underground storage tank. Such form can be obtained from the fire department.

Section 3. Testing

3-1. The tank owner shall have each tank and its piping tested for tightness fifteen and twenty years after installation and annually thereafter. A tank shall be tested by any final or precision test, not involving air pressure, that can accurately detect a leak of 0.05 gal/hr, after adjustment for relevant variables, such as temperature change and tank end deflection, or by any other testing system approved by the Board of Health, as providing equivalent safety and effectiveness. Piping shall be tested hydrostatically to 150 percent of the maximum anticipated pressure of the system. Certification of the testing shall be submitted to the Board of Health by the owner, at the owner's expense. Those tanks subject to the testing requirements of this regulation shall submit the certification of testing to the Board of Health by ( ). Tanks which are currently tested under the provisions of 527 CMR 9.13 are exempt from this section. For purposes of this section, tanks of unknown age are assumed to be 20 years of age.

Section 4. Maintenance of Fuel Storage Systems

4-1. All underground fuel lines which do not have secondary containment shall be replaced with an approved double-containment system at which time any service to the system requiring a permit is performed.

4-2. All above-ground elements of a fuel storage system shall be maintained free of leaks and visible rust.

4-3. All in-tank or interstitial-space monitoring systems shall be checked on a monthly basis to verify system integrity. Records of these checks shall be sent to the Board of Health on an annual basis.

Section 5. Report of Leaks or Spills

5-1. Any person who is aware of a spill, loss of product, or unaccounted for increase in consumption which may indicate a leak shall report such spill, loss or increase immediately to the head of the fire department and to the Board of Health.

Section 6. Tank Removal

6-1. All fuel, gasoline or other chemical tanks not regulated under 527 CMR 9.00 (farm or residential tanks of 1,100 gallons or less and underground tanks storing fuel for consumptive use at the property) in service on the effective date of this regulation, shall be removed thirty (30) years after the date of installation. If the date of installation is unknown, the tank shall be assumed to be twenty years old. All underground storage tanks currently subject to the removal regulation (30 years or older) must be removed by (   ).

6-2. Prior to the removal of an underground storage tank governed by this regulation, the owner shall first obtain a permit from the head of the fire department, pursuant to M.G.L., C. 148.

6-3. Any person granted a permit by the Marshal or the head of a local fire department to remove a tank under the provisions of M.G.L., C. 148 or 527 CMR 9.00, shall within 72 hours provide the permit granting authority with a receipt for delivery of said tank to the site designated on the permit.

6-4. Before any person is granted a permit by the Marshal or the head of a local fire department to remove a tank under the provisions of M.G.L., C. 148 or 527 CMR 9.00, and said tank is not being transported to an approved tank yard, the person requesting the permit shall provide the permit-granting authority with written approval from the owner/manager of the disposal site. (Reference: 502 CMR 3.00 for tank removal and disposal procedure).

Section 7. Costs

7-1. In every case, the owner shall assume responsibility for costs incurred necessary to comply with this regulation.

Section 8. Variances

8-1. Variances from this regulation may be granted by the Board of Health after a hearing at which the applicant establishes the following: (1) the enforcement thereof would do manifest injustice; and (2) installation or use of an underground storage tank will not adversely affect public or private water resources. In granting a variance, the Board will take into consideration the direction of the ground water flow, soil conditions, depth to ground water, size, shape and slope of the lot, and existing and known future water supplies.

Section 9. Severability

9-1. Provisions of this regulation are severable and if any provision hereof shall be held invalid under any circumstances, such invalidity shall not affect any other provisions or circumstances.

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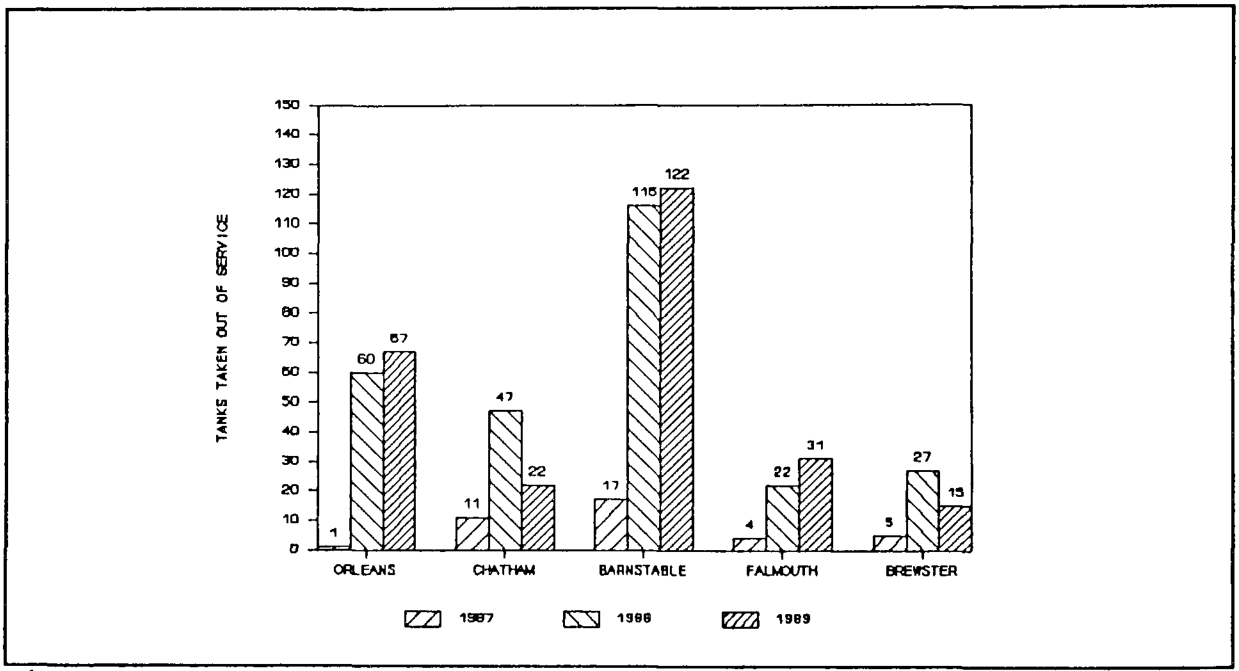

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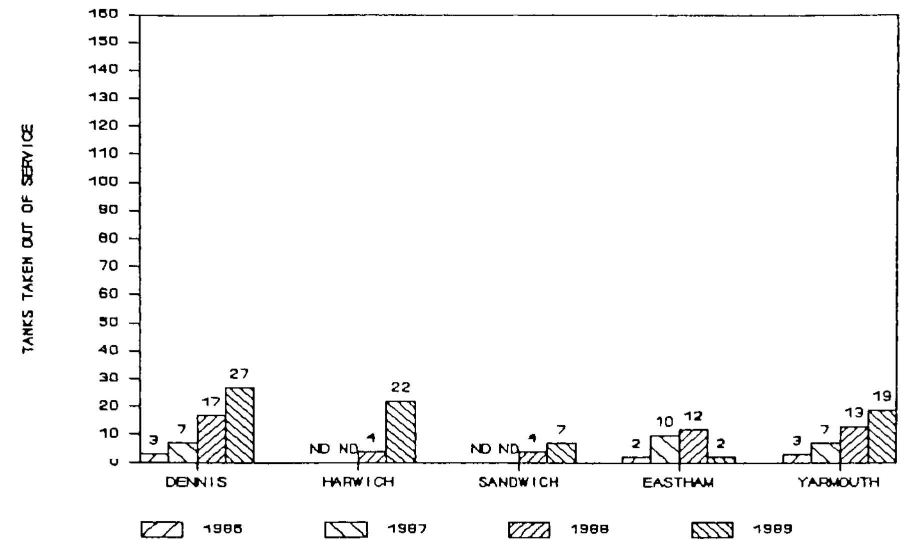

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1989	10%	10%	2%	.7%	3%

Total number of tanks is estimated, numbers removed are from fire department records. ND= No data.

Among towns having a comprehensive regulation, there are differences in the success of the program as evidenced by the number of tanks taken out of service. Although it is difficult to totally isolate those factors which account for the success of residential UST programs, our experience in nine towns allows us to draw some conclusions.

The most successful programs exist in the towns of Orleans and Barnstable. Several factors contribute to the success in Orleans. Foremost, since they were the first town to adopt the regulation, they received maximum input from our department. Also, both the health and fire departments made strong commitments toward addressing the economic and regulatory issues associated with tank removal. In early 1987, while the costs of removing tanks were high due to the absence of Cape companies in this industry, officials in Orleans, following careful research of the regulations involved, established policies and procedures which minimized the costs to the average tankowner. In short, Orleans encouraged individuals to take advantage of a two-year abandonment period (following removal of product from the tank), which spreads the costs of tank removal and replacement over a broader period. In addition, this town allows the disposal of tanks at the local landfill (a practice not allowed in some other Cape towns), thus reducing the overall costs of removal.

The success of the program in Barnstable can largely be attributed to the commitment of the town in terms of personnel and effort. This town's hazardous waste specialist was designated the responsibility for overseeing the UST program and some of the five town fire departments are quite committed to the program. In addition, the health department aggressively solicited the participation of the oil dealers in the notification process. In the Town of Chatham, where there was an intermediate level of success between Orleans and Barnstable, the alternate was true. In this town, the fire department took the more aggressive role in the enforcement of the UST regulation. In addition to the supportive agencies in each of these three most-successful towns, another factor, that of the economic level of the community, may come into play in determining the overall number of UST removals. It is interesting to note that the Cape towns exhibiting the highest estimated per capita income levels are Orleans and Chatham (U. S. Bureau of the Census, 1985).

Among the Cape towns which opted to adopt only the registration requirement of the UST regulation or which opted not to update their UST regulation, there was, again, varying degrees of success in eliciting removals. In the towns of Dennis and Harwich which have mandatory UST registration (Dennis requiring oil-dealer participation in the notification process), it is projected that nearly 10% of the UST will be removed from service during 1989. When the Town of Harwich recently adopted a comprehensive regulation, the fire department immediately received numerous inquiries regarding tank removal. The experience in Dennis and Harwich contrasts with that of Sandwich, Eastham and Yarmouth which generally remove less than 5% of their tanks/year.

In summary, our experience indicates that a reduction in the threat to groundwater is related to the level of regulation adopted. When there was no residential UST regulation or public education program, we observed annual removal rates of 1% or less. The general public education which occurs when there is an aggressive regional program seemed to also benefit towns which did not adopt any regulation (1-4% annual removal). Towns actively registering tanks, but having no further regulation, had up to 10% of their UST removed annually. Adoption of a comprehensive UST regulation resulted in an annual removal rate as high as 18%. The most important factors in determining the success of the UST program in Barnstable County were the support of a regional agency, commitment of fire and health department personnel at the local level and a public education effort. The acceptance of the comprehensive regulation was significantly fostered by the development and use of inexpensive testing and removal methods.

Commercial UST Program

Existing Massachusetts regulations (527 CMR 9.00 Tanks and Containers) impose various restrictions on motor fuel UST. Part of BCHED's program is to assist the local fire departments with the enforcement of the sections which require these tanks to be registered and to be tested at certain ages. Our experience in the last two years has indicated that although compliance with the registration requirement is quite good (99.5%), many tanks are not being tested as they should.

In the summer of 1989, visits were made to 15 of the 19 Cape fire departments (at present, visits to remaining departments are being arranged). Records on approximately 770 tanks were reviewed, updated, and records of previous tightness tests were checked. Letters were then sent to tank owner/operators whose fire department files did not show appropriate tests. Of the 194 (25%) tanks in this category, 31 (16%) responded with records showing either that the tanks had previously been removed or that the required testing had been done. The reason for inaccurate fire department records in these 31 cases could be because the tank owner/operators were negligent in sending the information to the fire departments, or because the fire departments lost/misplaced the information. Of the remaining 163 tanks which still appear to have been out of compliance at the beginning of the summer, owner/operators of 76 (47%) have responded to our letter with schedules for testing and/or removal of the tanks. At the time of this writing, owner/operators of 87 tanks (53%) have yet to respond to our letter, however some notifications have only recently been issued.

In summary, the passage of comprehensive state commercial UST regulations does not mean, of itself, that the threat to groundwater has been alleviated. Indeed, over 20% of the active commercial UST in our area were out of compliance with state testing regulations prior to our efforts. However, with a fairly-minimal effort such as sending a reminder letter, a significant increase in compliance can be obtained.

References

Stiefel, C.L. and G.R. Heufelder. 1988. Journal of New England Water Works Association, Volume 102(4): 254-266.

Appendix

FUEL STORAGE SYSTEM REGULATIONS

Whereas, leaking fuel storage systems pose an immediate and serious threat to Cape Cod's sole source aquifer, and,

Whereas, the Town of (   ) does not have records to locate all such systems installed within the Town,

Therefore, under Chapter 111, Section 31, of the Massachusetts General Laws, the(   ) Board of Health hereby adopts the following regulation to protect the ground and surface waters from contamination with liquid toxic or hazardous materials.

DEFINITIONS: "Toxic or hazardous materials" shall be defined as all liquid hydrocarbon products including, but not limited to, gasoline, fuel and diesel oil, and any other toxic or corrosive chemicals, radioactive materials or other substance controlled as being toxic or hazardous by the Division of Hazardous Waste of the Commonwealth of Massachusetts, under the provisions of Massachusetts General Laws, Chapter 21C, Section 1, et. seq.

The following regulations apply to all toxic or hazardous material storage systems:

Section 1. Installation of Fuel Storage Tanks

1-1. Following the effective date of this regulation, the installation of all underground fuel, gasoline or other chemical storage tanks shall conform with the following criteria: In that the United States Environmental Protection Agency designated the Town of (   ) as overlying a sole source aquifer, secondary containment of tank and piping and an approved in-tank or interstitial space monitoring system shall be required for new or replacement tanks.

1-2. Following the effective date of this regulation, all tanks installed aboveground outside shall be of material approved for outside use.

Section 2. Tank Registration

The following regulations shall apply to A) all underground tanks containing toxic or hazardous materials as defined above which are not currently regulated under 527 CMR 9.26 - Tanks and Containers, to B) all tanks containing fuel oil, whose contents are used exclusively for consumption on the premises, and to C) farm and residential tanks of 1,100 gallon capacity, or less, used for storing motor fuel for non-commercial purposes.

2-1. Owners shall file with the Board of Health, on or before (   ) the size, type, age and location of each tank, and the type of fuel or chemical stored in them. Evidence of date of purchase and installation, including fire department permit, if any, shall be included along with a sketch map showing the location of such tanks on the property. Upon registering the tank with the Board of Health, the tank owner will receive a permanent metal or plastic tag, embossed with a registration number unique to that tank. This registration tag must be affixed to the fill pipe or in such a location as to be visible to any distributor when filling the tank and to any inspector authorized by the Town.

2-2. Effective ( ) every petroleum and other chemical distributor, when filling an underground storage tank, shall note on the invoice or bill for the product delivered, the registration number appearing on the tag affixed to the tank which was filled. Every petroleum and other chemical distributor shall notify the Board of Health of the existence and location of any unregistered or untagged tank which they are requested to fill. Such notification must be completed within two (2) working days of the time the distributor discovers that the tank registration tag is not present.

2-3. Prior to the sale of a property containing an underground storage tank, the fire department must receive from the current owner a change of ownership form for the registration of the underground storage tank. Such form can be obtained from the fire department.

Section 3. Testing

3-1. The tank owner shall have each tank and its piping tested for tightness fifteen and twenty years after installation and annually thereafter. A tank shall be tested by any final or precision test, not involving air pressure, that can accurately detect a leak of 0.05 gal/hr, after adjustment for relevant variables, such as temperature change and tank end deflection, or by any other testing system approved by the Board of Health, as providing equivalent safety and effectiveness. Piping shall be tested hydrostatically to 150 percent of the maximum anticipated pressure of the system. Certification of the testing shall be submitted to the Board of Health by the owner, at the owner's expense. Those tanks subject to the testing requirements of this regulation shall submit the certification of testing to the Board of Health by ( ). Tanks which are currently tested under the provisions of 527 CMR 9.13 are exempt from this section. For purposes of this section, tanks of unknown age are assumed to be 20 years of age.

Section 4. Maintenance of Fuel Storage Systems

4-1. All underground fuel lines which do not have secondary containment shall be replaced with an approved double-containment system at which time any service to the system requiring a permit is performed.

4-2. All above-ground elements of a fuel storage system shall be maintained free of leaks and visible rust.

4-3. All in-tank or interstitial-space monitoring systems shall be checked on a monthly basis to verify system integrity. Records of these checks shall be sent to the Board of Health on an annual basis.

Section 5. Report of Leaks or Spills

5-1. Any person who is aware of a spill, loss of product, or unaccounted for increase in consumption which may indicate a leak shall report such spill, loss or increase immediately to the head of the fire department and to the Board of Health.

Section 6. Tank Removal

6-1. All fuel, gasoline or other chemical tanks not regulated under 527 CMR 9.00 (farm or residential tanks of 1,100 gallons or less and underground tanks storing fuel for consumptive use at the property) in service on the effective date of this regulation, shall be removed thirty (30) years after the date of installation. If the date of installation is unknown, the tank shall be assumed to be twenty years old. All underground storage tanks currently subject to the removal regulation (30 years or older) must be removed by ( ).
6-2. Prior to the removal of an underground storage tank governed by this regulation, the owner shall first obtain a permit from the head of the fire department, pursuant to M.G.L., C. 148.
6-3. Any person granted a permit by the Marshal or the head of a local fire department to remove a tank under the provisions of M.G.L., C. 148 or 527 CMR 9.00, shall within 72 hours provide the permit granting authority with a receipt for delivery of said tank to the site designated on the permit.
6-4. Before any person is granted a permit by the Marshal or the head of a local fire department to remove a tank under the provisions of M.G.L., C. 148 or 527 CMR 9.00, and said tank is not being transported to an approved tank yard, the person requesting the permit shall provide the permit-granting authority with written approval from the owner/manager of the disposal site. (Reference: 502 CMR 3.00 for tank removal and disposal procedure).

Section 7. Costs

7-1. In every case, the owner shall assume responsibility for costs incurred necessary to comply with this regulation.

Section 8. Variances

8-1. Variances from this regulation may be granted by the Board of Health after a hearing at which the applicant establishes the following: (1) the enforcement thereof would do manifest injustice; and (2) installation or use of an underground storage tank will not adversely affect public or private water resources. In granting a variance, the Board will take into consideration the direction of the ground water flow, soil conditions, depth to ground water, size, shape and slope of the lot, and existing and known future water supplies.

Section 9. Severability

9-1. Provisions of this regulation are severable and if any provision hereof shall be held invalid under any circumstances, such invalidity shall not affect any other provisions or circumstances.

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Charlotte Stiefel is an Environmental Program Specialist with the Barnstable County Health and Environmental Department. She received a degree in biology, with honors, from Gustavus Adolphus College in St. Peter, Minn. She has held several positions related to environmental regulation and has worked in local, state and federal government offices. She is now in her third term as an elected water commissioner in the North Sagamore Water District.

George Heufelder is the Environmental Program Manager with the Barnstable County Health and Environmental Department. Following the receipt of his Masters Degree in Biology from Eastern Michigan University, he was involved in a number of environmental monitoring projects conducted by Great Lakes Research Division, University of Michigan. In his capacity at BCHED he is instumental in writing, obtaining and conducting grants to address critical environmental issues.

JOINING FORCES:

PUBLIC AND PRIVATE MANAGEMENT OF GROUND WATER RESOURCES

John S. Malleck and Lisa K. Voyce
U.S. Environmental Protection Agency, Region II

ABSTRACT:

This paper describes a new program designed to protect public water supplies from contamination, the Wellhead Protection Program; and provides a framework for implementing the Program, through a collaborative government and business matrix organization.

Local involvement is the key to success of any plan to protect ground water resources; and "local" includes the town council, planning board, health department, water and sewer authorities, land developers, and businesses that are responsible for protecting, or are using, underground sources of water. Federal and State government also play a role in determining guidelines for implementation, providing technical assistance, and developing funding options for Wellhead Protection.

John S. Malleck

John Malleck currently manages both the Office of Ground Water Management and Underground Injection Control Section for EPA Region II. He is responsible for the cross-program implementation of the Agency's Ground Water Protection Strategy, Sole Source Aquifer Designation and Demonstration Programs, the Wellhead Protection Program, Agricultural Chemicals in Ground Water Strategy, Superfund compliance with water programs, and regulation of injection well activity for New York, New Jersey, Puerto Rico and the Virgin Islands.

Mr. Malleck has worked for EPA for ten years. Prior to his current assignment, he supervised the beginning stages of the Underground Injection Control program, when no one really knew how many wells were in the Region, or where they were. He has also served as project officer for EPA water and air quality grants, and was instrumental in developing the national Sole Source Aquifer program.

He earned a M.S. in Water Resource Management from the University of Michigan, and a B.S. in Environmental Science from Rutgers - The State University of New Jersey.

THE UIC CLASS IV-V WELL SURVEY IN MAINE:

INVENTORY, ASSESSMENT AND COMPLIANCE

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Abstract

The Maine Department of Environmental Protection, Bureau of Water Quality Control administers the Safe Drinking Water Act Underground Injection Control (UIC) Program. The focus of Maine's program is on Class IV and Class V injection wells. In 1988 and 1989, a questionnaire requesting information on discharges was sent to service stations. The survey responses, in association with field inspections and categorization of floor drain discharges served as the basis for the development of a UIC Class IV and Class V program.

This paper will describe the program and how it relates to other state ground water protection efforts, specifically:

-- the relationship of the UIC program to the Maine Groundwater Management Strategy and interagency coordination with the Wellhead Protection Program

-- the use of existing state computer database systems to provide information on potential Class IV and Class V injection wells

-- the use of mail surveys to inventory the nature and extent of UIC activities

-- how automation of the UIC database efficiently manages survey results in order to expedite the mailing of regulations and best management practice notices, and increases the efficiency of compliance and initiation of enforcement activities

-- the development of a field inspection and enforcement/compliance strategy with an interagency approach

-- the development of a program for municipal officials to provide technical assistance information on how communities can control Class IV and Class V UIC wells

-- the future direction of Maine's UIC program

Introduction

Underground Injection Wells are regulated by the federal Safe Drinking Water Underground Injection Control Program. The U.S. Environmental Protection Agency (EPA) promulgated regulations (40 CFR Parts 124, 144, 145 and 146) to implement the Safe Drinking Water Act (SDWA). The EPA regulations and the SDWA contain provisions to delegate UIC primary enforcement authority to states having the necessary legal authority, technical expertise, and administrative capability. The Maine Department of Environmental Protection (DEP) demonstrated the necessary requirements and was awarded UIC primacy on September 26, 1983. (Maine State Planning Office, 1989)

The DEP consists of six Bureaus: Water Quality Control; Air Quality Control; Land Quality Control; Oil and Hazardous Materials Control; Solid Waste Management; and Administration. The UIC program resides within the Bureau of Water Quality Control, which consists of five Divisions: Policy, Information and Grants; Licensing and Enforcement; Operation and Maintenance; Municipal Services; and Environmental Evaluation and Lake Studies. The UIC program was initially the responsibility of the Policy Section, but now is the responsibility of the Division of Operation and Maintenance.

In Maine, the discharge of pollutants to ground water is a violation of both state and federal laws. Appendix A contains excerpts from the applicable state statutes. The Maine UIC program is established by Chapter 543 of the rules of the Board of Environmental Protection (06-096 Code of Maine Rules 543, July 1983), which is contained in Appendix B. The rules mandate a program and procedures for the permitting of proposed Class I, II, and III wells using the authority established in the EPA regulations cited above. The Board, under the state authority of 38 M.R.S.A. Sections 420(2) and (3), prohibits the permitting of Class IV wells. Class V wells may also be maintained, provided a waste discharge license is obtained from the Board and all other applicable necessary approvals are obtained. A waste discharge license is not required for subsurface waste water disposal systems designed and installed in conformance with the Maine Subsurface Wastewater Disposal Rules (10-144 Code of Maine Rules 241, July 1980) and used only for the discharge of sanitary waste water.

The UIC Program, a Component of Maine's Groundwater Srategy

The Maine Groundwater Management Strategy (GWMS) was developed to accomplish the State's ground water management goals and to implement its ground water policies. The GWMS identifies in detail the necessary elements for sound ground water management. Contained within the element "Controlling Sources of Contamination," is a description of the DEP UIC program and the direction it will take over the next two years. The UIC program plays a central role in addressing this strategy element in a comprehensive manner. This element, in combination with the others (Program Coordination; Research; Classification; Data Management; Compliance and Enforcement; Technical Assistance; Education; and Public Involvement) describes the necessary components for sound ground water management. These elements are interdependent and the necessary parts of a complete state strategy. Each of these elements depend on the implementation of the others and is important to ensure the continued availability of high quality ground water for the growing needs of Maine. (Maine State Planning Office, 1989)

Due to Maine's hydrogeologic setting, the pressurized disposal of large quantities of waste materials below the land surface is impractical and ususally not cost effective. Areas of the state with rocky outcrops tend to be fractured near the land surface. In the majority of these settings, the openings are saturated with ground water. The pressurized emplacement of liquid waste materials into the subsurface through these fractured openings is difficult for most injection well pumps to accomplish.

Other areas of the state contain sand and gravel aquifers that typically overlay marine clays or areas of fractured bedrock. In these locations, the pressurized injection of liquid waste is more feasible than in fractured bedrock settings, yet costs are still high relative to other disposal practices. In addition, Maine's sand and gravel aquifers are typically used as both public and private water supplies. More than sixty percent of Maine households obtain their drinking water from ground water through public and private wells and springs. (Maine Department of Environmental Protection, 1986)

For the above reasons, the majority of facilities considered UIC wells for the disposal of waste are gravity feed/low technology systems. They are usually a dry well or septic tank/leach field system. The term "well" is applied loosely and in Maine relates to a specialized form of subsurface disposal. (Maine Department of Environmental Protection, 1986)

In 1981, an inventory of injection wells in Maine found no Class I, II, III, or IV wells, but fourteen Class V wells were located. In 1986, a reassessment found that none of the Class V wells were still in operation, although monitoring was still required at some of the sites. In 1987, additional Class V wells were reported and actions were taken to eliminate the discharge of pollutants at these sites.

In 1987, a report to Congress was submitted by EPA summarizing the results of State surveys concerning Class V injection wells as defined by the 1986 Amendments to the SDWA. Thirty Class V well types were identified nationally in the survey. Class V wells determined to have a high ground water contamination potential included septic systems, waste disposal wells, and automobile service station waste disposal wells. (U.S. Environmental Protection Agency, 1987) Based on these results, the DEP embarked on a comprehensive evaluation of threats to ground water quality from service station floor drains. The DEP's program activities to investigate these threats included inventory, inspection, enforcement/compliance, technical assistance, and public education activities geared toward Class IV and Class V UIC wells. The components of the UIC program are described in the following sections. Relationships between the UIC program and other state agency ground water protection efforts and strategy elements will also be discussed. (U.S. Environmental Protection Agency, 1987)

Administration

During 1988 and 1989, the goals of the DEP UIC work plan included: 1) evaluating the nature and extent of selected UIC Class IV and Class V injection activities in Maine; 2) eliminating Class IV and Class V injection wells through voluntary compliance and/or formal enforcement actions; and 3) providing an information program to the general public to assist residents in better understanding the issues related to the protection of Maine groundwater resources.

The goals of the UIC program were accomplished through the following activities:

1. Existing state computer database systems were used to obtain mailing information on potential Class IV and Class V injection wells, and mail surveys were used to evaluate the nature and extent of UIC activities. Surveys were mailed to automobile service stations, businesses likely to have Class IV or Class V injection wells;

2. Field inspections of selected businesses with suspected Class IV or Class V injection wells were performed;

3. Facilities operating Class IV or Class V injection wells were notified of applicable Maine statutes and requested to comply voluntarily;

4. Formal enforcement action was initiated against selected facilities operating Class IV or Class V injection wells; and

5. Fact Sheets were provided to the potential violators and the general public explaining the UIC program and the need to protect the groundwater. The fact sheets also suggested best management practices for materials commonly found at the targeted facilities.

Use of Existing State Computer Database Systems

Numerous businesses regulated by a variety of state and federal agencies may have underground injection wells. One area of concern targeted by the UIC program was floor drains at automobile service stations. The potential for locating injection wells at these facilities is very high due to the nature of the materials used during the course of business. Most automobile service stations have underground oil and gasoline storage tanks, which are regulated by the DEP, Bureau of Oil and Hazardous Materials Control. Information was already on file which would assist in the inventory of injection wells. Tapping into existing computer databases expedited the process of investigating potential Class IV and Class V injection wells.

The Bureau of Oil and Hazardous Materials Control licenses or registers facilities dealing with the wholesale oil distribution, retail oil distribution, oil storage at commercial and industrial establishments, oil storage at residential, public, agricultural, and federal facilities, chemical storage, and hydraulic lifts. The UIC program initially targeted retail distributors of gasoline. Information on contact official, address, telephone, and potential impact on groundwater for these facilities is maintained by the Bureau on the State's mainframe computer. The information necessary to conduct a UIC survey was downloaded to a microcomputer, and manipulated using dBase III Plus. The database of retail distributors of gasoline was further broken down by extracting only motor vehicle inspection stations. This resulted in a manageable number of facilities which were surveyed in 1988. Surveys were sent to 1,156 facilities. In 1989, surveys were sent to the remaining 1,949 facilities on the retail gasoline distribution list.

Another type of business of concern to the Department was food processors. Very few of these businesses are licensed under the State's waste discharge laws, making the possibility of illegal discharges to the surface or groundwater very high. The State Department of Agriculture, Food and Rural Resources provided mailing information on licensed food processors. Since the mailing information is maintained on a microcomputer, the database was easily converted for use on the DEP microcomputer.

The Use of Mail Surveys

Surveys were mailed to over 3,000 automobile service stations in 1988 and 1989. Facility, owner, and operator information obtained from the Bureau of Oil and Hazardous Materials Control assisted in personalizing the surveys. The survey requested information on predominant soil type, number and location of floor drains, the discharge location of the floor drains, distance to the nearest water supply, and the type of water supply (public or private). A self-addressed stamped envelope was provided with each survey, resulting in a nearly 100% return rate. A copy of the survey is attached as Appendix C.

Surveys were also sent to 175 food processors in 1989. The information requested was similar to the automobile service station survey, and also asked for additional information, such as the volume of process or cooling water used, treatment of the water, discharge location, whether or not cleaning compounds were used, and if chlorine was added to the water discharged. Again, the surveys were "personalized" using information obtained from the State Department of Agriculture.

The information obtained through the survey of automobile service stations and food processors has assisted the DEP in targeting facilities with potential Class IV and Class V injection wells for corrective and/or enforcement action.

Automation Efficiently Manages Survey Results

As the surveys were returned, the responses and corrected facility information were entered into the computer database. The 1988 automobile service station survey information has been collected and evaluated. Of the 1,156 surveys sent in 1988, the following breakdown of facilities were targeted for further attention:

356 facilities with floor drains discharging directly to the soil
119 facilities with floor drains discharging to septic systems
222 facilities with floor drains discharging to publicly owned treatment works
75 facilities with floor drains discharging to surface water

Facilities with discharges to surface water were referred to the Water Bureau Division of Licensing and Enforcement for investigation as illegal overboard discharges.

As a courtesy, Publicly Owned Treatment Works (POTWs) were notified of facilities discharging to their treatment plant, with the request that the DEP be notified if they took any action against the facilities. Of the 100 POTWs involved, about 25 wrote the DEP about inspections they made of the targeted facilities, or provided information on local regulation of floor drain discharges. Many municipal officials called the DEP to discuss the UIC program and its impact on the town. Overall, the response from local officials was very good.

Facilities with discharges to the soil or septic systems were targeted for investigation as part of the UIC program. These facilities, in addition to those with discharges to a POTW, were sent a letter providing information on applicable regulations and best management practices (BMPs) for materials commonly found at automobile service stations. (The "Fact Sheets" containing this information are attached as Appendix D.) The letters were generated automatically based on the type of survey response coded into the computer. The facilities were asked to respond in writing within 20 days and provide information on their disposal practices of materials such as waste oil, spent solvents, parts cleaners, and degreasers. Of the 475 facilities required to respond to the notice of regulation letter (those facilities with discharges to the soil or septic systems). the breakdown of responses is as follows:

69 facilities eliminated or never had a floor drain
214 facilities discharged only water through the floor drain
8 facilities connected the floor drain to a municipal sewer system
5 facilities connected the floor drain to a holding tank
18 facilities are no longer service stations
1 facility actually discharges to the surface water, not the soil
156 facilities did not respond
4 facilities were duplicates

Those facilities with continuing discharges, and those facilities not responding to the notice of regulation letter will be further investigated as part of the UIC program.

The 1989 automobile service station survey information has also been collected and evaluated. Of the 1,949 surveys sent, the following breakdown of facilities were targeted for further attention:

63 facilities with floor drains discharging directly to the soil
47 facilities with floor drains discharging to septic systems
216 facilities with floor drains discharging to POTWs
17 facilities with floor drains discharging to surface water

The notification and enforcement procedure used for the 1988 survey results, described above, was also used for the 1989 survey results. The responses to the notice of regulation letter for 1989 survey responses are still being received, and therefore have not yet been compiled.

The results of the food processing survey have not yet been tabulated.

Enforcement/Compliance Strategy

The DEP initially intended to tie its UIC enforcement program to the State's Wellhead Protection Program. Injection wells located within wellhead protection zones would receive top priority for enforcement. However, due to legislative delays in the implementation of Maine's wellhead program, a different method for prioritizing enforcement actions was established. The Maine Department of Human Services, Division of Health Engineering regulates drinking water supplies in the state, and will administer the Wellhead Protection Program. Staff of this agency assisted the DEP in reviewing public water supplies in the State to determine the source and volume provided. Public water utilities with ground water supplies serving more than 400 people were given the highest priority for enforcement.

The 156 facilities not responding to the notice of regulation letter (1988 survey) were prioritized first. A list of the 20 most critical facilities was referred to the Division of Licensing and Enforcement for further action. The Division sent certified letters to the 20 facilities, requiring them to respond within 20 days to avoid issuance of a consent agreement with monetary penalty. Most of the facilities responded within the time allowed, and voluntarily eliminated their floor drain.

Field Inspections

During 1988, assistance with field inspections of UIC facilities was provided by the Division's field personnel during the course of their regular duties inspecting treatment plants and investigating complaints. About 184 inspections were made. Field personnel also assisted in collecting Federal Underground Injection Reporting System (FURS) data elements not collected originally in the 1988 survey.

A Conservation Aide was hired for the summer of 1989 to perform field inspections of facilities with potential Class IV and Class V injection wells. Over 100 facilities were inspected throughout the state. The facilities targeted were in two categories: 1) those who stated in the 1988 survey they had a floor drain discharge, then stated in their response to the notice of regulation letter they had eliminated it; and 2) those facilities targeted for enforcement due to a lack of response to the notice of regulation letter. The results of the 102 facilities inspected in 1989 is as follows:

55 facilities eliminated the floordrain
16 facilities discharged only water through the floor drain
2 facilities connected the floor drain to a municipal sewer system
1 facility connected the floor drain to a holding tank
5 facilities are no longer service stations
13 businesses closed
10 facilities did not plug the floor drain (after stating they would)

Technical Assistance for Municipal Officials

During the summer of 1988, the Maine Department of Human Services, Division of Health Engineering conducted a pollution source inventory project. Funding for this effort came from the UIC program. The inventory focused on Class IV and Class V wells considered to have the potential to contaminate the Portland Water District ground water supply wells (a Wellhead Protection Area) serving the town of North Windham, Maine.

This project provided insight to the sources of information available and steps involved in conducting an inventory. The project was successful, due largely to the orderly and accurate nature of town records of land use activities. Based upon the project findings, the water district made recommendations to the Town of North Windham for incorporation into a land use ordinance. The intent of the proposed ordinance is to reduce the risk of contamination of the Town's public water supply. The results of this project have contributed to the development of a technical assistance program for municipal officials. (Maine Department of Human Services, 1988)

The DEP is compiling a written handbook detailing threats to groundwater, how those threats may be mitigated through implementation of BMPs, applicable statutes, and how other municipalities have managed and controlled threats to their groundwater. The handbook is intended as a reference book, advising a municipal official of the responsible agency for groundwater problems. The Department proposes to identify known threats to the groundwater in each Maine municipality. This will be done using existing computer databases containing information on businesses whose activities are likely to affect groundwater. The Department also proposes to present a series of public information meetings with municipal officials to present the handbooks, review actions municipalities may take to control groundwater contamination, and receive the municipalities input on how the DEP may better serve their needs to protect Maine's groundwater.

Future Direction of Maine's UIC Program

The DEP plans to continue working with automobile service stations to follow through on the information collected as a result of the 1988 and 1989 surveys. All facilities not responding to the NOR letter will be recontacted or referred for enforcement depending on the facility's proximity to underground drinking water supplies. In addition to investigating those facilities not responding to the NOR letter, all facilities with discharges located near underground sources of drinking water will be investigated further, even if they responded to the NOR letter. Facilities not eliminating their floor drain after stating they would do so will be recontacted and added to the enforcement list if necessary. Any facility with the potential to endanger underground sources of drinking water will be required to eliminate its discharge.

As the UIC program continues, the DEP plans to investigate other businesses with a high potential for groundwater contamination due to the nature of the product involved or materials used. Some of the businesses the DEP will review are: funeral homes; dry cleaners; automobile body shops and rustproofers; and boatyards.

It is possible floor drain discharges will not be allowed from these types of facilities in the future, but to implement this policy may require amendment of the existing regulations. Under the present regulations, a business could obtain a waste discharge license for a floor drain discharge if all requirements were met. The DEP feels there is too great a risk involved to allow floor drain discharges from businesses dealing with materials that could contaminate ground water supplies if handled incorrectly or in case of an accident. Since floor drain discharges have continued since the State's UIC regulations were adopted in 1983, the requirement to eliminate the discharges after this length of time may not be well received by the businesses affected. At the very least, the DEP must begin an extensive public education process to smooth the way for such a major initiative.

References

Maine Department of Environmental Protection, Maine's Underground Injection Control Program, Revised Interim Report, December 1986.

Maine Department of Human Services, Pollution Source Inventory Pilot Project (North Windham, Maine), 1988.

Maine State Planning Office, Maine Groundwater Management Strategy, June 1989.

U.S. Environmental Protection Agency. Report to Congress, Class V Injection Wells, September 1987.

Biographical Sketches

Mary Rudd James, Maine Department of Environmental Protection, State House Station #17, Augusta, Maine 04333

Employed by the Maine Department of Environmental Protection since March 1986, Mary James has been involved in the licensing of surface water discharges and land use activities, and developed state regulations for the siting of a low-level radioactive waste disposal facility. She became the UIC Coordinator for Maine in January 1989. Prior to joining the DEP, she worked for the Maine Attorney General's Office, the U.S. Attorney's Office, and the National Park Service. She attended Michigan Technological University, and received a B.S. in Natural Resources from Michigan State University.

Anthony J. Pisanelli, U.S. Environmental Protection Agency-Region I, JFK Federal Building, Boston, MA 02203-2111

Since 1987, Anthony J. Pisanelli, Hydrologist, has served as the Maine State Ground Water Program Manager in the Ground Water Management and Water Supply Branch of the U.S. Environmental Protection Agency in Region I, Boston, Massachusetts. Prior to joining EPA he was employed by the New England Interstate Water Pollution Control Commission as their Ground Water Coordinator.

Mr. Pisanelli holds a B.A. from Clark University in Biology and Environmental Affairs and a M.S. from the University of Vermont in Water Resources. In addition he has completed graduate coursework in geology, hydrogeology and geochemistry of ground water. Presently he is an associate member of the American Institute of Hydrology and a member of the National Water Well Association and American Water Resources Association.

APPENDIX A

Excerpts from Title 38, Maine Revised Statutes Annotated, Regulating the Discharge of Pollutants to Groundwater

Section 361-A. Definitions

* * *

1. **Discharge.** "Discharge" means any spilling, leaking, pumping, pouring, emptying, dumping, disposing or other addition of any pollutant to water of the State.

* * *

4-A. **Pollutant.** "Pollutant" means dredged spoil, solid waste, junk, incinerator residue, sewage, refuse, effluent, garbage, sewage sludge, munitions, chemicals, biological or radiological materials, oil, petroleum products or by-products, heat, wrecked or discarded equipment, rock, sand, dirt and industrial, municipal, domestic, commercial or agricultural wastes of any kind.

* * * *

Section 413. Waste discharge licenses

1. **License required.** No person shall directly or indirectly discharge or cause to be discharged any pollutant without first obtaining a license therefor from the board.

* * *

1-B. **License required for subsurface waste water disposal systems.** No person shall install, operate or maintain a subsurface waste water disposal system without first obtaining a license therefor from the board, except that a license shall not be required for systems designed and installed in conformance with the State of Maine Plumbing Code, as promulgated under Title 22, section 42.

* * * *

Section 420. Certain deposits and discharges prohibited

No person, firm, corporation or other legal entity shall place, deposit, discharge or spill, directly or indirectly, into the inland ground or surface waters or tidal waters of this State, or on the ice thereof, or on the banks thereof so that the same may flow or be washed into such waters, or in such manner that the drainage therefrom may flow into such waters, any of the following substances:

1. **Mercury.**

* * *

2. **Toxic or hazardous substances.**

* * *

3. **Radiological, chemical or biological warfare agents.**

* * * *

Section 543. Pollution and corruption of waters and lands of the State prohibited

The discharge of oil into or upon any coastal waters, estuaries, tidal flats, beaches and lands adjoining the seacoast of the State, or into or upon any lake, pond, river, stream, sewer, surface water drainage, ground water or other waters of the State or any public or private water supply or onto lands adjacent to, on, or over such waters of the State is prohibited.

* * * *

Section 1317-A. Discharge prohibited

The discharge of hazardous matter into or upon any waters of the State, or into or upon any land within the state's territorial boundaries or into the ambient air is prohibited unless licensed or authorized under state or federal law.

Appendix B

06-096 DEPARTMENT OF ENVIRONMENTAL PROTECTION

Chapter 543 RULES TO CONTROL THE SUBSURFACE DISCHARGE OF POLLUTANTS BY WELL INJECTION.

SUMMARY: These rules specify the State's program to control the subsurface discharge of pollutants by well injection, in order to protect underground sources of drinking water. Well injections are classified by type, and different types are regulated differently. Class I wells (deep well injection), Class II wells (injection of fluids associated with oil and gas production). and Class III wells (injection of fluids associated with solution mining of minerals) are regulated just as they would be if no State program were adopted, since the applicable federal regulations are incorporated in this chapter by references. New Class IV wells (injection of hazardous waste or radioactive waste into or above water-bearing formation) are prohibited and those in existence are required to be closed. All other types of discharge by well injection are subject to licensing under 38 M.R.S.A., §413(1-B).

1. Definitions

As used in these rules, the following terms have the following meanings. Other terms used in these rules have the meanings set forth at 38 M.R.S.A., §361-A.

A. Aquifer means a geologic formation, group of formations, or part of a formation composed of rock or sand and gravel that stores and transmits significant quantities of recoverable water, as identified (or subsequently confirmed) by the Maine Geological Survey.

B. Board means the Maine Board of Environmental Protection.

C. Fluid means any material or substance which is capable of movement, whether in a semisolid, liquid, sludge, gas or other physical state.

D. Formation means a body of rock or sand and gravel characterized by a degree of lithologic homogeneity that is mappable on the earth's surface or traceable in the subsurface.

E. Total Dissolved Solids means total dissolved (filterable) solids as determined by standard test method 92 in "Standard Methods for the Examination of Water and Wastewater," 14th edition, 1976, which is "Glass Fiber Filtration at 180 ^{o}C."

F. Underground Source of Drinking Water (USDW) means any aquifer, except those aquifers exempted in accordance with section 5 of these regulations.

G. Well means a bored, drilled or driven shaft or a dug hole, which has a depth greater than its largest surface dimension.

2. Classification of Wells

A. Class I. Wells used to discharge hazardous waste or any fluids beneath the lowermost formation containing an underground source of drinking water, except those wells that fall within the definition of a Class II or III well.

B. Class II. Wells used to discharge fluids:

1. Which are brought to the surface in connection with conventional oil or natural gas production and may be commingled with wastewaters from gas plants which are an integral part of production operations, unless those fluids are classified as hazardous waste at the time of their discharge; or

2. for enhanced recovery of oil or natural gas; or

3. for storage of hydrocarbons which are liquid at standard temperature and pressure.

C. Class III. Wells used to discharge fluids for extraction of minerals, including:

1. Mining of sulfur by the Frasch process;

2. in situ production of uranium or other metals. This category (C)(2) includes only in situ production from ore bodies which have not been conventionally mined. Solution mining of conventional mines, such as stopes leaching, is included in Class V.

3. solution mining of salts or potash.

D. Class IV. Wells used to discharge hazardous waste or radioactive waste into or above an aquifer, whether or not the aquifer is an underground source of drinking water.

E. Class V. Wells not included in Classes I, II, III, or IV.

3. Prohibited Discharges.

A. General. All subsurface discharges of fluids into or through a well are prohibited except as authorized in accordance with these rules.

B. Hazardous Wastes. The subsurface discharge of hazardous waste into or through a Class IV well is expressly prohibited. For the purposes of these rules, "hazardous wastes" are those substances identified as hazardous by the Board in Regulations, chapter 850, section 3(C). This prohibition is established pursuant to the authority conferred upon the Board by Title 38, M.R.S.A., §420(2), and is subject to the following limited exception.

A Class IV well being used to discharge hazardous waste on the date these rules are officially proposed may continue to be used for such a discharge for a period of no more than six months after the effective date of these rules, provided that during that time there is no increase in the amount, or change in the type, of hazardous waste discharged, compared to that previously discharged.

C. Radioactive Waste. The subsurface discharge of radioactive waste into or through a Class IV well is expressly prohibited. Any discharge of radiological warfare agents or high level radioactive waste to the waters of the State, directly or indirectly, is expressly prohibited by Title 38 M.R.S.A., §420(3). Any other waste that contains radioactivity, regardless of amount or concentration, is declared to be a toxic or hazardous substance pursuant to Title 38 M.R.S.A., §420(2), based upon the criteria stated therein, and its discharge to the groundwater is prohibited.

D. Preservation of Drinking Water Quality. Any subsurface discharge into or through a Class V well that would cause or allow the movement of fluid into an underground source of drinking water that may result in a violation of any Maine Primary Drinking Water Standard, or which may otherwise adversely affect human health, is prohibited.

NOTE: Maine Primary Drinking Standards are set forth in Rules of the Department of Human Services, 10-144A CMR c. 231.

4. Permitted Discharges.

A. Class I, II and III wells. Discharges of fluids into or through Class I, II, or III wells may be maintained, provided that those requirements applicable to State programs in the regulations adopted by the United States Environmental Protection Agency pursuant to the Federal Safe Drinking Water Act on or before April 1, 1983, are satisfied. These regulations are found in Title 40 of the Code of Federal Regulations, Parts 144, 145, 124 (insofar as they are made applicable to State programs by 40 CFR §145.11) and 146. For purposes of this subsection 4(A), the terms "Director" and "State Director" shall mean the Maine Board of Environmental Protection or its delegated representative.

NOTE: The subsurface discharge of hazardous waste is also regulated by Rules of the Board of Environmental Protection, chapter 854, section 5(E).

B. Class V Wells. Discharges of fluids into or through Class V wells may be maintained, provided that (1) a waste discharge license therefore is issued by the Board prior to commencement of the discharge (or it is determined by the Board that the proposed discharge is beyond the Board's waste discharge licensing jurisdiction), and (2) any other applicable statutes and regulations administered by the Board are satisfied, including the requirements of section 3(D) of these regulations.

NOTE: Since Class V wells are a catch-all category, it is difficult to specify what other laws might apply. but for example, the Maine Hazardous Waste, Septage and Solid Waste Management Act, 38 M.R.S.A. §§1301, et seq., or the Site Location of Development Act, 38 M.R.S.A., §481 et seq., might apply.

5. Exemption of Certain Receiving Waters

After notice and opportunity for a public hearing, and subject to the approval of the U.S. Environmental Protection Agency. an aquifer or a portion thereof may be exempted from being an underground source of drinking water when the Board identifies the location of the aquifer or portion in clear and definite terms, and finds that it meets each of the following three criteria:

A. The groundwater contained in the aquifer or its portion has been classified GW-B by the Maine legislature in accordance with Title 38 M.R.S.A., §371-B;

B. It is not being used as a public source of drinking water; and

C. It will not in the future serve as a public source of drinking water because:

1. It is so contaminated or so situated that it would be economically or technically impractical to recover the water or render it fit for human consumption; or

2. It is mineral, hydrocarbon or geothermal energy producing, or has been demonstrated by a license applicant as part of a license application for a Class II or III well operation to contain minerals or hydrocarbons that are expected to be commercially producible, considering their quantity and location.

BASIS STATEMENT: The provisions of this chapter are required in order to satisfy the State Program requirements of the Underground Injection Control Program of the Federal Safe Drinking Water Act, 42 U.S.C. §300f et seq. The Board is aware of no existing Class I, II or III wells in Maine and expects there never will be any. For that reason only, the federal regulations are incorporated verbatim by reference, as the simplest way to satisfy program "delegation" requirements. The remaining provisions of this chapter are somewhat more stringent than federal requirements because of the pervasiveness of groundwater in Maine, its interconnectedness, and its present and future wide-ranging use as drinking water.

After public hearing on September 22, 1982, this rule is adopted this 22nd day of June, 1983.

AUTHORITY: 38 M.R.S.A. §343
38 M.R.S.A. §413
38 M.R.S.A. §420

EFFECTIVE DATE: July 4, 1983

Accepted for filing: June 29, 1983

Appendix C

State of Maine
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Water Quality Control
State House Station #17, Augusta, ME 04333

FLOOR DRAIN SURVEY

NAME OF BUSINESS: ELM STREET MARKET

FACILITY INFORMATION

Facility ID#: MES200000001
Street Address: ROUTE 16 ELM STREET
Town or City: Anson Zip Code: 04958
County: ______ Is the facility on land owned by an Indian Tribe?
Facility Phone: 2076352503 Facility Contact Person: ______

OWNER INFORMATION

Type of ownership: ______ (private, public, state, federal or other)
If OTHER, please explain: ______
Owner: ______ Organization (if any): JOHNSON PRODUCTS, INC.
Street Address: P.O. BOX 300, 2 WEST MAIN ST.
Town or City: NEWTON JUNCTION State: NH Zip Code: 03859
Owner Phone: 6033827900

OPERATOR INFORMATION

Operator: ______
Name of Operator's Business: HINKLEY, MARK & GLENNA
Street Address: ROUTE 16 ELM STREET
Town or City: NORTH ANSON State: ME Zip Code: 04958
Operator's Phone: 2076352503

*** *** *** *** *** *** *** *** *** *** *** *** ***

PREDOMINANT SOIL TYPE. The facility is located on (check one):

______ Sand and gravel soils
______ Clay soils
______ Shallow to bedrock soils
______ Do not know
______ Other (Please explain below)

______

______

FLOOR DRAIN(S). Does the facility have floor drains? (Y/N) N

DISCHARGE LOCATION. If YES, indicate the number and discharge location of the floor drain(s).

______ Municipal sewer system
______ Holding tank
______ Septic system
______ Pipe to stream or river
______ Directly into the ground
______ Other (Please explain below)

______

______

DISTANCE TO NEAREST WATER SUPPLY: ______ feet

WATER SUPPLY. Is the water supply public or private? ____ pub. ____ pri.

A self-addressed stamped envelope is enclosed for your return of the completed survey.

For additional information, please contact Mary James of the DEP at (207) 289-7196. Thank you for your assistance and cooperation.

DEPARTMENT OF ENVIRONMENTAL PROTECTION

Bureau of Water Quality Control **March 1989**

Underground Injection Control Program

Fact Sheet #1

WHAT IS THE UNDERGROUND INJECTION CONTROL PROGRAM?

The Underground Injection Control (UIC) Program was established by the federal Safe Drinking Water Act. The UIC Program regulates the subsurface discharge of pollutants in order to protect underground sources of drinking water. In Maine, the Department of Environmental Protection (DEP) administers the UIC Program, with support from the U.S. Environmental Protection Agency (EPA). The Maine UIC Program has been in effect since 1983, when the Board of Environmental Protection adopted regulations to control the subsurface discharge of pollutants by well injection.

The UIC regulations identify five types of injection wells. The term "well" is applied loosely and is basically a specialized form of subsurface wastewater disposal. Cesspools, septic systems, wells, pits, ponds, and lagoons are considered injection wells, and are subject to the UIC regulations if used for the discharge of pollutants.

WHY IS THE UIC PROGRAM IMPORTANT?

More than 60% of Maine households draw their drinking water from groundwater through private wells, public wells, and springs. Although most of Maine's groundwater is still of high quality, the growth and dispersion of Maine's population and associated land use activities are threatening the quality of Maine's groundwater resources and increasing the need for potable groundwater. The continued high quality of this resource is of great concern. In 1985, the Maine Ground Water Policy was set forth in an Executive Order. The primary goal of the Policy is to protect, conserve, and manage Maine's groundwater resources to protect the public health, safety, and general welfare; to meet future water supply needs; and to sustain economic growth. As the towns of Gray, Friendship, Saco, Winthrop and Houlton have learned, a single pollution incident can significantly effect the health and financial welfare of an area's residents. The regulation of the subsurface disposal of pollutants is crucial to protecting underground sources of drinking water.

Contamination effects from UIC sites can range from minimal decline in water quality to the presence of toxic levels of heavy metals, organic and inorganic contaminants, and radioactive materials. The UIC program attempts to prevent potentially harmful discharges from occurring, recognizing that prevention of groundwater contamination is better than cleanup in terms of health, engineering and cost.

WHO IS REGULATED UNDER THE MAINE UIC PROGRAM?

Anyone disposing of waste or wastewater through an injection well, including a cesspool, septic system, well, pit, pond, or lagoon is required under 38 M.R.S.A. Section 413(1-B) to obtain a waste discharge license from the DEP. A license is not required for systems designed and installed in conformance with the Maine Plumbing Code and used solely for the discharge of sanitary wastewater.

The UIC regulations include five classes of injection wells. The first four classes are defined as:

Class I: a well used to inject hazardous wastes beneath an aquifer.

Class II: a well used to inject fluids associated with oil and natural gas production.

Class III: a well used to inject fluids associated with mineral extraction.

Class IV: a well used to inject hazardous waste or radioactive waste into or above an aquifer.

The DEP is not aware of any Class I, II, or III wells, but they may be licensed under the regulations if all requirements are met. **Class IV wells are prohibited in Maine.**

A Class V well is any well that does not fall under the definition of Classes I-IV and typically injects non-hazardous fluids into or above an aquifer. Class V wells may also be licensed under the UIC regulations.

Facilities which discharge wastes to municipal sewers or directly to surface waters are not regulated under the UIC program, but are regulated by local ordinance and other laws administered by the DEP.

WHAT TYPES OF WASTES ARE A THREAT TO GROUNDWATER?

Industrial and commercial wastes discharged through subsurface disposal systems can include petroleum products, cleaning solvents and degreasers, industrial and agricultural chemicals, storm water runoff, and a host of other chemicals. Because the constituents of these products are often persistent in groundwater, the cumulative impact of continual disposal of these wastes from one or several sources has the potential to cause widespread contamination of the groundwater resources.

The potential for contamination to groundwater can vary considerably based on several factors: design, construction, and operation of the disposal system; quality and volume of the material discharged; where disposal occurs in relation to the drinking water source; and localized hydrogeologic conditions.

HOW DO YOU OBTAIN APPROVAL FOR A CLASS V INJECTION WELL?

Facilities utilizing Class V injection wells must obtain a waste discharge license from the DEP. Again, a license is not required for systems designed and installed in conformance with the State of Maine Plumbing Code and used solely for the discharge of sanitary wastewater.

The first step in obtaining a waste discharge license is to submit an application to the DEP. The application will be reviewed by the DEP and other state agencies before a decision is made to approve or deny the discharge. Any discharge must meet the requirements set forth in the laws and regulations administered by the Department in order to be approved.

For more information, please contact:

Department of Environmental Protection
Bureau of Water Quality Control
State House Station #17
Augusta, Maine 04333
(207) 289-3901

DEPARTMENT OF
ENVIRONMENTAL PROTECTION

Bureau of Water Quality Control May 1989

Underground Injection Control Program

Fact Sheet #2

AUTOMOBILE SERVICE STATIONS AND RELATED BUSINESSES

THE PROBLEM. What should be done with waste oil, hazardous waste, and contaminated wastewater? At an automobile service station, these materials include solvents, cleaners, used oil and fluids, detergents, heavy metals, gasoline, and kerosene. In the past, our solution was to pour everything down the drain, outside on the ground, or in the nearest stream. We thought, "out of sight, out of mind." We have become painfully aware of the ignorance of this concept. What we poured down the drain yesterday is in our drinking water today. Now, we are more aware of the danger these materials pose to our environment, especially to our drinking water supplies. The Underground Injection Control (UIC) Program was created in response to this new awareness.

Danger to Groundwater. The UIC Program regulates the subsurface discharge of pollutants in order to protect underground sources of drinking water. Many situations exist that allow damaging materials to enter the groundwater and contaminate drinking water supplies. One example is found at automobile fuel and service stations, body shops, rustproofing operations, and automotive dealerships. These businesses often have floor drains located in service bays. If the drains are connected to shallow disposal wells or septic tanks, materials such as gasoline, oil, antifreeze, transmission fluid, brake fluid, and kerosene can enter the drains and adversely effect the groundwater around the site. Contamination of nearby drinking water wells could occur. To avoid increasing contamination, these types of discharges are now prohibited in Wellhead Protection Zones, which are areas containing significant underground sources of drinking water.

The Department of Environmental Protection has established several Best Management Practices to assist people located in Wellhead Protection Zones in complying with state laws and regulations. For example, in areas not served by a sewer, floor drains are not permitted unless connected to a holding tank with automatic shut-off or high level alarm. Holding tanks (including oil/water separators) containing hazardous waste must be pumped by a licensed hazardous waste hauler and shipped with a legal manifest (shipping document) to a licensed factility for recyling or disposal. Holding tanks (or oil/water separators) containing waste oil may be pumped by a licensed waste oil dealer and hauled to a waste oil recycling facility.

Floor drains connected to dry wells, cesspools, septic systems, and other types of wells regulated by the UIC Program are prohibited in Wellhead Protection Zones. These disposal methods are a major source of pollution. Leaching of motor oil, brake fluid, anti-freeze, etc. will occur and will contaminate underground sources of drinking water. Corrective measures include digging up the wells, removing the contaminated soil, installing a holding tank, and often finding new drinking water supplies for a neighborhood or entire town.

Danger to Surface Water. Interior floor drains discharging directly or indirectly to surface waters are another potential danger. Spills can occur, and floor washdown will enter the floor drain. The discharge of waste oil, contaminated wastewater, and hazardous wastes would result in the contamination of surface waters. Discharges of this type are not allowed. All other discharges to surface waters require proper treatment, and a waste discharge license from the DEP. For more information on discharges to surface waters, contact the Division of Licensing and Enforcement within the Bureau of Water Quality Control at the DEP at 289-3901.

Sanitary Sewer Connections. Floor drains connected to the sanitary sewer are subject to the regulation of the local sewer district. State law prohibits the unlicensed discharge of oil, gasoline, and hazardous waste to the sanitary sewer. In addition, many towns have ordinances prohibiting similar discharges to the sewer system. Some towns allow floor drain connections to the sanitary sewer if the discharge is pretreated. Local ordinance may require that a floor drain be connected to an oil and grit separator that collects heavier-than-water runoff before discharging the relatively "clean" water to the sewer system. For more information on sewer connections of floor drains, contact your local sewer district.

Hazardous wastes. Hazardous wastes typically generated at automobile service stations include waste solvents from parts cleaning, waste paint thinners, waste battery acid, and hot tank caustic cleaners. These wastes must be segregated from wastewaters, waste oil, and other wastes. Businesses that generate less than 220 pounds or 25 gallons per month or accumulate no more than 220 pounds of hazardous waste at any one time may qualify as "small quantity generators." At a minimum, such generators are required to label, properly package, ship, manifest and use a licensed hazardous waste tranporter to ship the materials to a hazardous waste facility. If you generate more waste than the amounts described above, the requirements are more detailed. For more information on hazardous waste generator requirements, contact the Division of Licensing and Enforcement in the Bureau of Oil and Hazardous Materials Control at the DEP at 289-2651.

THE SOLUTION. How can you help protect our drinking water supplies?

1. **Substitute.** Substitute non-hazardous materials whenever possible. Environmentally, this is the preferred solution.

2. **Segregate.** Segregate waste oil for recycling. Waste oil may be offered for sale or used as a fuel supplement if it meets certain standards, has not been mixed with any hazadous waste, and does not exhibit any hazardous waste characteristics.

3. **Recycle.** Use a recycling service to periodically pick up spent solvents and other hazardous materials, and replenish your supply. Due to the complex nature of the requirements concerning the handling, storage, and disposal of hazardous wastes, many service stations have minimized the amount of solvents, paint thinners, and caustic cleaners they use in order to qualify as small quantity generators. Many small quantity generators (as well as large quantity generators) have found contractual recycling services to be an efficient way to remain in compliance with the disposal requirements. Companies offering such services must be licensed by the DEP as a hazardous waste transporter. For a complete list of licensed hazardous waste transporters, contact the Division of Licensing and Enforcement in the Bureau of Oil and Hazardous Materials Control at the DEP at 289-2651.

THE FUTURE. Some of the materials we use on a daily basis cannot be "disposed of" -- they will be with us forever. Whatever was disposed of improperly in the past is now part of our environment: the air we breathe, the food we eat, and the water we drink. Now we must make every effort to handle materials such as waste oil, hazardous waste, and contaminated wastewater properly. Proper use and disposal of these materials is vital to avoid further damaging one of our most precious resources -- water.

For more information, please contact:

Department of Environmental Protection
Bureau of Water Quality Control
State House Station #17
Augusta, Maine 04333

PLANNING TECHNIQUES FOR ESTIMATING GROUNDWATER IMPACTS

OF ON-SITE SEPTIC SYSTEMS

Elizabeth Beardsley and Carol Lurie

Camp Dresser & McKee Inc.
One Center Plaza
Boston, MA 02108

Abstract

In New England and in many other parts of the country, a large proportion of the population relies on individual on-site septic systems. Septic systems rely on several processes for purification of wastewater and pose a potential risk of contamination to groundwater, particularly in areas with highly permeable soils, high groundwater, or bedrock fractures. Cumulative effects of septic systems make pollution from septic systems a serious hazard to groundwater.

There are two distinct approaches to planning and management of individual septic systems: maintenance/rehabilitation of existing systems, and proper siting of future systems. Maintenance, upgrade, and/or rehabitation of existing systems is critical to prevent pollution of groundwater and is a method for managing existing situations. Planning for the adequate siting of systems, however, can prevent <u>future</u> contamination problems.

Two analytical planning techniques can be used to assess the impact of individual septic systems from residential development on groundwater quality: residential build-out analysis and nutrient loading models.

A residential build out analysis is a technique for determining the number of residences which can be built in a given area. This number is compared to the number of existing residences to estimate the potential impacts of residential growth. An important consideration of bulid-out analyses is that their accuracy is dependent on that of the data. Realistic soil data, in particular, is needed to estimate the areas which are unbuildable, and, through the build-out analysis, project the potential number of residences and septic systems. Build-out analysis is best used as a rule of thumb analysis to give an idea of order of magnitude of a situation, and to identify geographical areas of concern.

Nutrient loading calculations are performed to estimate the nutrient contribution from septic systems to groundwater. There are several different nitrate loading models which are in use. These models are usually based on a loading rate which assumes that total nitrification occurs in the system and have the advantage of minimal data requirements compared to more advanced groundwater models. Nitrate

loading is an important technique because it is the most readily available method for quantifying the cumulative effects of septic systems on groundwater. However, applications of this technique should be undertaken with a thorough understanding of its inherent assumptions.

Septic system siting is regulated at the state level. Existing septic system regulations of most New England states are limited in that they do not contain an upper limit on permeability, and by the regulations' site by site, rather than cumulative, approach to management of septic system siting.

Introduction

The National Well Drillers Association ranks septic systems third in order of importance as groundwater pollution sources, behind landfills, and lagoons and other waste pits. Septic systems pose a potential risk of contamination to groundwater, particularly in areas with highly permeable soils, high groundwater, or bedrock fractures. In New England and in many other parts of the country, a large proportion of the population relies on individual on-site septic systems. Cumulative effects from these systems make pollution from septic systems a serious hazard to groundwater, and addressing this hazard becomes important as water supplies become more precious.

How Septic Systems Work

Septic systems are economical on-site structures designed to dispose of household wastewater underground. They are designed to perform three functions: trap oil and grease, digest solids, and percolate remaining wastewater into nearby soils.

A schematic diagram of a typical system is shown in **Figure 1**. A septic system is made up of a septic tank and a leaching area, both located underground. The septic tank is a watertight concrete tank with an inlet, an outlet, and manhole covers which allow access. Household sewage, including wastewaters from the bathroom, kitchen, and laundry room, flows by gravity to the tank, where solids settle to the bottom and form a sludge. Oil and grease float to the surface and form a scum.

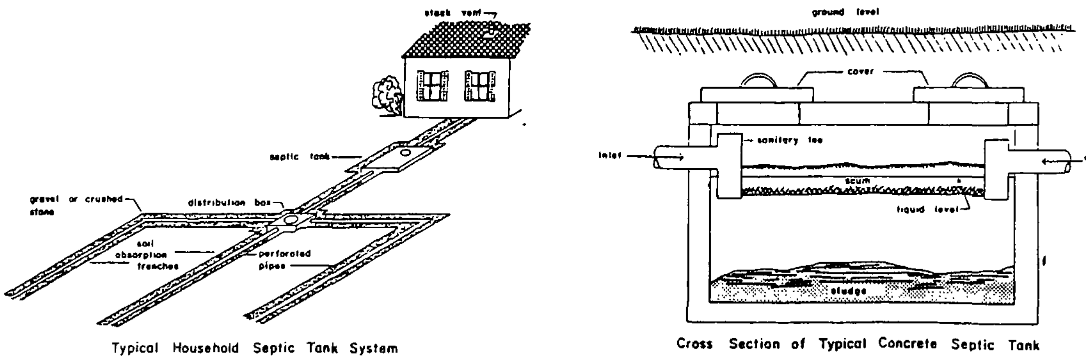

Figure 1: Typical Septic System
(Source: Lake Cochituate Watershed Association, 1985)

If the septic system is operating properly, bacteria grow in the septic tank and reduce some of the sludge and scum to liquid by digestion and partial decomposition. Oil and grease are not fully digested, but are trapped until removed from the tank by pumping.

The remaining "conditioned" wastewater flows through the outlet to the leaching area. The outlet is positioned below the water surface so that the oil and grease scum remains in the tank. The leaching area may be a leaching field, leaching pit, or leaching trench, and essentially consists of a distribution box and several perforated pipes laid in gravel-lined trenches. The purpose of the leaching area is to disperse wastewater into the soil.

As wastewater percolates from the pipes through the stone and soil, contaminants, including nutrients, are removed from the wastewater in several purifying processes. Viruses, nutrients, and bacteria adhere to soil particles, nutrients are then consumed by organisms in the soil, and consumed by plants. If the septic system is functioning correctly, the wastewater will be of non-polluting quality by the time it reaches groundwater resources. **Figure 2** illustrates these processes.

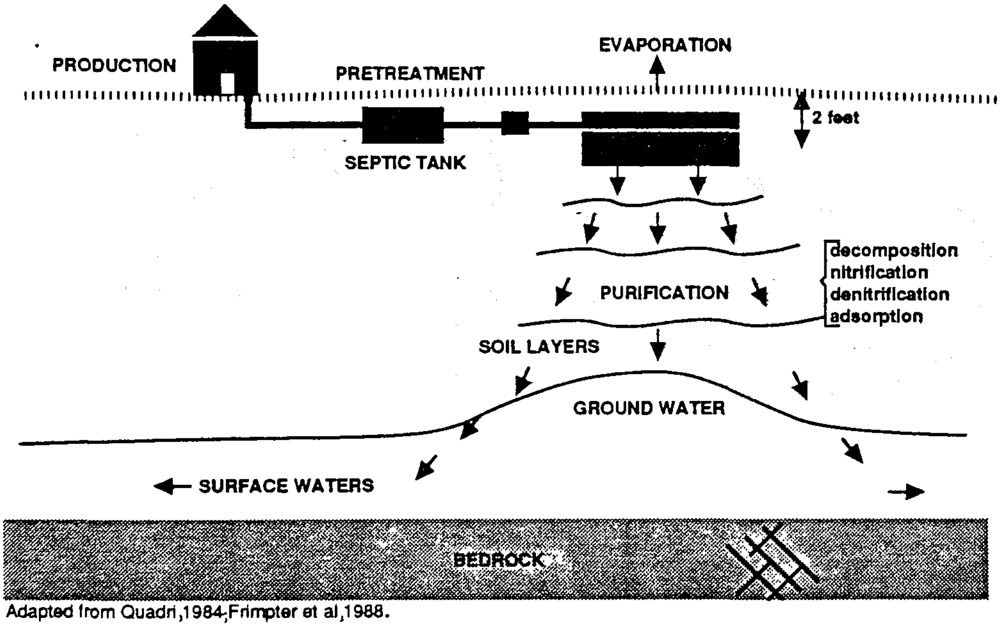

Figure 2: Subsurface Disposal Processes

Impacts of Septic Systems on Groundwater

Household sewage typically contains subtantial concentrations of ammonia-nitrogen, phosphorus, and oil and grease, as well as biological oxygen demand (BOD), chemical oxygen demand (COD), and suspended and dissolved solids. Average characteristics of household wastewater discharged to septic systems are shown in **Table 1**.

Table 1: Characteristics of Influent Wastewaters to Septic Tank Systems

CONSTITUENT	CONCENTRATION (mg/l)
BOD	300
COD	750
TOC	200
TS	780
SS	250
TKN	38
Ammonia-N	12
Nitrate-N	0.6
TP	25
Phosphate	8.8
Oil and Grease	94

Source: Bauer, Conrad, and Sherman, 1979

As septic systems rely on several processes to purify wastewater, there are numerous conditions which can cause systems to fail to treat household sewage adequately. The numbers and densities of septic systems make pollution of groundwater from septic system effluent a significant concern.

One recent public education brochure puts the problem in these terms:

> "The indirect discharge of pollutants from improperly located, malfunctioning or crowded septic systems plus pollutant-rich urban stormwater discharges cause major problems to the waters of New England. The addition of nutrients and pathogenic organisms present a potential hazard to both human health and the water quality of our lakes." (Lake Cochituate Watershed Association, 1985).

The Cape Cod Planning and Economic Development Commission (CCPEDC) has correlated the increase in groundwater nitrate concentrations with an increase in housing and septic system density. Contamination from septic systems is a serious threat to the groundwaters of New England.

Groundwater pollution from septic systems has several different causes:

(1) poor siting of system
- soils that do not adequately filter the wastewater before it reaches groundwater (including excessively permeable soils)
- too many systems in a given area, leading to significant cumulative impacts

(2) poor design and/or construction
- tank and/or leaching area undersized
- designed for seasonal use and converted to year-round

(3) maintenance or operations problems
- leaks in pipes or in the tank
- sludge build-up in the tank, leading to overflow and soil clogging
- scum build-up

Groundwater contamination from septic systems with maintenance and/or operational problems can be prevented by remediation. However, groundwater contamination from septic systems that are poorly sited cannot easily be mediated. For this reason, individual and overall siting of septic systems is extremely important.

The main concern, then, for groundwater pollution is the quality of the effluent from the septic tank portion of the system, and the efficiency of contaminant removal in the soil underlying the leaching area (Cather, 1985). This efficiency in constituent removal is affected by several criteria:

- the soil character
- soil permeability and percolation rate
- depth of soil below leaching area to groundwater
- presence of clay or impermeable layers
- presence of cracks in bedrock

The importance of this concern is supported by the literature, although most studies cited in the literature appear to have been concentrated on the efficiency of the septic tank portion, with fewer studies investigating the leaching area. One research study involved sampling of groundwater under and adjacent to leaching fields (Cogger et al, 1988). A strong relationship between wastewater loading rate and nitrate concentration was observed. In addition, there was a direct relationship between the depth to groundwater and the level of denitrification which occurred.

For wastewater to be adequately filtered, a certain contact time between the water and the soil is required. If the soil is not permeable enough, or if a clay layer is present, a failure will occur, and wastewater may be diverted, such as through horizontal movement. Furthermore, if the soil is excessively permeable, it is not able to provide attentuation of contaminants because of the speed at which the wastewater moves. The depth from the leaching area to groundwater is important because it is related to the contact and filtering time; if the depth is insufficient, water will not be sufficiently treated. The combination of excessively permeable soils and high groundwater conditions is especially prone to insufficient wastewater purification.

Although septic systems are regulated at the state and local levels, most regulations are based on a maximum percolation rate (i.e., limit slow permeability), and do not have a minimum percolation rate. The regulations neglect to consider potential pollution resulting from siting in excessively permeable soils. As a result, overall siting of septic systems is inadequate to protect groundwater.

Planning to Prevent Potential Contamination

An ample body of knowledge exists on how to prevent septic system failure and malfunctioning through proper maintenance. Recently, it seems that much interest has been shown in improving the public awareness and use of preventive measures such as pump-outs at regular intervals and water conservation. From our observations, cities and towns are becoming interested in enforcing septic system repairs; in some cases they are mandating septic system maintenance (for example, the Rhode Island On-site System Maintenance Act).

Repair and maintenance are important; however, they come into play after the septic system is in place. An important consideration is proper siting of the system. If improperly placed, failure and/or groundwater pollution is inevitable if soil characteristics and other site conditions are not conducive to wastewater treatment. For example, nitrate-nitrogen, a known public health problem in groundwater, may persist if sited in excessively permeable soils even if a system is properly maintained. Groundwater contamination may occur even if the system has not visibly failed (i.e., if there are no back ups).

Maintenance, upgrade, and/or rehabitation of existing systems is critical to prevent pollution of groundwater and is a method for managing existing situations. Planning for the adequate siting of systems, however, can prevent future contamination problems. If the cumulative contamination of groundwater by septic systems is to be prevented, the siting of septic systems must be improved.

Planning Techniques

While on-site septic disposal systems are generally not a problem to groundwater (unless sited too close to wells) when considered individually, the cumulative impact of many septic systems in areas characterized by unsuitable soils or other conditions suggests the need for the development of a land use management strategy to reduce or offset this potential cumulative impact.

This paper examines two related analytical planning techniques used in determining the impact of individual septic systems from residential development on groundwater quality: build-out analysis and nutrient loading.

A residential build-out analysis is a technique for determining the number of residences which can be built in an area served by septic systems, as permitted by regulatory requirements as well as environmental constraints. This number is compared to the number of existing residences to study the impacts of residential growth. Nutrient loading calculations are used to estimate the nutrient contribution from septic systems to groundwater. Nutrient loading analyses for nitrates are examined, and conditions and assumptions which limit the applications of nutrient loading are discussed.

Build-out Analysis

The first step in understanding the magnitude of the possible or existing impact from septic systems in an area served exclusively by on-site septic disposal systems is to estimate the potential for development of dwelling units with associated septic systems in the area. This can help determine possible future environmental and water quality conditions. One method of determining the current and future development potential of an area, and by implication the cumulative impact of septic systems, is by conducting a build-out analysis.

A build-out analysis estimates the maximum amount of dwelling units that can be built in a defined area based on current zoning and land use regulations, and regulations governing the location of septic systems. Environmental factors, including soil characteristics, wetlands, topography, and groundwater levels are specifically taken into account, often using a series of graphic map overlays. The estimated number of septic systems in a study area can then be used as a basis for the nutrient loading calculation to project potential impacts from septic systems to groundwater resources.

The build-out analysis assumes that the major current regulatory requirements are followed. For Massachusetts, these regulations include:

- Zoning Regulations
- the Wetlands Protection Act
- Regulation of Septic System Location and Design (Massachusetts Title V)

There are two main approaches for conducting a build-out analysis:

1) Parcel-by-parcel build-out (tabular or graphical)
2) Generalized build-out (graphical)

In the town of Hopkinton, Massachusetts, we applied the first methodology to determine the different impacts on land use between residential development using traditional on-site septic disposal systems versus the use of small private treatment plants. In the town of South Kingstown, Rhode Island, we conducted a generalized build-out analysis for several watersheds, the results of which were used to project the impact of development through nutrient load modeling and resultant water quality implications.

Build-out Methodology

Essentially, the build-out analysis has three major steps:

A) Determination of vacant developable land

B) Determination of vacant developable land by zoning district

C) Calculation of the potential number of dwelling units (and septic systems) that could be built in an area

The analysis is conducted by developing a series of map overlays. We have in some cases used a Geographic Information System (GIS) as a tool in this process. These steps and components of the build-out analysis are detailed below.

A) Determine vacant developable land

   1. Map soils that cannot be built on

      Soils cannot be built on for two reasons: (1) the soils (topography) are too steep to build a residence economically, or (2) the soils do not meet the minimum requirements to install a septic system to serve the residence.

      For the town of South Kingstown, a map overlay was developed based on the classification of soils by the U.S. Department of Agriculture, Soils Conservation Services (SCS). Soils are classified as severe for septic systems when they exhibit a high groundwater table, slow percolation rates, susceptibility to flooding, presence of rocks and boulders, slope, and/or excessive permeability. Unsuitable areas were then mapped on an overlay.

      For the town of Hopkinton, the Soil Conservation Service data was translated into the criteria specified by Title V, the state regulation which governs the location and design of septic systems.

Areas which did not meet minimum criteria, according to SCS data, were mapped as unbuildable on an overlay.

2. Map wetlands

Wetlands are a constraint to development because federal and state regulations often restrict filling of wetlands. An overlay map of wetlands is compiled based on the best available data. This may be town maps, the U.S. Fish and Wildlife Wetlands Inventories, U.S.G.S. topographic maps, or aerial photographs.

3. Create composite environmental factors map

The next step is the creation of a composite map of soils and wetlands that shows the environmental factors that limit development potential.

4. Map existing land use and developed/undeveloped land

An existing land use map is then developed which shows areas in the study area that are used for different purposes such as residential, commercial, industrial, municipal, transportation, and recreational uses. Maps are either developed from existing information, or through interpretation of aerial photographs.

The land use categories are divided into two groups - developed and undeveloped. Developed uses would include those already committed for use such as residential, commercial, industrial, paved areas such as highways, and conservation land. Land uses considered undeveloped include vacant areas, agricultural land (not under permanent development restrictions), golf courses, or any land within a community that has the potential for being developed. Land use categories vary according to study area. Areas which are undeveloped are identified for input to the next step.

5. Map vacant developable land

The next step in the process creates a map showing land that is vacant and can be developed (developable). The environmental constraints composite map is overlain with the land use map. A map is created showing only land which is undeveloped and has no environmental constraints, termed "vacant and developable" land (see **Figure** 3). This map thus takes environmental factors as well as existing land use into account.

B. Determination of vacant developable land by zoning district

Once the vacant and developable land is identified, the zoning of the municipality is taken into consideration.

6. Map zoning districts

The zoning map of the municipality is then superimposed onto the vacant developable land map. This composite map forms the basis

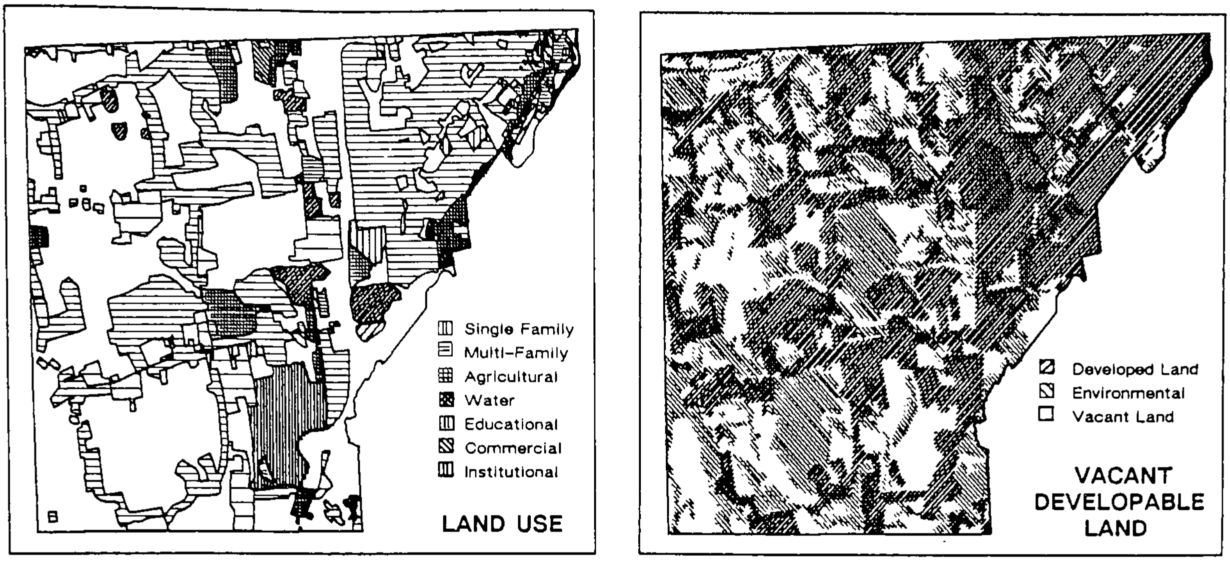

Figure 3: Land Use and Vacant Developable Land

for calculating the potential number of dwelling units by zoning district.

C. Calculations

7. Measure vacant developable land by zoning district

All areas of vacant developable land falling within each zoning district are measured. This calculation is simplified if the mapping is done using a Geographic Information System (GIS).

8. Subtract a percentage for roads and infrastructure

In order to estimate future residential dwelling development potential, a percentage must be subtracted for land that would be used for roads, utilities, service easements and other municipal uses. Typically a factor of fifteen percent is used for residential development.

9. Calculate the number of new dwelling units

After the total area of land available for building lots is calculated, the next step is to calculate the number of possible dwelling units for each zoning district. This is based upon the minimum lot size requirements as specified by the zoning code. Each vacant developable area is evaluated in terms of the permissable number of dwelling units per acre. If the build-out analysis is being conducted on a parcel-by-parcel basis, several scenarios may be developed to project different development patterns which are possible.

10. Calculate the total number of dwelling units and septic systems

Based on the above, the next step is to add the potential number of dwelling units that could be built to the number of dwelling units that already exist in the study area. The existing number of dwelling units, or base case, is determined through examination of aerial photographs, field checking, and examination of septic system permits and other town records.

The total number of existing and potential dwelling units and associated septic systems serving these residences is used as a basis for calculating nutrient loading on water resources of the study area.

The build-out analysis thus gives an estimate of the current and future development potential of an area, and the potential number and location of on-site septic systems that could be built.

Nutrient Loading Analysis

Nutrient loading analysis is a technique which has been used increasingly as a tool for determining the density of development that can be sustained given soils conditions. Nutrient loading utilizes the location and/or number of septic systems and loading rates to determine the nutrient load to groundwater. It is sometimes carried further and is used with groundwater flow and quality data to project the concentration of a parameter resulting from a specific development.

While nutient loading analyses can be performed for phosphorus and other parameters, this paper focuses on nitrogen, specifically nitrate-nitrogen.

Nitrogen Loading Analysis

Nitrogen loading analyses may take several varied forms. In general, the analysis involves multiplying the number of septic systems by the quantity of nitrogen present in the effluent over a given period of time. In different models or applications, this quantity may be input to other equations to determine concentration.

The simplest nitrogen loading calculation involves multiplying the number of actual or potential septic systems in the study area by a loading rate:

$$NO_3 \text{ load} = (\text{lbs/system/yr}) \text{ X } (\text{systems})$$

$$NO_3 \text{ load} = (\text{lbs/person/yr}) \text{ X } (\text{persons/residence})(\text{\# residences})$$

The loading rate is usually in lbs/person/year, with the result in lbs/year. It may be necessary to understand the demographic characteristics of the study area to determine the average number of persons per residence or septic system.

This technique was used in South Kingstown in conjunction with the build-out analysis. In the South Kingstown study, the town wanted to predict the effects of development on several salt ponds which were largely fed by groundwater. Using nitrogen loading rates, an annual nitrogen budget was developed to show the nitrogen contribution, in pounds, from different sources such as septic systems, agriculture, fertilizer, roads, runoff, and precipitation. These calculations were performed for the existing situation, and also for the build-out condition, under which many more houses and septic systems would be present in the watershed.

Several models have been developed for Cape Cod, Massachusetts. Cape Cod is characterized by sandy soils which are well to excessively drained, and is a sole source aquifer. The combination of these environmental conditions and rapid development rates have caused concern over septic system effects, leading to modelling efforts, notably by the Cape Cod Planning and Economic Development Commission (CCPEDC).

The model developed by CCPEDC models the dilution of nitrate moving from septic systems into groundwater (Quadri, 1984). The model assumes a complete mixture of two volumes - recharge and septic system effluent - and the formula solves for the mixture concentration:

$$\text{NO}_3 \text{ concentration in groundwater} = \frac{(\text{recharge vol})(\text{recharge conc.}) + (\text{system vol})(\text{system conc.})}{\text{recharge volume} + \text{system volume}}$$

The nitrate concentration of septic system effluent is estimated using standard septic system flow estimates, and per-person nitrogen loading rates. (This assumes total conversion of ammonia to nitrate.) CCPEDC has used this model to estimate the density that can be supported while maintaining desired nitrate levels in groundwater.

A more advanced version of this nitrogen loading model was developed as part of the Cape Cod Aquifer Management Project (CCAMP) (Frimpter et al, 1988). The model presented is more detailed, and is adapted for use specifically in predicting nitrate concentrations in municipal wells. This model allows for inclusion of sources other than septic systems:

$$\text{NO}_3 \text{ concentration in groundwater} = \frac{\text{nitrate from precipitation} + \text{nitrate from sources}}{\text{total volume}}$$

(simplified form)

Precipitation and well withdrawal take the place of recharge. Generally, however, the two models operate on the same principles of total mixing and dilution.

Other models, such as for Winnebago County, Illinois, involve extensive groundwater sampling to construct complex mass balance relationships (Jaffe and DiNovo, 1988).

To assess the impacts of a proposed residential and resort development, one method used nitrogen loading as a check for a more sophisticated and complex solute transport model (Atwood, 1989). The solute transport model is more advanced, but has greater site-specific data requirements, including groundwater flow, quality, boundary conditions, water table contours, and hydraulic conductivity. This data is used in solute transport equations which solve for concentration at different locations of the site. A more advanced model such as this has the advantage of probable greater accuracy and gives concentrations for various locations on the site (rather than a single value); however, required data is often not available, especially for large-scale planning applications.

Nitrogen loading calculations similar to those developed by CCPEDC were used to check the validity of the solute transport model.

In Acton, Massachusetts, a different approach was used (Jaffe and DiNovo, 1988). In this case, the base flow water quality of streams in the study area was assumed to be proportional to the number of septic systems in the drainage basin. Once this proportion was established for the existing condition, the effect of build-out on groundwater could be estimated. This model was used to determine the maximum density to result in a certain concentration without reliance on a per-person type rate.

Nitrogen and other nutrient loading models vary from the very simple to the very complex. Generally, models are based on the concept of septic systems as a significant, or in some models as the significant, source of nitrate-nitrogen to groundwater, and are based on a loading rate in the units lbs/system/year.

Applications and Implications

Build-out and nitrate loading analyses can be used to assess present and future effects of septic systems on groundwater. These techniques are useful in large-scale applications or where limited site-specific data is available. These planning methods have many different applications and also involve certain assumptions and implications, as discussed below.

Build-out Analysis

The purpose of the build-out analysis is to estimate the development potential of an area. The build-out analysis is a very useful tool, but like any simplifying model, must be only used where appropriate.

Applications. There are many different applications and forms of build-out analysis. This paper applies the build-out analysis to residential development utilizing septic systems, which can then be used with nutrient loading analyses. Build-out analysis of this type is only suitable in an area that is exclusively served by septic systems. Some other applications of build-out analysis include maximizing the area of commercial development, and making population and infrastructure estimates.

Build-out analyses vary in complexity and scale. Some analyses are conducted on a parcel-by-parcel basis, involving the use of assessors' maps. Generalized analyses utilize available land use and natural resource maps, usually at a smaller scale which precludes consideration of individual parcels. Build-out analyses can be very simple, utilizing existing data, or complex, requiring extensive data collection and scale transformation efforts. Most build-out analyses are based on spatial relationships.

Parcel-by-parcel analyses have a greater degree of accuracy and of precision. However, there may be some loss of accuracy in the application of soil and wetland constraints, if soil and wetland data is available only at a coarser level of detail than the parcel size. Also, the parcel-by-parcel analyses are more time-consuming. Generalized build-out analyses can be somewhat less accurate than the parcel-by-parcel, but the result is valid as an estimate of the magnitude of potential growth, rather than a precise number of dwelling units.

Accuracy of Data. A build-out analysis is only as accurate as its data. In most cases there are several different data sources involved, each at a different level of detail and from different base years. Soil and wetlands data vary substantially in accuracy, and it is imperative that inconsistencies or limitations of the data are factored into the analysis.

Soils data, in particular, are problematic. If the goal of the analysis is to determine the number of units which can be built in compliance with regulations, the soil parameter values which are selected as constraints must be the same as those unsuitable in the regulations. Translating municipal or regional data sources to these site-specific parameters can be difficult.

For a build-out analysis in Haverhill, Massachusetts, Soil Conservation Service soil maps were found to be misleading in terms of whether the area could actually be developed with a septic system. For many areas, the SCS data indicated inadequate permeability; however, Board of Health records showed that very few lots failed to pass a percolation test. Since SCS data suggested that development could not occur, yet local experience showed that these areas were allowed to develop, soil factors (in the form of percentages of watershed area) were developed to account for the soil developability, based more heavily on slope and rock outcrops than permeability.

The actual areas where septic systems cannot be built could also depend to some extent on the rigorousness of the Board of Health or agencies permitting the systems.

In states where regulations do not limit septic system siting in excessively permeable soils, such soils should not be considered to be constrained from development. Although these soils may be unsuitable from a groundwater pollution standpoint, they can (and will) be developed with a septic system and be in accordance with the regulations.

Validity of Result. While the build-out analysis projects the state of development when all available land is built upon, the build-out does not imply that the development will actually happen. The likelihood of development occuring is dependent on inter-related factors such as the economy, real estate market, and population trends in the region. In view of these considerations, it is difficult to bring in a temporal factor, which would be needed to estimate the phasing of potential development.

Use of Result. Build-out analysis is best used as a rule of thumb analysis to give an idea of order of magnitude of a problem. It is also well-suited to identify areas of concern - such as large developable areas without infrastructure or conservation protection.

Nitrate Loading

Nitrate loading is an important technique because it is the most readily available method for quantifying the cumulative effects of septic systems on groundwater. The purpose of nitrate loading calculations is to project the potential impact of septic systems to groundwater. The result of calculations is usually in the form of lbs/year, and can be used as input to further calculations to project a concentration (i.e. in units of mg/l or ppm).

Nitrogen loading is important to consider because excess nitrogen loading to soils can result in conditions of elevated nitrate or ammonia in groundwater which in turn can cause health problems and/or contaminate wells beyond use. An understanding of nitrogen loading prior to development is imperative if nitrogen contamination of groundwater from septic systems is to be minimized.

Applications. There are numerous ways in which nitrate loading calculations are used. Nitrate loading can be used:

a) for site-specific impacts
b) to evaluate the use of septic systems versus treatment
c) to determine the maximum number of septic systems that could be supported
d) for an existing situation to determine the percentage of nitrogen contributed by septic systems
e) to assess future conditions in conjunction with build-out analysis

The loading rate is often applied in site-specific applications as part of overall nitrogen budgets or in predicting nitrate concentrations in groundwater. For example, the South Kingstown study calculated nitrogen loads to salt ponds from septic systems and other sources within the watersheds for the present situation and the future. These numbers were used to determine the relative present and future importance of each source of nitrate. Other applications use nitrogen loading on proposed development sites to determine if on-site septic systems could be used, or if wastewater treatment is required.

In some circumstances, the calculations are used to make non-specific findings, such as a general determination of the maximum number of septic systems which could be supported while maintaining groundwater quality at a certain nitrate level. For example, nutrient loading was used in a general application by CCPEDC to calculate the lot size appropriate for septic systems on Cape Cod. When using the results of a general analysis like this in large-scale planning, it is imperative to consider the nature of the model, which by nature does not consider existing nitrate levels, groundwater flows, hydrogeology, and other nitrogen sources.

Nitrate loading calculations can be dependent or independent of build-out analysis. In some cases, it may be desired to compute nitrogen loading for an existing situation, without consideration of future development. For example, nitrogen loading calculations might be used to determine whether septic systems are a significant contributor to known groundwater pollution compared to other sources within a watershed. This might be done through comparison of annual loads without needing to calculate nitrate concentrations. This has the advantage of avoiding inherent uncertainty associated with assumptions involved in the concentration calculations.

To project future groundwater pressures, nitrogen loading calculations must be used in conjunction with build-out analysis. The result could again be either an annual load or a projected concentration.

Accuracy of Data. The simplest of nitrate loading models requires for data the number of existing or potential septic systems, and the nutrient loading rates. The number of existing septic systems is generally readily estimated, and the number of potential systems can be projected with the build-out analysis to a certain level of accuracy. The accuracy of these simplified nitrate loading analyses hinge on the appropriateness of the nitrate loading rates.

Nitrate-nitrogen loading rates vary; values used in studies cited herein ranged from 5 lbs/person/year to 10 lbs/person/year. Nitrate loading rates are based on research which was focussed on estimating flows and contaminant loads to treatment works, and on some actual monitoring of effluent. These rates are based on assumptions which include the level of nitrification and the degree of attenuation through the soil. One rate assumes total nitrification in the septic system, with no removal of nitrate in underlying soils (Frimpter et al, 1988), while another assumes 50% nitrification only (CDM, 1988).

Nitrogen loading rates were originally developed from septic system research in 1960s and 1970s which was concerned with flow volumes and with the load to the septic tank rather than the effluent from the leaching area. Recent research in the area of the actual quality of effluent which leaching fields are discharging to the ground, and the actual degree of attentuation which various soils are acheiving in view of different groundwater conditions appears to be lacking.

It is valuable and important to consider the assumptions involved with a particular rate before its application. It may not be accurate to apply the same rate to different soil and geohydrologic conditions. Septic tank and leaching field performance will shape the degree of nitrification which occurs, while underlying on-site soil conditions and the depth to the water table will affect the degree of attenuation of nitrate.

One main advantage of nitrate loading is its minor data requirements. The data necessary to use a more advanced model, such as a solute transport model, is often not available. Nitrate loading, with all its inherent assumptions, is a valuable tool for estimating the nitrate contribution of septic systems relative to other nitrate sources, or for projecting the increase in nitrate load with development. The projection of nitrate concentrations in groundwater should be made only with an understanding of the assumptions of the analysis.

Use of Result

In view of the assumptions used in nitrate loading analyses, there are several ideas to consider in application of the analyses and results. First, there are problems with transferring loading rates and other absolute numbers from one study area to another. These rates were developed in part from well-used data concerning sewage generation, but are also based on nitrification, attenuation, and other processes which may be shaped by site-specific conditions. An understanding of on-site soil properties and the processes assumed in the development of a specific loading rate are advisable.

One good use of the analysis is to estimate the nitrate contribution from septic systems relative to other sources. While this application still relies on the loading rate, the same assumptions involved can be used when estimating the contribution from the other sources. The result of this application is a relationship, rather than an absolute number. The use of nitrate loading with a build-out analysis is also useful to project change in nutrient load and relative contribution of nitrate.

Regulation of Septic Systems

Build-out and nutrient loading analyses are techniques which help to assess eumulative impacts of septic systems and development. In order to minimize the potential for contamination of groundwater from septic system effluent, siting of septic systems should consider cumulative effects. Currently, however, siting of septic systems is mainly regulated on an individual system basis.

The siting, as well as the design and installation, of septic systems are regulated on a state and local level. Regulations typically use parameters such as soil type or classification, percolation rate, depth of permeable soil, depth to seasonal high water table, and depth to bedrock to site septic systems. Regulations also contain setback requirements and detailed sizing and design guidelines. **Table 2** lists selected standards for septic system siting for several New England states.

Table 2: Septic System Regulations of Selected States

SITE CONDITIONS	ME	RI	NH	VT	ME
PERCOLATION RATE: SLOW LIMIT	30 min/in	40 min/in **	60 min/in *	60 min/in	system based on soil profile texture
FAST LIMIT	None	None		1 min/in	
SOIL DEPTH ABOVE HIGH WATER TABLE	4 feet	4 feet	4 feet	3 feet	15 - 48 inches
SOIL DEPTH ABOVE IMPERVIOUS LAYER OR BEDROCK	4 feet	5 feet	6 or 8 feet	3 and 4 feet	15 - 48 inches
SLOPE	slope constrained by lateral distance requirements		35%	10% (trench) 20% (bed or pit)	10% (trench) 20% (bed or pit)

(1) Regulations shown apply to leaching bed systems.
* Certain soil types that are floodplain soils or very poorly drained
** 20 min/inch over 2000 gpd.

Analysis of these regulations show that in most states, there is no consideration for excessively permeable soils. That is, siting regulations rely upon minimum percolation rates. The installation of a septic system in excessively permeable soil (i.e., with a percolation rate of 1 min/inch) will be acceptable from a regulatory standpoint, but is likely to be a potential source of contamination. When systems are placed in such excessively permeable soils, and high groundwater and/or shallow depth to bedrock is present, that septic system has a strong potential for contamination of groundwater.

Other problems with regulations are that often, percolation tests may be repeated until one test is adequate, although the soil may not be suitable for attenuation of wastewater on a daily basis. In some areas, soil testing can be done at any time of year. The depth to groundwater distance (i.e., high water level) may not be accurate if measured in fall or winter.

The most serious limitation of the regulations in general is their site by site, rather than cumulative, approach to management and location of systems. Nitrat loading analyses show that when considered on a cumulative basis, the impact is considerably greater than the impact of individual systems is believed to be, and support the need to reevaluate the way that the management and siting of septic systems is approached.

Finally, current regulations generally do not provide for planning on a large-scale basis. Municipal subdivision regulations often allow for wastewater planning, but where land is developed by individuals, there is currently no real method for bringing in considerations of cumulative impacts.

Regulation of septic systems began with the goal of protecting human health from failed systems and from direct well contamination. Now, regulation of septic systems must have the goal of protecting groundwater as well as the need to accommodate development at some level.

Conclusion

Septic systems represent a significant threat to groundwater, as there are various conditions under which insufficiently treated wastewater can reach valuable groundwater resources. There is a now serious need for the consideration of cumulative effects in planning and regulation. This need is reinforced by results from different build-out and nitrate loading applications.

Build-out and nitrate loading analyses are methods that help to assess cumulative impacts, but the application and validity of these and other methods must be developed further. Improvement of septic system siting can occur with increased research on leaching area effluent volume and quality, the development of different and realistic loading rates for different hydrogeological conditions, and development of practical methods for accurately estimating the purification value of a soil sample.

Regulations in most New England states must be changed to address excessively permeable soils as a first step, and to allow for large-scale siting and planning as a second step. Innovative development of ways to incorporate these and other techniques into general planning must occur to protect groundwater while allowing development.

In conclusion, build-out and nitrate loading analyses indicate that septic system are a potential threat to groundwater quality. While maintenance of systems is important, planning for and regulation of septic system siting must be improved so that cumulative impacts and excessively permeable soils are considered.

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Carol Lurie is a community planner with extensive experience in developing watershed protection programs, comprehensive planning and community participation. She coordinated the Haverhill, Massachusetts, Watershed Management Plan, and the South Kingstown, Rhode Island Wastewater Management District Plan both of which dealt directly with protecting groundwater quality in fragile environmental areas. She has a Masters degree in City Planning from the Massachusetts Institute of Technology, and is currently assisting the City of Providence in developing the city's Comprehensive Plan.

Elizabeth Beardsley
Environmental Engineer

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Elizabeth Beardsley is an environmental engineer and planner with experience in water quality and watershed protection projects. She was involved in technical analyses for the Haverhill, Massachusetts, Watershed Management Plan, including review of water quality data, development of protection measures, and recommending a water quality monitoring program. She is also involved with a project for Lake Quannapowitt, in Wakefield, Massachusetts, under the Clean Lakes program. She holds a Bachelor's degree in Civil Engineering from Stanford University.

ROAD SALTING IMPACTS IN MASSACHUSETTS

James K. Barrett[1]
Matthew P. Dillis[2]

Normandeau Engineers, Inc. has completed an evaluation of impacts from snow and ice control activities on the Massachusetts State Highway network. This analysis was done for the Massachusetts Department of Public Works' (MDPW) Snow and Ice Control Program Generic Environmental Impact Report (GEIR) released in April, 1989. The GEIR evaluated MDPW's snow and ice control program and the social, environmental, health and economic implications of deicing chemicals and abrasives use.

Statistical analyses were performed to develop relationships between road salt application rates and accident frequency using MDPW's Material Control System, a computerized data bank listing total salt use, application rates and spreader route length for each spreader truck and storm event. An extensive literature search provided statistical relationships between road salt application rates, annual corrosion costs and health impacts. Literature searches were also used to develop the environmental impact costs and economic benefits to commerce related to snow and ice control.

This analysis concluded that snow and ice control provided economic benefits in the categories of traffic safety and commerce but created costs in the categories of corrosion, public health and the environment. Surprisingly, health effects related to sodium in drinking water were found to be very low in comparison to corrosion costs. Environmental costs were also small compared to corrosion but this may be due to the lack of quantitative information. The GEIR concluded that road salt impacts could be significantly reduced and substantial financial savings achieved by optimizing road salt use.

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[2] Staff Engineer, Normandeau Engineers, Inc., Concord, New Hampshire.

James K. Barrett, a Group Manager for Normandeau Engineers, Inc. possesses degrees in engineering and geology. During his 15 years of professional experience, he has performed and managed numerous ground water investigations for municipal and industrial water supply developments, contamination assessments and hazardous waste investigations. Mr. Barrett's experience includes dewatering investigations and water quality impacts analyses for major mining and mill tailings disposal projects; water supply well field design and installation; hazardous waste investigations at NPL sites throughout the U.S.; design of ground water monitoring programs and water quality sampling networks; aerial photography interpretation; isotopic studies; and computer modeling.

The Massachusetts Department of Public Works has decided to extend their level of research, therefore the project is still ongoing. If you would like a copy of the final paper, please contact the author at (603) 224-5770

AN EPA/LOCAL PARTNERSHIP AT WORK -

THE CREATION OF A GROUND WATER PROTECTION PROGRAM

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Abstract

The Region III Ground Water Protection Section is using Geographic Information System (GIS) technology to work with local water resource agencies to develop and implement county-wide ground water protection plans. The purpose of working with local agencies is to identify and target for priority regulatory attention those areas that are susceptible to contamination. The GIS technology enabled EPA to provide technical assistance to local agencies in a program with limited federal resources.

The GIS case study demonstrated the use of GIS technology in ground water protection applications and illustrates how the Region and the local officials worked together to develop a mutually beneficial ground water protection program. Program development, data collection, map coverage construction, composite map construction and evaluation are topics of discussion. Emphasis is placed on the application of GIS, its potential for protecting underground sources of drinking water, and its impact on management-making decisions. Major project benefits to the local agency and to EPA are also presented.

Introduction

GIS is a computerized system used for the storage, manipulation, display and analysis of spatial environmental data. It is a data integration tool which combines sophisticated mapping capabilities with a large computing capacity.

It enables extensive multi-media analysis and evaluation in geographic areas which were previously too time consuming or difficult to investigate.

In 1988, the Region obtained the GIS, as well as ARC/INFO software, PRIME computer expansion, a digitizer, plotter and other mapping accessories. The project team staff time, coupled with increased PRIME computer use, represent a considerable investment of resources. This pilot project in Ground Water Protection applications was undertaken to explore the full use of this tool in the Region.

The Regional GIS pilot project had these objectives:

* Develop a management tool which would help the Region more effectively and efficiently address ground water problems and protect underground sources of drinking water

* Develop Regional expertise and procedures for the use of GIS software and hardware

* Demonstrate several applications of this technology which yield tangible results to Regional managers

* Provide recommendations to managers regarding GIS uses to assist in determining environmental and program priorities, and directing compliance monitoring and enforcement efforts of the Region.

<u>Project Description</u>

The project sought to demonstrate an application on a county-level scale. New Castle County (NCC), Delaware was selected as the study site:

* It is one of the most vulnerable and ground water dependent counties in the Region

* Large amounts of digitized data were readily available for use through a cooperative arrangement with the USGS and NCC Water Resources Authority (NCC WRA)

* The County has an ongoing interest in implementing wellhead protection measures.

Initially, the project goals were broadly defined: to identify public water supplies and potential contamination sources; to study areas that were susceptible to contamination; to evaluate risks to ground water; to delineate wellhead protection areas, and to target areas for priority regulatory attention.

The initial project was to implement the data collection, conversion and evaluation. The NCC WRA had an abundance of digitized information available, but was on a different GIS, called AERI. The USGS also provided data which was already digitized in ARC/INFO format. In order for the AERI data to be scanned, the data was first converted to ARC/INFO format. Once converted, the data was examined and the necessary information was extracted for this project. Test plots of facility site locations were constructed and compared to source maps to evaluate the quality of the data. Upon completed, these map coverages were constructed:

* Locations of EPA regulated facilities; including NPDES major discharges, CERCLA sites, and RCRA facilities

* Location of high risk (ie., older than 15 years) underground storage tanks (USTs)

* Location of public water supply (PWS) wells

* Location of PWS surface water intakes

* County/subcounty DRASTIC evaluation

* Population density

* Land use applications

* Septic tank suitability evaluation

* Recharge areas

* Aquifers

* Slope

* Soils

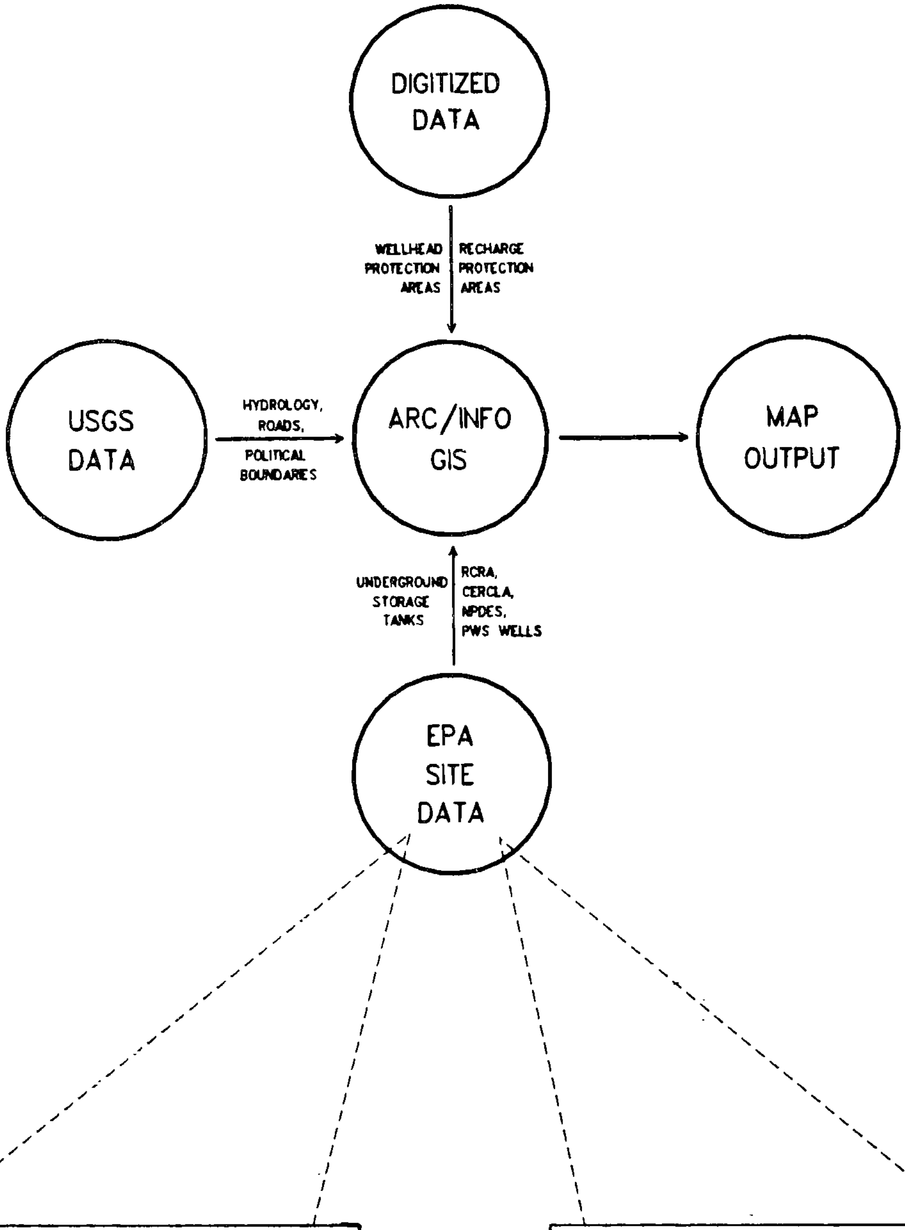
* Geology

* Hydrology

Figures 1 and 2 illustrate the methodology and construction of the map coverages, locating the potential sources of contamination relative to the public water supply wells, ground water recharge areas and wellhead protection areas. Site data for a specific facility can be retrieved from the INFO file (of ARC/INFO) and displayed as illustrated on Figure 1. Other data files were constructed (not shown) that contain such information as: PWSs using ground water that are in violation of maximum contaminant levels (MCLs), population dependency on ground water, reported incidents of contamination and status of remediation.

The next aspect of the project was to identify areas that were vulnerable to contamination. The "DRASTIC" methodology, developed by the National Well Water Association (NWWA) and EPA, was used to evaluate ground water pollution potential to assess the county's vulnerability to ground water contamination (refer to Figure 3). DRASTIC is an acronym representing the most

Figure 1



SAMPLE INFO DATA FILE – UNDERGROUND STORAGE TANKS

SITE ID	FACILITY ID	NAME	ADDRESS	RISK
1	3-000001	RICKS AUTO REPAIRS	505 S MARKET ST.	HIGH
2	3-000003	DELAWARE AUTO SERVICE	1603 PENN AVE	HIGH
3	3-000007	PEP BOYS INC	2904 CONCORD PIKE	LOW
4	3-000008	FREEDOM FORD INC	300 E LEE BLVD	LOW
5	3-000118	DE VALLEY HYDRAULICS	325 QUIGLEY BLVD	LOW
6	3-000778	TEXACO	341 ELKTON ROAD	LOW
7	3-000218	DELAWARE TRUCK STOP	184 S DUPONT HWY	LOW
8	3-000207	SHELL STATION	1022 DELAWARE AVE.	HIGH
9	3-000186	CHRYSLER CORP	550 S COLLEGE AVE	HIGH
10	3-000179	BRANDYWINE FIBER PRODUCTS	1501 POPLAR	HIGH

SAMPLE INFO FILE – REGULATED FACILITIES

SITE ID	FINDS NO	NAME	SITES
1	DED981037138	NVF (STATE LINE LANDFILL)	CERCLA
2	DED002339901	HOCKESSIN FOOD CORP	NPDES
3	DE0000552	HOCKESSIN WELL NO G-3	PWS
4	DED001315647	HERCULES INC.	RCRA
5	DED980918049	REEVIS & REEVIS CLAY PIT	CERCLA
6	DE0000664	CRESTFIELD WATER CO	PWS
7	DED981035383	CHERRY ALLEN MARSH SITE	CERCLA
8	DE0000015	WINTERSET FARMS TRAILER PARK	PWS
9	DED003913266	DIAMOND SHAMROCK	RCRA
10	DED054717939	ALLIED CHEMICAL CORP	NPDES

LOCATION OF POTENTIAL SOURCES OF CONTAMINATION

RELATIVE TO GROUND WATER RECHARGE AREAS/WELLHEAD PROTECTION AREAS

NEW CASTLE COUNTY, DELAWARE

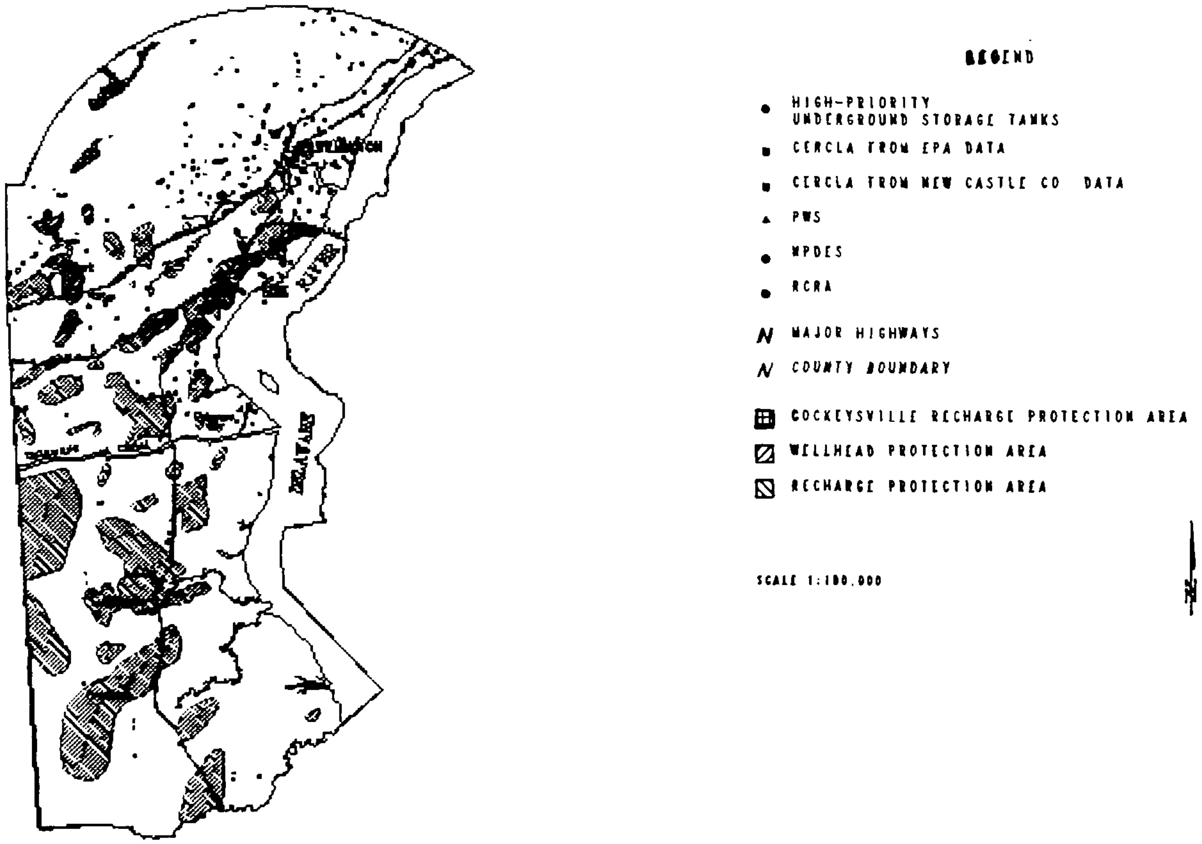


FIGURE 2

POTENTIAL VULNERABILITY BASED ON DRASTIC INDEX

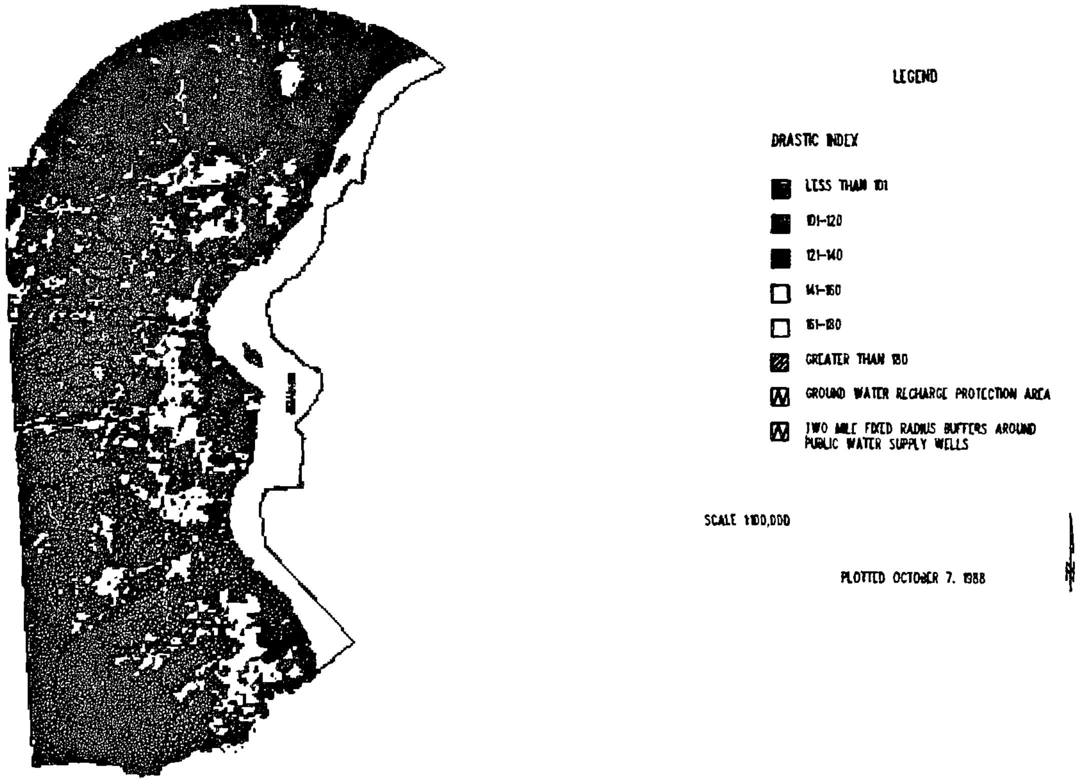


FIGURE 3

important factors controlling ground water pollution potential, including: Depth to ground water, net Recharge, Aquifer media, Soil media, Topography, Impact to the vadose zone, and hydraulic Conductivity of the aquifer. DRASTIC ratings, assigned by the NWWA to 5.5 acre grid cells, were aggregated and categorized to reflect the county's total vulnerability range (less than 101 - greater than 180). The higher the DRASTIC score, the greater the vulnerability to contamination.

To delineate Wellhead Protection Area (WHPA) boundaries around PWS wells, the arbitrary fixed radius method was employed. A two-mile radius was selected to minimize underprotection resulting from not directly incorporating processes of ground water flow. In the map on Figure 4, WHPA's and Recharge Areas containing highly vulnerable hydrogeologic settings - where DRASTIC scores exceed 160 - were identified for further analysis. These areas were evaluated relative to each other by this equation:

RATING = 2 (MCL VIOLATIONS) * 2 (RCRA RELEASES) * 2 (USTs 15 YEARS OR OLDER) * # of CERCLA SITES * 2 (RCRA SITES) * 3 (USTs)

The equation incorporates a range of risk-related factors including potential sources and known incidents of contamination. The map on Figure 5 shows the ten areas of highest risk for ground water contamination. Their characteristics are summarized in Table 1.

Based on this evaluation, the Wellhead Protection Area in the city of New Castle appeared to be undergoing the highest degree of environmental stress. It is this area that would receive the highest priority of EPA compliance monitoring and enforcement.

<u>Project Results</u>

The GIS project for ground water protection resulted in both tangible and intangible benefits to the Region and the NCC WRA. The following are tangible results:

* A true Federal/local partnership was developed to work towards a common goal - with no money other than in-kind services from both parties

* The development of a management tool to assist managers in determining environmental and program priorities

* Delaware and New Castle County were assisted in the development and implementation of their Wellhead Protection Programs

* EPA provided a technical assistance vehicle for states/locals in a program where Federal resources are limited

WELLHEAD PROTECTION AREAS AND RECHARGE AREAS CONTAINING HIGHLY VULNERABLE HYDROGEOLOGIC SETTINGS

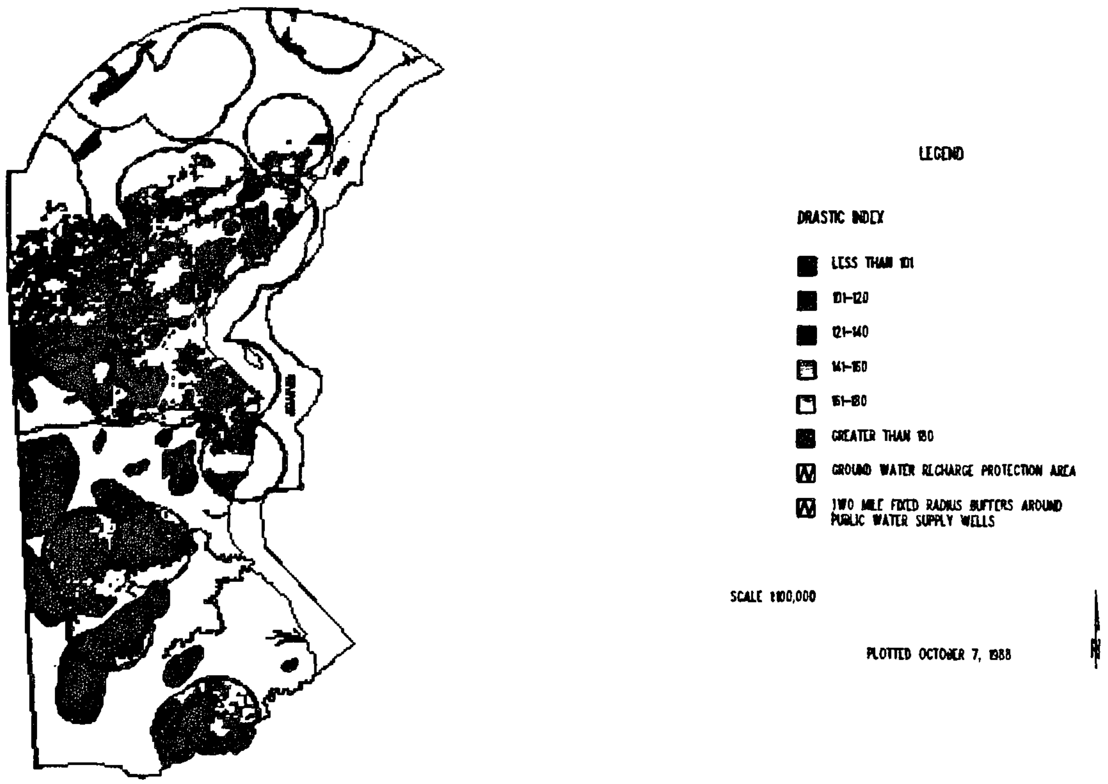


FIGURE 4

TARGETING OF HIGH RISK GROUND WATER AREAS

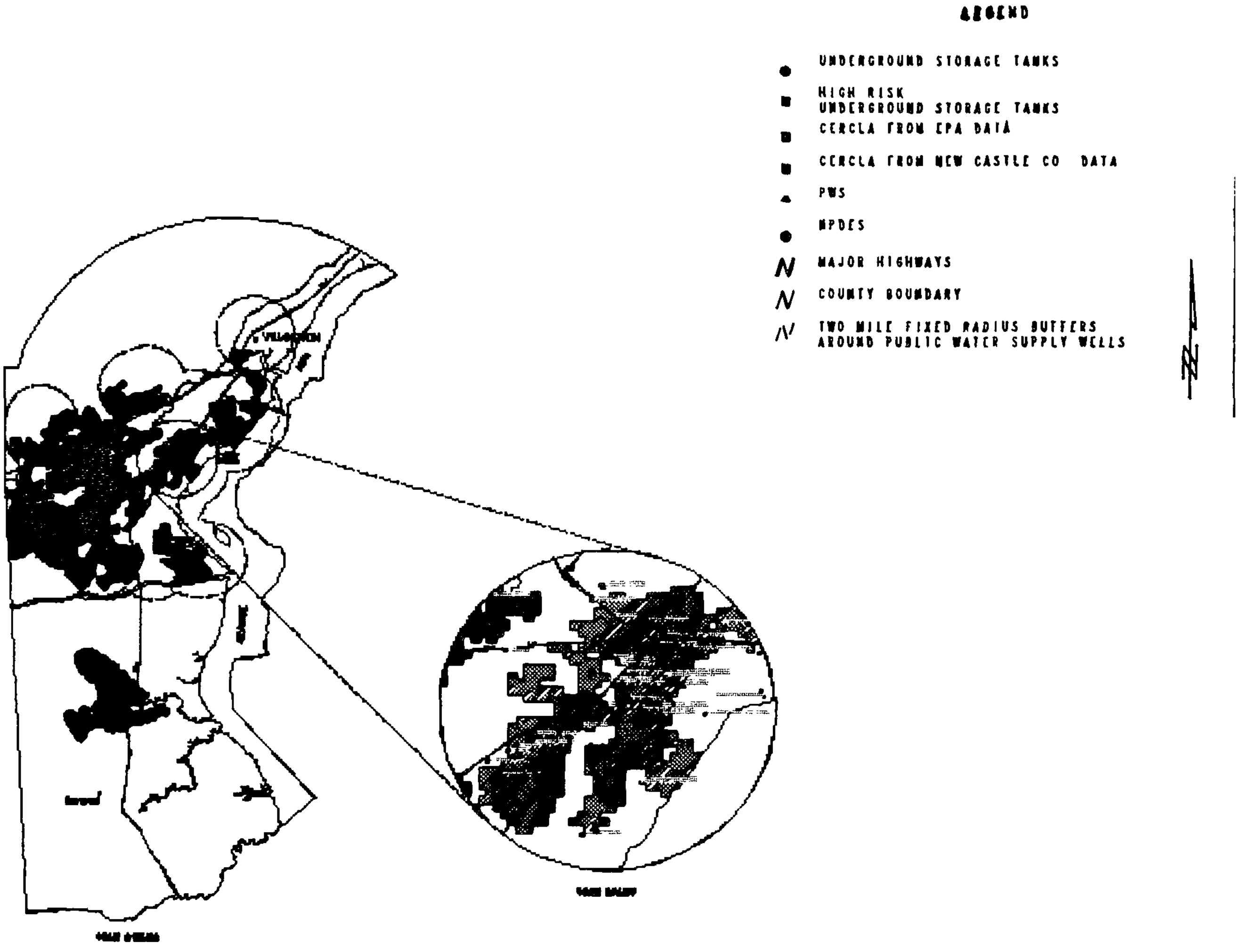


FIGURE 5

TEN GEOGRAPHIC AREAS AT HIGHEST RISK FOR

GROUND WATER CONTAMINATION

WELLHEAD PROTECTION AREAS

AREA 1
RATING 119
25 PWS WELLS
26 USTs
16 HIGH RISK USTs
9 CERCLA SITES
POPULATION SERVED-5,500

AREA 2
RATING 113
15 PWS WELLS
20 USTs
19 HIGH RISK USTs
13 CERCLA SITES
POPULATION SERVED-30,000

AREA 3
RATING 36
2 PWS WELLS
2 HIGH RISK USTs
2 CERCLA SITES
1 RCRA FACILITY
14 RCRA RELEASES

AREA 4
RATING 26
6 USTs
5 HIGH RISK USTs
2 CERCLA SITES

AREA 5
RATING 26
8 USTs
1 HIGH RISK UST

RECHARGE PROTECTION AREAS

AREA 1
RATING 59
12 PWS WELLS
13 USTs
7 HIGH RISK USTs
6 CERCLA SITES
POPULATION SERVED-5,500

AREA 2
RATING 34
1 PWS WELL
2 CERCLA SITES
1 RCRA FACILITY
14 RCRA RELEASES
1 MCL VIOLATION

AREA 3
RATING 21
4 PWS WELLS
5 USTs
3 HIGH RISK USTs

AREA 4
RATING 15
3 USTs
3 HIGH RISK USTs

AREA 5
RATING 12
4 PWS WELLS
2 CERCLA SITES
5 HIGH RISK USTs

TABLE 1

* The Region's understanding and assessment of the scope and nature of environmental problems was dramatically improved

* GIS techniques proved useful to others in the Region and states.

Future Directions

Based upon successful experience with the GIS project, the Region committed program resources for a number of GIS projects. For the Ground Water Protection Program, the identification of Regional ground water sensitive areas will be initiated to oversee and direct EPA-funded activities in states under the Clean Water Act (CWA). Further, a detailed analysis (on a larger scale) will be implemented for those counties undergoing environmental stress, due to the number of contamination sources and higher degree of ground water vulnerability.

Also proposed are a number of Federal/state/local cooperative initiatives to use the GIS technology and Regional expertise to further their ground water protection programs:

* Delaware: To assist in data sharing on pollution site locations and WHPP assistance.

* Pennsylvania: To identify ground water areas most vulnerable to contamination, and to assist with their WHPP development.

* West Virginia: To assist the Department of Natural Resources and the Department of Health promote WHPP development and the tracking of ground water trends.

* Jefferson County, West Virginia: Begin joint GIS initiative to facilitate a pesticides management plan.

* Anne Arundel County, Maryland: To explore joint GIS approaches and WHPP development.

* Carroll County, Maryland: Begin joint GIS initiative to facilitate WHPP development.

* Lancaster County, Pennsylvania: Begin joint GIS initiative to facilitate a pesticides management plan.

Acknowledgements

The author wishes to acknowledge the assistance provided by the following people at EPA, Region III: Jon Capacasa, Chief of the Drinking Water/Ground Water Protection Branch, Dr. Ava Nelson Zandi of the Ground Water Protection Section, and David West of the Information Resources Management Branch.

Biographical Sketch

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I am a 1972 graduate of Ohio State University with a B.S. in Geology, and have completed graduate work in Water Resources Engineering. I have spent the last 16 years working in the related fields of environmental engineering and hydrogeology. My initial involvement was with the New Jersey Department of Environmental Protection, Division of Water Resources, where I worked as a ground water geologist and later as an environmental engineer.

Since 1976, I have been working on the federal level for EPA, Region III. I have been involved in virtually all existing surface and ground water related programs. In 1983, I became involved in the ground water protection program. As a member of the Ground Water Task Force, I helped develop the Agency's National Ground Water Protection Strategy in 1984.

Currently, my position is Chief of the Ground Water Protection Section, which is primarily responsible for the coordination of all ground water-related programs in the Regional Office. I oversee the State Ground Water Protection Strategy Program, the Regional Geographic Information System (GIS) Ground Water Program, and the Wellhead Protection Program.

A COMPUTERIZED DATA MANAGEMENT SYSTEM FOR WELLFIELD PROTECTION

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Abstract

The City of Columbus, Ohio operates a municipal wellfield capable of producing approximately 30 million gallons per day (mgd). Water is withdrawn from a glacial aquifer by four collector wells adjacent to the Scioto and Big Walnut rivers. The wellfield land area is presently subjected to pressures of urban housing, commercial and industrial development, sand and gravel mining, and highways frequented by hazardous material cargoes.

The pressures of development and the resulting pollution sources in the area have created potential for wellfield contamination. The "Wellfield Protection and Management Plan" prepared by Malcolm Pirnie, Inc. for the City in July, 1988 proposed creation of a comprehensive ground water monitoring network covering a two-mile radius around the wellfield. The monitoring network is expected to generate a large amount of data regarding the water quality and flow characteristics of the surface and ground water.

Malcolm Pirnie, Inc. developed for the City of Columbus an easy to use computerized database management system to effectively manage this large database. This paper will describe the major components of this system. The system can store and retrieve data, prepare reports and create graphics. The graphics program can compare the collector well discharge to the water quality parameters over the time span of the data. Having established the background water quality, the database system can readily show any changes in water quality. In addition, the water quality data can be exported to a spreadsheet or other programs, to develop Piper water quality diagrams or perform other more complex forms of analysis.

The database system generates graphic data presentations as information is collected. This allows the City to make quick, reasoned and appropriate decisions regarding wellfield protection.

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Introduction

Any successful wellfield protection program includes three major phases. First, the aquifer and its relation to surface features is studied and a suitable protection program is developed. This is the foundation of the program, where the contamination-susceptible areas are delineated and a plan of action is developed. Second, the program is implemented by protecting the areas vital to the wellfield. This is frequently the most difficult phase because it typically involves controlling and often changing the land use within the wellfield. Third, a monitoring system must be developed to detect potential adverse impacts on water quality and quantity. If this last phase is omitted or if the data collected is not analyzed, the long term wellfield protection may be jeopardized.

This paper outlines a data management system which was developed for the City of Columbus, Ohio, as part of a complete wellfield protection program.

Background

The City of Columbus operates a 30 mgd wellfield south of the City referred to as the South Wellfield (Figure 1). The situation in Columbus is somewhat unusual, because although the wellfield draws water from an area of approximately 9 square miles, the City controls only a very small portion of the land.

The Columbus South Wellfield obtains water from a glacial outwash valley fill aquifer deposited in a pre-glacial valley. Water is withdrawn from four collector wells, three located along the Scioto River and one located along Big Walnut Creek as shown on Figure 1. The water withdrawn represents a mixture of approximately 87 percent ground water and 13 percent stream water induced by pumping (Sedam, 1988).

Figure 2 shows three geologic cross sections drawn through the wellfield. In general, the glacial outwash deposits can be subdivided into lower and upper sand and gravel units separated by a clay till which thins toward the center of the valley. Where the clay till is absent, the upper and lower outwash units coalesce. In some areas of the wellfield, outwash deposits are separated from the bedrock by another clay till layer deposited directly on bedrock.

Underlying the glacial valley fill is the Devonian age Ohio shale and Columbus limestone. The Silurian age Bass Islands dolomite underlies the Columbus limestone. In the southern portions of the wellfield, the Columbus limestone thins and may be absent (Schmidt, 1958). The shale-limestone contact bisects the wellfield with shale underlying glacial deposits to the east and limestone underlying glacial deposits to the west.

Under the natural ground water flow system in the South Wellfield, recharge to the glacial outwash flows down the valley to the south with a large percentage discharging to the Scioto River. This natural ground water flow system has been locally affected by ground water withdrawal. Figure 3 shows water levels in the glacial outwash aquifer measured July

1, 1986. Two prominent cones of depression have developed in the area as a result of pumping. The first is associated with quarry dewatering north of the wellfield, the second is associated with pumping from the South Wellfield.

The potentiometric surface in the bedrock aquifer is dominated by pumping from a private limestone quarrying firm. Most of the ground water flow in the bedrock is in the limestone and dolomite carbonate formations which are recharged in outcrop areas to the west. A percentage of the carbonate bedrock water discharges into the glacial aquifer, the remainder flows downdip into a deeper bedrock flow system. The degree of interconnection between the glacial outwash aquifer and the carbonate bedrock aquifer is controlled by the presence or absence of the clay till layer on the bedrock surface.

The water treatment facilities in the South Wellfield were designed to handle a mixture of ground water and surface water drawn from the glacial valley fill aquifer. Because of the high concentrations of dissolved solids in the carbonate bedrock water an increase in the percentage of water from the carbonate bedrock aquifer could affect the treatment process. Several authors have evaluated the character of ground water in the South Wellfield (de Roche, 1984, Schmidt, 1958). Schmidt (1958) obtained an average hardness of 386 ppm total hardness from 6 well samples in the glacial aquifer as compared to an average of 1129 ppm total hardness from 11 samples from wells in the Columbus limestone and Bass Islands dolomite. Ground water from the Bass Islands dolomite is particularly high in hardness and total dissolved solids, and is very difficult to treat.

Factors Potentially Affecting the Wellfield

The south side of the City of Columbus is principally an industrial area, with several manufacturing facilities, landfills, and quarrys. The landfills are having an effect on ground water quality (deRoche, 1985) however, they are located near the large limestone quarry located to the north of the wellfield (Figure 1). Presently, the large cone of depression created by quarry dewatering intercepts a large portion of the ground water flow. If the quarry dewatering were to cease, and the wellfield was expanded, the possibility exists that landfill affected water would migrate towards the wellfield. In addition, within the zone of contribution to the wellfield there is a jet fuel pipeline, two gas stations, several residential developments and a racetrack. The water quality of the Scioto river is affected by urban runoff and the discharge of treated wastewater from the Jackson Pike sewage treatment plant located upstream. Most of the land use in the South Wellfield is currently agricultural, however because of the value of the sand and gravel deposits in the area an increasing percentage of the area is being mined. Therefore, there are several factors that could have an adverse impact on the South Wellfield:

- surface spills,
- infiltration of contaminated river water,
- quarry dewatering,

- sand and gravel mining,
- landfill leachate in ground water,
- mixing of bedrock water,
- droughts
- man-made reductions in recharge.

In order to assess the impact of these factors, the City must monitor precipitation, surface water quality and flow, and ground water quality and flow. These factors may be subdivided into two categories: water supply and water quality. The water supply factors that require monitoring are:

- effects of local quarry dewatering
- effects of riverbed siltation
- effects of reduced precipitation
- effects of sand and gravel mining
- effects of wellfield discharge on local private water supplies

The water quality factors that require monitoring are:

- the influx of bedrock water induced by pumping
- the quality of stream water
- the impact of surface land use
- the impact of nearby landfills

In order to assess the impact of these factors, a wellfield monitoring plan was designed. Figure 4 shows the location of the proposed surface and ground water monitoring locations. Under the proposed monitoring plan:

1. Surface water will be monitored for flow and water quality within a two mile radius of the wellfield.

2. Ground water level will be monitored continuously at several locations near the collector wells and semiannually within a two mile radius.

3. Ground water quality will be monitored within a one mile radius of the wellfield.

The monitoring program developed was designed to expand on the wellfield monitoring already being conducted by the US Geologic Survey and the Ohio EPA. To provide adequate protection, a large area must be monitored; therefore, the volume of data generated is considerable.

Database Management System

For the amount of data generated, manual data reduction would be neither efficient nor practical. Therefore, the City required an easy-to-use data management system to quickly demonstrate changes in water quality and/or quantity. Therefore, a customized application was developed using the dBASE III PLUS[1] database management software and its programming language. dBASE III PLUS was chosen for the database system because of its wide use and compatibility with other programs.

Figure 5 depicts the structure of the data base system developed. All files are linked to a master data file a the site identification number. The master data file contains information on the location, date of installation and construction particulars of a particular monitoring station. The program is operated by responding to a series of menu driven prompts. Information can be easily input and retrieved via this menu driven system, and output to printed reports or data files.

Even with a data base which allows easy retrieval of data, the vast amount of data available makes meaningful interpretation very difficult. To help solve this problem, a graphics capability was developed within the database system using the DGE[2] program. A user-specified time period of for any of the database parameters can be graphed by entering the starting date. The mean, standard deviation and best-fit lines can be displayed as an option. An example of a yearly graph of chloride concentration in a collector well is shown in Figure 6. Another option available is a time series graph. This graph displays the entire data set on a particular parameter by moving the data horizontally across the screen, similar to an oscilloscope.

Single parameter graphs are useful for identifying changes from the historical background, but do not provide much information regarding the possible causes of changes in background. In order to provide a method to evaluate changes in background information, several graph types showing various data comparisons were developed for the database system. Presently, the three following graph types can be generated:

- Collector well discharge versus monitoring well water level and precipitation,
- Collector well discharge versus collector well water quality parameters,
- Stream discharge versus stream water quality.

Examples of each of these graphs are shown on Figures 7 through 9. As the database system is used and enhanced, additional comparison graphs will be developed. Figure 7 shows the comparison of water levels in a monitoring well near collector well 101, the combined collector well discharge, and the stream discharge measured upstream of the wellfield. The relation between pumping rate and water level for this monitoring well is not clearly evident because it is in a location that

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[1] dBASE III PLUS is a trademark of Ashton-Tate Corporation

[2] DGE is a registered trademark of Pinnacle Publishing Inc.

occasionally floods. As the wellfield monitoring system is developed, additional continuous water levels recorders will be installed to provide a better picture of the relation between collector well discharge and water levels in the area.

Figure 8 shows changes in concentrations of hardness, calcium and alkalinity when collector well number 103 (CW-103) is pumped at a higher discharge rate of 5.6 mgd. These changes are presumably related to an increased influx of bedrock water, from either the Columbus limestone or the Bass Islands dolomite. To date, the other collector wells in the wellfield have not shown the same increase in these parameters. Because CW-103 contributes only 18% of the water pumped, the treatment process has not been affected by the water quality changes observed. Figure 9 shows the same concentrations in CW-101 when pumped at a higher discharge rate of 7.2 mgd. There is no apparent increase in these chemical parameters associated with the higher discharge rate in CW-101. Apparently, in the vicinity of CW-103, there is a better connection between the bedrock aquifer and the glacial aquifer.

Figure 10 shows the stream discharge in the Scioto River and the 5-day Biochemical Oxygen Demand (BOD_5) and Dissolved Oxygen (DO) concentrations. This graph shows a good correlation between low DO and low stream flow. This is probably because there is a sewage treatment plant upstream of the wellfield and at low flow a large percentage of the streamflow is treated waste water.

In addition to the above comparisons, water quality data can be exported to a Lotus 1-2-3 file and graphed in Piper or Stiff diagrams. A program developed by Cheng (1988) can be used to develop Piper diagrams. Additional graphs could be developed to compare quarry dewatering discharge, wellfield discharge, to monitoring well water levels, combined raw water chemical character to total wellfield discharge and collector well pumping level to collector well discharge. Data comparisons like these need to be evaluated frequently for any wellfield to identify problems in the early stages of development.

Summary

All too often, data on wellfield parameters is collected but not evaluated for trends or changes in background until a problem has been developing for some time. The database system developed allows the City of Columbus plant operators to evaluate wellfield data as soon as it is collected.

Conducting a wellfield protection study and implementing the wellfield protection plan is the first step in safeguarding municipal groundwater supplies. However, a comprehensive monitoring plan and an easy to use data management system are necessary to provide early detection factors having an of adverse impact on water quality or quantity.

Acknowledgements

We appreciate the assistance provided by Bill Eitel, Mike Brown and the staff of the Parsons Avenue Water Plant in conducting this study.

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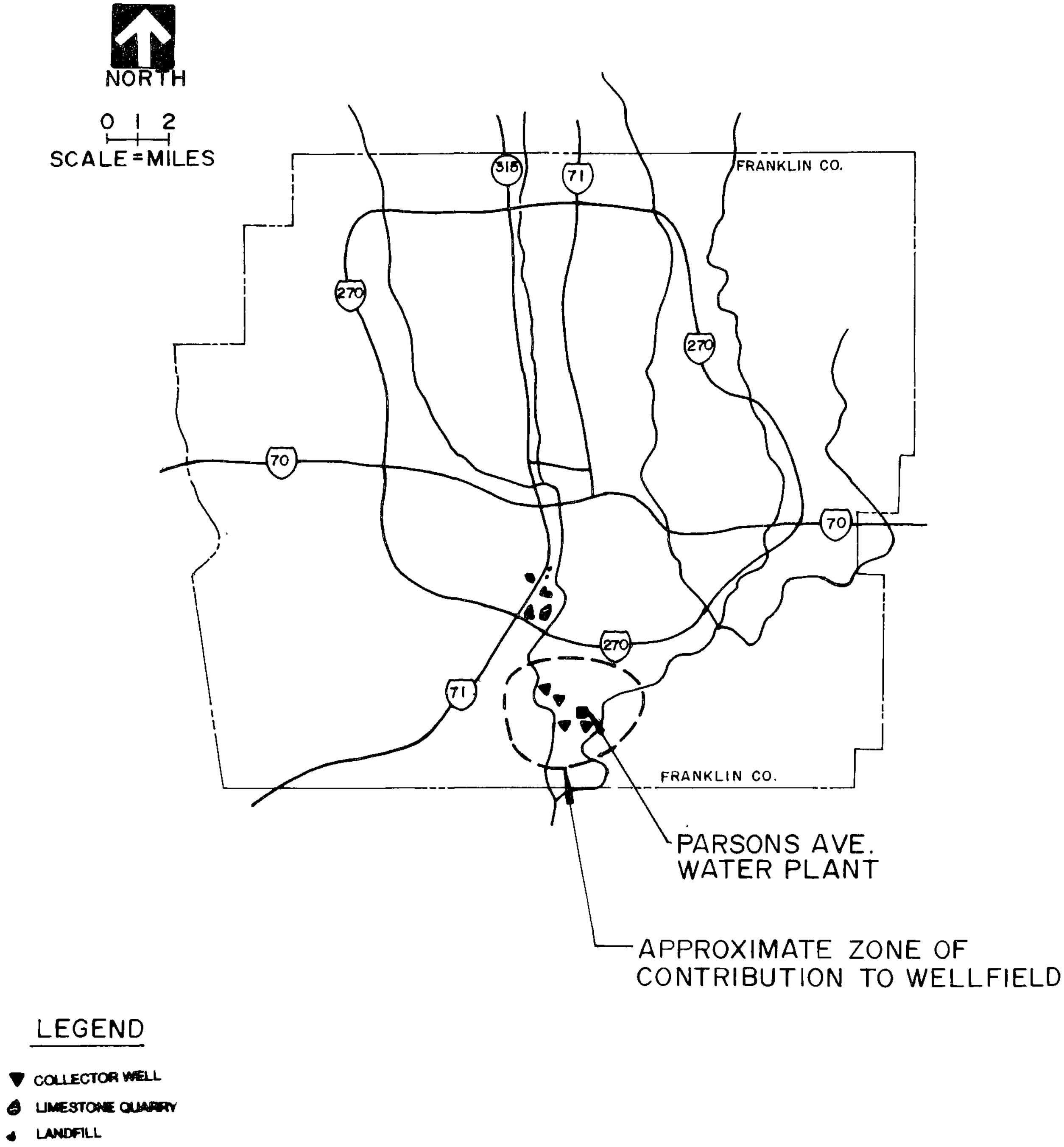
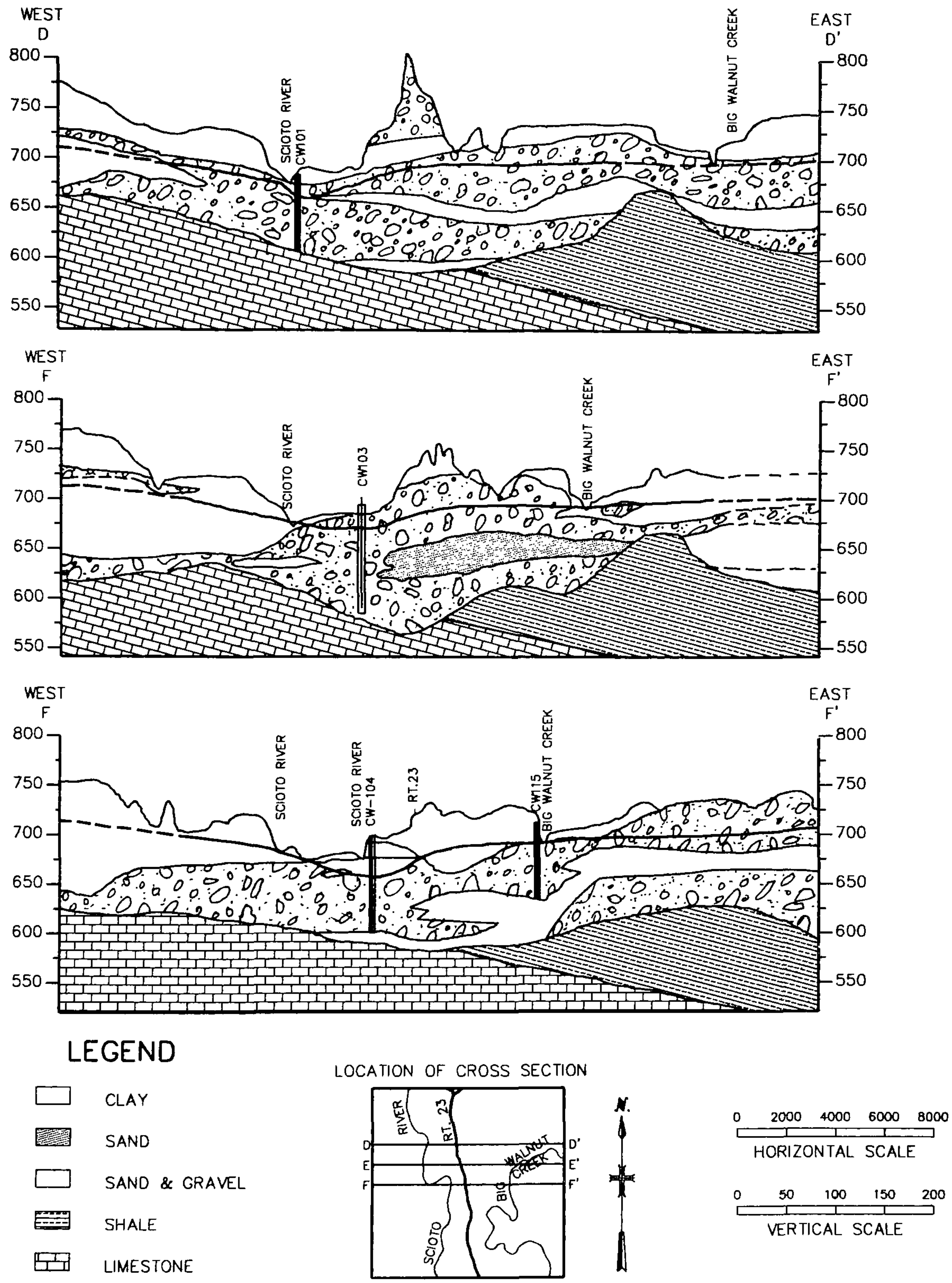


LOCATION MAP
COLUMBUS SOUTH WELLFIELD

FIGURE 1

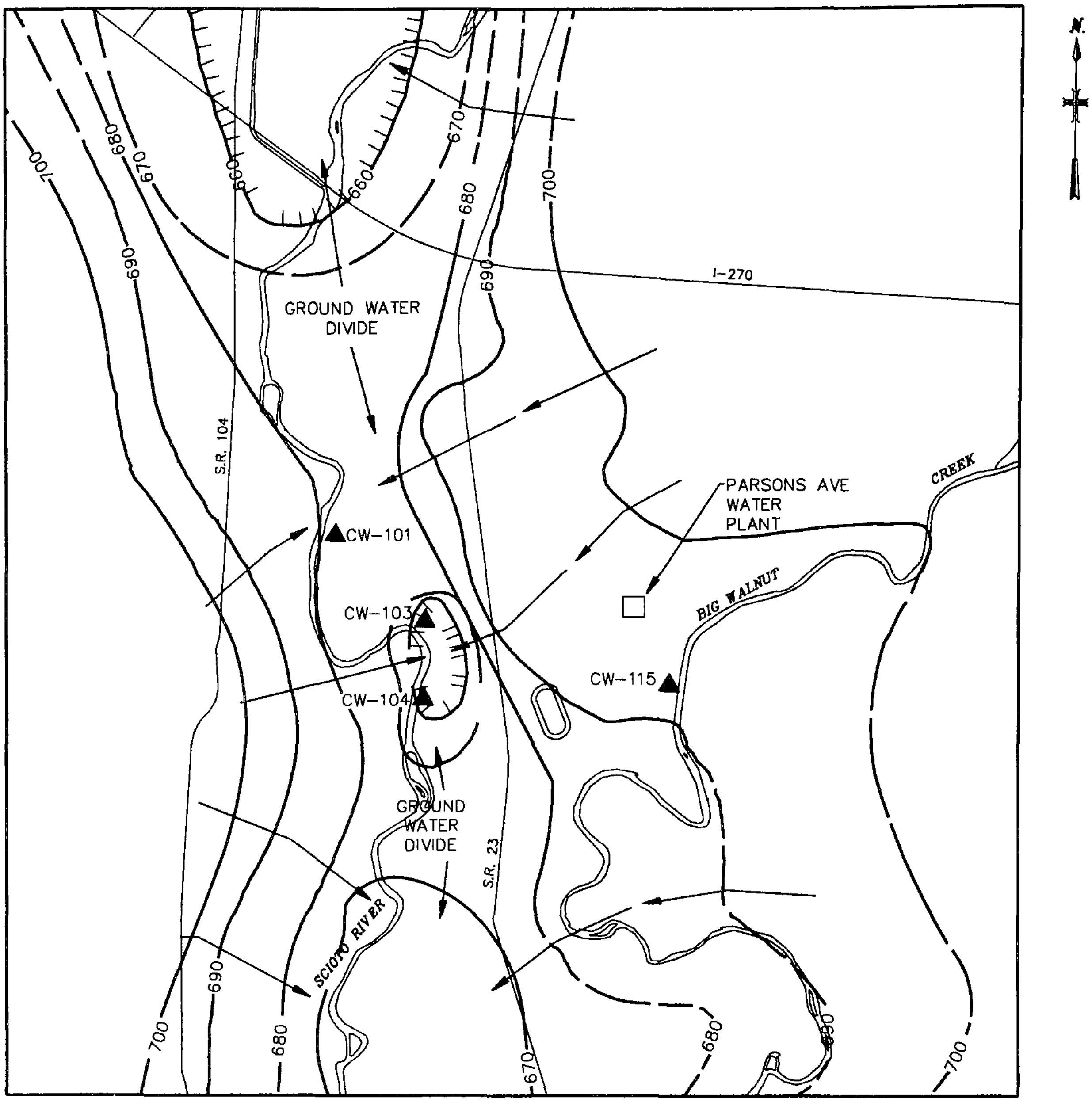
MALCOLM PIRNIE



MALCOLM PIRNIE

GEOLOGIC CROSS SECTIONS

FIGURE 2



LEGEND

- ▲ COLLECTOR WELL
- ● WELL
- —690— POTENTIOMETRIC LINE
- — — — POTENTIOMETRIC LINE, APPROXIMATE EXTRAPOLATION
- ——— PAVED ROAD
- ———→ GROUND–WATER FLOW PATH
- (hatched oval) GROUND–WATER DEPRESSION

QUADRANGLE LOCATION

0 2000 4000 6000 8000

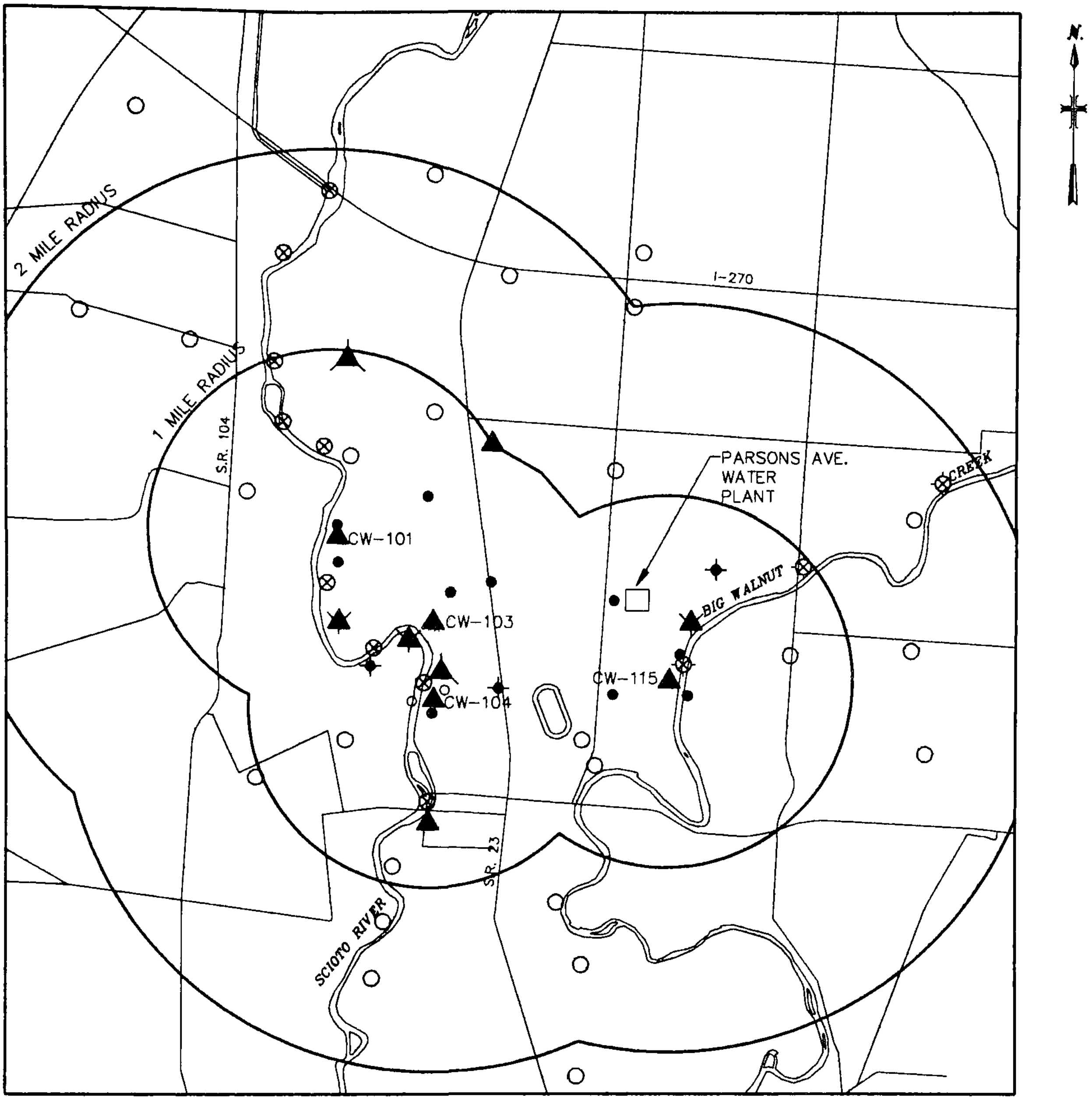
SCALE

CONTOUR INTERVAL = 10 FEET

MALCOLM PIRNIE

GROUND WATER LEVEL MAP
JULY 1, 1986

FIGURE 3



LEGEND

SEMIANNUAL STATIC WATER-LEVEL
- ○ EXISTING

SEMIANNUAL WATER QUALITY AND STATIC WATER-LEVEL
- ● EXISTING
- PROPOSED DRILLING LOCATION

CONTINUOUS WATER-LEVEL RECORDER
- ▲ EXISTING LOCATION, PROPOSED WATER-LEVEL RECORDER AND SEMIANNUAL WATER QUALITY MONITORING
- PROPOSED WATER-LEVEL RECORDER AND SEMIANNUAL WATER QUALITY MONITORING
- PROPOSED WATER-LEVEL RECORDER LOCATION

SURFACE WATER SAMPLING LOCATIONS
- ⊗ EXISTING SURFACE-WATER AND SEDIMENTATION SAMPLING STATION (OEPA)
- PROPOSED SURFACE-WATER AND SEDIMENT SAMPLING LOCATION

QUADRANGLE LOCATION

0 2000 4000 6000 8000

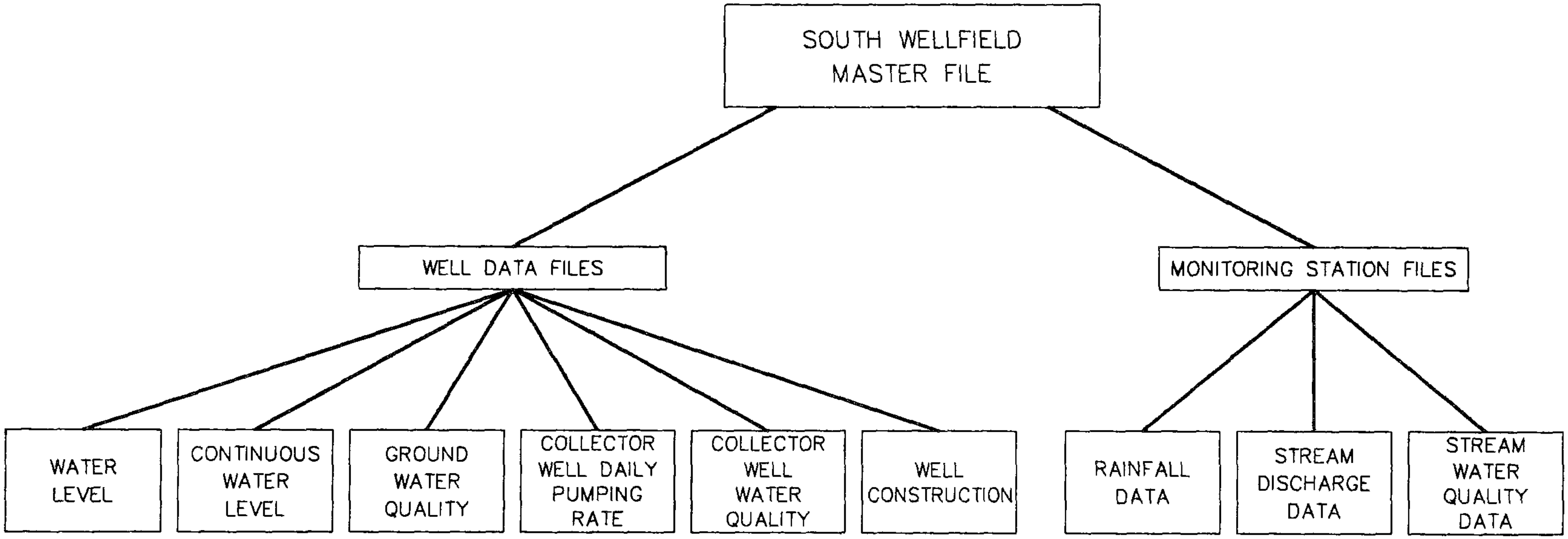
SCALE

CONTOUR INTERVAL = 10 FEET

MALCOLM PIRNIE

PROPOSED MONITORING NETWORK

FIGURE 4



MALCOLM PIRNIE

DATABASE MANAGEMENT SYSTEM STRUCTURE

FIGURE 5

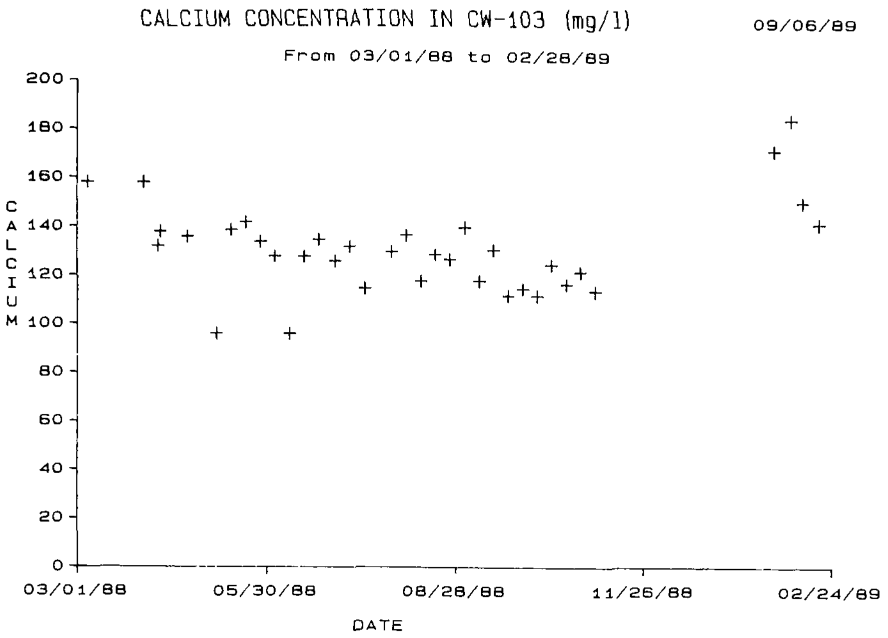


FIGURE 6

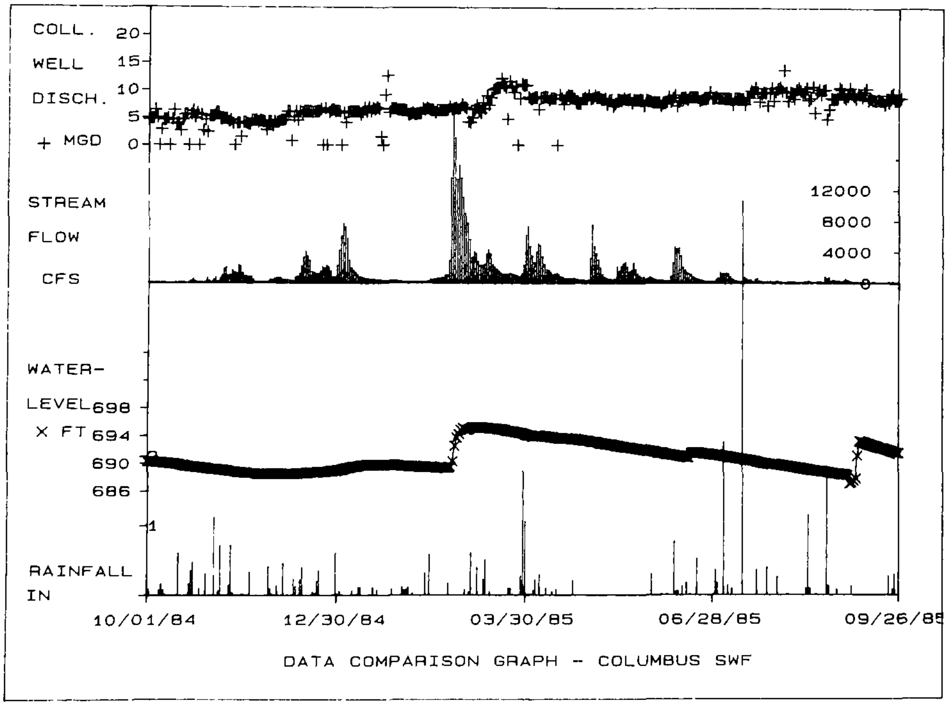
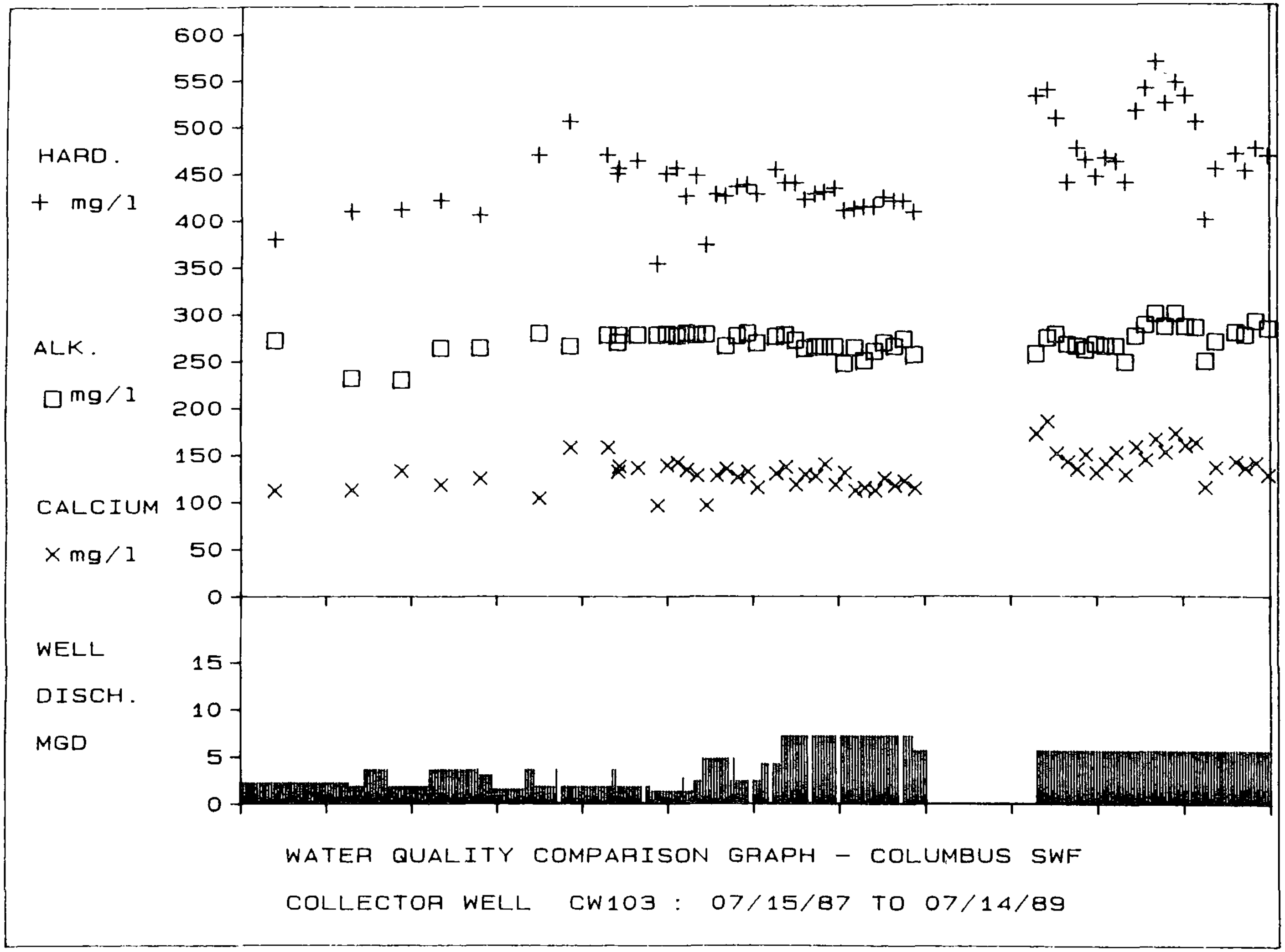


FIGURE 7



600
550
500
450
400
350
300
250
200
150
100
50
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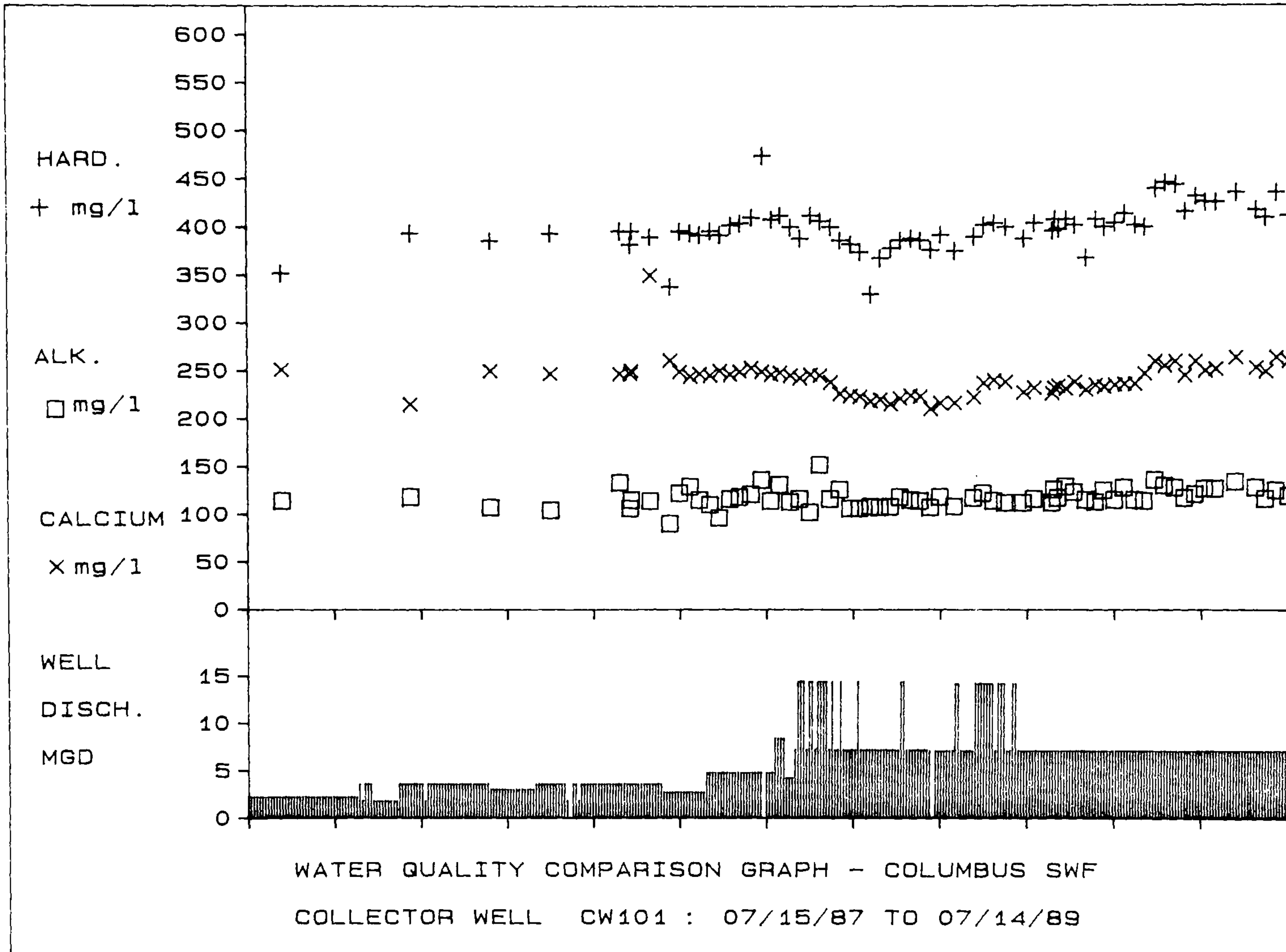
HARD.
+ mg/l
ALK.
□ mg/l
CALCIUM
× mg/l
WELL
DISCH.
MGD
15
10
5
0
WATER QUALITY COMPARISON GRAPH - COLUMBUS SWF
COLLECTOR WELL CW103 : 07/15/87 TO 07/14/89

FIGURE 8


HARD.
+ mg/l
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WATER QUALITY COMPARISON GRAPH - COLUMBUS SWF
COLLECTOR WELL CW101 : 07/15/87 TO 07/14/89

FIGURE 9

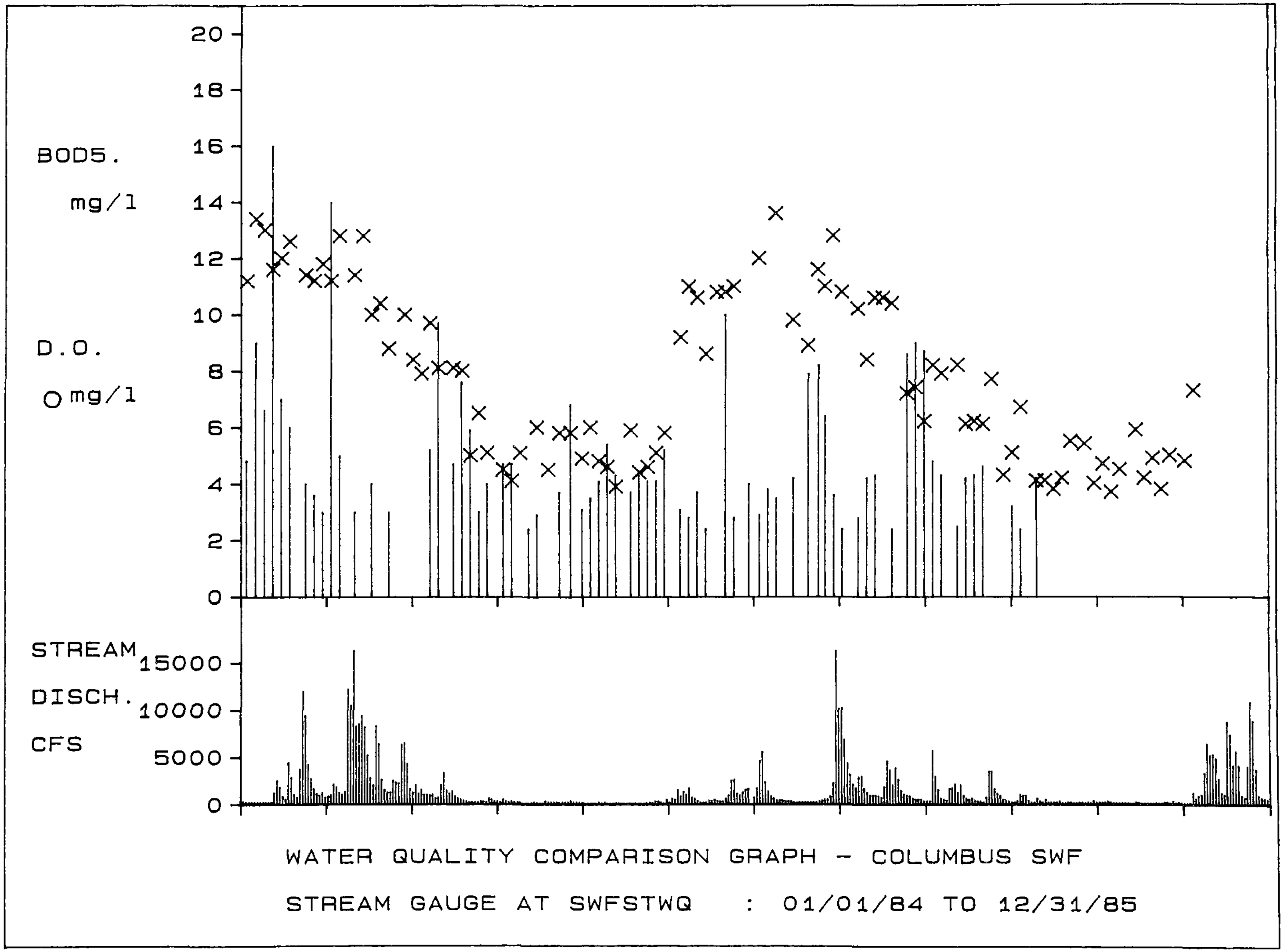
BOD5. mg/l
D.O. mg/l
20
18
16
14
12
10
8
6
4
2
0
STREAM DISCH. CFS
15000
10000
5000
0
WATER QUALITY COMPARISON GRAPH - COLUMBUS SWF
STREAM GAUGE AT SWFSTWQ : 01/01/84 TO 12/31/85

FIGURE 10

Ground Water Resource Based Mapping
Nashua Regional Planning Area
New Hampshire

David Delaney
Hydrologist

U.S. Environmental Protection Agency - Region I
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(617) 565-3615

INTRODUCTION

The EPA and New England environmental protection, water resource planning and economic development agencies are becoming increasingly aware that the collective consideration of water resources, waste disposal and land use is critical to sound environmental decision making. EPA, Region I is actively involved in four principal ground water resource management initiatives: wellhead protection area delineation and management; sole source aquifer designation; ground water resource classification; and, Geographic Information System technology use.

The New England states and the EPA share a common goal to protect valuable and highly vulnerable environmental resources. The EPA is working to improve ground water resource protection by continuing to develop and use Geographic Information Systems. Geographic Information Systems (GIS) can facilitate use of environmental resource data to support in Federal and State environmental program decisions and work products. Use of Region I GIS is helping EPA better identify environmental problems and to assess their nature and importance. Environmental program management can be enhanced by using GIS to develop more comprehensive technical bases for regulatory decisions.

EPA encourages proactive environmental protection. Resource information displayed through GIS is improving our ability to focus regulatory activity to protect critical resources. Further, successful integration of EPA data bases with GIS can improve use of limited staff and contractor resources. Staff evaluating permits, conducting compliance monitoring and site inspections and pursuing enforcement can be assigned to regulatory activities impacting priority resources that are most at risk. EPA program use of GIS can increase the consistency and success of EPA environmental decisions resulting in more efficient water resource planning and protection. GIS link of EPA data bases will increase our ability to better respond to EPA, State and Local need for data and technical assistance to support ground water resource protection and management programs.

PURPOSE

The often close proximity of contaminant sources to potable water resources place human health at risk. The purpose of this mapping initiative is to use GIS to depict ground water resources in two New England pilot study areas and to show the geographic relationship between these resources and potential contamination sources. Maps and information compiled will be used to support the following Office of Ground Water Protection goals to:

- improve EPA and State capability to identify, environmental problems and to assess their nature and importance,
- support state development and implementation of wellhead protection programs,
- promote inter- and intra- agency program coordination of resource protection efforts, and
- demonstrate use of resource mapping to support prioritization of EPA program activities.

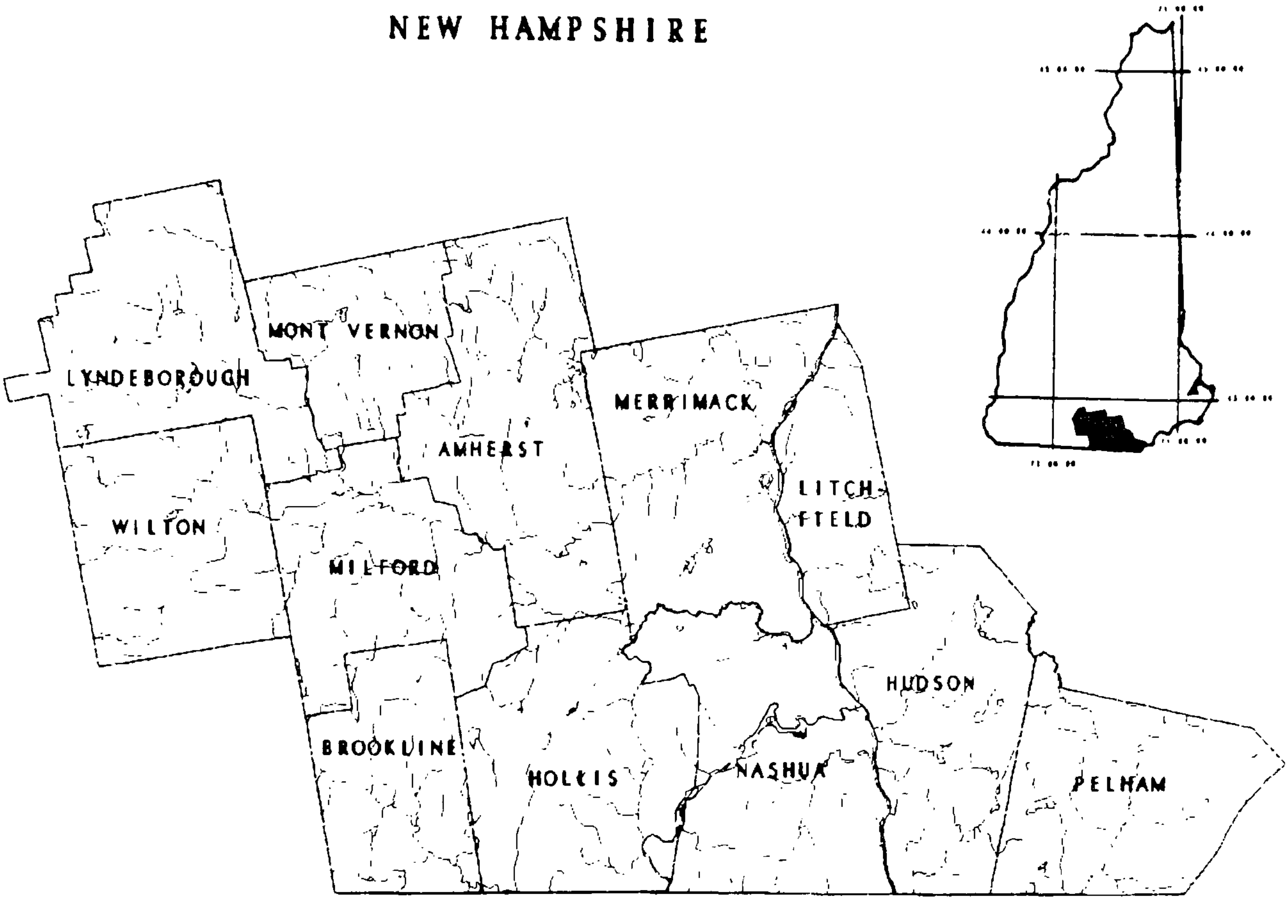
SCOPE

There are extensive hydrologic, environmental and geographic data base for New England. The EPA, Region I, Ground Water Management Section has compiled these types of information to support the Branch River Basin, Rhode Island, and the Nashua Regional Planning Area, New Hampshire, mapping initiatives. These pilot mapping demonstration areas were selected because GIS compatible digital US Geological Survey maps describing the availability of ground water in stratified drift aquifers and digital line graph data are available.

Most of the people living within the pilot areas drink ground water, a resource that is susceptible to contamination by many land use activities. Release of contaminants associated with some land use activities can degrade water resources and other important environments. A major goal of this initiative is to show the close geographic relationship between resources and potential contaminant sources. These pilot areas were chosen partly because there are a manageable number and a good spectrum of Federal and State regulated facilities that can contribute to environmental contamination. State and Federal efforts to identify contamination sources and critical environmental resources in these pilot areas offer an opportunity to combine our water resource protection efforts. These small scale initiatives support development of a broader regional understanding of surface and ground water resources as a framework for addressing issues related to regional water resource protection, water supply allocation and waste disposal.

Ground Water Resource Based Mapping
Nashua Regional Planning Area
New Hampshire

NASHUA REGIONAL PLANNING AREA
NEW HAMPSHIRE



EPA initiated a ground water resource-based mapping pilot project in New Hampshire to provide assistance with ground water protection. Discussion with the New Hampshire Department of Environmental Services (NH DES) resulted in selection of the Nashua Regional Planning Area pilot study area. The Groundwater Protection Bureau of NH DES is actively inventorying Underground Injection-Class V wells, solid waste dumps, contaminant releases, wastewater discharges and underground storage tanks and delineating wellhead protection areas and water resources in support of groundwater protection within the Nashua Regional Planning Area. NH DES indicated that they have access to the University of New Hampshire Geographic Information System (GIS) that will provide the state with capability to use GIS products.

The Nashua Regional Planning Area is located in south central New Hampshire. The area includes the towns of Amherst, Brookline, Hollis, Hudson, Litchfield, Lyndeborough, Merrimack, Milford, Mont Vernon, Nashua, Pelham and Wilton, Hillborough County. This 322 square mile area was chosen because of its manageable size and because the project area is close to Region I, Boston, minimizing travel and facilitating field work.

There are a number of Federal and State data management systems containing information describing the Planning Area hydrology, water resources, water supply, potential contamination sources, and geography. Approximately 160,000 people live in this rapidly growing part of southern New Hampshire. Drinking water is provided primarily by public water supply and private wells. The project area has cultural and hydrologic characteristics common to rural New England. Within the project area there are approximately:

- 198 wells providing public water supply (68 community wells and 130 noncommunity wells),

- 5 community surface water supply intakes,

- 41 national pollutant discharge elimination system permitted outfalls,

- 7 national priority listed CERCLA sites,

- 43 non national priority listed CERCLA sites,

- 20 facilities reporting as per SARA Title III regulations,

- 186 Resource Conservation and Recovery Act regulated facilities (Nashua Facilities not inventoried), and

- 110 agricultural chemical application sites

Maps and information compiled can be used to support proactive environmental protection. Resource and contaminant source information displayed through GIS can improve our ability to focus regulatory activity to protect critical resources.

The GIS data bases developed allow identification and delineation of important Nashua area water resources and facilitate evaluation of impact of potential contaminant sources near water supply sources. This information helps provide a data intensive forum for discussion of water resource and waste disposal management options.

David Delaney, Hydrologist, U.S. Environmental Protection Agency, Ground Water Management and Water Supply Branch, Region I, Boston.

Worked from 1967-1979 with U.S. Geological Survey, Water Resources Division, New England District, conducting water resource investigations in Massachusetts. Since 1979, worked with EPA as a senior Water Management Division hydrologist providing program technical support and conducting special projects associated with water resource protection and management. Provided technical support on Waste Management Division RCRA and Superfund enforcement projects.

A MODEL COMMUNITY PROGRAM FOR PRIVATE WELLS

Roy F. Jeffrey and Karen K. Filchak

University of Connecticut
Cooperative Extension System
Storrs, Connecticut

Abstract

Successful implementation of a comprehensive municipal groundwater protection program requires knowledgeable consumers. The University of Connecticut Cooperative Extension System's "model town" program was set up in order to bring individuals into the groundwater protection process. Implemented in 1989, the program provided groundwater information to residents of the rural towns of Brooklyn and Pomfret so that they could properly assist in the management of their private and public groundwater supplies. A variety of delivery systems were used to transfer drinking water supply information to individuals in the two municipalities. A key part of the program was the formation of community advisory groups which included the chief elected official (first selectman), representatives of municipal agencies and organizations as well as other interested persons.

The "model town" program methodology was designed to supplement Connecticut's aggressive groundwater protection program. The State's effort is targeted at the major aquifers where most municipal and industrial supplies are located, but does not directly address many of the more rural areas where over one-sixth of the population derives its drinking water from individual and smaller community wells.

Introduction

Protecting groundwater quality has become a major concern in Connecticut during the 1980's. Because of this concern, the State has begun an aggressive groundwater protection program.

The program is multifaceted and is targeted to a wide variety of audiences. A major focus of this program is the development and implementation of protection measures in areas which overlay major public water supply aquifers.

The University of Connecticut Cooperative Extension System (UConn CES) is part of a unique national public education organization that serves as a link between knowledge and its useful application. In Connecticut, this means taking research-based information to more than one-half million residents annually.

The design and implementation of educational programs for the protection of water quality is a major initiative of the Extension System at both the national and state level. A state Extension project team received United States Department of Agriculture (USDA) funding to develop educational programs about the importance of regular testing of rural water supplies, how to interpret water test data and treatment methods to assure safe drinking water. Thirteen Water Quality Fact Sheets were developed to supplement this program.

As part of the USDA water quality grant, in March 1989 UConn CES initiated a demonstration "model town" program in the municipalities of Brooklyn and Pomfret.

<u>The Setting</u>

Connecticut has a population of 3.2 million people with over 32% deriving their drinking water from groundwater sources (Table 1).

Table 1. Groundwater Supply Statistics (Environment Committee, 1989)

(1985 Data)

Supply Source	Pop. Served	% of Pop.	Water Withdrawn*	% of all water drawn from all sources
1400 Commun. Supply Wells	518,190	16.2	65.6 MGD	16
250,000 Ind Homes	514,990	16.1	38.6 MGD	10
TOTAL	1,033,180	32.3	104.2 MGD	26

*Million (s) gallons per day (MGD)

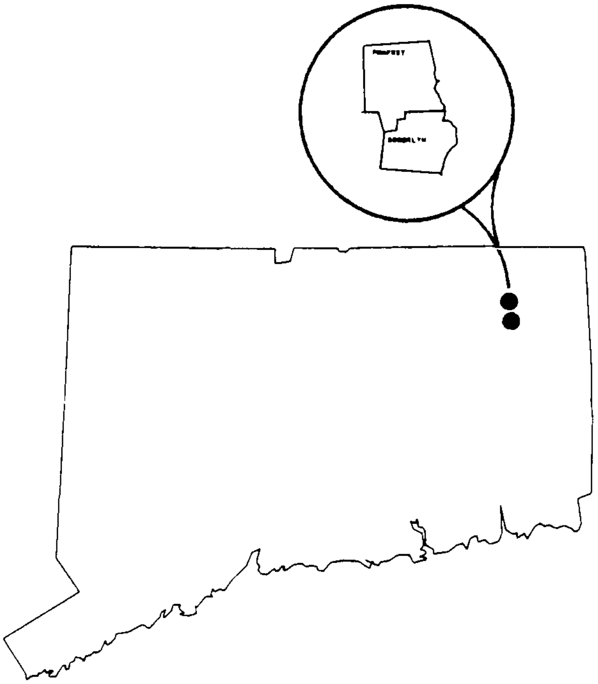


Figure 1 Model Town Location Map

The two towns selected for the program, Brooklyn and Pomfret, are in northeast Connecticut (Figure 1) and are served entirely by groundwater sources. Although part of Brooklyn overlies a public water supply aquifer, most persons residing in the two municipalities rely on individual groundwater supply wells (Table 2). Most of these individual wells are located in areas outside the aquifer areas targeted for protection through the State program.

Table 2. Water Supply Service Systems (State of Connecticut, 1986)

Brooklyn		
Population on community wells	2484	(43%)
Population on individual wells	3346	(57%)
Total population	5830	(100%)
Pomfret		
Population on community wells	250	(1%)
Population on individual wells	2500	(99%)
Total population	2750	(100%)

Planning projections indicate these two communities will face growth pressures during the next several years from the Hartford, Providence and Worcester metropolitan areas. Most of the growth in Brooklyn and Pomfret is expected to occur outside any major public water supply aquifer area which may be targeted by the State for protection. As a result, there will be an increasing need for local government and citizen involvement to protect water quality.

Why the Model Town Approach

The Connecticut Aquifer Protection Task Force was charged in 1987 by the State Legislature to examine means and methods to protect the State's groundwater supplies. In their February 15, 1989 report to the legislature the Task Force indicated a need for education to play a major role, (Environment Committee, 1989).

> "The Task Force feels the role of education in protecting groundwater cannot be overstated. As with many environmental issues, a successful program for protecting Connecticut's drinking water requires a change in the attitudes of society based on enlightened sensitivities to the finite resources upon which it depends."

In order to implement a comprehensive local groundwater protection program, it is important to educate citizens about the topic so they may become willing and knowledgeable partners with the governmental sector. A program of this sort differs from a more traditional municipally-operated program such as transportation planning and management which is usually initiated and carried out almost exclusively at the governmental level. The "model town" program was designed to bring the individual into the process of groundwater protection by helping residents understand how to manage their groundwater supplies as well as learn how public and private actions can influence water quality. It was hoped that, if successful in the "model community" setting, the program could be used by other municipalities in the State.

Brooklyn and Pomfret were selected because all the residents in each community received their water from public and private groundwater sources. In addition, each town had a chief elected official (first selectman) who was interested and involved in water quality issues.

Implementation

A variety of delivery methods were used to transfer drinking water supply information to the local residents. Approaches included direct mailings, educational forums, activities with community organizations, interaction with the media and one-to-one consultations.

It should be noted that the issue of water quality is not one in which one agency or organization has sole responsibility. For this reason UConn CES recognized the need to network with others interested in water quality and coordinated project activities with the State Health Department, District Department of Health and the local Council of Governments.

A key part of the program was the formation of an advisory group in each community. Membership in the groups included the chief elected official (first selectman), town commission members and other interested persons. Individuals in each community were identified and contacted by the first selectman.

Advisory group meetings were held to explain the project's goals, present an overview of the town's water supply situation, discuss possible role(s) of the advisory group, review available Extension resources and consider means to disseminate information. Advisory group members could become involved in several ways:

1. Advisory - recommend methods or potential audiences with which the Extension project team might work.

2. Coordinating - be involved in scheduling programs, exhibits, etc.

3. Participation - be available to respond to certain inquiries or assist in information dissemination (i.e. distributing fact sheets, staffing exhibits, etc.)

The importance of the advisory groups should be emphasized. These groups were able to bring local knowledge, guidance and ideas to the Extension project team that might otherwise have been overlooked. As a follow up to the meetings, advisory group members were kept informed by a newsletter.

Activities

Program activities were conducted during the seven month funding period which began in March 1989. These activities included:

1. Special Mailing - Because Brooklyn and Pomfret have relatively small populations (5830 and 2750 respectively), it was

felt that a direct mailing to all residences would achieve maximum exposure, while still being economically feasible. An informational packet was mailed to 2356 residential units with private wells. The packet contained a cover letter that described the groundwater quality issues and outlined an opportunity for residents to take advantage of a reduced rate standard parameters water test. Also included were the fact sheets "Testing the Private Well" and "Maintaining Your Septic System" plus an order form for other Water Quality Fact Sheets.

Informational packets were also mailed to 260 residential units on a public water supply. They received the same materials except that the fact sheet "Testing the Private Well" was replaced with "Customers on Public Supplies."

A follow-up packet with information on how to participate in the reduced rate water testing was sent to all who inquired.

2. Educational Presentations - Brooklyn and Pomfret had a limited number of groups to which formal educational presentations could be made. However, targeted groups did include local churches, school PTO's and horticultural societies.

3. National Drinking Water Week - This was a national effort to increase public awareness of the drinking water supply. The project team participated in this effort by distributing information packets. One packet was distributed through a local garden center in Brooklyn and contained information on water quality and the home landscape. This packet included a cover letter about National Drinking Water Week (NDWW), a NDWW sticker and the Extension fact sheet "Well Water and the Home Landscape." Another packet was distributed in conjunction with a well drilling and treatment company's efforts to promote National Drinking Water Week. This packet provided information about how people with a private water supply could get a water test. The packet included the same NDWW information but with the Extension fact sheets "Testing the Private Well" and Nitraties."

4. Water Quality Quiz Board - A self-contained quiz board was developed and offered at fairs and other public gatherings so that participants could determine their knowledge of basic water facts. The portable board was designed with a light-response mechanism which indicated the correct answer. This board served to facilitate discussions about water quality issues with representatives of the project team.

5. Media - A variety of media outlets provided an important and cost-effective opportunity for information dissemination.

An interview about the program was conducted on radio station WINY in Putnam. Several public service announcements (PSA's) about various aspects of the home water supply (water testing, septic system management, and the home landscape) were developed and aired.

The two major newspapers in the two-town area carried articles about the program. An article in the Norwich Bulletin promoted the program and an article in the Patriot Observer provided information on understanding the home water supply.

A one minute educational spot on residential water quality was produced and aired on Connecticut Public Television (CPTV) Channel 24. CPTV's viewing audience includes the model town area.

6. School Programs - The project team initiated work with Ragged Hill Woods, a non-profit environmental education program in northeastern Connecticut, to provide water quality curriculum to participating area schools. Extension water quality materials were incorporated into the curriculum used in the Ragged Hill Woods program.

7. Regional Council of Governments - A presentation by the project team was made to the ten chief elected officials represented on the Northeast Council of Governments. The presentation provided an overview of the program. The potential for similar programs region-wide was highlighted.

8. Agency Coordination - A key component of the program was coordination with a variety of state, regional and local organizations. Cooperative Extension, like most other agencies which have a responsibility in the groundwater protection area, is a relatively small organization with a state-wide delivery system. For this reason it is extremely important for agencies to work together to achieve common objectives. Close coordination with representatives of the State Health Department, Northeast Regional Health District, Northeast Council of Governments and a non-profit environmental education program enabled the project team to move forward with the program.

Evaluation

Since project activities ended in September, 1989, a formal evaluation has not been completed. Requests for water testing information and additional facts sheets, however, indicates a strong level of interest in this area.

The evaluation instrument that will be administered to residents of the model town area will determine the:

.Amount of information received
.Source of the information (mailings, media, etc.)
.Value and usefulness of the information

.Readability of the fact sheets
.Any additional information sought or actions taken (i.e. water tests) as a result of the model town program.

Summary and Conclusions

This program addressed the need for citizen education about groundwater protection. The small population size of Brooklyn and Pomfret presented limited opportunities for formal and informal presentations but did provide an excellent opportunity for the dissemination of information by direct mailings and follow-up contacts. Involvement and support of the chief elected officials was a critical factor to the success of the program.

Based on discussions with representatives of the Northeast District Department of Health and the Council of Governments, expansion and transferability of this sort of citizen education program should include consideration of the following:

. Delivery methods should be expanded through workshops for local and regional organizations which deal with topics in this area and have direct contact with the public. Organizations should include realtors, water testing laboratories, health departments and local building inspectors.

. Recognition that local and regional government leadership should be prepared to respond to increased interest and participation by citizens in protecting groundwater quality.

Implementation methods may vary in other geographic regions, specific to those locations, such as population, sources of drinking water and community involvement.

References

1. Department of Environmental Protection, 1986. Connecticut Natural Resources Atlas Series: Community Water Systems in Connecticut. State of Connecticut. Hartford, CT.

2. Environment Committee, 1989. Report of the Aquifer Protection Task Force. State of Connecticut General Assembly. Hartford, CT. 72 PP.

Biographical Sketches

Roy F. Jeffrey has been an Extension Educator with the University of Connecticut Cooperative Extension System since 1980. He is responsible for working on a variety of environmental management programs at the municipal level, including composting, groundwater protection and agricultural land preservation.

Mr. Jeffrey received his BS and MS degrees in Plant and Soil Sciences from the University of Maine. He has worked extensively in environmental planning and has previously been a planner with the City of Bangor, Maine, the Southwestern New Hampshire Regional Planning Commission, and Prince George's County, Maryland.

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Karen Filchak has been an Extension Educator with the University of Connecticut Cooperative Extension System since 1977.

Ms. Filchak has worked with a variety of audiences including the general public, professional organizations, teachers, agencies and the media. Among topics addressed in public service announcements, interviews and articles with television, radio and newspapers are residential water testing, household hazardous wastes and septic system maintanance.

Ms. Filchak received her BS and MA degrees from the University of Connecticut in Design and Resource Management and Higher Technical and Adult Education, respectively. Additional graduate studies in public health and water policy were completed at the University of Massachusetts. She has also completed Cornell University's course "Local Groundwater Management: Aquifer Contamination Protection and Community Response."

Ms. Filchak has had statewide program responsibility for residential water quailty since 1985.

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BOARDS OF HEALTH PROTECTION FOR PRIVATE WELLS AND GROUNDWATER

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Abstract

In Massachusetts, people depending upon private wells are unprotected against improper siting, poor installation and contamination, except where local health boards have adopted regulations. Effective private well protection utterly depends upon the local board of health adopting a well protection policy which is consistent with local needs and conditions. In addition to specific private well regulations, there are other actions which local boards can take as part of an overall groundwater protection program.

The following paper i a brief summary of the local initiatives available for the protection of private wells and groundwater. For more detailed information, please refer to the Board of Health Handbook for Private Well Protection and the references cited therein. To obtain a copy of the Handbook contact the Massachusetts Association of Health Boards (508) 643-0234.

PRIVATE WELL PROTECTION
THE LEGAL AUTHORITY OF BOARDS OF HEALTH

Boards of health in Massachusetts are potentially the single most effective agent for environmental protection, particularly for ground and surface waters. Mass. General Law Ch. 111 s. 31 grants health boards broad powers to prevent and abate threats to public health. State Supreme court rulings have in recent years tended to affirm and even expand the interpretation of these local powers. For example, in United Reis Homes, Inc. v. Planning Board of Natick, 359 Mass. 621 (1971) the Court stated, "Boards of Health have plenary power to make reasonable health regulations and to remove or prevent nuisances, sources of filth and causes of sickness." In a more recent case, Independence Park, Inc. v Board of Health of the Town of Barnstable (S J C. No. 4817 August, 1988), the Supreme Court ruled that, "If we did not defer to the board of health's conclusion that an existing regulation mandating sewers in some circumstances did not preclude an order to build sewers in different circumstances, we would be forcing boards of health to be omnisciently comprehensive in writing their regulations. That would be an intolerable burden and an unattainable objective." In this broad interpretation of the board of health's authority under MGL Ch. 41 s.81U, the court recognized that it is impossible for health boards to foresee and prevent through regulation every circumstance which might lead to groundwater contamination. And while the board cannot contradict its own regulations, neither is it limited to them when it makes binding recommendations on subdivision plans.

Board of health regulations also take precedence over zoning. If nitrate loading or private well regulations result in the necessity for larger lot sizes than required under town zoning, the board of health regulations must be met. It is important to note however, that local health boards do not have statutory authority to regulate growth, and therefore, the intent of the regulation must be the protection of public health and the prevention of nuisances.

In theory, a board of health's regulatory authority is limited only by its ability to track and measure the causes of groundwater contamination. Whenever scientific evidence links environmental and public health, boards of health have a unique ability to extend their authority quickly and efficiently. As long as a regulation is neither illegal, arbitrary, unreasonable nor inconsistent with its stated purpose, there is a legal presumption in favor of the regulation

Unfortunately, only a small percentage of health boards actually utilize their full authority. In some communities the digging or drilling of private wells remains completely unregulated. It is entirely legal in many parts of the state for a well to be drilled within a few feet of a septic system.

A strong board of health that is committed to groundwater protection can act much more efficiently than state or federal government. To begin with, the local board and its agent should be familiar with areas of critical environmental concern, such as aquifers, wetlands and recharge areas. The board of health can also adopt or amend regulations without going through a lengthy hearing process. Board of health regulations take effect after they are voted, published in the local paper and posted with the Town Clerk. A copy should also be sent to Department of Environmental Protection. This ability to move swiftly is necessary so that health officials can act effectively to protect the public health. If a developer or any other aggrieved party wishes to challenge the board of health's action in court, the burden is on the complainant to prove that the contested actions do not tend to protect the public health.

Across the country, there is a growing recognition of the economic value of private water supplies and the public health necessity for protective regulation. It is now recognized that regions which are served only by private water supplies should be treated as environmentally sensitive For example, some underground storage tank regulations and hazardous waste cleanup standards provide the same level of protection to areas relying upon private wells as to the zones of contribution to public wells

There are no comprehensive state regulations governing private wells Although this may be partly due to political and economic considerations, it would also be very difficult to administer uniform standards governing private wells in Massachusetts. Natural conditions vary considerably across the state and result in very different problems and requirements. Local variables include geology, groundwater flow and other hydrologic factors, and land use For example, in the stratified drift, sole source aquifer of Cape Cod, regulators must protect relatively shallow wells which are at risk from rapid transmission of pollutants through porous soils and which are sited on comparatively small lots within a larger setting of explosive growth patterns. At the other hydrogeological extreme are deep drilled wells in bedrock, where yields may be marginal, and the incidence of natural contaminants such as arsenic or radon is occasionally high.

Local geology and soil conditions should be addressed in private well regulations. These conditions include the characteristics of the aquifer, the soil percolation rate, the depth of the well and groundwater flow. Local land use patterns should also be considered. For example, if the well sites are on or near agricultural land, it may be necessary to test for pesticide contamination. If there are major sources of pollution such as auto junkyards or landfills, there should be special setback and groundwater monitoring requirements to map the migration of any contamination plumes.

Creating A Local Private Well Policy:

Seven Decisions Which Define This Policy

1. Water quality standards must be defined.

2. Minimum distances for setback of wells from sources of contamination must be established.

3. Will board of health regulation be extended to include construction and quality control?

4. What well water tests will be required?

5. When will water testing be performed?

6. When and under what conditions will water treatment systems allowed?

7 Will non-potable wells be permitted?

Other Board Of Health Aotions Which Should Be Part Of An Overall

Groundwater Protection Strategy

1. Household & small generator hazardous waste pickups

2. Nitrate loading regulations

3. Underground storage tank registration & testing

4. Subdivision review (required under MGL Ch. 41§81U)

5. Public & Environmental Health Review Regulations

6. Registration of Private Wells Near Utility Rights of Way
   (333 CMR 11 04:(2)(c), 1986)

7. Banning septic system "cleaners"

8. Local pesticide use regulations

9. Local Emergency Response Planning Committees
   (required under Federal Emergency Planning and Community Right to Know Act of 1986)

10. Toxic materials registration

11. Solid waste disposal regulations

12. Septic system siting and construction regulations
    (beyond Title 5)

Biographical Sketch

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PRIVATE WELL PROTECTION IN SAND AND GRAVEL AQUIFERS

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ABSTRACT

No state laws exist governing the sighting of private wells relative to septic systems. Current state laws concentrating on the sighting of septic systems relative to private wells are quite limited. Three municipalities on Cape Cod (Falmouth, Mashpee, and Wellfleet) have enacted public health bylaws to directly provide for private well protection. The procedure is currently applied to proposed subdivisions and to private lot positioning of well and septic systems in partially built-out subdivisions.

The need for private well protection was demonstrated from the results of a survey of private well contamination in the Mares Pond region of Falmouth, Massachusetts. The private well survey found that 29 of our 44 wells had elevated indications of contamination. Impacted wells were being affected by plumes of wastewater leachate from on-lot of neighboring-lot septic systems, a phenomenon termed "short-circuiting" or "cross connecting". The source of contamination was more often the next-door neighbors septic system than the on-lot system. The frequency and impact of "short-circuiting" was related to ground water flow velocity (direction and rate) and to recharge (local precipitation). The special importance of the Mares Pond residential well study was that it demonstrated that the frequency of nitrogen contamination was related to orientation of septic system and well within the groundwater flow field, not just simple distance of separation.

The private well protection procedure is devised specifically for unconfined (watertable) sand and gravel aquifers like Cape Cod and southeastern Massachusetts Local watertables mapping direct flow measurements and a small pump test are combined to obtain information about the hydraulic conductivity of the local aquifer, groundwater flow directions and velocities. Precipitation recharge values are obtained from the USGS Water Resources Division. A sensitivity analysis of the factors of velocity, recharge, and anisotropy (vertical versus horizontal hydraulic conductivity) was

conducted to evaluate the relative impact on zones of contribution of the private wells.

An elliptical approach is strongly recommended over circular distances regions in which groundwater velocities exceed .5 ft/day. A line is extended upgradient from the proposed position of the well. The length of the upgradient line is determined by the local groundwater flow velocity, anisotropy, field porosity, and recharge rate. Tables of probable distances can be generated for differing regions of coastal aquifers. A protective distance of 100 ft from the line is provided as added protection for seasonal variation in flow and recharge consistent with current circular (fixed distance) approaches. Civil engineers are required to plot the protective zones on plat maps of proposed subdivisions showing position of septic systems, road catch basins, and fuel storage regions.

INTRODUCTION

Except for the limited municipal sewer systems in the towns of Barnstable, Chatham and Falmouth, Cape Cod residents rely upon on-site septic systems for wastewater disposal. Roughly 1/3 of all residents obtain their drinking water from private on-lot wells. While municipal regulations and the state environmental code for location of on-site septic systems have emphasized placing the septic leaching facility away from the private well, as of 1989 there are no comprehensive guidelines for private well construction and protection. The purpose of this report is to review current regulations for the sighting of private wells and to propose a strategy for protecting private wells based upon the natural motion of groundwater.

Existing Regulations

There are no state laws governing the sighting of private wells relative to septic systems. Current state laws govern only the sighting of septic systems relative to private wells and are quite limited. They are inadequate to ensure protection of drinking water sources from chemical pollution. The Massachusetts Environmental Code (Title V; DEQE, 1977) is the primary law governing septic systems. The code requires a four foot vertical separation between the bottom of a septic leaching facility and the maximum water table height, as well as a minimum 100-foot horizontal distance between the leaching facility and drinking water wells. The rationale for setting the horizontal separation distance was based largely on the migration of indicator bacteria.

The Contaminaiton Threat

The family of microorganisms known as coliform bacteria is a common indicator of pathogenic (i.e. disease-causing) pollution. Coliform bacteria are attenuated (largely through natural die-off and some filtration) as they move from a septic leaching facility through the soil into the groundwater and then with the groundwater through an aquifer. The Massachusetts Department of Environmental Protection (DEP) considers 100 feet a sufficient distance to remove coliforms in addition to bacteria, there may be viruses in domestic wastewater that flow into the household septic system from which the leachate mixes with groundwater. Since tests for the presence and concentration of bacteria are simple, while tests for viruses are complex, mandated separation distancees between well and septic system are generally based on bacterial indicators.

Two non-biological components of septic system effluent are major threats to private wells: nitrate-nitrogen and organic chemicals.

The effluent from a typical household septic system with a mean flow of 65 gal/day has an average nitrogen concentration of over 30 ppm (CCPEDC, 1979). Typically this nitrogen reaches the aquifer as nitrate-nitrogen (NO^3 -N) In concentrations of more than 10 ppm, NO^3 -N is known to cause oxygen deficiency in infants being breast or formula-fed. Physiologically, methemoglobin is produced instead of normal hemoglobin, impairing the proper supply of oxygen to the tissues. Increased methoglobin concentrations in the blood stream have been shown on a physiological continuum down to about two ppm in children in day nurseries exposed to elevated nitrate-N in their ingested water (Subbotin, 1961).

Even minute amounts of organic chemicals in drinking water present serious health hazards. Such chemicals like solvents (TCE,benzene) have been shown to cause many types of cancer (especially cancers of the digestive system and liver), kidney diseases, diseases of the nervous system, congenital malformations and fetal deaths (Tardiff and Youngren, 1986).

It is all too easy to attribute pollution by organic chemicals solely to commercial/industrial establishments-e.g., paint and autobody shops, filling stations, printing enterprises, etc. Yet, sinks in kitchens and bathrooms, toilet bowls and careless disposal of substances in driveways should also be a major concern. Almost every household on Cape Cod uses and discards several or all of the following substances: household cleaning agents and degreasers; oven cleansers; paint and paint thinners (trupentine); septic cleaners (acid-organic types); spray deodorants; and garden herbicides and pesticides.

Small capacity home wells are particularly susceptible to organic chemical contamination. Whereas municipal wells derive some protection from their large volumes of mixing and withdrawal, private wells are not so protected. Domestic sewage has frequently been found to contain trace amounts of petroleum distillates as well as benzene, toluene, chlorinated hydrocarbons such as trichloroethane, trichloroethylene, tetrachloroethylene, dichlorobenzene and alkyl phenois.

It should be noted that unlike nitrogen and biological pollutants, organic chemicals do not enter household sewage continuously. Gasoline, paint thinners, solvents and even pesticides are typically discharge only at irregular intervals. Furthermore, once discharged into sewage, some proportion of these chemicals is absorbed into soil particles or broken down by bacterial action. That not-withstanding, some organic chemicals are very persistent, and if a neighbor's septic system lies within the recipient well's zone of contribution, a quantity of a discharged chemical will probably enter that well and, as shown in Table II, the volume of such chemicals sufficient to exceed recommended concentraion levels in drinking water is very small.

TABLE I

Quantity of organic materials disposed through a home septic system sufficient ot achieve critical concentrations in drinking water lying within the contribution zone of a well with 300 gallons per day withdrawal.

Substance	Concentration in product %	Recommended maximum concentration in drinking water (ppb)	Quantity to achieve critical level
Gasoline, unleaded			
Benzane	1.0-2.1	5	1 pint
Toluene	2.2-9.9	2,000	50 gallons
Xylene	0.7-3.4	440	10 gallons
Pesticides			
Aldicarb	1.5-50	9	1/10 pints
Chlordane	varies	0	less than 1/100 pint
Solvents			
Trichloroethylene	1-5	5	1/10-1 pint (TCE)

1986 amendments to EPA Safe Drinking Water Act.
Does not include removal through treatment by the septic system or adsorption/dispersion in sewage plume.

The Mares Pond Study

In the summer of 1982, the Town of Falmouth, in cooperation with the Barnstable County Public Health Department, conducted a survey of private wells in the Mares Pond area. The survey results indicated high levels of iron, ammonia and nitrate-nitrogen in numerous wells. The Town health officials and local residents expressed concern that a health hazard might be developing, hence the Town undertook a special study of sources of private well contimination (Kerfoot, 1987).

The results of the private well study were revealing. In the region adjacent to Mares Pond, 29 out of 44 wells had elevated

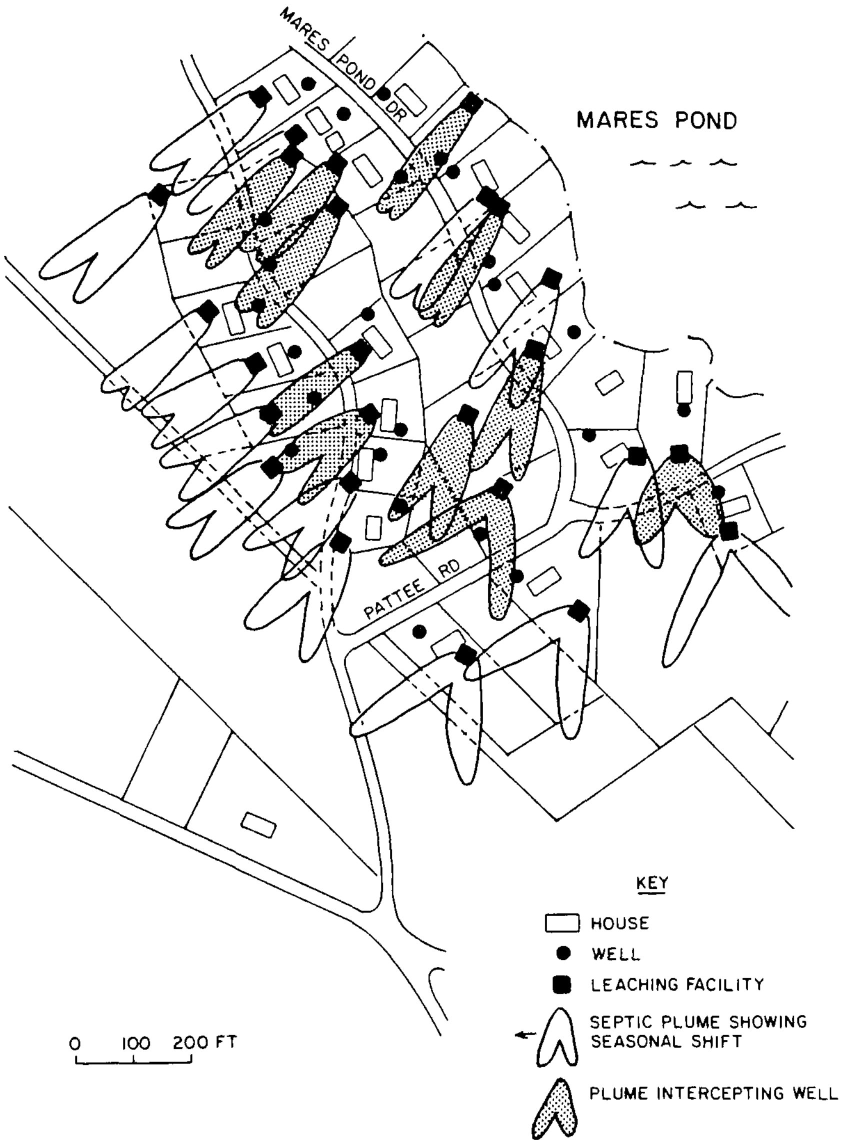

Figure 1 The location of wells, septic systems and septic plumes in a small section of Mares Pond area.

indicators of contamination. The study showed that the contaminated wells were being impacted by plumes of wastewater leachate from on-lot or neighboring-lot septic systems, a phenomenon termed "short-circuiting" or "cross-connecting." The source of contamination was more often the next-door neighbor's septic system than the on-lot system. Apparently more care was exercised in positioning septic systems in relation to on-lot wells than to neighboring-lot wells. The Mares Pond area was developed primarily in single family half-acre lots and exhibited a rapid groundwater flow, ranging from one to five feet per day, in sand/gravel soil conditions.

To demonstrate that the septic system plumes could be contaminating the wells, the frequency of short-circuitings was projected for the study region using a dispersion plume model (Wilson and Miller, 1978). The observed frequency showed no significant difference from the model's predicted occurrence of short-circuitings. (See Figure 2.) The lengths of the projected plumes ranged from 150 to 250 feet (using one ppm total nitrogen as the edge of the plume). Three wells were found to have NO3-N concentrations from 14 to 27 ppm during a drought period from March to June 1982. By 1983, when the rains increased groundwater recharge, the nitrate levels dropped to below 10 ppm (the EPA-recommended level for safe drinking water).

Large lot size did not guarantee adequate protection for the private wells. One house studied was sighted on a lot larger than one acre, but its well was nevertheless contaminated. The study showed that the orientation of the septic systems relative to wells and groundwater flow was the important factor in producing "short-circuiting."

The problems identified in the Mares Pond study are not unprecedented A 1978 report prepared for the Health Department of the Town of Barnstable showed a significant correlation between nitrogen concentration at muunicipal water supply wells and the expected nitrogen content based upon on-lot septic system and lawn nitrogen loadings (KVA, 1978) The first detailed report devoted entirely to private well-water quality on Cape Cod found that the Barnstable County planning guideline of five ppm NO^3-N was exceeded at 273 wells and the U.S. Environmental Protection Agency drinking water standard of 10 ppm was exceeded at 93 wells (Persky, 1986). Figue 3(ibid.) shows the correlation between nitrate-nitrogen in the private drinking water supply and the density of housing units per acre. The special importance of the Mares Pond study is that it demonstrated that the frequency of nitrogen contamination is not just a simple matter of housing density. but also of the orientation of private wells and septic systems within the groundwater flow field.

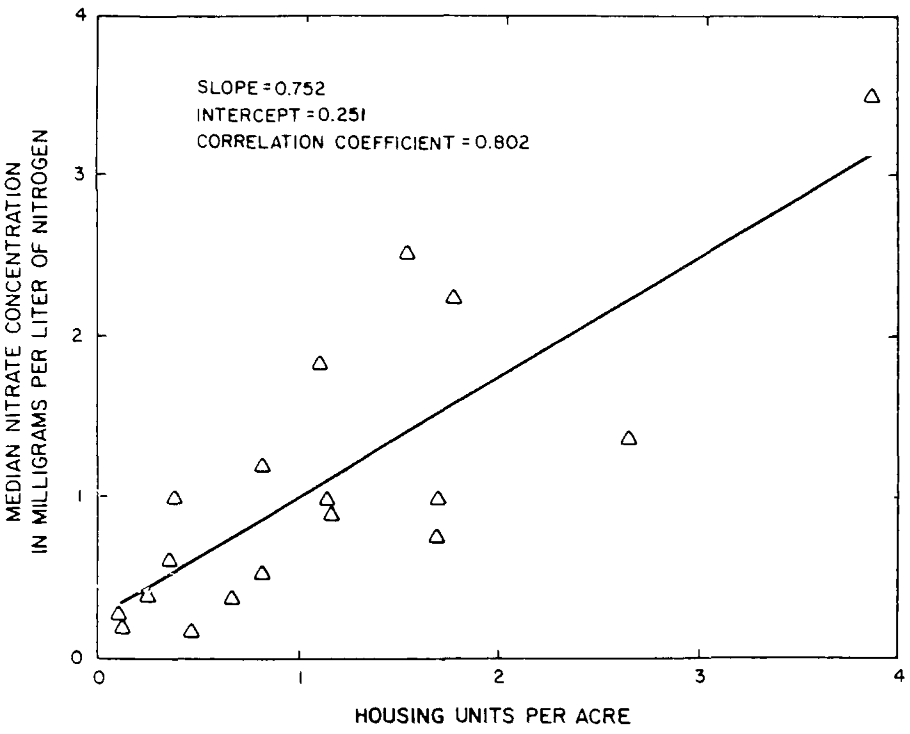

Figure 2 Median nitrate concentration as a function of housing density

An Explanation Of Short-Circuiting

How does the short-circuiting of private wells and septic systems occur? In general, groudwater moves through the aquifer (the water-yielding subsurface soils) from higher elevation to lower elevations. Note that the word "elevation" as used here refers to elevations of the groundwater (or water table) not to elevations of land.

Groundwater is quite mobile and flows continually beneath the land surface. Figure 6 (Kerfoot, 1987) is a frequency diagram of measured velocities of groundwater from over 100 locations in the Town of Falmouth. With a velocity mean of 2.5 feet per day and a mode of 1.2 feet per day, groundwater flow is a significant factor that must be taken into account to protect wells from sources of contamination. These flow rates have been confirmed by the United

States Geological Survey (LeBlanc, et al., 1987). An independent tracer study at a site in the northern end of Falmouth yielded a mean velocity of 1.5 feet per day and maximum velocities as great as three feet per day. As the velocity of flow increases,

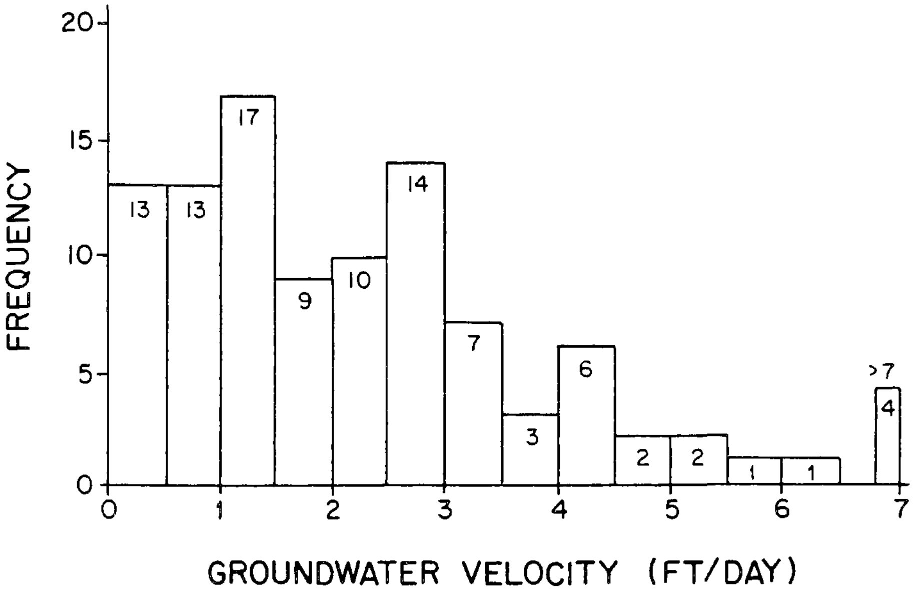

Figure 3 Frequency distribution of groundwater flow rates in Falmouth, Massachusetts

constituents of a typical sewage plume can travel farther from the source and the threat of contamination increases.

When a well is placed in the aquifer and pumped, thus withdrawing groundwater, the configuration of the water table about the well is modified. (See Figure 4) This modification is known as a "cone of depression," and is accompanied by changes in groundwater flow directions in the vicinity of the pumping well (Driscoll, 1986). These miodified conditions, coupled with the natural (or static) groundwater conditions, dictate the area of capture, or zone of contributionn (ZOC), to the well.

While the volume pumped is considerably smaller for a private well than for a public supply well, pumping of a private well also causes a depression in the nearby water table and influences groundwater flow conditions. A methodology has been developed to predict these flow conditions and subsequently to deliniate an area of capture for the well (Kerfoot, 1985). This method is based on the determination of groundwater flow directions and velocities in the vicinity of the well. The boundaries of the ZOC are then extrapolated from this basic information. Water table mapping in combination with a small pump test, to obtain information about the hydraulic conductivity of the local aquifer, can be used to determine groundwater flow directions and velocities.

Based on a typical pumping rate for a private on-lot well (approximately five gallons per minute for 60 minutes each day) and typical groundwater flow velocities (approximately one to two feet per day), a zone of contribution can be calculated that measures over 150 to 200 feet in length and over 40 to 60 feet laterally, This zone clearly exceeds the State Environmental Code's 100-foot regulatory distance in the upgradient direction.

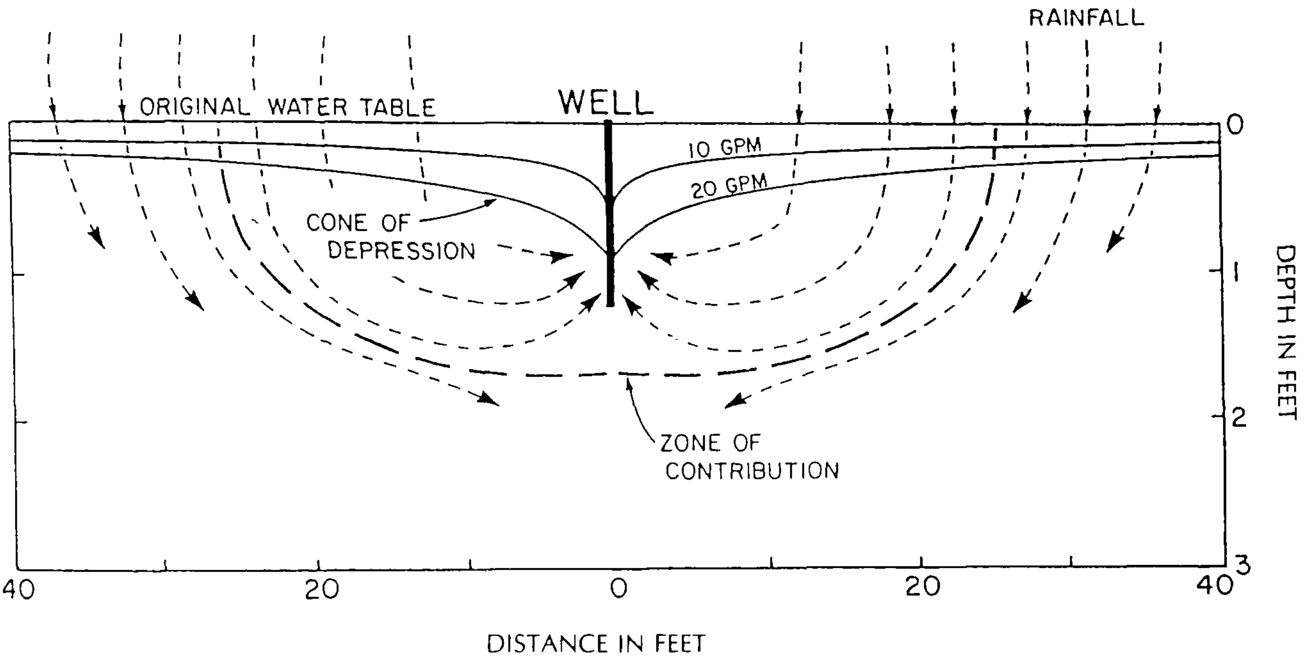

Figure 4 Cross-section through a cone of depression. (Adapted from Strahler, 1972)

When houses are built fairly close together on individual lots, each of which contains a private well and septic system, the possibility of short-circuiting between wells and septic systems from nearby lots must be of concern.

Delineating The Zones Of Contribution For Private Wells

To understand how private wells derive their water and how the zone of contribution develops and is shaped, it is helpful to look at three examples, starting with the simplest conditions and adding complexities that better reflect actual hydrogeologic conditions. An assumption common to the three examples is that the well's pumping rate is 300 gallons/day.

Example 1: A well pumping in an area where there is no horizontal groundwater flow:

In areas where there is no significant groundwater gradient and thus no detectable horizontal groundwater flow, a well will pull equally in all directions from the surrounding strata. The immediately surrounding groundwater subsides symetrically, causing a "drawdown" cone of depression around the well pipe. After the pump is run for a brief period, the cone no longer deepens, but reaches a steady state. At this time, the volume of groundwater being withdrawn through the well is balanced by an equivalent volume of recharge water. The displaced water volume moves outward until it is balanced by the volume of infiltrating recharge. The recharge area or ZOC of the well becomes a circle whose daily recharge matches the daily withdrawal (i.e., 300 gallons/day) of the well.

In this simple case, neither the well depth nor the well screen configuration nor three-dimensional hydraulic conductivity differences of the geological strata are significant variables. The ZOC will be circular with an area sufficient to produce a volume of recharge equal to the well's withdrawal, if the recharge varies between 18 inches per year (.004 ft^3/square foot/day) and 24 inches per year (.0055 ft^3/square foot/day), the area of the circular ZOC would be between 10,000 ft^3 and 7,399 ft^3 with a radius between 56 and 48 feet. (Note: A higher rate of groundwater recharge results in a smaller ZOC for a well pumping at a constant rate.)

The recharge values for a particular area can usually be obtained from publications of the USGS Water Resources Division. Generally, during summer the ZOC areas enlarge as withdrawal increases with lawn watering and recharge decreases with evaporation.

It is worth repeating that the current Massachusetts sanitary code (Title V) requires a 100-foot separation between an on-lot septic leaching facility and a private well. For this example, the Title V requirements add a protective zone of about 50 feet beyond the normal recharge zone. If there were no horizontal groundwater flow, this protective zone would be effective.

Example 2: A well pumping in an area where groundwater flows horizontally beneath the site at a rate of one foot/day and in which the hydrogeologic conditions are "isotropic" (i.e., water will flow into a pumping well at an equal rate from both the vertical and horizontal directions):

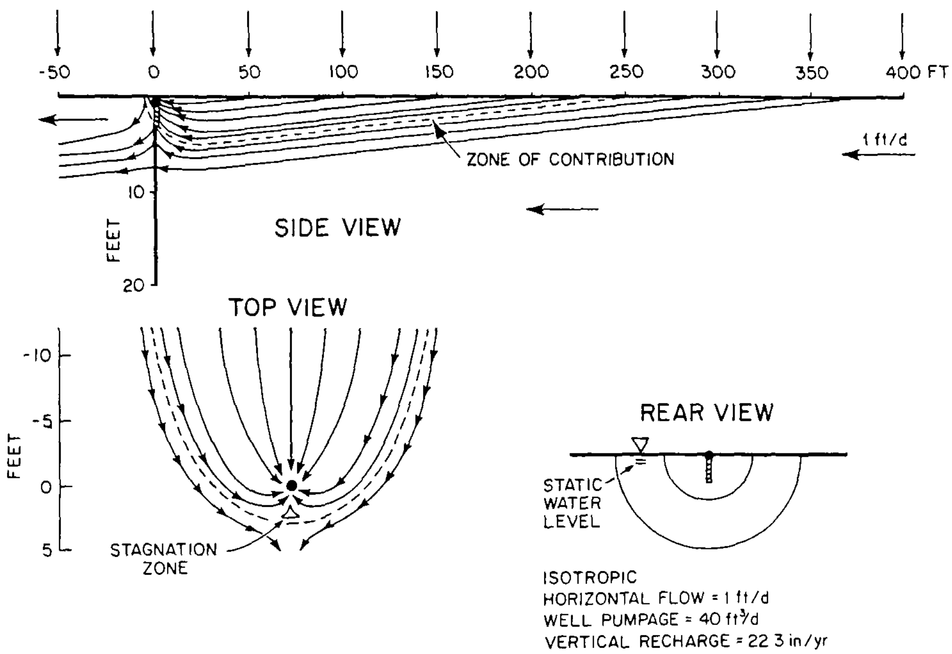

Figure 5 Computing the recharge zone (ZOC) by flow streamline analysis following water particle movement

The conditions of Example 2 are common in the area midway between the center of a groundwater lens and the shoreline when there is a mixed medium sand substrate. A gentle gradient of groundwater exists across the area in which the well is dug, often about 0.3% (0.3 feet vertical drop across 100 feet lateral distance). Two aspects have changed from Example 1. First, the circular ZOC now begins to extend upgradient, becomes more elliptical in shape, and develops a groundwater divide on its downgradient side. Second, the shape becomes more sensitive to the depth of penetration of the well screen into the aquifer. Basically, there are two flow fields, one originally existing as a constant regional flow from elevations of higher water level to lower water level, and a second induced by water being withdrawn from the well. These combine to form a unique flow field (Figure 5).

Figures 5 and 6 show cross-sections of the flow fields. The rainfall recharge intercepted by the well now extends farther upgradient than downgradient. The pathway of the recharge moves downward and is pushed horizontally by the background flow and pulled by the well withdrawal. With varying rates of recharge, the boundary of the ZOC changes One can look at the dimensions of the well withdrawal field by tracing the pathway of recharge water particles (Figure 10). If the recharge is 18 inches/year and there is an effective porosity (i.e., void space between soil particles) of 0.25 (25%) in the sandy substrate, the vertical movement of a water particle is six feet/year downward, assuming a constant groundwater gradient across the site. A three-foot long well screen with a uniform withdrawal pattern would pull in water recharged as far as 350 feet upgradient.

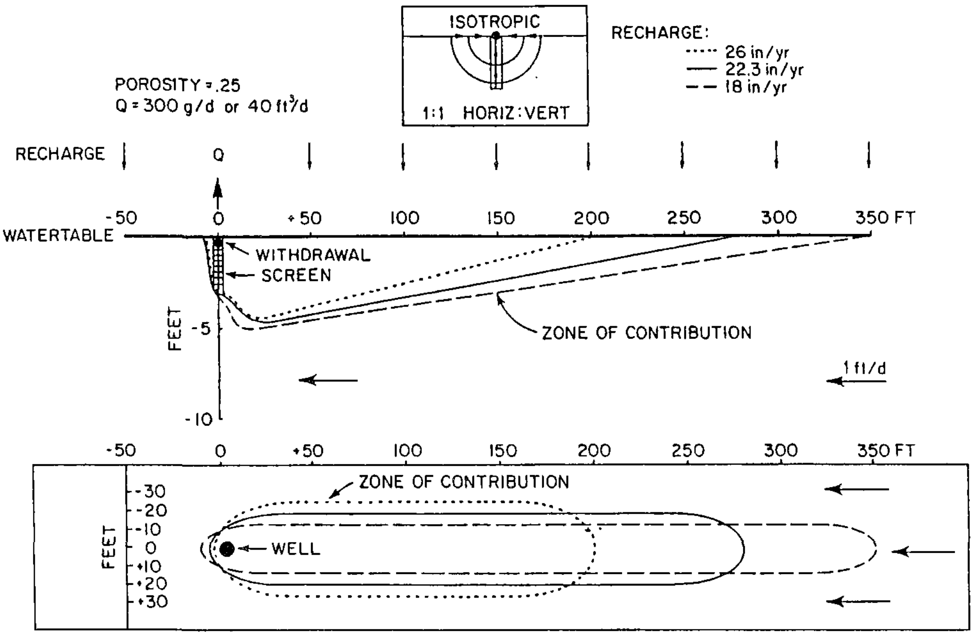

Figure 6 Recharge zones under differing recharge rates.

Assuming the isotropic conditions of this example, in which water particles can enter the well screen on symetrical paths from both the horizontal or vertical directions, the ZOC would be about 30 feet wide and 280 feet long with a total area of 8,000 ft2

Example 3: A well pumping in an area with horizontal groundwater flow of one foot/day, where there are non-isotropic hydrogeological conditions; that is, with water flowing into the well screen four times faster from the horizonal direction than from the vertical:

The most common condition observed on Cape Cod is represented by Example 3. The Cape Cod aquifer generally conducts water more readily in a horizontal than a vertical direction This occurs because the substrate was deposited in layers (stratified) during the last glacial period. Commonly, the ratio of vertical to horizontal conductivity varies from 1:3 to 1·10 (Guswa and LeBlanc, 1981).

If one substitutes a 1:4 vertical to horizontal conductivity ratio for the isotropic conditions of Example 2 and computes the flow changes, the ZOC flattens out substantially and shortens. This is because the physical arrangment of sand and silty alternating layers causes water to run into the well more easily laterally than verticallly, Since the vertical withdrawal shortens, the distance of upgradient withdrawal lessens. Given a recharge rate of 18 inches/year, the lateral distance across the ZOC increases from about 40 to more than 80 feet and the length of the ZOC is shortened to about 125 feet. The area of the ZOC remains constant at 10,000 ft^2, balancing the daily mean withdrawal. As before, recharge from rainwater falling inside the ZOC flows into the well. Figure 7

The distance from the well to the upstream origin of incoming flow lengthens as the regional groundwater flow rate increases.

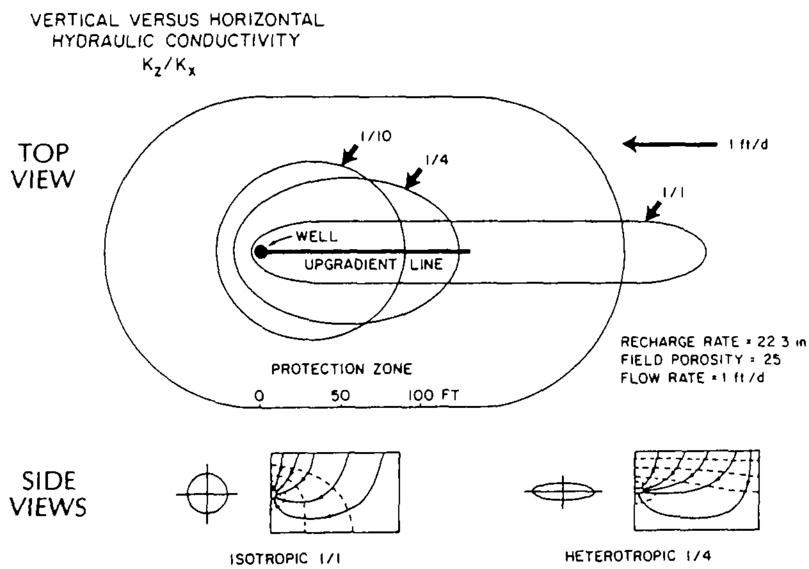

Figure 7 Variation in Anisotropy.

A Simple Procedure For Private Well Protection

Using a short and simple procedure, health agents and engineers can delineate an effective protective zone for typical residential private wells. The procedure is based on the initial determination of groundwater flow direction and velocity, using a water table map and data on the hydraulic conductivity of the regional aquifer and/or direct measurements using a groundwater flow meter (Kerfoot, 1987).

First, the well is sighted. From that point a line is drawn directly upgradient, i.e., the upgradient line. Its length is dependent upon the recharge rate and velocity of the groundwater. If the groundwater flow rate is zero, its length is zero, and there is essentially no upgradient line. Under these conditions, as outlined in Example 1, the ZOC to the residential well is a circular area with a radius of about 53 feet. The Title V guidelines extend beyond this region, out to 100 feet, and provide an effective protection zone. (Figure 8) Where there is regional groundwater flow, there will be a significant upgradient line, which will increase in length with increased flow velocities. Table II can be used as a guide for the relationship between groundwater flow velocity and the length of the upgradient line.

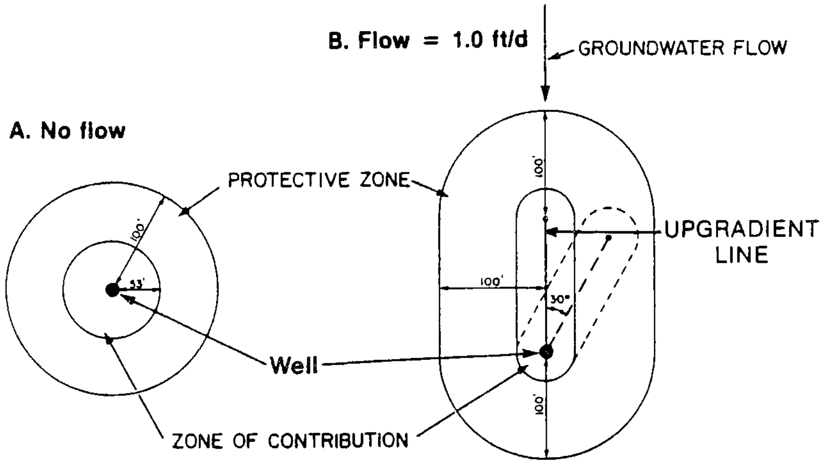

Figure 8 Protective Zones

A. Contrast between the fixed protective distance of the current Title V regulations.

B. The proposed upgradient protective distances.

Table II
The relationship between groundwater flow velocity and the length of the upgradient line.

Groundwater Flow (ft/day)	Length of Upgradient Line (ft)
0	0
.5	65
1.0	125
1.5	190
2.0	250
2.5	315
3.0	375

A three-foot well with a five-foot vertical zone of capture is assumed. A hydraulic conductivity ratio (vertical to horizontal) of 1:4 is assumed. A field porosity of .30 is used for the broad sandy outwash plains. A mean annual recharge of 18 inches is assumed. The upgradient line represents an upgradient extension of the midpoint of the vertical intercepted flow withdrawal by the well screen (Kerfoot, 1988).

An approximation of the length of the upgradient line can be obtained from the following equation:

Length of Focal Line

$$F = \frac{365\ SnV}{R} \sqrt{\frac{2}{a^2+b^2}}$$

Where:

R = Recharge (ft/yr) = 1.5 ft/yr
n = Field porosity = .30
V = Transport Velocity = 1 ft/day
S = Depth of Influence of Screen = 5 ft
a = Vertical Hydraulic Conductivity = 1
b = Horizontal hydraulic conductivity = 4

F = 125 ft

The actual vertical withdrawal zone should be confirmed on site with a small pump test and direct measurement of hydraulic conductivity variation.

As a final step, a 100-foot buffer zone is drawn about the upgradient line and its two end points. For and area where there is no groundwater gradient, the well protection zone would be the same circle as that mandated by Title V, but for areas with more usual hydrogeologic conditions the result of this procedure would be an ellipse-like protective zone as shown in Figure 12B.

The elliptical approach has four advantages:

1) It changes the protective zone into a shape which accounts for the flow dynamics in an aquifer;

2) It is consistent with the concept of the Title V mandated 100-foot protective buffer zone between septic system and well;

3) It provides additional protection against seasonal groundwater fluctuations in the direction of groundwater flow (up to 30-degree directional changes);

4) Its larger size compensates for increased withdrawal rates and enlargement of the ZOC area during summertime periods of low recharge.

Summary And Recommendations

There are no state laws or regulations for private well construction and protection as there are for public water systems. While the Massachusetts Environmental Code (Title V) requires a septic system to be at least 100 feet from a drinking water well, the regulation does not require that a new well be located 100 feet from an existing septic system. Furthermore, Title V does not consider local or regional groundwater flow conditions that may make this distance inadequate to protect the private well from biological and chemical contamination introduced into the groundwater by the homeowner or his near neighbors. Adequate protection can be assured by orientation of septic systems and private wells, on-site and on adjacent home lots, that considers this essential factor. Models for delineating the zone of contribution (ZOC) of groundwater to a private well are presented in this report. They are based on typical hydrogeologic conditions for Cape Cod. Simple procedures are described that will enable health agents and engineers to delineate an effective protective zone for local residential wells.

As knowledge of both the characteristics of groundwater on the Cape and potential health risks from contaminated private wells has increased, it is essential to use this information to adopt better approaches for preventing pollution problems.

In the interest of the public health of all private well users, the following recommendations are made:

1) The adoption of local health regulations which require that well and septic system placement be based on groundwater direction and rate of flow. Health regulations should also include provisions for water quality testing of new wells to determine existing sources of contamination.

2) Development of state regulations more stringent than Title V for private well protection.

3) A county-wide education program to explain the health risks involved in groundwater cross-contamination of wells by septic systems.

4) Development by appropriate state and federal agencies of procedures for identifying private well zones of contribution in varying geological conditions for use by professional civil engineers.

5) Support for more basic studies by the USGS to further define groundwater gradients, flow characteristics, hydraulic properties, recharge rates and chemical dispersion characteristics.

ACKNOWLEDGEMENTS

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