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GROUND WATER MANAGEMENT IN RHODE ISLAND A POLICY ANALYSIS

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GROUND WATER MANAGEMENT

IN RHODE ISLAND

A POLICY ANALYSIS

BY

WM. BRYAN DIXON

A THESIS PROJECT SUBMITTED IN PARTIAL FULFILLMENT

OF THE

REQUIREMENTS OF THE DEGREE

OF

MASTER OF COMMUNITY PLANNING

UNIVERSITY OF RHODE ISLAND

1982

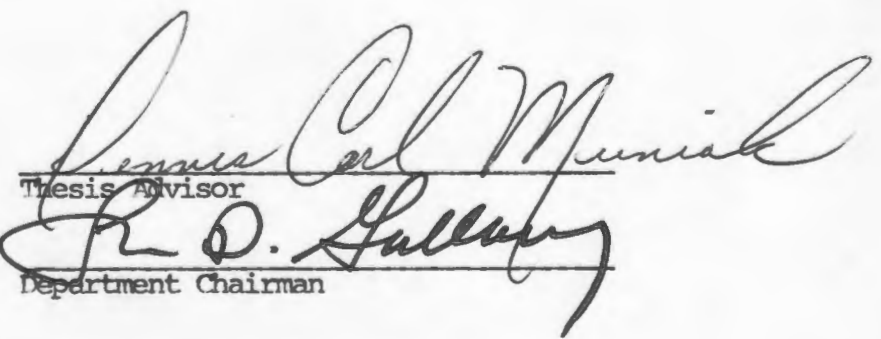
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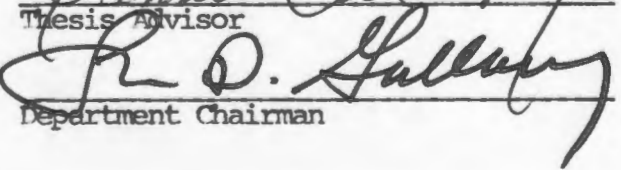
THESIS PROJECT

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1982

ABSTRACT

The ground water in Rhode Island is plentiful and generally high quality. There have been no major conflicts thus far over allocation of ground water, though aquifer yields are limited. There have been instances of pollution from waste disposal practices such as landfills, septic systems, and seepage pits, and some aquifers have been rendered undrinkable because of dense overlying urban development. The real extent of pollution is unknown, as there is no comprehensive ground water quality monitoring program. Quality is monitored only where contamination sources are known and major, or where ground water is currently used for public water supply. There is no regulation of ground water withdrawals (quantity).

Management of the ground water in Rhode Island is incomplete and fragmented among various levels of government, agencies and departments. The federal government has funded ground water research and programs geared to specific pollution problems (such as hazardous waste). At the state level, the Water Resources Board has concentrated on developing major public water supplies and depends primarily on surface water. The Statewide Planning Program has studied instances of ground water pollution and has proposed new legislation to manage the ground water resource, but these proposals have not been adopted by the legislature. The Department of Health limits itself to regulation of public drinking water systems and prefers a narrow interpretation of its responsibilities to protect future supplies. The Department of Environmental Management operates several programs

which protect ground water quality and attempts to adopt a comprehensive perspective but is limited by specific authorizing legislation to specific sources of pollution (such as septic systems and landfills). At the local level, only one town has attempted to zone for aquifer protection. Other towns fear that the courts will not support such regulation based on the existing enabling legislation.

Ground water management requires a comprehensive perspective, however. Sources of contamination are many, and polluted aquifers may never cleanse themselves. Land use decisions made without regard to ground water may effectively eliminate the resource, imposing costs on future generations for expensive treatment plants or limited development opportunities.

Management is possible, but must follow from a knowledge of the resource and available options. To this end, this paper defines the policy and program choices in Rhode Island, and includes some consideration of implementation.

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To these people and others whose work I have relied on, I am indebted for what understanding I have of these issues. The strengths of this thesis reflect their efforts. The weaknesses are my own.

Most importantly, I acknowledge the support and encouragement of my wife, Jean Marie. She has been my financial and emotional foundation throughout these graduate years. I depend on her for my stability and happiness.

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LIST OF ABBREVIATIONS

CWA - Clean Water Act

DEM - Rhode Island Department of Environmental Management

DEP - Connecticut Department of Environmental Protection

DOH - Rhode Island Department of Health

DOT - Rhode Island Department of Transportation

EPA - United States Environmental Protection Agency

FWPCA - Federal Water Pollution Control Act

ISDS - Individual Sewage Disposal System

RCRA - Resource Conservation and Recovery Act

RIPE - Rhode Island Projects for the Environment

SDWA - Safe Drinking Water Act

SPP - Rhode Island Statewide Planning Program

SSAP - Sole Source Aquifer Protection Program

UIC - Underground Injection Control Program

USGS - United States Geological Survey

WRB - Rhode Island Water Resources Board

gpd - gallons per day

mgd - million gallons per day

Chapter 1.

There is as yet no comprehensive ground water policy or management in Rhode Island. In recent years, however, the need for ground water management has become more obvious as aquifers are found to be polluted by waste disposal practices and land uses which did not take ground water into account.

Rhode Island has developed numerous programs to manage other aspects of the environment and to mitigate impacts on natural systems. Some of these programs and policies offer some protection for ground water but none form a comprehensive management scheme.

This investigation attempts to lay the groundwork for ground water management in Rhode Island. Chapter 2 discusses the hydrogeological characteristics of ground water which must be recognized in any successful management scheme. Chapter 3 describes the nature of the ground water resource in Rhode Island and the literature available regarding threats to ground water quality. Chapter 4 examines the existing policies and programs in Rhode Island to determine what protection they offer and where they fall short. Chapter 5 then examines the policy and program choices for policy makers seeking to develop ground water management in Rhode Island, with some suggestions for a workable approach.

The emphasis throughout is on policy. Policy is a commitment toward a stated end utilizing a defined means. Policy requires a clear, unambiguous definition of the ideal sought (goals) and the interim targets which help to attain the ideal (objectives). Policy is also specific about what actions are to be taken to accomplish

the objectives and goals. Different policies may serve different goals with the same programs, or the same goal with different programs. Policy thus serves to link purpose and action. Policy formulation is most critical when conflicts arise between goals and/or programs. Programs without a coherent policy foundation are doomed to be incomplete and inefficient. Moreover, policies without specified goals or without consideration of implementation are also doomed to inefficiency, or worse, they may create larger problems. Ground water management can be rife with conflicting goals and programs. Should we develop the land or preserve the ground water? A road salting program may prevent traffic accidents, but the salt may ruin an aquifer. Ground water management thus requires careful policy formulation.

The emphasis herein is also on Rhode Island. Other states have different geology and hydrology, and public policy institutions not found in Rhode Island.

The conclusion is a discussion of policy choices. A specific recommendation would be worth little until choices are made as to what is needed and how it can be best achieved in Rhode Island. A clarification of the issues should make the choices more obvious, though not necessarily easier. Further work is necessary on parameters which can only be identified here.

Chapter 2. Ground Water: The Issues

Ground water is that water which lies between the soil particles and within the bedrock beneath the earth's surface. It accounts for over 98% of the fresh water available to humans. In the U.S. ground water accounts for 2,000 to 3,000 times as much storage as exists in all of the surface rivers and lakes at any moment (Fetter, 1980). Access to ground water is gained by tapping surface springs or by digging or drilling wells into the earth's surface until ground water is reached, and then lifting or pumping it to the surface. Ground water, however, is part of the larger hydrologic environment. It is stored moisture, ever replenished by precipitation, allowing plant growth during dry periods, and providing a baseflow to wetlands, streams and lakes between rainstorms, which helps to maintain habitats for aquatic and terrestrial species.

Despite the renewable and extensive nature of ground water, the use of ground water and the land above it can have profound effects on the quantity and quality of the resource. Heavy pumping by one user or paving over large areas of the recharge zone (the land above and around ground water aquifers which feeds precipitation to the aquifers) can reduce the resource, precluding its use by others. Landfills, septic systems, heavy road salting, agricultural operations, and other human activities can degrade the quality of ground water for many years.

Because ground water resources are shared by many users, and today's use of the resource and the related land surface can affect users for many years, it is appropriate that governments attempt to conserve, allocate, protect and otherwise manage the resource. Sound

management can help to assure equity among users across space and time. For ground water policy to be relevant and effective, however, it must follow from an understanding of hydrologic principles, knowledge of the resource and potential threats to ground water, and a consideration of policy options for management, including questions of which activities to control and which level of government should be authorized to control them.

General Ground Water Principles

Hydrologic cycle

Ground water is one stage in the hydrologic system (see Figure II-1). That part of precipitation which does not evaporate, run off into surface streams and lakes, or which is not absorbed by plants (evapotranspiration), eventually percolates through the soil and reaches the water table, the surface of the underground, water-saturated zone. Other inputs to ground water include the effluent from individual subsurface disposal systems (ISDSs , or septic systems) and in some cases, injection wells (used for pumping water into the ground for storage, or disposal of wastes), and in some cases by overlying streams (e.g. during floods or heavy pumping of nearby wells).

Ground water flows from higher elevations toward sea level. One can predict the direction of flow by mapping the elevation contours of the water table, much as the land surface is represented on topographic maps. The direction of flow from a given point, then, is toward lower water table elevations - i.e., perpendicular to the equi-elevation contour at that point, and "downhill" (or down-gradient, or down-dip) (see Figure II-2). If the land surface dips

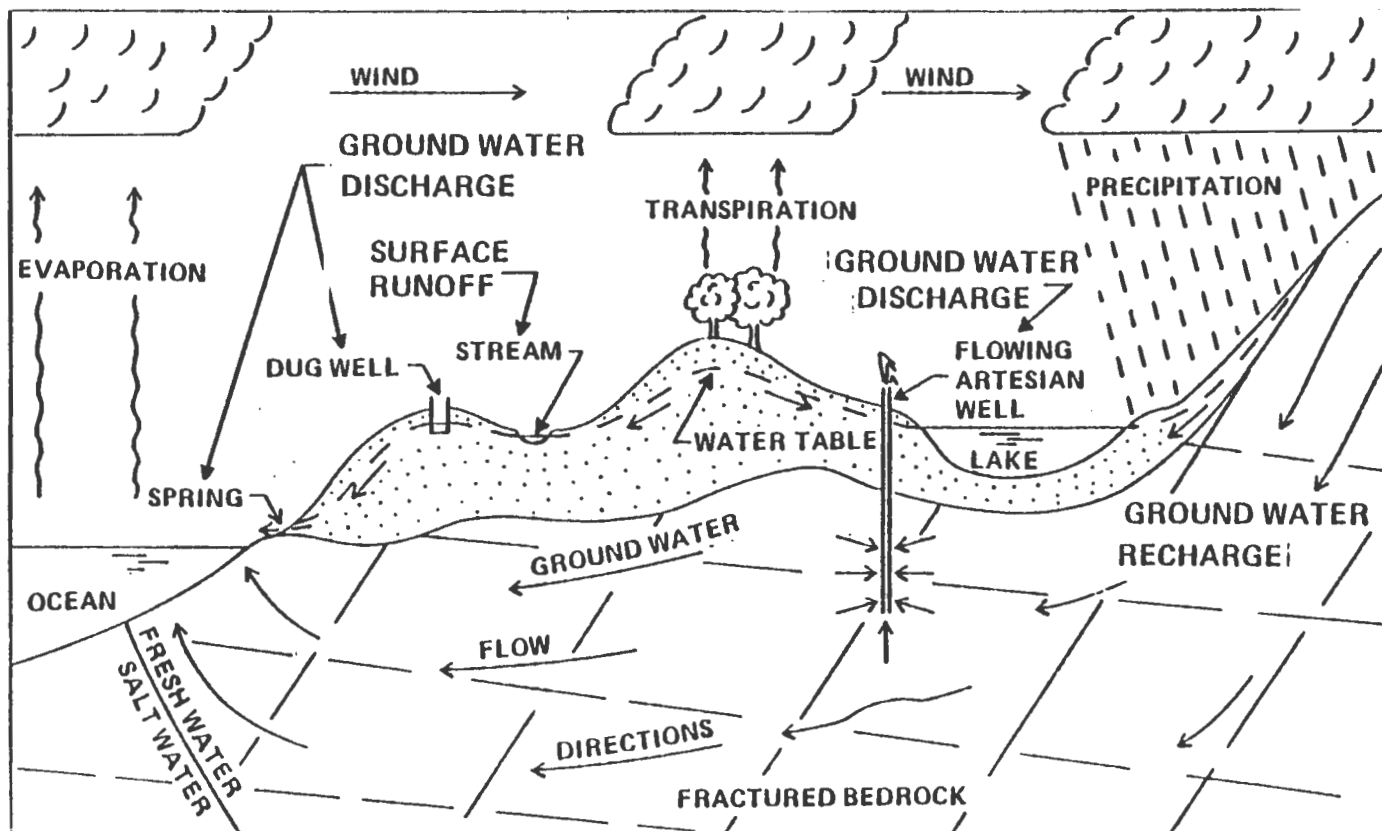


Figure II-1. The hydrologic cycle (from Caswell, 1979, originally from Caswell, 1974).

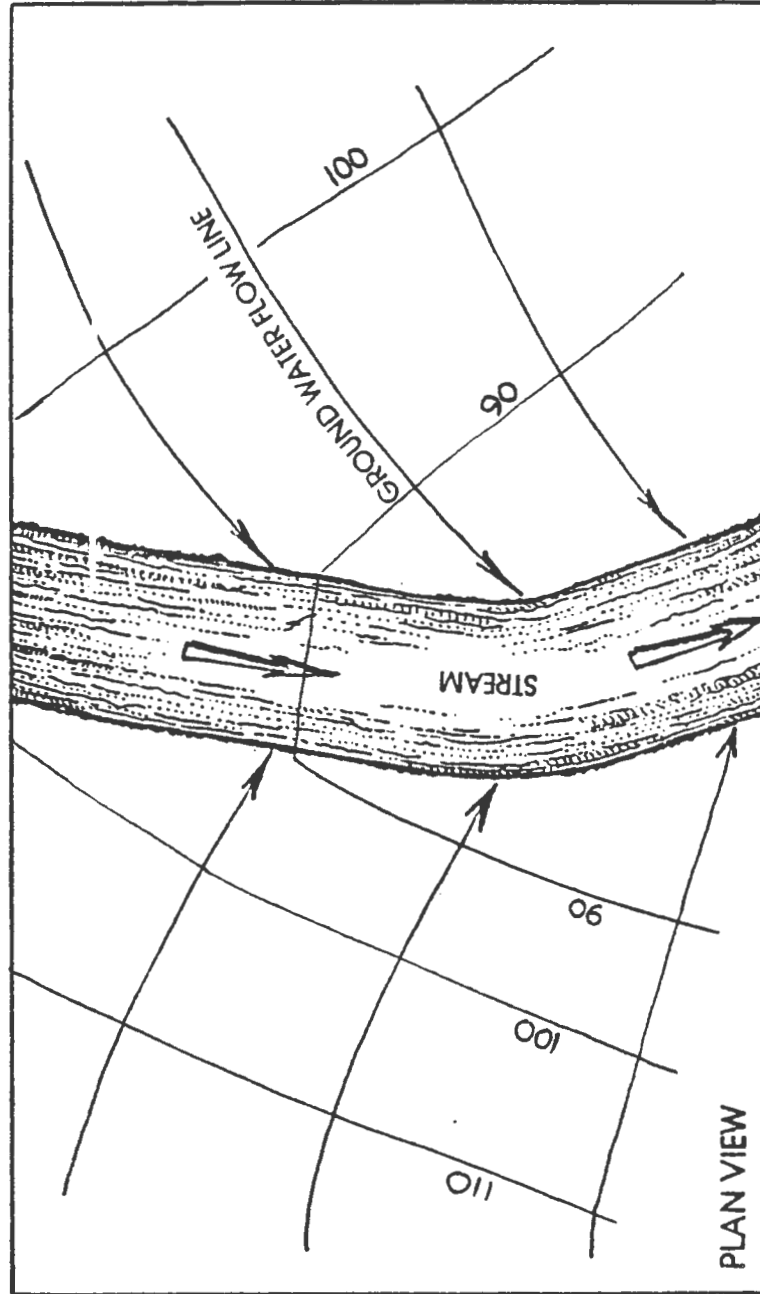


Figure II-2. Flow of ground water perpendicular to equi-elevation contours (from Caswell, 1979).

below the water table, the ground water is expressed as a wetland, spring, stream or lake (see Figure II-2). Ground water which flows into a stream is said to be "discharging" into that stream. The much less common situation in New England is where a stream is higher than the water table, and "recharges" the ground water.

Aquifers and recharge zones

Large bodies of ground water which lie in surficial materials which easily relenquish that water - such as glacial outwash (areas of stratified sands and gravels) - are called "aquifers". Formal definitions usually include both requirements: size and relative ease of withdrawal. If the surficial deposit is not thick, such as where the bedrock is close to the surface and does not itself have large fractures or joints, or if the surficial materials do not readily transmit water, such as when clays and fine particles are mixed in the deposit, the structure would not be labeled an "aquifer". Glacial till is one example of such a material. Till is unstratified sands, silts, clays, gravels, and boulders which may hold large quantities of water, but which does not allow rapid underground flow, and hence, a well in till will not yield quantities of water for more than a few households. Not even all areas of outwash are aquifers, as often the outwash is only a few feet thick and would not yield large quantities of water to wells. Geologic formations which are relatively impermeable are labeled "aquicludes", e.g. dense unfractured granite, clay strata, or fragipan. (Fragipan is dense basal till thought to have resulted from the pressure of overlying glaciers. Fragipan is so compact it is virtually impermeable, and is often found only several feet below the surface.)

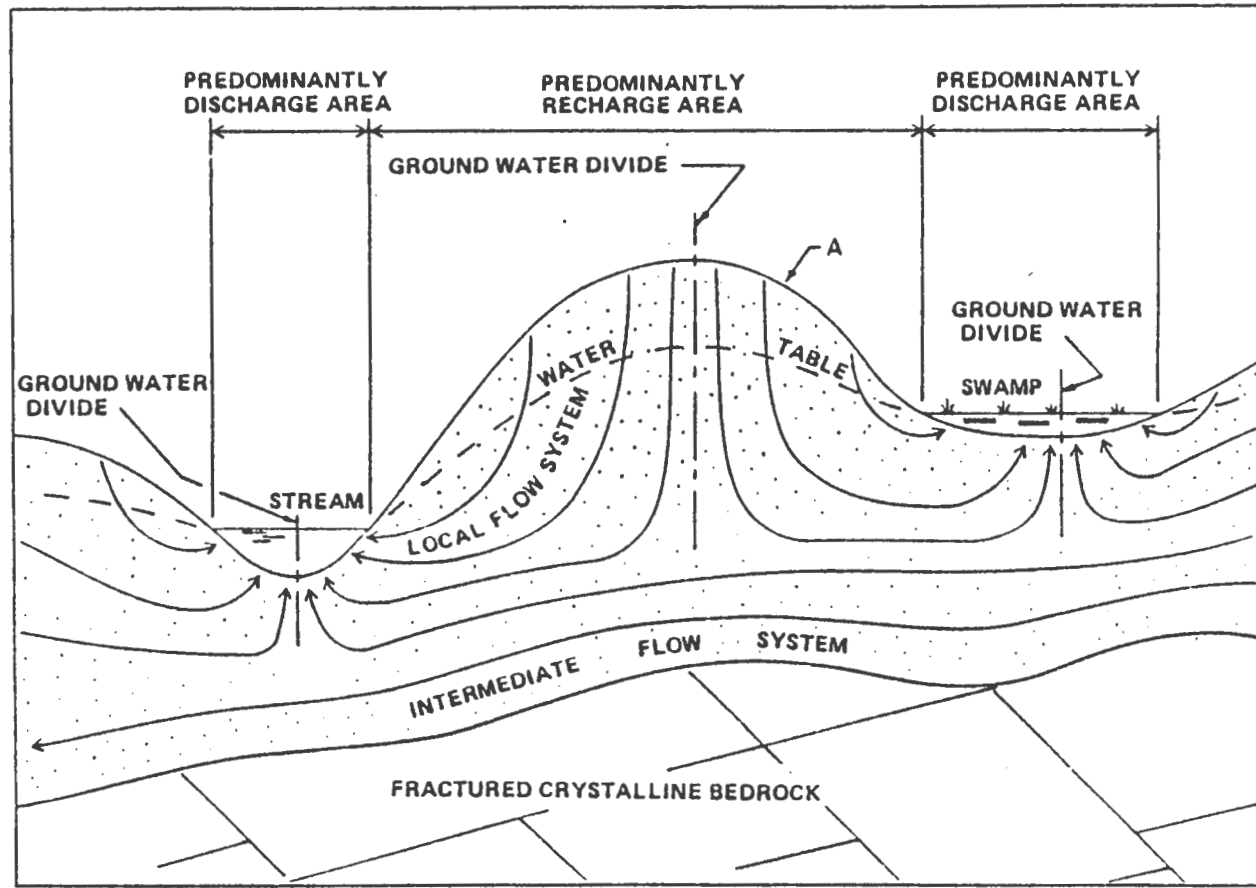


Figure II-3. Relationship of water table to surface water (from Caswell, 1979, originally from Caswell, 1974).

An example of an aquifer is the deposit in the town of Richmond underlying the Wood River (see Figure II-4). The river flows southward between two bedrock ridges which are covered by a thin layer of till. The valley, however, is filled with up to 100 feet of very permeable sands and gravels (glacial outwash or stratified drift) deposited by rivers draining the melting glaciers. The outwash is thick and saturated with ground water and could provide water in quantities suitable for public water source. The saturated outwash there qualifies as an aquifer.

A distinction is sometimes made between an aquifer and an underground reservoir:

"Aquifer: A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells or springs."

"Ground-water reservoir: Parts of the stratified-drift aquifer where water is accumulated under conditions that make it suitable for development and use."

(Dickerman and Johnston, 1977, p-8)

While an aquifer is rarely defined in exact terms, a ground water reservoir can be, e.g., as an:

"Area underlain by stratified glacial drift with a transmissivity greater than 4000 ft^2 and a saturated thickness of more than 40 ft^2 ." (WRB, 1980)

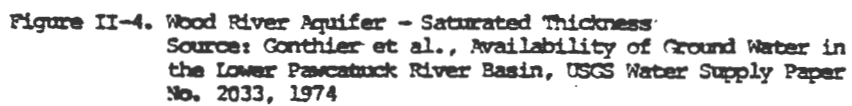


Figure II-4. Wood River Aquifer - Saturated Thickness

Source: Gonthier et al., Availability of Ground Water in the Lower Pawcatuck River Basin, USGS Water Supply Paper No. 2033, 1974

(Transmissivity is a property related to permeability - the greater the transmissivity, the more readily can water be extracted.)

The area directly above and adjacent to the aquifer is called the recharge zone. This area may not contain large amounts of ground water itself, but precipitation falling on it flows down to the water table or underlying impermeable surface, and then laterally to join the deep deposits which make up the aquifer proper, thus recharging the aquifer. (See Figure II-1.)

A distinction is sometimes made between primary and secondary recharge areas, however, the distinction is made differently by different authors. Often, the area directly above the "aquifer" is referred to as the primary recharge zone, since water percolates more or less vertically to reach the aquifer. The aquifer is most sensitive to contamination in this primary recharge zone because pollutants travel the least distance to reach the aquifer and so minimal adsorption (molecular attraction) of pollutants by soil particles can occur. The secondary recharge zone is some area around the primary zone. where water must travel down and then laterally to reach the aquifer. Contamination of this area is not as critical since more opportunity for adsorption of pollution is possible, and some dilution may take place before reaching the aquifer. The areal extent of the "secondary" recharge zone may be the ground water divide between aquifers (in which case all land would be in either primary or secondary recharge zones), or more narrowly, the land within some distance of the primary recharge area. (One useful possibility might be to define the secondary recharge area as the extent of outwash materials surrounding the principle recharge area, leaving

till and less permeable surficial materials out of the recharge area.) In reality, however, such distinctions should be considered somewhat arbitrary, as some pollutants can travel far and water from patches of upland till may be induced into wells, even beneath streams.

Ground water is not a mysterious forever unseen underground entity. It plays an important role regarding surface water. In the case of the Beaver River, the stream level is the expression of the height of the ground water. The discharge of the aquifer is to the stream and the increase in streamflow between where it enters the aquifer and where it leaves it approximates the yield of the aquifer, which varies with season and year depending primarily on the precipitation.

The hydrologic cycle is completed as the ground water evaporates, through vegetation or after discharge into the surface water bodies, and becomes atmospheric water, which falls again as precipitation.

Threats to ground water resources

Aquifers, therefore, can provide large quantities of water, for residential, agricultural or industrial use. The advantages of the ground water resource are that ground water is usually naturally free of contamination (except that dissolved iron, calcium and magnesium may make the water hard, which may foul plumbing or discolor sinks). In addition, the land above an aquifer and recharge area may safely sustain some development, unlike surface water reservoirs, which flood the land rendering it useful only as a water supply, and perhaps for recreation.

Ground water can be overused, however. Ground water mining (pumping more from the aquifer than is recharged by precipitation) leads to a lower water table. This not only renders existing nearby shallow wells useless, and "dries down" streams, killing fish and aquatic life. It may also lead to land subsidence which destroys an aquifer's storage capacity by collapsing the subsurface pores. Overpumping near salt water bodies may cause displacement of fresh ground water by saline water (salt water intrusion). Eventually, this salt water could reach the well and render it unpotable for years, until natural fresh water percolation in the absence of pumping displaced the new saline boundary.

Pollution of ground water is a much more intractable problem than pollution of surface water. Unlike rivers, ground water moves very slowly - sometimes only a few feet each year. Its large yields result from the volume of storage and large areas of recharge. This means that once an aquifer is polluted, it may be years before the contaminant is discovered in down-gradient wells. By that time, the plume of contamination may be measurable in square miles. A contaminated aquifer will probably not flush itself for decades. Residual pollutants adhering to soil particles may mean that some trace of the contaminant will persist for much longer. Many contaminants such as nitrates can be eventually diluted to safe levels, but carcinogens such as benzene are toxic at such low concentrations that a few spilled gallons could ruin square miles of an aquifer.

Sources of Ground Water Contamination

There are many potential sources of ground water contamination,

some have occurred in Rhode Island, others have not yet occurred. It is beyond the scope of this work to present in depth the various facets of ground water pollution. Yet, in order to understand policy requirements, some knowledge of potential problems is necessary. Hence, a brief outline of potential threats follows. Some sources have been omitted because Rhode Island geology makes them unlikely - such as contamination of aquifers by underlying polluted confined aquifers which were tapped by now abandoned wells. Confined aquifers are uncommon in Rhode Island.

The extent of the literature on ground water pollution is exemplified by a recent computer search of the articles included in Water Resources Abstracts dealing with both ground water and pollution, which yielded over 2200 citations since 1968. References for this section will not be specific, as many texts on ground water discuss the general nature of ground water contamination. Especially useful references include Todd (1981) and EPA (1976). It is important to remember that ground water is not only important in large quantities. Wells yielding household quantities can be constructed nearly anywhere in Rhode Island (Lang, 1961). Less than 10% of Rhode Island's population depends on private individual wells, but this accounts for over 70% of the land area in the state (Kumekawa, et al., 1979) - an area which would be costly to supply with public water. In some towns, all of the residents now rely on individual wells.

Sources of ground water pollution can be conceptually organized by where they originate (adapted from EPA, 1976):

- A. Contamination originating on the land's surface
 - 1. infiltration of polluted surface water into ground water (induced or natural)
 - 2. land disposal of wastes
 - 3. stockpiles
 - 4. holding ponds, lagoons
 - 5. road salt (storage and application)
 - 6. agricultural operations (e.g., pesticides)
 - 7. accidental spills
- B. Contamination originating below ground
 - 1. septic systems
 - 2. waste disposal in excavations
 - 3. underground storage, pipelines, sewer lines
 - 4. induced recharge, salt water intrusion
 - 5. sumps, dry wells, injected waste
 - 6. water supply wells - improper construction

An additional consideration is that not all pollutants have the same effect on ground water quality. Some, such as phosphates, magnesium, calcium and potassium are adsorbed by the soil and do not leach readily. Others, such as sodium, sulfate, chloride, and nitrates do leach and may travel great distances (Hill, 1972).

Contamination Originating on the Land's Surface

Infiltration of surface water

Situations where surface water recharges ground water are rare in Rhode Island. The surface water is usually supplied by discharge from ground water and reflects the water table. Indeed, surface

streams usually act as gutters, draining the ground water from the soil. However, there may be instances where a stream crosses an aquifer such that the level of the stream is higher than the local water table. This situation would be more likely in drought years when some aquifers may be lowered faster than their upstream counterparts. Large capacity pumps placed close to streams may lower the water table nearby below the stream level. In these cases, a polluted stream could infiltrate the soil and degrade the ground water.

Land disposal of wastes

Probably the most publicized source of ground water pollution is the dump or landfill. In the past, municipal dumps were frequently placed in any low spot easily purchased. Sanitary landfills were an improvement with respect to odor and vermin reduction since each day's deposits were covered with clean fill. Rainwater was still able to infiltrate the deposits, however, causing the leaching of heavy metals, nitrates, solvents, pesticides, cleaners and other pollutants. Often, these materials were liquid to begin with and therefore required little additional water to leach. The worst situations are the deposits of hazardous materials from industrial sources which have been deposited in thousands of dumps and landfills across the country. A House Subcommittee identified over 250 hazardous dumps across the country which posed a "great potential threat to drinking water supplies" (NYT, 9/28/80). The problem is compounded by the unknown location of many abandoned dumps.

Recent improvements in landfill technology include siting the landfill over impermeable materials such as clays, or constructing

artificial bottom liners of plastic or concrete and collecting the leachate for treatment, preventing its percolation into the ground water. Final covering with an impermeable cap prevents rainwater from creating leachate.

Other land disposal problems include leachates which form from sewage, septage, or treatment plant sludges which are spread on the land surface for disposal. If composted first, some nitrates can be removed. However, heavy metals in sewage sludge from industrial areas may still leach into the ground water.

Stockpiles

The most pervasive stockpile problem is the storage of road salt, used to de-ice highways in winter. Precipitation dissolves the exposed salt and it may then infiltrate into the ground water. Recent changes in storage practices have led to covering salt piles with impermeable domes. (This is also an economic advantage since it prevents loss of salt to dissolution.) The primary problem with salt leachates is the increase in sodium levels in ground water which can aggravate certain circulatory problems in humans (such as hypertension) which makes high sodium levels in drinking water an important consideration (Hang and Salvo, 1980). High saline runoff can also damage plant life.

Holding ponds and lagoons

In some areas, an industrial firm has put waste materials into ponds or lagoons to allow solids to settle out or liquids to evaporate. Since these are often unlined depressions, the waste materials will also seep through the soil to the ground water. Even

if the lagoon is located in clays (which are rare in Rhode Island), the chemicals may alter the structure of the soils and leach into the ground water. Plastic, concrete and asphalt liners may crack or be altered by the chemicals. The impact can be very large since the chemicals are often concentrated. Clean-up may require removal of vast quantities of contaminated water and soil.

Salt application on roads and parking lots

Just as dissolution of salt at uncovered salt piles can pollute ground water, so too does the applied salt. While some runs off to surface streams, some undoubtedly reaches ground water. Heavy doses on major roads crossing aquifers could pose problems if wells were located nearby.

Agricultural operations

Farming poses two potential problems for ground water. Fertilizers used on crops and turf and high densities of farm animals can lead to locally high nitrate levels in ground water. Nitrates in significant concentrations in drinking water cause high nitrite levels in warm-blooded animals. Nitrites interfere with the ability of hemoglobin to transport oxygen. Infants and fetuses are especially sensitive and react with a condition known as methemoglobinemia, or "blue-baby". It has been argued that a greater nitrate danger to individual private wells exists from the excessive application of lawn fertilizer by the homeowner. Either the farmer or the homeowner, however, can miscalculate or intentionally overdose the plants, resulting in excess nitrates leaching into the ground water.

The major problem associated with agriculture is the leaching

of pesticides into ground water. This has posed a major problem on Long Island with the heavy use of Temik on potato crops (Hang and Salvo, 1980, p.II-32).

Accidental spills

Even if all pollution sources were removed from sensitive lands, some threat would exist where major roads or railroads cross aquifers. In an accident, a tank car, plane or truck could rupture, leaking large volumes of contaminants. Ironically, accidents may be more frequent in bad weather - just when immediate clean-up is more difficult. Toxic substances which were not immediately contained could irreparably harm sensitive aquifers. Radioactive substances are especially dangerous because of half lives which might be thousands of years.

Contamination Originating Below Ground

Septic Systems

Individual subsurface disposal systems (ISDS, or septic systems) and cesspools have mixed value. On the one hand, they provide a source of recharge to ground water. A household will thereby replenish the water it removed via a well. If a large area is served by a public water system from another aquifer, but relies on ISDS, an aquifer may receive a positive net recharge.

The problem with cesspools and ISDSs is that certain pollutants are not neutralized. If the system is well designed, the soil will remove nearly all bacteria, viruses, phosphates, magnesium, calcium and potassium within a few inches. Other substances, such as nitrates, sodium, chlorides, and sulfate are not readily adsorbed or broken down, and can enter the ground water, only to be withdrawn in a well.

In recent years, problems have begun to emerge from disposal of household toxics and the use by homeowners of ISDS degreasing agents. The problem is compounded when the ISDS is close to the household well or when the ground is underlain by shallow rock and the well is ~~down gradient from~~ the leach field.

Waste disposal in excavations

Following the extraction of minerals, sand or gravel, an open pit may be left exposed. These pits were often the site of municipal dumps, or became receptacles for a variety of wastes from hazardous materials to snow removed from roads and streets (often containing large amounts of road salt). Since the site of the sand and gravel operations may be extensive and may in fact be part of an aquifer system, the potential for ground water pollution is great.

Underground storage and pipelines

Underground storage tanks (e.g. gasoline) may corrode over the years and leak a steady flow of contaminants directly to the ground water. Sewer lines are often built of short sections of pipe and these may be separated by freezing ground, releasing raw sewage. These underground leaks may go undetected for years, and in the case of pipelines, may be so expensive to find and repair that the owner makes little effort to stem the leak. Leaks in underground gasoline storage tanks may also occur in residential installations.

Induced recharge

An operating well will cause a local lowering of the water table, a cone of depression. It will also alter the local natural flow patterns of ground water. If located near a stream, the stream

may be induced to recharge the ground water removed by the well. If the stream is polluted, the ground water will then be degraded. If located near salt water, the zone separating salt from fresh water may move inland toward the well causing it or intermediate wells to pump salt water. Pumping must then be reduced perhaps entirely - until natural fresh water recharge can displace the salt water.

Sumps, dry wells, injected waste

Sumps and dry wells used to collect runoff or dispose of liquid waste are obvious direct sources of ground water pollution. While in some areas of the country, deep wells are drilled to allow injection of waste into subsurface spaces the geology of Rhode Island is such that anything injected into the ground will probably appear in the ground water.

Improperly constructed wells

Dug wells are usually large diameter (three feet) and uncased. These holes in the ground can channel polluted runoff directly into the ground water. The principle cure is to regulate well drillers and apply construction standards to ensure that the well is sealed from surface infiltration which might degrade the water below.

The next chapter reviews the literature on ground water contamination problems in Rhode Island, though this literature is incomplete and needs updating in many cases. Some known problems are being monitored, others are unknown and await detection. Policy must at least address the known problems, but should also consider the potential ones presented above.

Chapter 3. Ground Water Resources in Rhode Island

Any analysis of policy needs for ground water management must consider the nature of the resources to be managed. The purpose of this chapter is to describe in general terms the nature of the Rhode Island ground water resources, their current use, and existing threats to their quality.

Nature of the Ground Water Resource

The location and extent of Rhode Island ground water is determined largely by the surficial deposits left by the receding glaciers. Where the ice melted it deposited boulders, gravel, sand, silt and clay. Left undisturbed by other major forces this deposition became glacial till, which covers nearly all of the bedrock in Rhode Island. The rivers and streams resulting from the melting ice then redeposited glacial rubble in the pre-glacial valleys, in stratified deposits called "outwash".

Till and outwash have very different water-bearing properties. Till, made up of an unstratified, unsorted conglomeration of materials of varying textures, is usually not very thick (generally about twenty feet, Lang (1961)). Though porous, till does not readily yield water because the pores are small (surface tension thus holds a greater percentage of the water) and not well interconnected (Fetter, 1980, Lang, 1961).

Glacial outwash, however, may be much thicker (in the valleys often over 100 feet) and consists of stratified layers of "uniform" materials. During the deposition period, the finer particles were washed out to sea, and the remaining deposits are primarily sands and gravels, with an occasional thin layer of silt. Sands and gravels tend

to have large interconnected pores and hence yield large volumes to wells. Although a well in till usually will yield enough water to supply a household, outwash deposits are necessary for volumes required by public water supply.

Investigations of ground water in Rhode Island began at least as early as 1904 and a list of ground water publications has been compiled by the USGS (1977). Beginning in 1945 the USGS published water resources studies in cooperation with various Rhode Island "development" agencies in an attempt to define the ground water resources of the state for public and industrial use.

Following a series of "bulletins" and maps of geology and hydrology published by the USGS, WRB and others, Lang (1961) reported on the ground water reservoir areas in the state to determine "(1) the size of the ground water reservoir, (2) the quantity of water for replenishing the reservoir, (3) the present development of the water resources in the area, and (4) the possible conflict between established water uses and possible future large scale ground-water withdrawals". Lang recommended several of the areas for further study. Subsequent studies to define the potential sources of public ground water supply were geographically focused on southern Rhode Island: the Pawcatuck River basin, and the Potowomut-Wickford area (Allen et al. 1966, Rosenshein et al., 1968, Gonthier et al., 1974). Before retiring, Allen wrote a report assessing twenty-one ground water reservoir areas in Rhode Island in terms of their potential for public supply. The text remains unpublished, but maps of the twenty-one areas were printed. These maps identify stratified drift (outwash) aquifers, the water-rich reservoir areas within them and the "secondary recharge areas" (WRB, 1980). Also identified were sources of contamination (e.g. landfills, salt piles) and existing and potential

pumping centers (groups of interrelated wells) and the safe yield of each (that maximum yield which preserves streamflow and wetlands even during the dry periods). These maps show the current and (one estimate of) potential use of the ground water resource, and its spatial relation to surface water of various qualities.

The summary map is reproduced in Figure III-1. A list of the aquifers is reproduced in Table III-1 along with the yields of existing and potential centers. Estimates of potential yields were not made for aquifers in the northern part of Rhode Island either because areas are adequately served by surface water, or because the potential for pollution is too great. For example, the Blackstone aquifer could yield very large quantities, but this would mean inducing recharge from the Blackstone River where the water is not drinking quality. The aquifer underlying Providence, Cranston, and Warwick would also yield large quantities, but because of the intense urban development, the potential for pollution is unacceptably high (Calise, 1982).

Ground Water Use in Rhode Island

As of 1977, there were more than 500 public water supply systems (Hagopian, 1982) supplying an average of 114 million gallons per day (mgd) to more than 90% of the residents of Rhode Island (Kumekawa et al., 1979). In 1970, ground water accounted for over 24% of the water from public supplies (Allen, 1978). Some towns rely entirely on ground water for water supply, public or private.

In 1979, the US Army Corps of Engineers published a study conducted by Metcalf and Eddy (1979) ~~to assess the future needs~~ for domestic and industrial water in Rhode Island and surrounding Massachusetts communities in the Narragansett Bay basin and to develop structural and non-structural alternatives for supply. In the course of

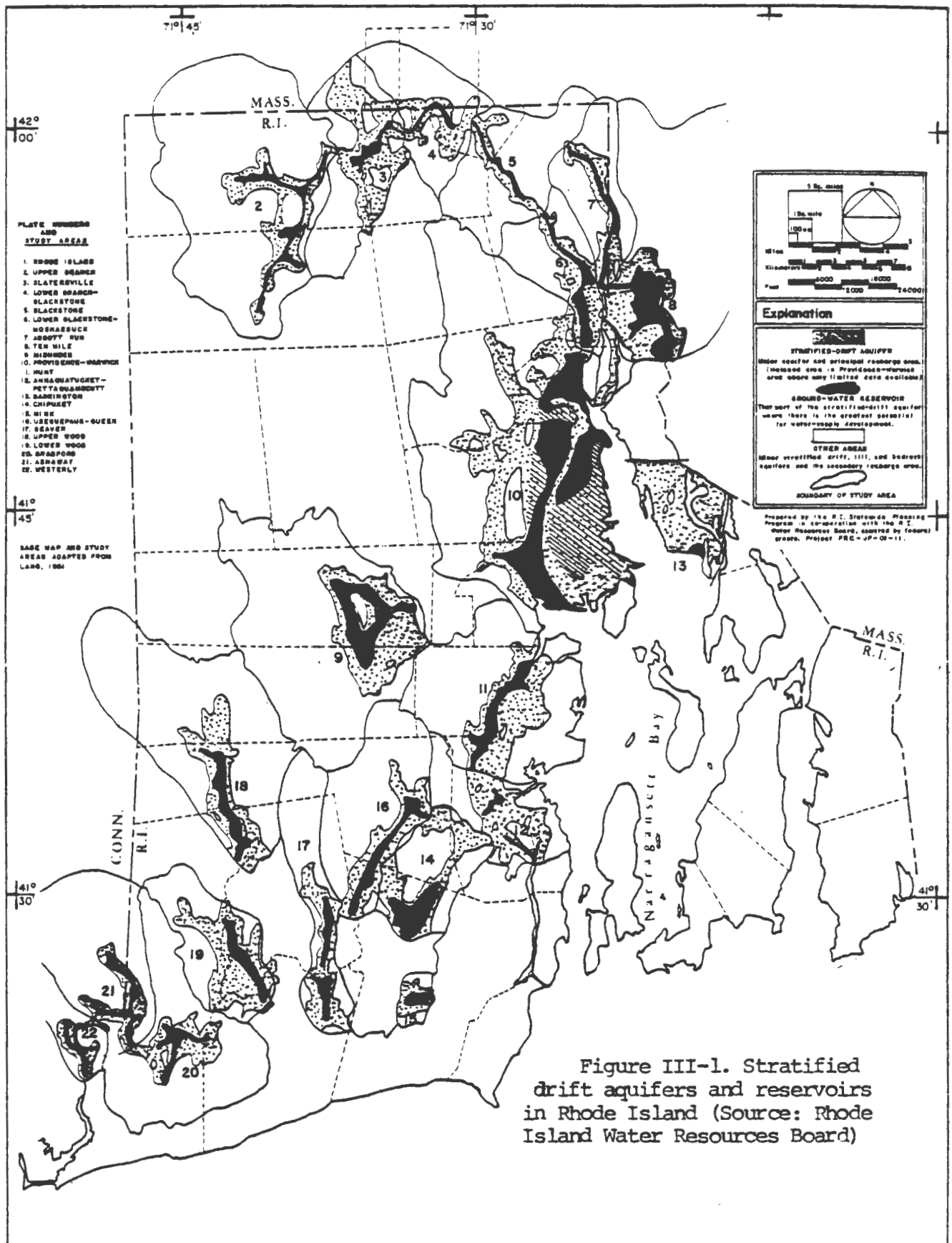


Table III-1. Reservoir areas and yields of pumping centers in Rhode Island

Aquifer area	Reservoir number	Yield to existing centers (mgd)	Number of existing centers	Additional potential yield to one or more centers	
				WRB/SPP (mgd)	SPP (1981) (mgd)
Upper Branch	2	0.33	2		
Slatersville	3	0.29	2		
Lower Branch-					
Blackstone	4	0.5	1		
Blackstone	5	1.6	2		
Lower Blackstone-					
Moshassuck	6	4.53	10		
Abbott Run	7	4.9	12		
Ten Mile	8	2.4	3		
Mishnock	9	2.25	3		
Providence-					
Warwick	10	4.1	4		
Hunt	11	2.01	4		
Annaquatucket-					
Pettaquamscutt	12	2.00	3		3.3
Barrington	13	1.00	1		
Chipuxet	14	1.25	2	1.75	
Mink	15	1.7	3		
Usquepaug-Queen	16	0.16	2	2.00	4.0
Beaver	17	0.36	1	3.00	
Upper Wood	18	0	0		6.0
Lower Wood	19	0.26	2	5.9	6.0
Bradford	20	0.15	1		2.45
Ashaway	21				
Westerly	22	2.4	3		
TOTALS		32.19		12.65	26.50

Source: Water Resources Board (1978)

the study, Metcalf and Eddy concluded that:

- 1) per capita water consumption in 1975 ranged between 35 and 168 gallons per day (gpd) in various communities (this shows the invalidity of per capita projections);
- 2) based on past and projected estimates demand for public water supply for present and future is:

1975	222 mgd
1995	314 mgd
2020	420 mgd

private water supply demand is expected to decrease from 47 mgd in 1975 to 38 mgd in 2020, primarily because of greater reliance on public water supply systems;

- 3) no additional major industrial demand is expected to upset the residential: commercial: industrial demand ratios;
- 4) by the year 2020, without new systems, demand will surpass supply in 94% of the communities studied;
- 5) sufficient water resources are available, but inter-community transfers will be necessary;
- 6) conservation efforts could reduce demand substantially, but new supplies would still be needed;
- 7) ground water is preferable to surface water, environmentally and economically.

General recommendations included:

- 1) active conservation efforts to reduce demand;
- 2) residential: commercial use be limited to 1.5:1.0 ratio;

- 3) plumbing codes be changed to require flow restrictors in new construction;
- 4) retrofit programs be instituted to reduce leakage and use;
- 5) water pricing be restructured to discourage high use;
- 6) well fields be sited for minimum damage to surface water or vegetation;
- 7) adoption of waste water disposal practices which will recharge aquifers; and
- 8) including reduced streamflows resulting from nearby ground water pumping in consideration for waste loads and flows in streams.

The study recommended development of ground water resources because, although pumping capacity was 45.5 mgd in 1975, the sustained safe yield of Rhode Island aquifers is 138.4 mgd. (No satisfactory explanation was offered however, on how safe yields were calculated.) These estimates of safe yields and proposals for further ground water development were site specific and excluded aquifers in major urban areas; near known salt storage problems; or near highways. The study assumed that water would be transferred between communities in cases where towns had no local aquifers. Areas of known or suspected nitrate, chloride, or chemical contamination were avoided.

The study developed several alternatives emphasizing surface or ground water, and/or conservation efforts. The recommended alternative was the "least cost plan". This plan emphasized conservation efforts, one new surface reservoir (Big River) and new wells were proposed to meet new demand and replace small surface reservoirs which would probably require expensive treatment to meet new criteria

in the future. New surface water reservoirs were de-emphasized because by flooding the land they take it out of otherwise productive use. Ground water requires only the 400' radius around the well. In passing, there was some recognition that ground water recharge areas would need protection, but it received no substantial attention. Table III-2 shows those towns in Rhode Island where future ground water development was recommended for two alternatives; the latter was preferred for economic reasons. Estimates of costs are annualized (at $6\frac{5}{8}\%$) and include capital improvements, operation and maintenance costs, and electric power. These estimates include treatment and transmission costs but not the cost (or benefits) of the conservation efforts or of opportunity costs when aquifer recharge areas are removed from dense urban development.

Table III-1 cannot be compared directly with Table III-2. The former lists ground water sources by aquifer, the latter by town. Table III-1 includes an estimate of potential yield of 26.50 mgd from "South County" (SPP, 1981). The estimates in Table III-2 for Washington County alone sum to 9.5 mgd for Alternative 5. Alternative 3, however, relied more heavily on ground water and proposed that yields be developed of 22.75 mgd in Washington County. There is thus good agreement on the possible yields (not surprising since the same WRB-USGS data is used), the discrepancies arise when specific well proposals are formulated.

The result, however, is a recent estimate of the extent to which ground water may be needed for public water supply. Although the Metcalf and Eddy study seems "long range", the year 2020 is less than 40 years away. Since ground water is flushed very slowly, consideration of 40 years is minimal, and not extreme at all. Hence, ground water yields should probably be treated on the basis of "potential"

Table III-2. Yield of proposed well fields through 2020
(million gallons per day)

City/Town	"Alternative 3" ¹	"Alternative 5" ¹
Burrillville	4.25	2.25
North Smithfield	3.0	2.0
Lincoln	1.5	
Glocester	1.0 (Foster) ²	
Cumberland	4.5 (Attleboro)	1.5 (North Attleboro)
	5.5	2.0
Pawtucket	3.0	
Warwick	12.0 (Providence)	3.0 (West Warwick)
West Warwick		
Coventry	3.0 (Providence)	3.0 (Providence)
West Greenwich	2.0 (Providence)	2.0 (Providence)
East Greenwich	4.0	4.0
Exeter	4.0 (Newport-Jamestown)	0.75
	1.5 (North Kingstown)	
	1.0	
North Kingstown	7.0 (part to Narragansett)	5.5
South Kingstown	2.25 (part to Narragansett)	0.25
	3.0 (Newport-Jamestown)	
Richmond	1.0	0.75
Charlestown	1.0	0.75
Hopkinton	2.0	1.5
Tiverton		1.0
		2.5 (Fall River)
Plus Big River Reservoir (surface water)	26.0	26.0
Flat River	13.0	
TOTAL	109.5	58.85
Annualized costs (millions)	\$5.55	\$2.34

¹ The fundamental difference between the alternatives is that Alternative 5 includes reduced demand from conservation efforts, and is not constrained by intermunicipal transfers.

² Communities in parenthesis would receive water exported from community at left. "Providence" is the Providence Water Supply Board.

Source: Metcalf and Eddy, 1979.

rather than "proposed", and aquifer protection should be geared accordingly.

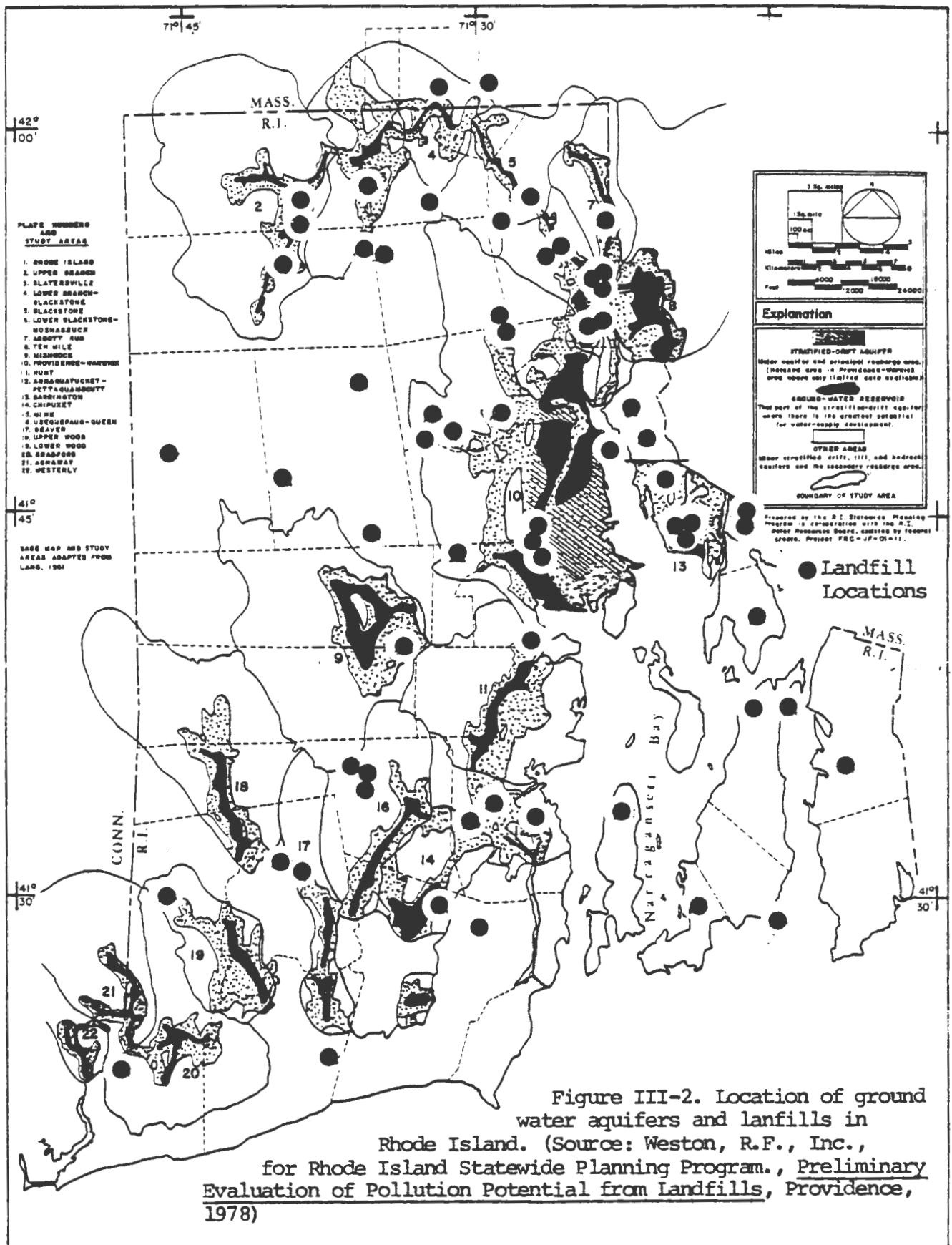
Threats to Ground Water Quality in Rhode Island

Although there are a number of potential threats to ground water quality, only a few have received any systematic study in Rhode Island. Most of these studies were performed for the 208 Water Quality Management Plan for Rhode Island, and they addressed, in some detail, impacts on ground water quality from landfills, ISDS, road salt, and surface impoundments.

Landfills

A number of landfills across the U.S. have resulted in severe, irreparable contamination and subsequent **abandonment** of public water supplies. Fortunately, the landfills in Rhode Island are generally not up-gradient of public water supply well fields. A preliminary evaluation of landfills (SPP, 1978b) found 16 landfills which were in the ground water, 11 which were near ground water reservoirs and 42 which had indirect effects on ground water reservoirs. Of these, at least two sites held hazardous wastes. A number of sites were then chosen for more detailed study of the ground water impacts. Figure II-2 (from Figure 1, SPP, 1978b) shows the location of the chosen landfills as darkened triangles, with respect to ground water areas identified by the WRB (1978) (circled numbers refer to the landfill numbering in the report).

These landfills were then examined to determine the direction of ground water flow and their relationship to surface water (Weston, 1978a). Monitoring wells were drilled, and chemical samples and/or electrical resistivity measures were taken to establish the nature and location of the leachate plumes. Problems were encountered in gaining access to the privately-owned sites and only one round of chemical



analysis was made. (In some cases, DEM has made subsequent analyses.) Although leachate plumes from the landfills were found, the conclusion was that none of the landfills studied posed a major threat to drinking water supplies. In some cases, (e.g. Sanitary Landfill in Cranston) the leachate plume probably discharged into a major surface water stream or river, which diluted the leachate. In other cases the site was well above the water table. A typical data summary for one landfill is reproduced in Table III-3. Note that there was limited testing for organic chemicals or pesticides. Later DEM analyses at some sites, e.g. the Sanitary Landfill site, did reveal significant levels of various organics.

DEM defines existing landfills as "sensitive" if they lie within the recharge areas of aquifers identified in the SPP 208 map, "Water Related Sensitive Areas" (SPP, 1979, Stevenson, 1982). The "sensitive" landfills include municipal landfills in Burrillville, Glocester, Pawtucket, and North Kingstown, and several private landfills including J. M. Mills (Cumberland), Sanitary Landfill, Inc. (Cranston), and Landfill and Resource Recovery, Inc. (Burrillville). None of these has been proven to be up-gradient of a public water supply well, but there is a possibility that the J. M. Mills site is close enough to a Cumberland well to have been responsible for its closure (Stevenson, 1982). These sensitive landfills may be closed if pending legislation passes the state legislature (see next chapter).

Several instances of well contamination have occurred from accidental spills. One example was the closing of both public and private wells in North Smithfield. The contaminant was found to

Table III-3. Water quality analyses from ground and surface water around a closed landfill in North Kingstown. (Source: Weston, Inc., Detailed Analysis of Landfill Impacts, for Statewide Planning Program, Providence, July, 1978)

Parameter*	Downgradient				Upgradient	
	NK-1	NK-2		NK-4		NK-3
Date	1/12/78	1/12/78	4/12/78	1/12/78	4/12/78	1/12/78 4/12/78
COD	80	45	0	3	5.1	5 3.9
pH	6.4	6.3	7.4	6.5	7.0	6.2 7.2
Total Dissolved Solids	274	121	91	98	7.3	97 77
Iron	4.6	< .02	--	2.53	2.26	< .02 1.16
Sulfate	2.8	6.0	.81	7.4	13.2	< 1.0 < 1.0
Chloride	10.0	5.0	16.5	13.0	13.7	14.4 14.4
Alkalinity	--	--	--	--	--	-- --
Manganese	0.11	0.18	0.07	--	0.71	0.9 0.98
Nitrate	0.24	<.05	1.5	--	< .05	0.16 < .05
Total KJELDAHL Nitrogen	.5	2.8	1.96	--	1.96	2.8 2.52
Ammonia	--	--	--	--	--	-- --
Turbidity	30	12	38	--	25	44 31
Nickel	--	--	--	--	--	-- --
Copper	--	--	< .02	--	0.04	-- < .02
Lead	--	--	--	--	--	-- --
Chromium	--	--	--	--	--	-- --
Zinc	1.11	0.04	< .02	--	<.02	-- < .04
Cadmium	< .02	< .02	< .02	--	<.02	-- < .02
Mercury	--	--	--	--	--	-- --
Phenol	< .001	< .001	< .001	--	< .001	-- < .001
Hydrocarbons	<.5	--	--	--	--	-- --
Trichlorethylene	< 2	--	--	--	--	-- --
Fecal Colliform	--	--	--	--	--	-- --

*All concentrations given in milligrams/liter, except mercury which is given in micrograms/liter, pH is given in pH units, and fecal colliform is given in plate count/100 ml, and trichlorethylene in parts per billion.

be trichloroethylene, and resulted from a 500 gallon spill at Stamina Mills (now closed) years ago.

Septic Systems

No comprehensive study of individual sewage disposal systems (ISDS, or septic systems) has been done in Rhode Island. One analysis of the problem has relied on existing data (SPP, 1979a). Another analysis involved surveys of rural villages (Hughes and Riendeau, 1982).

The SPP attempted to ascertain the extent of the problem as part of the "208" effort (SPP, 1978b). Two forms of data were utilized: DOH reports on the geographical distribution of the failure and/or repair of ISDSs, and well water quality data from the WRB and DOH. The report concluded that there appears to be no large scale concentration of ISDS failures which affect a public water supply. However, individual private wells may still be threatened by their own or neighboring ISDS pollutants.

As noted in the foregoing chapter, the major ISDS pollutant is nitrate, which results from the breakdown of organic matter, including sewage as well as food wastes (a major source in homes with in-sink garbage disposals), and agricultural and domestic fertilizers. Nitrates are problematic because they are not adsorbed by the soil and hence, once reaching the water table, nitrates can travel great distances. Given enough time, nitrates in the ground water will eventually be broken down to nitrogen gases (which then rise to the atmosphere) or are discharged to surface water.

SPP also used well water quality data from the DOH. Wells with over 10 ppm of nitrate (EPA drinking water standard) were identified and compared with the surrounding land use to determine whether the high levels were correlated with urban development. The results are not definitive since not all areas within the state are represented in the well tests. The study concluded, however, that:

- 1) nitrate levels greater than 10 ppm were recorded at various sites and times in Rhode Island (some as early as the 1950's);
- 2) nitrate levels were generally higher in ground water than surface water;
- 3) nitrate levels were generally higher in non-sewered areas;
- 4) no correlation existed between nitrate levels and land use (e.g. residential, agricultural, wooded, commercial, vacant);
- 5) no long term trends in nitrate pollution were evident (in individual areas or statewide).

Rhode Island Projects for the Environment (RIPE) has demonstrated more recently that rural villages are prone to ISDS pollution of ground water (Hughes and Riendeau, 1982). In 1979 RIPE began a 50% interview survey of households in 15 rural villages to identify ground water quality problems and public knowledge of pollution problems. This was reinforced with a 30% survey of ground water quality on lots suspected of ground water contamination. Well water samples were

checked for **coliform** bacteria, nitrates and surfactants. They found a profound ignorance among most of the public about ground water and water supplies, and about the relationship of septic systems to ground water. This was uncorrelated with socioeconomic status or educational level. After surveying a village the data were reviewed to identify areas within the village with ground water quality problems. These areas were brought to the attention of the residents and the local governments. Recommendations were made to include ground water quality as a goal in the comprehensive plan and to zone for aquifer protection where possible. In one case (Charlestown Beach) most homes were located on lots smaller than one quarter acre and ground water quality had been degraded as a result of the inadequate sewage disposal practices. RIPE urged that a public water supply system be developed. Problems arose, however, as Charlestown has no public system and the nearby system serving South Kingstown refused to extend service because of inadequate supplies.

RIPE also uncovered other problems such as apparent leaks from underground gasoline storage which affected wells in Wyoming (Canob Park, Hopkinton). Efforts to resolve ground water quality problems in these villages are frustrated by the general lack of understanding of ground water and unwillingness to maintain septic systems, and the inability of otherwise unorganized citizens to coordinate their efforts and develop alternative water supplies. Town governments in rural towns are reluctant to dedicate scarce public funds for new systems to serve these small areas.

Road Salt

As a result of its "bare pavement" policy the R.I. DOT applies an average 50,587 tons of salt to state roads each winter (SPP, 1978c). In addition, each town or city may have its own salt storage pile and may salt town roads. Though salt may reduce the number of injuries resulting from snow covered roads (a debated assumption) it results in the deterioration of plant life, soil permeability, vehicles, bridges, roads, subterranean utility lines, etc. By far, however, the most serious potential problem is in elevating sodium levels in drinking water which aggravate human circulatory problems.

Two studies attempted to assess the extent of ground water pollution from salt storage piles in Rhode Island. SPP (1978c) found 34 uncovered piles. Kelley and Urish (1981) examined 4 sites in detail. Both studies lead to the conclusion that salt piles have resulted in substantial pollution of ground water. Municipal wells were not found to be threatened, though domestic wells may be. SPP (1978c) recommended installation of asphalt aprons and the covering of salt piles to reduce this contamination and prevent the loss of salt.

Recently, however, the Town of Lincoln lost 45% of its public water supplies when three wells were closed due to chemical contamination. A new well site capable of 1.0 mgd was finally located but preliminary testing found unacceptable levels of sodium, apparently from an up-gradient DOT salt pile (Trudeau, 1982). Hence, although existing ground water supplies have been spared, potential supplies have been damaged because of inadequate measures to contain the runoff from salt storage piles.

Surface Impoundments

In 1979 the DEM Division of Water Resources undertook a study to identify and assess the pollution potential from the surface impoundments in Rhode Island. Impoundments were located by reviewing DEM files, contacting local engineers and planners, and scanning USGS topographic maps and Statewide Planning Program aerial photos. A summary of the findings is reproduced in Table III-4. Three types of impoundments were discovered. Storage impoundments were generally lined or discharged to surface water allowing for **settling of solids**. Aeration impoundments usually included some mechanism to aerate the wastes to improve oxidation or bacterial decomposition. Seepage impoundments were intended to leak the wastes into the ground (disposal). Since there were no regulations governing non-hazardous liquid waste impoundments at the time, only three of the sites had monitoring wells, and only two of them sampled the ground water.

The waste in the industrial impoundments consisted of industrial rinse waters, (which contain alkalies, acids, light oily wastes or degreasers) or dye wastes and sanitary wastes. Municipal impoundments usually held water purification sludge or septage (semi-solids pumped from cesspools and septic tanks). Agricultural impoundments usually held wastes from poultry, dairy or pig operations.

Each impoundment was rated on several measures: thickness and permeability of the unsaturated zone; thickness and permeability of the saturated zone; underlying ground water quality (measured as total dissolved solids); waste hazard potential (type of operation and waste,

Table III-4. Surface impoundments in Rhode Island

	Industrial	Agricultural	Municipal
Number of sites	31	9	7
Number of impoundments:	107	17	21
in outwash deposits	95	1	14
in till deposits	12	16	7
in major aquifers	46	-	-
average depth to water table (meters)	1.7	2.0	1.6
average depth of underlying water-saturated deposits (meters)	15.9	3.4	13.4

Source: DEM, Surface Impoundment Assessment, 1980

e.g., agricultural, chemical, radioactive); and potential endangerment to water supplies (distance to ground or surface water, up or down gradient). A high score indicated greater severity of actual or potential pollution, with a maximum score of 29 possible.

The study concluded from the assessment that:

- 1) no engineering design standards exist for surface impoundments;
- 2) the majority of impoundments were industrial;
- 3) the majority of impoundments were unlined seepage pits;
- 4) 75% of the impoundments were in moderately to highly permeable soils;
- 5) 43% of industrial impoundments were in "major shallow aquifer systems";
- 6) there was no recording of wastes disposed in impoundments;
- 7) many were near the water table.

At the time of the study, however, DEM concluded there was no threat to existing public supply well systems.

Three sites were especially severe. United Nuclear Corporation (Charlestown) and United Wire and Supply (Cranston) both rated 28 out of 29. Western Sand and Gravel impoundments (Smithfield) rated 21 to 25. The United Nuclear site was found to be releasing a plume of radioactivity and extremely high nitrates (greater than 1000 ppm) into the ground water which discharges into the nearby Pawcatuck River. The ground water around United Wire and Supply showed high concentrations of metals (e.g., lead) and was in a deep saturated deposit of outwash.

Cranston is almost entirely served by public water from the Scituate Reservoir, and does not use the ground water from the aquifer. Western Sand and Gravel was the site of extensive hazardous chemical dumping and is slated to receive clean-up efforts funded by the EPA under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 ("Superfund"). Phase III of the study (DEM, 1981) provided a more extensive analysis of selected sites, but confirmed that no existing public water supplies were in immediate danger. Apparently, one major reason is that industries were traditionally located near rivers in Rhode Island and, hence, the impoundments leak into ground water which quickly discharges into, and is diluted by, the surface water.

It is possible, however, for pollutants to travel beneath a stream when a well is heavily pumped. The preliminary results from test wells monitored by the EPA have indicated that three municipal wells in Lincoln were contaminated by pollutants dumped in a lagoon at an industrial site across the Blackstone River (Stevenson, 1982). This contamination was due to the heavy pumping of those wells which not only drew from the river, but pulled ground water which normally fed the river from the other side. Such complex hydrologic circumstances may be found to be more common as new cases of well contamination are studied, and should make policy makers more cautious in permitting industries in aquifer areas.

Summary

Several studies have examined potential ground water pollution from landfills, septic systems, road salt, and surface impoundments. None of these have been found to be causing major contamination in underground public water supplies. The extent of pollution of private water supplies or untapped aquifers is unknown in most cases. It is probable that most of the aquifers in Rhode Island remain of high quality (except for iron and manganese) and would be suitable for public water supplies. Rhode Island has inadvertently been spared serious ground water contamination common to other states. As the population of Rhode Island continues to grow, water demand will outstrip existing supplies and new supplies will be needed. The ground water resources are abundant and can provide a large share of the State's future water requirements - provided that these resources remain high in quality, are not allocated for other uses, and that ground water reservoirs and recharge areas are not rendered unusable by the incremental spread of urban development.

Chapter 4. The Status of Ground Water Management in Rhode Island

There is no program or organization in Rhode Island government dedicated to comprehensively managing ground water quantity or quality. What management and policies that do exist are fragmented and implemented by a variety of public agents. The chief actors in ground water policy in Rhode Island are 1) federal agencies (chiefly the EPA and USGS) in so far as they provide data, operate programs, channel money to the state for state-level programs, or set standards which the state must meet; 2) the state courts in so far as they set case law precedents governing liability applied to ground water withdrawal or pollution; 3) Rhode Island agencies and departments which develop and implement programs in response to policy mandates from the state legislature, chiefly the Water Resources Board (WRB, data gathering and statewide public water supply planning), the Statewide Planning Program (SPP, staff for the Statewide Planning Council, performing general land and natural resources planning), the Department of Health (DOH, responsible for ensuring the high quality of public water supplies), the Department of Environmental Management (DEM, responsible for enforcing legislation designed to protect natural resources, lead agency for most EPA regulatory programs), and municipalities, which are designated by the legislature to regulate land use. There are other, powerful actors in the development and implementation of state policy related to ground water such as special interest lobbying groups (e.g. Rhode Island Builder's Association), but though it would be very interesting, an analysis of their influence is beyond the scope of this work. In addition to existing programs, there were a number of bills submitted to the 1982 General Assembly which bear directly on ground

water management. These bills were designed to remedy shortcomings in current regulatory authority at both the state and local level.

Federal Policies

During the last decade, the federal government increased its controls over pollution of air and water. Several pieces of legislation have given programs to the EPA or to states to identify and regulate polluting activities. Although various policies were directed toward some aspects of ground water, it was not until recently that EPA confronted ground water as a separate resource. Federal policy-makers have concluded that, since the characteristics of ground water differ widely among the states, the efforts of the federal government should not be directed at new legislation, but rather toward fully utilizing existing legislation and encouraging the states to develop their own ground water policies and program (EPA, 1980). This "ground water protection strategy" hinges on three federal acts, the Safe Drinking Water Act of 1974 (SDWA), the Resource Conservation and Recovery Act of 1976 (RCRA), and the Clean Water Act of 1977 (CWA, as it amended the Federal Water Pollution Control Act of 1972, FWPCA). All three of these acts allow the state to take over the bulk of the regulatory authority. They will be discussed here in terms of how they relate to Rhode Island.

The two programs emerging from the SDWA most directly related to ground water are the Sole Source Aquifer Program (SSAP) and the Underground Injection Control Program (UIC). The former allows state and local governments to request EPA to designate aquifers and recharge areas as sole sources of public water supply and limit federal activities to protect ground water quality (EPA, 1980). This designation can block federal funds to projects which may endanger public health by degrading drinking water quality (Rogers, 1977). The major shortcomings of such a

designation are that 1) it pertains only to federal activities, which are not the major threat to ground water in Rhode Island, and 2) the purpose is limited to protecting existing drinking water, with no provisions for long term protection of potential supplies.

The UIC program is designed to protect current and potential drinking water supplies from contamination by wastes disposed in wells. It sets state program requirements and provides funds for identification of ground water resources. Originally, it was designed to regulate injection wells by permit or regulation. However, because injection wells are not common in the Northeast, DEM is adapting the program to any underground disposal of waste not regulated by hazardous waste or ISDS programs. Again, a major shortcoming is the limitation of purpose to protecting drinking water supplies, and not other ecological considerations (such as water quality in wetlands, etc).. There is a recognition, however, that potential supplies must be protected.

RCRA is important because it relates to solid and hazardous waste disposal. Under the act, EPA is required to take an active role in identifying hazardous wastes and monitoring their transportation, storage and disposal. Rhode Island has its own legislation regarding solid and hazardous wastes and has interim authorization to administer the EPA regulations on hazardous waste.

The CWA included a number of provisions which related to ground water, although indirectly. The Act was designed to improve the quality of surface waters. Typically, EPA and the federal courts have adopted a narrow interpretation of the CWA and applied its provisions exclusively to surface water quality (EPA, 1980), yet two other provisions

do bear on ground water. Section 208 provided funds for water quality planning, and Rhode Island used these to assess both surface and ground water problems (see, e.g., SPP, July 1977). (Some states, e.g. Connecticut, used these funds to develop comprehensive ground water protection programs.) In addition, since wells are sometimes designed to induce infiltration from surface water, any program which protects surface water quality through major aquifer areas may also protect water quality in wells.

The "Superfund"* legislation recently enacted by Congress set up a fund from taxation on industries to provide for the restoration of the worst hazardous waste dumps. While this is a post hoc measure, and cannot entirely remove ground water contaminants, the fund has made it possible to minimize further ground water pollution. Rhode Island is currently targeted for funds to clean up three sites: The Picillo dump, Western Sand and Gravel, and Landfill Resource and Recovery (Stevenson, 1982).

The last major federal activity involves the USGS. The USGS has been active for many years in Rhode Island in amassing data on water resources, independently and in cooperation with Rhode Island agencies. In recent years the USGS has attempted to model aquifers to predict safe yields to wells. DEM hopes to use the USGS expertise to develop more specific information on aquifer yields under the UIC program (Annarumo, 1978).

* "Superfund" is part of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980

Property Rights - State Courts

Any management of ground water in the form of policy, program or statute is overlaid on the rights of the property owner to use his property. The doctrines related to use of ground water vary among the states. The case law in Rhode Island has, until recently, applied the American version of the common law doctrine of absolute ownership of ground water (see Rose v. Socony Vacuum Corp. 54 RI 411, 173 A. 627-630, 1934; Gagnon v. Landry, RI 234 A. 2d 674-677, 1967; Burke et al. 1971). A recent ruling has dramatically changed the rule to be used in Rhode Island closer to one of strict liability (Wood v. Picillo, RI Supreme Court, April 9, 1982).

According to the English common law, a property owner may use (or abuse or contaminate) absolutely anything within the boundaries of, and underneath his land "to the center of the earth" (Adams, 1978, Bosch, 1978, Weston, 1976). The American rule was established in Wheatley v. Baugh 25 Pa. 528, 1855, which acknowledged the rights of the landowner to use ground water but separated ownership of the ground water, stating that no one can have exclusive rights to water or air (Weston, 1976). A distinction was also made between subterranean streams and percolating waters. Since there was little known about ground water flow in the 19th century, it was thought unreasonable to hold land owners accountable for percolating, diffuse ground water. Underground streams, however, could be traced and so the doctrine of riparian rights applied to surface water was also applied to subterranean streams. The specific doctrine which applied varied among the states, but for any state,

underground streams would be treated as surface streams and landowners were not permitted to unreasonably reduce a "downstream" landowner's use of the water. The riparian doctrines will not be discussed here because the presence of underground channels is uncommon in glacial deposits which are the major ground water bearing structures in Rhode Island. Subsurface channels would be more common in states where ground water was primarily found in bedrock fractures. It is possible, however, that riparian rights might be involved if a large well relied on induced recharge from an adjacent stream.

A landowner was not absolutely free. He could be held liable if he acted maliciously or negligently in changing the ground water quantity or quality and caused his neighbor harm. The limited knowledge regarding ground water hydrology was such that negligence was difficult to establish (Weston, 1976). Rhode Island case law bears on this directly.

In Rose the plaintiffs charged that the adjacent owner (oil refinery and petroleum storage) had polluted the ground water by dumping petroleum into unlined pits in the ground. The polluted ground water had then caused the death of 136 pigs and 700 hens. This established that the defendant had created a nuisance. Once a nuisance is established, the plaintiff would normally be granted some form of relief or compensation. In the case of percolating ground waters, however, the court ruled that negligence by the defendant must also be established because the defendant could not know exactly where the polluted ground water would go. Negligence is much more difficult to establish, however. The court recognized that in

some other cases negligence was not required, but that those cases took place in primarily agricultural areas. This case took place in a heavily industrialized area which relied on such operations as oil refineries for economic prosperity. Thus proof of negligence was required.

The court concluded that the defendant had not acted negligently since all the wastes had been kept on the defendant's property and were not allowed to enter streams leaving the property, and since no evidence existed that the defendant had acted intentionally to injure the plaintiffs. This case hinged on the belief that ground water flow could not be predicted and thus a stronger test was required. Since the defendant used practices common to an industrial area and did not act maliciously, he could not be held liable for damage.

Later, in Gagnon, the court further defined the law to require a polluting landowner to repair the source of the problem, once known, with reasonable promptness or be held liable for failing to prevent "continuing pollution of percolating waters" (Burke, et al., 1971). This was established statutorily in 1980 in Rhode Island: "any person who shall negligently or intentionally pollute ground water shall be liable to any other person who is damaged by such pollution". (General Laws of Rhode Island, 46-13-30.)

In the most recent case, Picillo, a farmer had allowed the burial and dumping of large quantities of chemical wastes on his property. Neighbors had been made ill by the fumes and nearby springs were found to be grossly contaminated by the same chemicals found at the dump. These streams emptied into public waterways supplying fish and other wildlife and recreation for the public. The dump thus caused both

private and public nuisance and the state (DEM) sought relief in the form of closing the dump and requiring the owners to clean up the property and remove the pollutants. The court refused to require proof of negligence since experts were able to establish the direction of ground water flow based on test wells and proved that ground water was polluted by the chemicals. The court found the defendants guilty of nuisance and required them to remedy the problem. The fundamental difference in this case from previous cases was the acknowledgement that ground water flow can be predicted and that the environment is threatened by many new forms of contamination which may have profound effects on man and the ecology in general. Since both public and private nuisance were established, the court declined to hold the defendant "strictly liable" (liable for any and all damages resulting from his actions whether purposeful or not), but suggested such a ruling would have been appropriate. Thus, this one case has moved Rhode Island ground water law into the present and will mean that landowners will be liable for polluting ground water which harms others.

The problems of relying on courts for managing ground water are manifold and the reader is referred to Burke (1971), Weston (1976), and Adams (1978), for a thorough discussion. The main weaknesses discussed by these authors are that courts do not have the expertise or comprehensive resource planning perspective to maximize the efficient allocation of resources and make trade-offs between conflicting goals. They tend to decide issues on narrow rather than broad grounds. For example, courts tend to avoid defining what is a legitimate social

purpose in land use, but rather prefer to decide what is not legitimate , case by case. Unless a particular landowner's problem has been decided in court before, he is uncertain what his rights and responsibilities are. Deciding issues on narrow grounds moves management incrementally away from certain problems, but seldom toward an ideal state. Further, cumulative impacts may ruin the resource as the allowable effects of individual users combine to render an aquifer unpotable. Then, they all lose. In practical terms, the courts become unwieldy since cases may not be decided for several years and the appeals process may extend the issue even longer.

The most important reasons for not relying on the courts are the post hoc nature of legal actions and the lack of long term, forward-looking judicial perspective. Suits can only be brought after the damage occurs. Rhode Island courts may refuse to decide pollution cases where only the possibility of damage exists. Once ground water is contaminated, however, the fault is less important than the fact that the resource has been eliminated. Ground water management requires a long term, site-specific, perspective, and a balancing of land use issues and flexibility to changing demands and situations. The courts are not suitable as a forum for the needed open debate.

State Level Policies and ProgramsWater Resources Board

The Water Resources Board (WRB) was established to develop public water supplies for the state (G.L. 46-15). Its duties and powers are:

"(a) to acquire land, dams, waters, water rights, rights of way, easements and other property; (b) to construct or purchase water reservoirs, wells and well sites, processing facilities, transmission or distribution systems and other facilities; (c) to formulate and maintain a long range guide plan and implementing program for development of major water sources and transmission systems; (d) to provide for cooperative development, conservation and use of the water resources, the Board may, (1) divide the state into water supply areas; (2) designate certain municipal water departments to serve as area wide supply agencies; (3) authorize water supply agencies to build facilities on land owned or land leased by the Board; (4) enter into contracts for the operation of these water supply facilities; (e) enter into contract to supply raw or processed water to public or private water supply agencies; (f) review

all plans and proposals for construction or installation of facilities for water supply; (g) make loans to publicly owned water supply agencies for acquisition of land, construction or purchase or installation of equipment from funds which may be appropriated for this purpose and made available to the Board for this purpose." (Munroe, 1972, p. 129)

To achieve its purpose, the WRB has studied surficial geology and both surface and ground water resources and contracted engineering firms to develop water supply plans. Two of these are of special interest and are relied on by the WRB today: Metcalf and Eddy (1967) and C.A. Maguire (1968a). As in all water supply plans, the reports begin with estimates of demand for the next several decades. They then develop estimated potential yields from surface and ground water reservoirs and then proposed specific delivery systems. Both rely heavily on surface water reservoirs, including future developments on the Big Flat, Moosup, and Wood Rivers. The reports differ substantially on the reliance on ground water supplies.

Metcalf and Eddy (1967) calculated safe yield to wells based on USGS figures for maximum yield. The latter represents the total water flow from a ground water basin. Safe yield was taken as one-half of then USGS estimates to ensure streamflow even during the dry months. C.A. Maguire (1968) reduced these estimates further to account for the expected seriously high levels of iron and manganese, and the poor quality of surface water which would be induced by wells along the Blackstone River. Table IV-1 shows a comparison of their estimates

Table IV-1. Estimates of safe yield
from ground water reservoirs and proposals for additional development

Aquifer Name, ¹ SPP/WRB number	Additional Safe Yield (mgd) ²				Yield at Proposed Centers (mgd) ³		
	Metcalf & Eddy 1967	C.A. Maguire 1968	WRB/ SPP 1978	Metcalf & Eddy ⁴ 1979	Metcalf & Eddy 1967 (to 2020)	C.A. Maguire 1968 (to 2015)	Metcalf & Eddy 1979 (to 2020) ⁵
Upper Branch #1	3.0			4.25			2.25
Slatersville #3	4.0	1.1		3.0			2.0
Lower Branch- Blackstone #4							
Blackstone #5	5.0	1.5		included in #7			included in #7
Lower Blackstone Moshanuck #6				3.0			
Abbott Run #7				10.0			3.5
Ten Mile #8	7.0	0		3.0			
Mishnook #9	6.0	4.3		5.0		6.0 ⁶	8.0
Providence- Warwick #10	10.0	3.0		12.0			
Hunt #11	8.0	2.0		4.0			4.0
Annaquatucket- Pettaquamscutt #12				7.0			5.5
Barrington #13	2.0					2.0	
Chipuxet #14	6.0	4.1		5.25			0.25
Mink #15			1.75				

Table IV-1. (cont.)		Additional Safe Yield (mgd) ²			Yield at Proposed Centers (mgd) ³		
		Metcalf			Metcalf	Metcalf	
Aquifer Name, ¹		&	C.A.	WRB/	&	&	&
SPP/WRB number		Eddy	Maguire	SPP	Eddy ⁴	Eddy	Eddy
		1967	1968	1978	1979	1967	1979
						(to 2020)	(to 2020) ⁵
Usquepaug- Queen #16	13.0]	11.0	2.0	6.5		0.75
Beaver #17				3.0	2.0		1.5
Upper Wood #18					2.0		1.5
Lower Wood #19				5.9			
Bradford #20	7.0]					
Ashaway #21							
Westerly #22							
Total proposed ground water ⁷ development						38 mgd ⁸ capacity	10.4 ⁹ 37.85
Surface reservoirs						107	130 5

Notes:

1. There is no #1 in the SPP/WRB schema.
2. Safe yield is less than potential to ensure minimum stream flow and reduce mineralization and contamination problems.
3. Yield at centers proposed in water supply plan - i.e. expected reliance on ground water
4. Data are for Alternative 3 - no conservation and maximum reliance on local ground water. Potential safe yield higher in some instances.
5. Data for Alternative 5 - demand assumed reduced by conservation and economics of surface versus ground water pumping, purchase, transmission, etc. dictates amount of ground water use proposed.
6. Safe yield of 12 mgd reduced to 6 because 6 mgd allocated to Big River Surface Reservoir.
7. Totals may not add where proposal includes ground water from reservoir not included in SPP/WRB (1978) schema.
8. Figure is for capacity of wells, not daily yield. Wells are usually constructed for peak demand, not average use.
9. Figure includes 6 mgd from Coventry, 2 mgd for Barrington, 2 mgd from Smithfield, 0.4 mgd from Gloucester.
10. mgd = millions of gallons per day

Source: SPP/WRB Groundwater Reservoir Maps, 1978

Metcalf and Eddy, (1967)

C.A. Maguire, (1968)

Metcalf and Eddy, (1979)

of "safe yield". Metcalf and Eddy's (1967) proposals for ground water development were limited to wells in southern Rhode Island serving southern Rhode Island communities (Washington County), Jamestown, and Newport (via a major pipeline over the Jamestown and Newport bridges). All other demands were to be serviced by surface water reservoirs. The purpose of the C.A. Maguire (1968a) report was to examine for the City of Providence the future need for public water and the potential supplies. It concludes that demand will outstrip supplies within its planning period (to 2015) and that development of the Big River, Wood River and Moosup River reservoirs will be necessary to meet that demand. The report included a warning:

"If ground water were to be depended upon as a major source of water supply as has been suggested in several past reports, some of the streams would become dry during the summer months and in all probability many of the wells would become contaminated or polluted, and of course unsuitable for public water supplies. It is hoped that some of the confusion and mis-statements which have been made on ground water usage and development in the State of Rhode Island in some prior reports will be clarified by Appendix A." (p.3)

C.A. Maguire did examine the needs of adjacent communities to determine whether the Providence Water Supply Board should include them in future supply plans. The conclusion was that ground water will "at very best provide a limited source of water amounting to less than 11 mgd of a

total...140 mgd" needed by the Providence area in 2015 (p.3). This ground water would be developed by communities south of Providence including West Greenwich, East Greenwich, Exeter, and North Kingstown.

"Appendix A" (C.A. Maguire, 1968b) calculates safe yield for only a subset of Rhode Island aquifers, due to its emphasis on the Providence area, and these figures are also shown in Table IV-1. This was not a statewide plan. The appendix examined selected case studies of well situations in New England and concluded that security of supply could best be met with surface supplies.

The WRB, relying on these two studies, places its major emphasis on surface water and has structured its development plans accordingly. The result has been an attempt to proceed with development of the Big River Reservoir (though it has met with limited success in bond referenda) and to acquire a few sites in southern Rhode Island for public supply wells. The extent of the ground water development seems to be acquisition and testing of a few well sites (and a 400 foot radius at each site), and a continuing program to improve the data base for predicting safe yield. The WRB has not, however, published or even proposed a "long term comprehensive public water supply plan" which adequately includes the entire state.

Table IV-1 is important because the extent to which ground water will be needed is an important aspect in deciding how to manage the resources. The WRB relies on the earlier studies which concluded there would be a large demand for water by the years 2015-2020. The demand was expected to be centered around the Providence and Newport areas and illustrates the weakness of such demand studies. The major population growth between 1970 and 1980 was in "South County", and the

Navy pullout in 1973 eliminates the short term supply problems in Newport. The more recent Metcalf and Eddy (1979) report recommends only a 26 mgd surface water reservoir instead of the 100+ mgd reservoirs recommended earlier. This is primarily due to an expected reduction in demand from conservation efforts (acknowledged by a more modern WRB) and a preferred reliance on ground water development.

The WRB thus plays a very limited role in ground water management. It has been responsible (with the USGS) for much of the data on ground water, but active management has been minimal, deferring to efforts to develop surface water resources. There are three major reasons why surface water receives so much emphasis. First, since Rhode Island is dominated by the city of Providence Water Supply Board's Scituate Reservoir there may be a tendency to develop other large systems to augment the Scituate Reservoir, and to supply the State from this system. Other systems have been proposed by Metcalf and Eddy (1967) and C.A. Maguire (1968) but these also tend to be large surface water reservoirs. A more recent analysis relies more heavily on ground water (Metcalf and Eddy, 1979) but its estimates of safe ground water yields are not thought entirely accurate by the WRB (Calise, 1982).

Secondly, economic analyses are incomplete. The engineering studies cited usually calculate the cost of acquiring land, and building the reservoirs, transmission lines and treatment plants. Only the later Metcalf and Eddy (1979) study included cost comparisons for various alternatives. None of the studies examined the opportunity cost of the flooded land beneath surface water reservoirs being taken out of any productive use. Likewise, any costs associated with

regulating land use over aquifers was ignored. There was an assumption in the past that surface water development was more expensive because it required more treatment than did ground water. C.A. Maguire, however, argues that the cost of iron and manganese removal is also high. Energy costs for lifting ground water must certainly have increased, though probably not as fast as real estate! Metcalf and Eddy (1979) made a much more substantial estimate of the costs of various alternatives, including pumping costs and iron/manganese treatment plants, and their proposals emphasized ground water much more than past reports.

The third, and major reason for the lack of emphasis on local ground water development and management by the WRB is institutional. Their legislative mandate is to provide major public drinking water supplies. They are not responsible for other uses of ground water. More importantly, they are not given any regulatory authority. Their only control lies in purchasing land and facilities (and perhaps knowledge). To protect supplies for high quality means they are limited to buying land. A surface water reservoir requires less land per volume of water than a ground water reservoir (since much of the recharge area would need to be purchased to provide complete control). The WRB does have authority to purchase development rights which it could use to ensure that development remained low in density and free of heavy industry. However, purchasing development rights is an untried technique of land use control in Rhode Island and the WRB does not wish to take the risk that it might fail. Without authority to manage ground water resources by regulation, the cost of purchasing ground water resources makes surface water

the only alternative. Thus, the WRB cannot be relied upon to manage the ground water of the state.

Statewide Planning Program

The SPP has no regulatory authority, and cannot control land use decisions. The SPP has, however, been the source of numerous studies, several of which bear on ground water.

The SPP was primarily responsible for the 208 Water Quality Management Plan. The plan identified ground water reservoirs in Rhode Island, and attempted to assess the ground water quality impacts of landfills, ISDSs, and road salt. These studies are discussed in the previous chapter. The final 208 Plan did make several recommendations which can be summarized:

1. Ground water reservoir areas which have significant potential for municipal water supplies should be identified (i.e., there should be a statewide water supply plan).
2. Sources of pollution such as landfills and road salt storage piles should be prohibited (by DEM) in these ground water reservoirs and their recharge areas (SPP, 1979, p. 381-2).
3. Pollution from ISDSs should be controlled by better maintenance programs, construction standards, and minimum lot sizes, i.e.,
 - a) 15,000 square feet for lots served by public water supply
 - b) 1.5 acres for lots with private

wells (p.50)

- c) 2.0 acres for lots located over
existing or potential (not "planned")
public water supplies (p.98)

Ground water management becomes more important since the 208 plan recommends ISDSs over public sewers (p. 100) whenever possible.

- 4. The State Building Code should be amended to ensure that underground storage tanks (e.g., gasoline, chemicals) do not pollute the ground water (p. 52).

SPP clearly recognized that ground water management required improved land use controls, and has developed various bills to achieve this. The most comprehensive legislation proposed was the state land use management bill (see, e.g. Rhode Island Senate bill 79-S292). This bill would have allowed the state to designate ground water reservoirs as areas of critical concern and required municipalities to exercise their authority to protect them. Failing local measures, the state could exercise its own land use controls. This (and other) reassignment of land use controls by the state has met with such resistance at the local level that the land management bill has effectively died each year (Gauvin, 1982). Since SPP met with such resistance in proposals for statewide land use control, a new effort has been made to achieve ground water management with legislation allowing the state to regulate sources of pollution (e.g. landfills) and to enable the towns to regulate land use explicitly for ground water protection. This legislation will be discussed in a later section.

SPP has, however, been the driving force in promoting new authority for ground water management.

A recent example of SPP's efforts to improve the base of information regarding management of ground water is a recent study of "South County", Rhode Island (SPP, 1981). The purpose of the study was to examine the ground water rich area of southern Rhode Island (generally, Washington County) in terms of 1) the quantity and quality of ground water, 2) threats to the resources, 3) existing ground water use, 4) potential additional safe yield, but most importantly, 5) existing land use, and 6) potential land use allowed by existing zoning. The report relied on sources of data from past SPP, DEM, and WRB studies, Kelly (1975), and Kelly and Urish (1980). The report discusses each aquifer in detail - important because the location of the pollution source within the aquifer is important with respect to directions of ground water flow and the location of well sites. The report found, as did previous studies, that existing public water supplies do not appear to be contaminated, that major sources of high quality ground water exist which are presently unallocated, that existing pollution sources tend to be located down gradient of pumping centers (current or proposed). Unlike other studies, however, the examination of current and zoned land use in the reservoir and recharge areas revealed that in many cases towns have not oriented land use control to protecting aquifers (see Table IV-2). In several cases, large areas of the recharge zone were zoned for industrial use, or medium to high density residential use where sewers were not available. Zoning does not necessarily mean those areas will be developed for industry or dense housing, but towns would be less able to prevent

Table IV-2. Land use and water supply
from Southern Rhode Island aquifers

Aquifer name and WRB/SPP number	Quality problems		Yields (mgd)		Land use (% of area)		1
	Substance	Sources (potential)	Existing Usage	Additional Safe Yield	Present	Zoning	
Annaquatucket- Pettaquamscutt #12	mineral- ization, nitrates, chlorides, calcium	landfills, salt/sand storage, ISDS	2.0	3.3	<u>Aquifer area</u> OS 51.8 Agr 9.0 R-ML R-M 12.5 R 4.5 C 1.0 Ind WD 0.4	7.0 30.2 49.3 3.5 9.7	
Chipuxet #14	mineral- ization manganese, calcium, sulfates	landfill (agriculture, ISDS, highway salt)	1.25	1.75	<u>Recharge area</u> OS 46.6 Agr 35.3 R 5.3 Ind 2.2 WD 0.1	 19.0	
Mink #15	chloride, sulphate, calcium, dissolved solids, nitrates, manganese	fertilizers (ISDS)	1.5	0	<u>Reservoir</u> OS 52.2 Agr 38.6 R-ML R-MH,L 4.5	100.0	
					<u>Reservoir & Recharge</u> OS 66.8 Agr 23.5 R-L 1.2 R-ML R-M R-MH 1.2	97.3 2.6	

Table IV-2. (cont.)

Aquifer name and WRB/SPP number	Quality problems		Yields (mgd)		Land use (% of area) ¹		
	Substance	Sources (potential)	Existing Usage	Additional Safe Yield	Present	Zoning	
Usequepaug- Queen #16	mineral- ization	Ladd School Sewage dis- posal (potato farm pesticides/ fertilizers)	1.12	4.0	<u>Recharge area</u>		
					OS	71.3	
					Agr	19.4	28.5
					R	12.0	
					R-L		19.5
					R-ML		29.6
					R-M		10.3
					Inst		10.6
Beaver #17	specific conductance chlorides, sodium , manganese	road salt (ISDS, gravel mining, indus- trial lagoons, salt storage)	0.72	3.0	<u>Reservoir area</u>		
					OS	64.9	
					Agr	19.1	
					R-L	1.6	
					R-ML		18.9
					R-M	4.1	70.2
					C		4.5
					Ind	1.6	6.3
					<u>Reservoir & Recharge</u>		
					OS	76.6	
Upper Wood #18	manganese, chloride	roadsalt	0	6.0	<u>Recharge area</u>		
					OS	78.0	
					Agr	6.0	
							primarily
							OS-some
							C and R in
							Southern tip

Table IV-2 (cont.)

Table IV-2 (cont.)		Yield (mgd)		Land use (% of area) ¹			
Aquifer name and WRB/SPP number	Quality problems		Existing Usage	Additional Safe Yield	Land use (% of area)		
	Substance	Sources (potential)			Present	Zoning	
Lower Wood #19	calcium, chlorides, sulphate, manganese, nitrates, radio- activity	Chariho School Septic Waste, United Nuclear Corp. lagocns, (other industrial lagoons)	3.62	6.0	Reservoir		
					OS	76.6	3.8
					Agr	19.4	
					R-ML		24.2
					R-M		53.3
					Inst	1.9	
					Ind		16.5
					Reservoir & Recharge		
					OS	84.4	7.8
					Agr	8.3	
					R-ML		26.3
					R-M		46.6
					C		2.0
					Ind		17.1
Bradford #20	nitrates	agriculture, ISDS (industrial lagoons)	0.15	2.45	Reservoir area		
					OS	9.0	44
					Agr	68.0	
					R-M	11.0	35.0
					R-H		6.0
					Ind	4.0	15.0
					Reservoir & Recharge		
					OS	92.0	27.0
					Agr		
					R-L	0.6	9.0
					R-ML	2.0	
					R-M	6.0	41.0
					R-H		2.0
					C		1.0
Ind	0.3	20.0					
Source: SPP, Land use and Groundwater Quality, South County, Rhode Island, 1981.							

Notes:

1. Land use abbreviations:

OS: open space, including wooded areas, wetlands, recreational lands, and vacant land

Agr: agricultural

R-L: low density residential (less than 0.5 units/acre)

R-ML: low to medium residential (0.5 - 0.9 units/acre)

R-M: medium density residential (1.0-3.9 units/acre)

R-MH: medium to high density residential (4.0-7.9 units/acre)

R-H: high density residential (8.0 units or more/acre)

C: commercial

Ind: industrial

Inst: institutional

WD: waste disposal

2. mgd = million of gallons per day

ISDS = individual sewage disposal system

Source: SPP, Land Use and Groundwater Quality, South County, Rhode Island, 1981.

such potential ground water pollution sources if they were proposed.

One reason for the apparent lack of local concern is that public water supplies in these rural towns are a distant possibility. The ground water might be needed most for other towns. Towns are not required to consider regional issues in establishing land use controls, and, hence, adopt a parochial attitude. After all, why should a town prohibit tax-paying industries merely to provide other towns with potable drinking water (unless compensation is available).

SPP and Senator Hagan (of North Smithfield, which has suffered from ground water pollution) has been the principal actors in attempts to improve ground water policy. Following unsuccessful efforts to enact a state land use bill, SPP attempted to develop legislation to broaden the authority of state and local governments to protect ground water quality. Senator Hagan has now proposed legislation to close gaps in current management.

Senator Hagan's bills include one measure which would provide for the regulation of well drillers and drilling practices by a "well drilling board" composed of a hydrologist, an employee of the WRB, an employee of DOH and two active well drillers with substantial experience (bill 82-52264). This board could establish programs to require better reporting of wells drilled (to monitor withdrawals and surficial geology), require construction standards for wells, and prevent wells from being located too near pollution sources (e.g. ISDSs). A curious omission is that DEM is not represented. DEM is the major land and water resources regulatory agent in Rhode Island. It would seem that coordination with DEM's ISDS, UIC and other programs would be enhanced by representation.

Another bill submitted by Senators Hagan and Smith would prohibit disposal of solid waste over legitimate ground water sources (bill 82-S2260). Senator Quattrochi submitted a similar bill (82-S2335) which would include recharge areas, and "existing" as well as "potential or planned" public ground water sources. Both bills require that the municipality have ordinances relating to ground water aquifers. Presently, however, this would apply only to the one town which has such ordinances.

SPP and others have developed a bill to broaden DEM's authority to include protection of ground water. The bill (82-47039) would amend the Water Pollution Act (G.L. 46-12) to include ground water as a "water of the state", and subject ground water to DEM authority which includes water quality classification and protection. This bill has profound implications in that DEM could plan for ground water quality and regulate anything which threatened that quality (including land use, major wells). This, and limited budgetary resources for DEM mean the bill will probably not succeed in 1982.

There is also a proposal being championed by the Rhode Island League of Cities and Towns to extend local zoning authority to include ground water quality objectives. Towns could then enact ordinances to safeguard aquifers without fear of litigation (Keller, 1982). To what extent they will do this is a serious question. Nevertheless, some towns (e.g. South Kingstown) are moving ahead with plans for aquifer protection (Prager, 1982). This bill will probably meet with harsh resistance from development interests because it is a major revision of the zoning enabling legislation (G.L. 45-24). The ground water provisions are only

part of a broad thorough update which expands municipal authority in many areas.

Department of Health

The DOH is designated as the primary enforcement agency under the federal SDWA, P.L. 93-523-1974 (Kumekawa, 1979,1). State statutes including the Public Drinking Water Supplies Act (G.L. 46-13, as amended) further define DOH's duties. DOH's authority is primarily over public drinking water supplies, defined as those which serve over 25 people (including restaurants). There are over 500 of these supplies in Rhode Island (Hagopian, 1982).

DOH approval is required for any site plan for public supply wells. The site plan must show all existing or proposed potential sources of pollution within 500 feet of a drilled, dug or driven well and within 1000 feet of gravel-packed wells. Land use must be controlled within 200' of the former and 400' of the latter to ensure water quality protection. DOH also routinely tests public water supplies for inorganics (arsenic, barium, cadmium, chromium, fluoride, lead, mercury, nitrate, delenium, and silver), organics (including endrin, lindane, methoxgchlor, toxaphene, 2,4-D, and 2,4,5-TP Silvex), turbidity, coliform bacteria (ground water must meet coliform standards before disinfection) and radioactivity. Additional testing may be done for halogenated compounds and aromatics. DOH is responsible for setting drinking water standards for the above. (DOH, 1977)

DOH performs only limited testing of ground water other than from public water supplies. This includes monitoring ground water quality around known waste disposal sites to help identify the

extent of contamination. DOH also tests, on request and at no charge, samples of water from private wells (though tests are limited to coliform bacteria, nitrate, chloride, and physical characteristics such as color, odor, etc.) (Kumekawa, 1979). The results of the private well tests are sent to the well owner, but are not correlated by DOH and are not made available to any other party (including other government agencies). This means such tests are useless for purposes of planning or statewide government monitoring. This extreme confidentiality is not mandated, but internal DOH policy (Hagopian, 1982).

Under G.L. 46-13 DOH may require a public water system supplier to correct a pollution source. Under G.L. 46-14 DOH may itself remove polluting material from a public water source.

Despite this seemingly broad authority, however, DOH is severely limited both by statute and internal policy. Its programs attempt to monitor only existing public water supplies. No effort is made to protect or monitor potential public supplies and no control is exerted over private supplies. A landowner, or any one else, may put a well anywhere, and is not bound by any construction codes, or water quality criteria. DOH tests private supplies, but the department's policy on strict confidentiality regarding the well quality means valuable ground water data are unavailable to analysts, public or private. Aquifers untapped by public wells remain unmonitored and uncontrolled. Any control over public water system quality is post hoc, and in the case of ground water potentially too late. The owner of a polluted well is limited to expensive treatment or abandonment.

Department of Environmental Management

Although other departments and agencies share the role of ground water management, DEM has the broadest regulatory authority. This authority is embodied in six program areas: water quality regulations, solid waste disposal, hazardous waste disposal, the UIC program, the ISDS program, and sewage sludge disposal requirements.

DEM - Water Quality Management Program

The water quality regulations (DEM, 1981b), authorized by General Laws 46-12, 46-17.1, and 42-35, set water quality standards for waters of the state, which are currently limited to fresh and marine surface waters. Pollution is identified as any "discharge of sewage or other waste into any of the waters of the state..." (DEM, 1981b, p.4). The regulations define water quality classifications by use (e.g. class A is suitable for drinking water; class B suitable for public water supply with treatment, agricultural uses, and fish/wildlife habitat). Criteria are established for each quality classification. Criteria include considerations of general aquatic life, aesthetics, dissolved oxygen, solids, color and turbidity, coliform bacteria, taste and odor, pH, thermal changes, chemical constituents, and phosphorus. Dischargers into these waters are regulated so as to attain and maintain the water quality classifications.

As is the case with similar federal programs, these regulations pertain only to surface waters. They are mentioned here because large wells may induce recharge from adjacent streams. These regulations enable DEM to control the quality of those streams.

In addition, there is a bill (82-H7039) to include ground water as a water of the state. This would enable DEM to classify ground water and control discharges into it, and perhaps, where water quality is affected, to control large users. The authorities and regulations for surface water pollution are clearly inadequate for ground water management, but lessons learned in surface water management may be applicable to ground water.

DEM - Solid Waste Program

Perhaps the most thorough management of ground water threats, although limited, are the solid and hazardous waste programs. DEM developed regulations pertaining to licensing and operating solid waste management facilities under authorization of G.L. 23-18.9 (DEM 1975a, 1975b). These regulations define ground water and state that, "Refuse shall not be deposited in such a manner that the refuse or leachate from it shall cause or contribute to pollution of any source of private or public water supply, any of the waters of the state, or any ground waters." (DEM, 1975a, p.7) Protection is thus extended beyond public sources to individual household wells and further, to untapped ground water. Implicit is the recognition that the value of ground water may not be realized until the distant future. In regulating existing operations, DEM requires a minimum distance of four feet between the bottom of the refuse and the maximum water table. DEM may require monitoring wells at facilities accepting certain wastes (e.g. fecal wastes or liquid wastes), or facilities within 200 feet of a drinking water supply or well. Other regulations attempt to minimize leachates by minimizing infiltration, for example by requiring daily cover

of the refuse.

DEM has also promulgated regulations for the licensing of new solid waste facilities (DEM 1975b). These include incinerators, transfer stations, and resource recovery operations as well as landfills. Although the latter poses the largest threat to ground water quality, plans for all facilities must include ground water information and borings must be left open for future measures.

DEM - Hazardous Waste Program

DEM regulation of hazardous waste follows authorization in the Hazardous Waste Management Act of 1979 (G.L. 23-19.1). This act sought "to establish a program of regulation over the storage, transportation, treatment, and disposal of hazardous wastes", to protect the environment and the public health and safety (G.L. 23-19.1-3). Hazardous wastes include toxic, flammable, irritant, reactive and radioactive wastes as well as wastes containing infectious agents (including septage pumped from septic tanks and cesspools). A manifest system similar to that required by the EPA was established and is monitored by DEM. DEM subsequently developed regulations for the operation of hazardous waste management facilities. As with solid waste management facilities, plans for hazardous waste facilities must provide data on ground water and nearby water supplies (not limited to public supplies). Operators are forbidden to deposit wastes such that they (or leachates) pollute any ground water (or water of the state). Construction requirements for landfills include minimum distances between the wastes and the water table, requirements for impermeable

liners, and the installation of monitoring wells.

Disposal of hazardous waste in landfills is regulated based on the construction of the landfill, and whether the underlying material is till or outwash. Hazardous waste may not be disposed where it might endanger a ground water drinking source outside of the facility, or where it might endanger a sole source aquifer. Further, hazardous waste facilities are prohibited in "the direct recharge area of an existing or planned surface or ground water community water system" (DEM, 1979, rule 3.02).

Ground water is further protected by the Hagan Bill", (G.L. 23-19.1-10.1) which states: "No hazardous waste, including septic waste, shall be disposed of in an area overlying an actual, planned or potential underground drinking water source as described on the ground water maps of the U.S. Geological Survey and the Rhode Island Water Resources Board providing such underground drinking water source was designated, on the basis of hydrologic data, as a future or potential municipal water source by the city or town in which the underground water source is located and further more providing that there is a local ordinance relating to groundwater aquifer zone." The problem is that, lacking specific enabling legislation, Rhode Island municipalities (except North Kingstown) have been reluctant to develop ground water ordinances, although this section may be interpreted to provide that authority.

In reality, local opposition to any hazardous waste facilities, or even non-hazardous landfills, will be so strong as to preclude new installation. DEM regulations will help prevent further ground water degradation and ground water provisions are in place

in the event a proposal is developed.

DEM - ISDS Program

DEM regulates the location, design, construction and maintenance of ISDSs under authority of General Laws 42-17.1-2(1), (m), (n), and (s) (DEM 1980b). The purpose of the regulations is to protect the "public health and interest" from the pollution of wells, water supplies or wetlands which may cause disease, odors, nuisance or inconvenience. The regulatory approach used by DEM is to require permits for ISDS construction, and to require repair of systems which fail.

The ISDS regulations (DEM, 1980b) attempt to ensure that nutrients in ISDS effluent are either broken down by bacteria or adsorbed by the soil (both to safeguard health and to prevent eutrophication of surface water), and that premature hydrologic failure of the system is prevented. The regulations dictate the design, size and location of the ISDS by calculating the expected loading (e.g., based on number of bedrooms in a house, or patrons at a restaurant), and the capacity of the soils to hold the discharged liquid and filter the effluent. The hydrologic capacity of the soils is based on permeability and the depth to the water table or bedrock. The filtering capacity is based on studies of soil properties.

Construction standards attempt to prevent ground water contamination by requiring enough soil between the leach field and the water table such that the nutrients (pollutants) are filtered or adsorbed. Properly functioning systems are expected to remove

nearly all of the bacteria, viruses, phosphates, and most of the metals within a few feet of the drainage pipe.

A recent amendment has included regulation of chemicals added to septic systems. Acids or solvents are sometimes added by the homeowner in an attempt to dissolve solids which have sealed the pores in the leach field. The ISDS regulations attempt to prevent ground water contamination by prohibiting the use of acids or organic chemical solvents in any part of the ISDS systems in areas served by individual wells. The use of acids in septic tanks is prohibited everywhere because of dangerous reactions between acids and the concrete of the tank (Angelli, 1982).

DEM's ISDS regulations are inadequate for protecting ground water from pollutants in four ways. First, although there is a limit set on the slowest percolation rate allowable, no limit exists on the maximum permeability. Sands and gravels with very rapid permeability do not allow adequate adsorption of nutrients because the effluent flows through so quickly. (Such soils may also lead to hydrologic failure, since the required size of the leach field is inversely related to permeability. After years of use, however, an organic "mat" forms in all systems, reducing the effective permeability to a common value. Systems designed for rapidly permeable soils may be too small once the permeability is reduced by the mat, and the effluent may rise to the ground surface.)

A second problem is that, while most pollutants are adsorbed, nitrates travel readily through the soil, with little attenuation in the typical ISDS system. Potential problems occur where an area relies on both ISDS and private wells. The simplest solution

would be to control the allowable density of housing units per acre to attain sufficient dilution. DEM has no such requirement.

The third problem is that, although ISDSs are required to be set back from wells at least 100 feet, the converse is not regulated. There are no setback requirements (or any other regulation) for private wells. The ISDS regulations suggest a setback of 100 feet but do not regulate wells. DEM officials are cognizant of this gap and attempt to control well location as much as possible, but in problematic cases the builder need only install the ISDS first and can then drill the well anywhere. Without routine well water monitoring nitrate levels could (and do) exceed water quality standards.

The fourth gap occurs in regulating subsurface disposal of wastes which are not sewage, and not "hazardous". These include industrial wastes such as cleansers, or cooling and process wastes which are disposed in leach fields. The ISDS regulations pertain only to sewage. The Underground Injection Control Program is being designed to close this gap (Annarumo, 1982).

DEM - Underground Injection Control

The UIC program is operated at the federal level, but the DEM water resources division is seeking to take over the regulation authority (Annarumo, 1982). The EPA developed a classification scheme of underground injection wells, based on the type of waste discharged (e.g., hazardous, cooling waters) and whether the underground point of injection was above, within, or below a formation supplying drinking water (DEM, 1981, p.12). The geology of Rhode

Island, however, does not lend itself to underground injection because few, if any, aquifers are sufficiently isolated from other strata to prevent contamination of water supplies. The UIC proposal seeks to prohibit nearly all "classic" forms of underground injection, and extend "underground injection" to include subsurface disposal of waste not regulated by the ISDS or hazardous waste programs. The program needs legislative authority, however, and increases in maximum penalties before Rhode Island can assume primacy from the EPA.

DEM - Sewage Sludge Disposal

Sewage sludge is the solids by-product of waste water treatment facilities (WWTFs) which settles during sewage treatment. Sludge from ISDSs (septage) is regulated as hazardous waste. Publicly owned WWTF sludge disposal is regulated under a separate program (DEM 1981d) and usually means deposition in a landfill. Other disposal options are also regulated, including land application (as fertilizer or soil conditioner), incineration and composting. Land disposal and application of sludge may potentially pollute ground water as infiltrating precipitation leaches pathogens, nitrates, metals or organic compounds.

DEM regulations seek to mitigate ground water pollution by requiring sludge disposal site plans to include data on ground water elevations, and direction and rate of flow. Monitoring wells are required in locations to be determined by DEM, and ground water quality must be sampled at least quarterly. A minimum thickness of soil is required between the bottom of the sludge deposits and the ground water table. Surface drainage must be directed away from the sludge to minimize

infiltration. Setbacks from wells are established and DOH review is required if the site is located near a public water supply. The composition, quantity and location of disposal is then monitored by DEM and maximum pollutant loadings are established (e.g. for metals).

Municipal Aquifer Protection

Before there was a bill to grant explicit authority for towns to zone for aquifer protection, one town - North Kingstown - needed such legislation, had a progressive planning department and town solicitor, and construed its zoning enabling wording to include aquifer protection. Other towns are apparently reluctant to enact such ordinances for fear the courts will strike them down.

Sections 10.4 and 10.5 of the North Kingstown ordinance relate to ground water recharge and reservoir areas respectively. Section 10.4 does little more than describe what constitutes a recharge area - but by including any area with a transmissivity greater than 0.0 gallons per foot per day includes the entire town. Section 10.5, however, is an overlay district and specifies that lots over ground water reservoirs (defined as areas with saturated outwash greater than 40 feet thick and transmissivity greater than 4000 gallons per foot per day) shall be at least 3.0 acres, and that impervious surfaces be limited to 20% of the lot.

It is curious that, although this 3 acre requirement is significantly greater than that justified by the 208 calculations (SPP, 1979, p.96) and no other justification apparently exists, the ordinance has not been challenged in the courts. This is probably due to two factors. First, the areas defined as reservoirs are narrow. The lot "location" is determined by the site of the principal structure. Since the area is narrow, the developer can arrange to place the structure outside the "reservoir" and avoid the 3-acre requirement. The planning department makes a conscious effort to prevent ISDSs locating in the "reservoir", and cluster

development possibilities make this even easier. In reality, of course, there is no sharp limit to a ground water "reservoir". Hence, the regulation has limited utility. The second reason is pragmatic. North Kingstown residents have been sensitized to environmental protection by years of progressive planning efforts. A developer seeking to challenge the 3-acre requirement would meet substantial resistance but even if he won he would create doubts in the citizenry regarding water quality, and commit "economic suicide."

Model Programs in New England - Connecticut

Connecticut may well be the most advanced state in terms of ground water management and, since it is geologically similar to Rhode Island, may be a good model. Connecticut utilized "208" funds to improve its ground water data base and developed policies which integrated surface and ground water management. Connecticut includes ground water as a "water of the state" in its water pollution act and thus authorizes the Department of Environmental Protection (DEP) to set quality standards and regulate (via permit) discharges into ground water much as surface water discharges are regulated. The quality standards for ground water are reproduced in Figure IV-3. Connecticut's policy is to:

"Restore and maintain groundwaters to a quality consistent with its use for drinking without treatment except in certain cases where:

- a. groundwater is in a zone of influence of a permitted discharge;
- b. groundwater is suspected to be contaminated (GB) and there is no overriding need to improve; and
- c. the groundwater classification goal is GC." (DEP,

1981, p. 4)

The DEP is in the process of examining each of the ground water basins (assumed initially to conform with surface water drainage basins) and incorporating local input in workshops in the classifications. Towns may then adopt more stringent standards and regulations, but the state may preempt local authority for statewide purposes. The

emphasis is on ground water quality, but quantity issues are addressed where withdrawals may affect quality. Connecticut does not distinguish between aquifers on the basis of whether they are used for public water supply (because of the interrelationship with surface water). Water quality standards are reviewed and modified where appropriate every three years as required by federal law (Gimbrone, 1981).

Table IV-3. Connecticut's Ground Water Quality Classifications

GROUNDWATER QUALITY		
CLASS	RESOURCE USE	COMPATIBLE DISCHARGES
GAA	Public and private drinking water supplies without treatment	Restricted to wastewaters of human or animal origin and other minor cooling and clean water discharges.
GA	Private drinking water supplies without treatment	Restricted to wastewaters of predominately human, animal, or natural origin which pose no threat to untreated drinking water supplies.
GB	May not be suitable for potable use unless treated because of existing or past land uses.	All the above plus it may be suitable for receiving certain treated industrial wastewaters when the soils are an integral part of the treatment system. The intent is to allow the soil to be part of the treatment system for easily biodegradable organics and also function as a filtration process for inert solids. Such discharges shall not cause degradation of groundwaters that could preclude its future use for drinking without treatment.
GC	May be suitable for certain waste disposal practices due to past land use or hydrogeological conditions which render these groundwaters more suitable for receiving permitted discharges than development for public or private water supply. Down-gradient surface water quality classification must be Class B or SB.	All the above plus other industrial wastewater discharges that do not result in surface water quality degradation below established classification goals. The intent is to allow the soil to be part of the treatment process.

*NOTE- The State policy regarding the dischargers responsibility for owning or having other property rights to a groundwater discharge zone of influence is implemented during the State's discharge permit review process and is applicable, no matter what the groundwater quality classification is.

Summary

Despite a lack of comprehensive ground water management in Rhode Island, some aspects of ground water protection and allocation are inherent in the policies of various agents. The federal government has decided not to attempt a new ground water program, but to rely on existing programs to help states manage ground water quality. These programs relate to clean surface water (which may be induced into ground water by heavy pumping), hazardous waste, drinking water supplies, and pesticide controls. Perhaps the most important programs involve data collection related to ground water resources, a crucial element of any management attempt.

The state has numerous programs which are related to individual facets of ground water management but are all lacking to some degree. The WRB attempts to define the resource, but its perspective is biased towards surface water and the provision of very large public water systems. It lacks regulatory authority over land use, and since purchase of ground water aquifers is very expensive but its only method of protecting quality, the WRB is unable to "manage" ground water. DEM has regulatory authority but only over certain threats to ground water, such as landfills, septic systems, hazardous waste, sludge disposal and surface water quality. DEM is denied broad authority to protect ground water since ground water is excluded as a "water of the state". DOH has broad powers to protect water quality but only when the source is for drinking purposes and is a public source. DOH does not attempt to protect the unused resource or private wells. The SPP develops statewide plans but has not attempted comprehensive water supply planning, since this authority

was delegated to the WRB. SPP has developed data on threats to ground water quality and has attempted to establish authority to protect ground water quality at both the state and local levels.

Municipalities have shown a stubborn reluctance to return any land use control to the state. Yet, cities and towns have refused to push their own authority to land use control of ground water resources. Each level of government thinks it is more capable of regulating than the others but each complains of the lack of financial or technical resources to regulate. New legislation may explicitly grant towns the authority to regulate land use for ground water protection, but there will likely be numerous problems associated with inter-municipal allocation of resources and the protection of resources in one town to be used in another.

The courts play a role in so far as ground water is perceived as private property and individuals are liable for damages to others' property. Historically, however, the courts have evidenced an ignorance of ground water principles and thus have been reluctant to provide substantial protection to individuals or the public from contamination or excessive use of ground water. This, and the post hoc nature of litigation, means that little reliance should be placed on the courts without substantial foresight authority being given to some public agent.

The nature of ground water requires a more comprehensive approach than other resources. Threats to quality and quantity are diverse and insidious. Contamination may require many decades to be purged, and unplanned development of large wells or urban

activity may preclude other, more valuable uses of ground water for drinking water supply. An understanding of the current management is necessary for better management but not sufficient. One must first examine what complete management should achieve (in terms of objectives, not necessarily specific programs) and the institutional limitations of existing state policy agents.

Chapter 5. Developing Ground Water Management in Rhode Island

Ground water management is a classic planning problem for it involves the public interest as it is affected by many actors, public and private. It involves balancing competing uses of the land and water and adopting a perspective of many decades. Ground water is replenished by precipitation, but ground water movement is so slow that pollution may be irreparable. Ground water management requires balancing interests and having foresight.

Ground water management is a proper role for government because it involves future generations which have no voice, externalities among current and future users, and requires consideration of cumulative rather than marginal impacts. Present users may not need ground water supplies and may opt not to preserve their quality. Future generations, however, may find a shortage of public drinking water, and may wish that urban development had been regulated over aquifers, or that recharge areas had been preserved. The cost of purifying water for future generations may well justify preservation in the present. Even in the present, economic externalities exist among ground water users. One firm may profit by allowing waste disposal on its land, but when ground water polluted by the waste forces another firm to abandon its well, the latter must bear the costs. One, or even several, landowners may have septic systems which have little effect on the ground water quality. However, a subdivision of 50 units on half acre lots may release enough nitrates to render the water unpotable. No one landowner caused the problem; rather, it was due to their cumulative impact. Hence, no one owner could

be expected to forego developing his land, or purchasing four half acre lots for one house. Management thus requires a perspective broader than individual landowners.

Ground water is a resource which should be managed for more than supplying the public with all the drinking water it can use. Private household wells may be located nearly anywhere, and no one should be allowed to render private supplies unpotable without purchasing that right. Ground water serves as more than drinking water, however. Ground water supplies the roots of trees and other vegetation. It supplies a base flow for streams and wetlands which play important roles in ecological systems. If too much ground water is removed, the land may subside, causing foundations and structures to crack and collapsing of water-holding pores in the soil. Hence, use of ground water for large drinking supplies must consider the entire hydrologic system.

Moreover, public water supply policy should not limit itself to providing as much water as the population might demand. There are competing uses of water and capital. Supply systems involve great expense for reservoirs, pumping and distribution. Policy can reduce demand as well as increase supply (e.g. by progressive pricing structures), making scarce capital available for other uses. Ground water is only part of the water resource. Public drinking supply is only one of the uses of this resource. Hence, water resources management should include ground water as an integral element, and should treat public water supply as only one of many uses of water - ground or surface.

Appropriate level of government

The state would seem to be the most effective level of government to manage ground water in Rhode Island. The federal government cannot realistically develop specific policies which are appropriate for all the differing hydrologic situations throughout the country. Moreover, ground water management involves choices among possible uses of land, water, and capital - choices from which the federal government is too removed to make equitable decisions. The federal government can, however, sponsor research in areas of hydrology and resource management which might pertain to more than one state, perhaps saving states from redundant work. The federal government may also have a role in ground water issues which affect more than one state. For example, aquifers may cross state boundaries, and industry may have to choose among several locations. The federal government can require consistency among states in ground water management to ensure that one state's activities do not harm another's waters, and that ground water management is not used exclusively for economic development purposes.

Local governments have been proposed as the most efficient level for ground water management in other states. Rayner (1972) argues that local governments are best suited for ground water management because they overlies the areas being controlled, are more responsive to public demands and more sensitive to the special needs of the citizenry, and local control means that those who benefit from management pay for it. He notes, however, that local governments are often unwilling to fund activities which they admit are needed especially when the costs are short term and the

benefits long term. Moreover, Raynor's arguments are based on the situation in a large state (Texas) where "local government" may encompass the entire ground water supply. In Rhode Island, however, nearly all of the aquifers underlie more than one town (see Figure III-1. which makes an aquifer-wide approach by one town nearly impossible. In addition, past plans (e.g. Metcalf and Eddy, 1967, 1979, Maguire, 1968) proposed developing ground water as a supply for a town far removed from the aquifer (for example, supplying Newport with water from Exeter), which makes local control impossible except via complex intermunicipal agreements between supplier and consumer (which may involve pipelines across still other towns).

The state should be best able to manage ground water in Rhode Island. The small size of the state means that statewide programs can reflect the specific hydrogeology of Rhode Island's aquifers. Problems of protecting aquifers underlying more than one community and arranging intermunicipal water transfers should be easier at the state level than the local level. State agencies have experience with developing ground water data and implementing other environmental regulatory programs. They also have technical staff which are knowledgeable about the particular ground water problems in the state, and have expertise in ground water hydrology. It was the states which originally relinquished authorities to the federal and local governments. The states are thus the ultimate authority to develop new policy to protect their resources, and to fund the programs to implement that policy.

A fourth level of government might help to integrate the broader perspective of state level management with concerns at the local level about relinquishing control of land use. Although Rhode Island is a small state, equivalent to "regions" within other states, an intra-state "regional" government may provide communities with more control over the policy formulation and implementation specific to each aquifer. Inputs to policy formulation might include determining how much growth should be allowed, and thus how much water will be required and how much of that can be provided by small domestic wells. When towns encourage development that relies on high quality ISDSs, recharge of the ground water is preserved and active management of ground water allocation may be simpler, if needed at all. Intra-state "regional" governments may have greater local credibility in determining the proper level of compensation when ground water is pumped for use in another community especially when this requires land use regulation by the original community to preserve ground water quality. This regional government may take the form of districts coterminous with the aquifer boundaries, or may include the entire towns. These decisions depend on what is to be controlled. Innovation will be the prime ingredient in overcoming past obstacles and achieving a more responsive institutional arrangement.

The nature of ground water management

Ground water management encompasses both policy and programs. Policy should be developed to define public goals. Policy implementation is the development of programs to support policy goals and evaluating those programs to determine their effectiveness, perhaps leading to a reformulation of policy and adjustment of programs. The term, "management", is used here to encompass this dynamic, iterative process of policy formulation and implementation. It is difficult for this writer to specify what the "ideal" ground water management should be, since it requires a determination of goals and probably a resolution of conflicting goals. Ground water hydrology and policy science can suggest guidelines for management, and numerous writers suggest policy choices which will need to be made. Other states have taken an active role in ground water management, and, with the EPA, provide guides for policy and programs.

Five principles serve as guidelines for ground water management. First, it should reflect hydrogeological principles and laws. (Cassel, 1979, Weston, 1976) Otherwise it will be unrealistic and will not last. For example, there is no hydrologic distinction between underground streams and percolating ground water. The distinctions made by the courts are invalid and lead to gaps in protection.

Second, management requires policy on what constitutes appropriate use of ground water (Weston, 1976). If all ground water is to be usable for drinking supplies, much more management is required. If some may be used for waste disposal, then landowners' rights to ground water may need to be purchased, and different

monitoring programs will be required to safeguard downstream ground water.

Third, management should seek to maximize economic efficiency (Weston, 1976, Adams, 1978). Legal doctrines in other states have not allowed land owners to transfer water from the parcel from which it was pumped. This was judged as an "unreasonable" use. The firm could, however, buy a narrow strip of land to connect two parcels and then pump all it wanted, even to the detriment of neighboring wells. Such a policy neither protects other users nor addresses the possibility that the firm may wish to pump only a small amount of water, and could make efficient use of the water, rather than perhaps requiring a long pipeline from some other source. The decision as to whether ground or surface water should be the source of public supplies should include evaluations of opportunity costs of flooded land, and expected energy costs of pumping wells (among many other considerations). Uncertainties are inevitable in these calculations, such as technological changes or unexpected population growth, but patently adopting an ultraconservative approach in favor of either ground or surface water may be more costly than a plan based on reasonable estimates which prove to be slightly inaccurate. It is certainly unfair to discount future generations and their need for potable water - and usable land.

Fourth, management to achieve certain policy goals may require new authorities (Dawson, 1979). Agencies will be unable to develop programs beyond the legislated authority without the risk of expensive litigation.

Finally, ~~new~~ legislation should specify the limits of various implementors to make policy in various areas, as well as stipulate where agencies will be expected to make policy. A clear, well defined role for implementors means they will more likely assume the responsibility they should, and forego making policy when they should not (see, e.g., Pressman and Wildavsky, 1980, Nakamura and Smallwood, 1980).

Policy formulation

Ground water management means that policy choices will be required. These choices arise from two sources. First, goals for ground water use must be established. The purpose of policy is to move toward these chosen, and perhaps idealistic goals. The goals may never quite be achieved but serve as a "beacon" to guide action. Second, ground water goals and policies will be formulated in a complex environment of other goals and policies, some of which will undoubtedly conflict with ground water goals. Development of ground water policies must therefore include the existing policies in other areas. Policies in the conflicting areas must also be reformulated to reduce the conflicts between various goals.

In discussions of goals for ground water use, most authors recognize water supply as the most valuable use of ground water. However, ground water serves other important functions such as maintaining the baseflow in streams and wetlands, crucial for certain aquatic and terrestrial habitats. There are both quantity and quality considerations for both water supply and ecosystem maintenance. Some of these choices are presented in Table V-1, Step 1.

Quantitative aspects of ground water for water supply involve decisions as to the amount required. These needs should be couched in a statewide water supply plan. Bartel (1973), in a study of water supply alternatives in Rhode Island, commented: "If there is an issue that transcends all others encountered in this study, it is the need for a clear definition of policies and objectives for water resources development in the state." (p. 3-28). This determination should consider future as well as present users, economic efficiency of various public water supply alternatives (including opportunity

Table V-1. Development and Redevelopment of Ground Water and Related Policy.

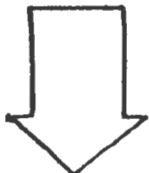
Step 1.
Develop Ground
Water Goals

Water Supply		Ecosystem Maintenance	
Quantity	Quality	Quantity	Quality
* All water supply from ground water?	*All drinking quality?	*Preserve low flow in streams?	*Prevent pollution of streams by discharging ground water?
* All from surface water?	*Some degradation allowed? where? how much?	*Which streams? how much flow?	
* What factors determine balance? costs?	*Goals for parts of aquifers?	*Certain species of fish more valuable?	*Heavy ground water use reduce surface flow, concentrate pollution already in streams?
	*Degraded aquifer reduce useable quantity?	*Which aquifers feed valuable wetlands?	
	*Treatment possible for polluted aquifers?		

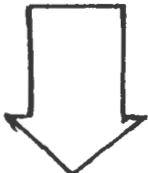
Step 2.
Consider Existing/
Future Policies
with Respect to
Ground Water Goals

Land Development
(location, density, timing)
Residential - no public sewer/water

Residential - both public water/sewer

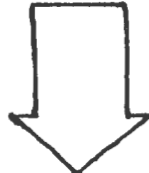


Recharge ground water with storm runoff

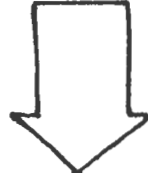


ISDS installation/maintenance, density
Well construction

Contaminated runoff



Recharge



Nitrates, detergents into streams, wetlands

Contaminated runoff

Table V-1 (cont.)

	Ground Water Management Goals			
	Water Supply		Ecosystem Maintenance	
	Quantity	Quality	Quantity	Quality
<u>Land Development</u>				
Commercial/ Industrial (including economic devel- opment)	Recharge Well interference	Polluted runoff Handling/spills of hazardous materials/ waste		Polluted runoff Handling/spills of hazardous materials/ waste
Agricultural		Use of fertili- zers/pesticides Selective pre- servation?		Polluted runoff
Transportation	Recharge	Bare pavement - use of salt		Bare pavement - use of salt
<u>Waste Disposal</u>				
ISDS Residential/ Industrial		Density Maintenance Industrial loading		Pollution of surface water
Landfills		Leachate (**)		Leachate (**)
Land Spreading		Leachate (**)		Leachate (**)
Seepage lagoons		Infiltration (**)		Infiltration (**)
Hazardous waste		Leachate, spills (**)		Leachate, spills (**)

Table V-1 (cont.)

	Ground Water Management Goals			
	Water Supply		Ecosystem Maintenance	
	Quantity	Quality	Quantity	Quality
Hazardous Materials Use				
ISDS "cleaners"		Individual wells - contamination Leak monitoring		Leak Monitoring
Storage (e.g. gasoline)				
Transportation		Spill containment		Spill containment
Public Water Supply				
Development of surface water	Integration of ground water resources Appropriate comparison criteria: land costs, pumping costs, transmission costs, etc.	Induced infiltration	Stream flow maintenance	
Environmental Quality Monitoring and Data Collection				
Surficial geology investigations	Location, extent aquifers	Plume movement Discover pollution early	Accurate predictions of stream flow effects	
Surface water investigations	Predict ground water baseflows	Predict induced infiltration problems		

(Double asterisk (**) implies substantial consideration in existing policy.)

costs of flooded land), and provisions for conservation. Simply providing all the water the population might want is not economic (Bartel, 1973). Private well supplies should be considered as well as large public supplies, an omission in current WPB planning and DOH monitoring. In determining needs and the role of ground water in supply, hydrologic data will be essential. Fortunately, Rhode Island has been as thoroughly studied as any other state, and a wealth of data is already available (Calise, 1982).

Other potential uses of ground water for water supply include livestock watering, irrigation, and industrial processes, and even waste disposal. These needs should be assessed and policy developed as to what role Rhode Island's ground water should play. Some states (e.g. Arizona, EPA, 1976) rank water users to decide which have priority in conflicts. Ranking usually gives top priority to drinking supplies, then livestock, agricultural operations and industry.

Once needs for ground water are determined, standards for quality may be devised. If not all of the ground water will be needed for high quality uses, or if some is already degraded, some ground water resources may be allocated for users needing lower quality - such as for waste disposal, or industrial development. It is entirely possible, probable even, that enough uncertainty about the future exists that all ground water should be maintained as pristine as possible. This policy decision should be explicit, however. Some states (e.g., Connecticut, see EPA, 1976) classify ground water much as surface water in terms of quality - in some cases as a goal to be achieved. Some

states only regulate aquifers where the quality of ground water is already below certain thresholds for dissolved solids (see Wickersham, 1981). Agencies may thus concentrate their efforts on those aquifers of reasonable quality.

Goals for ecosystem maintenance also include both quantitative and qualitative aspects. Minimum streamflow considerations may limit the amount of water pumped from certain wells, when that water is not allowed to recharge the aquifer (such as when sewers carry waste water to rivers or water is transferred to other basins).

Goals should be area-specific, perhaps different for different aquifers. With improving capabilities for the prediction of ground water flows, it may be reasonable to establish separate goals for different parts of the same aquifer, maintaining the upper parts for water supply, and the lower parts for uses requiring less than perfect quality. Recharge areas must be included in these policies since they are integral to the aquifer.

Ground water is affected by so many and varied activities of man that ground water policy must be integrated with other policy areas. Table V-1 lists some of these areas in Step 2, with the considerations most important for ground water management. The reader is cautioned that the list is not exhaustive. Other concerns undoubtedly exist especially at the local level, and new threats and considerations will probably emerge in the future. The principal policy areas of concern are land development, waste disposal, hazardous materials use, provision of public water supply, and environmental monitoring and data gathering.

Land development has been arbitrarily divided into residential, commercial/industrial, agricultural and transportation. This could be called land use, except that current land use is largely fixed in place. Future development can be shaped to conform with ground water goals.

Three parameters cut across all land development: location, density, and timing. Clearly, certain locations (such as primary recharge areas) are more sensitive than others. Many problems can be avoided by controlling the density of the land use (e.g. ISDS). Finally, when the land is developed may be important, both to stagger major short term impacts (such as heavy construction) and to monitor the cumulative impacts so that as each impact is assessed, a better idea of the ultimate carrying capacity of the aquifer is possible.

Waste disposal has been the most obvious threat to ground water quality. Consequently, these activities have been more thoroughly controlled. Existing waste disposal policies strive to prevent all ground water contamination from existing and future waste disposal operations, and these policies continue to be refined. Once ground water goals are determined on an area-specific basis, some relaxation of ground water protection may be possible in limited areas.

Hazardous materials uses are largely uncontrolled. This activity will probably require new policies and programs regarding ISDS "cleaners", chemicals storage, and transportation of substances which, if spilled or leaked, may degrade ground water quality. It is doubtful that local spill response crews (usually firemen) know which areas are most sensitive to ground water pollution. Policies and programs may

be developed to prevent inadvertant worsening of pollution from spills in highly permeable aquifer areas (e.g. to prevent large amounts of water being used to "wash away" the spilled materials, only to result in infiltration into the aquifer).

Public water supply plans are currently focused on large surface water supplies. Small local demands and ground water have been inadequately considered in the past, with the possible consequence of a loss of potential resources. Some coordination statewide is essential to integrate supplies and ground water protection between towns.

Ground water policies will require further monitoring and data collection to define the resource and to ensure that the resource remains useable. Surface water and ground water should be treated as the integrated resource they are.

Policy choices thus must reflect ground water goals and existing policies. This policy formulation process must include many interests and agencies at several levels of government. Policy should not be left to water development interests, public or private, or even those actors responsible for regulation. Policy formulation should be coordinated by some party with broad perspective and foresight in order to resolve the conflicts inherent in multiple uses of the land and water resources. These choices will be difficult and fraught with political and economic pitfalls, but only if they are made can programs be designed to effectively manage the ground water resource and activities which affect it.

Program choices

Program development, operation and evaluation is the implementation aspect of policy. In developing programs to implement policy several considerations are important (see e.g. Hatry et al., 1976). First, the program design should consider the actors intended to implement it. Their mandate must be clear and not conflict with other mandates. For example, DOT has a mandate to prevent traffic accidents by applying road salt. Aquifer protection may not be consistent with the clear, simple historical mandate for highway safety. The programs should depend on as few actors as possible, for the more actors involved, the greater the opportunity for misunderstandings, delays in communication or other problems in coordination. Legislative authority must be clear. DOH will not adopt a program for monitoring aquifers not used for public supplies until such responsibility is clearly established, even though DOH has the laboratory capacity for water quality analysis. In addition, any agency delegated to develop and/or to do something without providing the needed resources means a less than optimal enthusiasm, and probably less effective implementation of other programs. For example, the individual in DEM responsible for the underground injection control program in Rhode Island directs four other programs, often with demands more immediate in nature, which means the UIC program may be relegated to "spare time" (Annarumo, 1982).

Program choices in implementing ground water policy involve choices of techniques and targets. Table V-2 lists possibilities which have been used or proposed by various states and authors (see, e.g., Hanks and Hanks, 1968, EPA, 1976, Weston, 1976, Adams, 1978, Wickersham, 1981,

Table V-2. Ground Water Management Program - Techniques and Targets

<u>Program Techniques</u>	<u>Targets</u>	
<u>State Regulation</u>	<u>Ambient Quality</u>	<u>Mining</u>
Permits	Air	Operation
Performance Standards	Surface Water	Closure/ Reclamation
Licensing Operators	Ground Water	
Construction Standards		<u>Transportation/ Handling of Liquids</u>
Emission/Effluent Limitations	<u>Wells</u>	Pipelines
	Drilling	Sewers
	Pumping	Spills
<u>State Information Gathering</u>	<u>Waste Disposal</u>	
Monitoring Wells	Solid	<u>Highway Deicing</u>
Discharge Reports	Hazardous	
Site Identification/ Registration	Sewage Sludge	<u>Land Development</u>
Hydrogeological Data	Septic Systems	Density
	Agricultural	Location of Uses
<u>Other State Programs</u>	<u>Land Spreading</u>	Impermeable Surfaces
Public Education	Waste	
Public Investment	Fertilizer	
Emergency Response to Spills	Pesticides	
	Irrigation	
<u>Local Ordinances</u>		
Zoning	<u>Storage</u>	
Subdivision Regulations	Waste	
Other Ordinances	Gasoline	
	Other	

Source: See accompanying text.

and Giese, 1982). Which targets are addressed depends on how well the state can afford not to address targets, i.e. the perceived threat (perceived by analysts, not necessarily the public, though public perceptions of threats may make implementation easier). Which techniques are chosen depends on general policy implementation considerations (e.g., Hatry, et al., 1976), the seriousness of the threat, and the difficulty of reversing the target activity. A few examples illustrate the point. It would be unwise to expect the WRB to regulate environmental polluters, since the WRB has traditionally been limited to purchase of land and facilities. DEM would be a more logical choice since it has experience in regulating and has the institutional "infrastructure" in place (vehicles, secretaries, legal expertise). Permits would be appropriate for potentially major polluters, such as gasoline tanks or hazardous waste storage, or for "permanent" structures such as septic systems and pipelines. Performance controls might be appropriate for highway deicing or agricultural pesticides where the level or method of use is important. Information gathering via monitoring wells or registration of potential polluters (or well analyses) allows the state to plan future ground water programs based on the quality of the resource or the likelihood of a particular pollutant in a particular place (e.g., to ensure local firefighters do not automatically spray water on toxic chemical spills, which makes collection of the toxic material more difficult).

Public education seems essential in order to develop support for programs. An enlightened public will also avoid polluting ground water - with septic system "cleaners", for example. People who know what to look for can report a problem before it becomes a hazard,

whether it is a failing septic system or a neighboring business storing strange barrels. Education has increased public support for clean-up efforts in Narragansett Bay. Ground water more directly affects many people (they do not drink from the Bay) - the public should be capable of providing substantial support for ground water programs once they understand its importance.

Municipalities have traditionally controlled land use and development, and in Rhode Island have been unwilling to relinquish that control to the state. Once enabled, some communities will undoubtedly wish to protect local aquifers by creating aquifer overlay districts or limits on land uses. Local protection can be enhanced and shaped to provide for statewide protection. State investment, consulting and other services can serve to coordinate local efforts. Communities may be required to adopt certain minimum measures and neighboring towns may be given standing to participate in land use decisions affecting inter-town aquifers. The WRB might take a more active role in helping communities negotiate for intermunicipal water transfers and easing public doubts about intermunicipal equity by ensuring that all costs are included in intermunicipal agreements.

Summary and conclusions

Rhode Island's existing programs can be summarized and compared with possible programs to discover weaknesses (Chapter 3 discusses these programs in detail). The state does monitor air and surface water and accepts certain ambient standards based on air and water quality plans. These plans do not include impacts on ground water. In fact, the only Water Quality Management Plan which attempts to address ground water (Pawcatuck River Basin) treats seepage lagoons as a way to prevent surface water problems, ignoring the resultant pollution of ground water! The only ground water monitoring is at known sites of contamination and public water supplies. Only sketchy data are available for the untapped aquifers or aquifer areas distant (but perhaps up gradient) to wells. Existing ground water quality data is surely inadequate for detailed planning purposes. Sufficient data do exist, however, for an aquifer by aquifer approach to planning water supplies or land use. Decisions can be made on the conservative side and relaxed as additional data are available.

There is no regulation of wells, well drillers, well pumping, or well construction (including location). The exception is a requirement in site plans for public supply wells for information about nearby polluters, and ground water quality standards in existing public supplies. Well drillers are supposed to inform the WRB of where wells are drilled and what materials were encountered during drilling, but what data is supplied is often of little use for planning purposes. A geographic computer data base might help to integrate ground water data with other (e.g. land use) data.

The state has developed programs to regulate and monitor various waste disposal activities, and includes various specific provisions for ground water protection. The major gap - industrial subsurface

non-hazardous waste disposal - will be addressed by the UTC program.

Storage of "hazardous" waste is regulated by the standards required by DEM. Other storage, e.g. gasoline, may be regulated by construction standards or local ordinance but little or no monitoring has been done to detect leaks. Local problems with poor ground water quality have developed and been traced, but have met with limited success in compensation or remedy.

Some transportation of fluids is regulated, especially if liquids are "hazardous". Highway deicing takes little regard of ground water.

Only one community, North Kingstown, regulates land use for ground water protection purposes. Several communities are aware of the need but are hesitant to develop ordinances without specific enabling legislation. Except for regulation of specific activities such as waste disposal, the state does not regulate land use for aquifer protection.

What programs do exist to protect ground water statewide do so in a ground water policy vacuum. There is no comprehensive plan or ongoing discussion of ground water resources, in terms of allocation, uses, recharge, or threats. There is not even a plan for water supply, which should be part of water resources management. There is a plan for surface water, with quality standards and goals, and with recommendations for programs to implement the policy, but this plan is inadequate in its consideration of ground water resources, and thus invalid.

The "ideal" in Rhode Island might be outlined. Some form of task force with broad representation but some technical expertise is needed to formulate policies for ground water use and protection. The aquifers

should be considered both individually and with respect to statewide needs. This task force will probably rely most heavily on SPP for policy guidance, the legislature and governor's office for legitimacy, and the WRB and USGS for hydrologic data. Towns should have input and hearings and information programs can incorporate citizen input. A strong state role is essential if policy is to have a statewide focus. Existing DEM programs controlling pollution of ground water could be given an explicit authorization, such as defining ground water as a "water of the state". Local government will retain land use authority but specific activities can be regulated by DEM if local government is lax. Planning functions in the WRB belong under the SPP or the DEM Water Resources Division. DOH should be required to monitor untapped ground water and should support DEM in its resource management efforts. The programs and policies of other agencies, such as DOT and DED should be examined to identify conflicts with ground water management, and these conflicts should be resolved. Public education is critical.

Ground water is a special resource. It should receive priority in water resource management because it supplies surface water. It should receive priority in general resource planning because once polluted, it may never be cleansed. These seem simple, powerful arguments for ground water management. Yet it does not exist in Rhode Island (except in pieces). Ground water is largely invisible - it simply appears when a homeowner turns on the tap. Ground water has the potential to provide high quality potable water for a large part of Rhode Island - it does so already. Those who depend on it now and those in the future who need it for drinking water, or some as yet unimagined purpose are not guaranteed the quality or quantity which may

be rightly theirs. The forces which may ruin Rhode Island's ground water have been and continue to be unchecked. Aquifers have been damaged by land development and waste disposal. Rhode Island has been spared many of the problems encountered by other states, but not by explicit choice. Policy efforts have been directed at other issues, usually less long range than ground water quality. Fortune cannot be relied on to maintain Rhode Island's existing resources. Not to manage is to lose.

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