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AN ANALYSIS OF SELECTED POLICY ALTERNATIVES TO ALLEVIATE GROUNDWATER CONTAMINATION IN MICHIGAN

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PREFACE

This report is drawn from a study by Jessica T. Kovan, supported by The Institute of Water Research and The Michigan Agricultural Experiment Station, both at Michigan State University. The full study is an unpublished Masters thesis for the Department of Agricultural Economics.

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INTRODUCTION

Contamination of both ground and surface water is a policy issue of increasing urgency in the United States. Approximately 50% of the total population uses groundwater as the primary source of drinking water from groundwater. This dependence is even greater in rural areas where over 85% of the residents rely upon groundwater (CAST, 1985, p.7).

Contamination is a predictable side effect of legitimate and important human activities. These activities threaten the quantity of available and usable groundwater. Yet, because the resource is both buried and hidden, the identification and investigation of the problems of pollution are extremely complex. In addition, the clean-up of contaminants can be exorbitantly expensive. The central purpose of this report is to identify to what extent changes in Michigan's existing institutional structure could alter the human behavior leading to groundwater contamination.

THE GROUNDWATER RESOURCE

Groundwater is the water that saturates the spaces between the particles of soil and rock under the land surface. This water moves very slowly, both vertically and laterally, through forces of gravity and capilarity. The flow, which is considerably slower than that of surface water, may be measured in inches per day or feet per year. The speed and

amount of water moving through the soil depends on the porosity of soil or rock which makes up the formation. Thus, coarse-grained sediments such as sand and gravel permit the most rapid movement while fine-grained sediments, clays and silts, allow slower movement (CAST, 1985).

Groundwater is part of the flow system which moves from recharge areas to discharge areas. Recharge areas are those areas where a significant amount of groundwater is added to the aquifer. The place where groundwater is removed, such as rivers and streams, is considered the discharge area. An aquifer which has a large amount of porosity and permeability is capable of transferring significant amounts of water to the discharge point.

There are two classifications of aquifers; unconfined and confined. An unconfined aquifer is located near the land surface with its upper boundary being the water table, while confined aquifers are found further beneath the surface. Below and above the confined aquifer are impermeable layers of bedrock constantly keeping the water under pressure (Freeze and Cherry, 1979). Hence, an aquifer may be just below the surface of the land or can be hundreds of feet down. Its size can vary from a few acres to thousands of square miles.

Groundwater Quality in Michigan

In Michigan, a state bounded on three sides by the Great Lakes, approximately half of the residents depend on groundwater as a source of drinking water (Libby et al., 1986). Groundwater supplies 17% of public water systems and nearly

100% of private water supplies in Michigan (Bedell, 1982, p.43). The water is also heavily used in agriculture and industry. Irrigation withdraws 37% of the total water used from groundwater (Bedell & VanTil, 1979, p.37). As of July 1985, however, over 1000 contamination sites (known or suspected) have been identified throughout Michigan, and the number increases monthly (MDNR, 1985, p.1).

As is true in much of the U.S., this water resource is poorly understood in Michigan. Information within the state on groundwater geology, quantity, and quality is diffuse and inadequate (MDNR, 1985). Legislative guidelines mandating the use of the water are a potpourri of laws which provide a minimum of direction for the resource (MSU, 1985).

Physical Characteristics of Contamination

Within this analysis, groundwater contamination will be defined as the addition to water of elements, compounds, or pathogens that alter its composition (Pye et al, 1983, p.49). Pollution occurs when the concentration of contaminants alters the water to a point where it is "unfit" for present and future uses. This may be a consequence of physical and/or economic reasons and is directly related to how the water is being used. It may be "too costly" to overcome the quality problems in terms of what individuals or society may be willing to pay. The benefits of obtaining clean water from a particular source may be less than the costs involved.

Groundwater contamination occurs underground and out of sight, which creates a major difficulty for detection.

Sources of pollution are not readily observed and too often the contamination goes unnoticed until the damage is economically or technically irreversible. The actual tangible effects of contamination are visible long after the incident which caused the pollution. Thus, long time lags between occurrence and detection are a major impediment to identifying the source.

A large variety of compounds, both natural and man-made, are the constituents of groundwater pollution. The pollutants will usually enter the groundwater system from the surface of the land, percolating downward into the aquifer. Plant roots, small microorganisms, and other biological processes may remove a fraction of the contaminants, the amount being dependent upon the type of pollutant (Pye et al, 1983). Once in the aquifer, the movement of the pollutant is affected by both its density and its solubility in water. Movement within the aquifer is generally very slow. The rate can vary from a fraction of an inch to a few feet per day. Dispersion over time will cause a spreading of the contaminant in a particular flow pattern. The solute will continue to flow with the groundwater until it eventually reaches a point of discharge. Thus, unlike surface water, very little dilution of the contaminants takes place in groundwater (Pye et al., 1983).

This report focuses upon nonpoint sources of contamination with special emphasis on agricultural activities. Agriculture is increasingly recognized as a prominent nonpoint source of

groundwater contamination.[1] The major increase in usage of agricultural chemicals over the last 20 years is believed to have had large effects on the increasing levels of nitrates found in groundwater (Porter, 1977). The increased use of irrigation, pesticides, fertilizers, and changes in vegetative cover have all affected the quality of groundwater. Contamination is occurring as a residual of production practices.

Nitrate Contamination of Groundwater

The large growth in use of nitrogen fertilizers after World War II is correlated to the increasing concentration of nitrate levels found in plants and groundwater. Several studies have confirmed the linkage between nitrogen fertilizers and groundwater contamination at sites throughout the U.S. (Olson, 1985). With the confirmation of direct correlation between fertilizers and nitrate levels the United States Environmental Protection Agency (E.P.A), and many regional, state, and individual research projects, have begun investigating this pollution problem. Some states have actually introduced legislation to control the use of nitrogen fertilizer (Olson, 1985). Public knowledge concerning the problems which exist between nitrogen fertilizer and the environment is increasing.

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[1] Nonpoint source contaminants are defined as those (1) generated by diffuse not identifiable land use activities; (2) conveyed to groundwater and surface water through natural processes rather than by deliberately controlled discharge; and (3) not susceptible to "end of pipe" treatment, but controllable by changes in land management or process practices (CES, Jan. 1985, p.7).

The nitrogen found in crops is derived almost entirely from inorganic forms, principally nitrate, ammonium, and gaseous nitrogen. The general behavior of nitrogen found in the environment is complicated. It occurs in many areas within nature; the atmosphere, plants, animals, humans, soils, minerals, surface water, and groundwater. Most of the nitrogen in soils and organic residues is present in organic forms, which transformed by microorganisms create nitrates.

Nitrogen is a primary nutrient in most fertilizers used in crop production (CAST, 1985). These fertilizers contain nitrates, ammonium, or compounds which are easily converted to ammonium. Under favorable conditions of moisture, temperature and oxygen supply, the process of nitrification is enhanced. Thus, the potential for loss of nitrate to groundwater is increased when relatively large amounts of nitrogen fertilizer are added (CAST, 1985). Freeze and Cherry (1979) state that nitrates are the most common contaminant found in aquifer systems, while it has been shown that agricultural activities are the largest source of increased nitrate levels in groundwater (Madison & Brunett, 1984).

Nitrogen fertilizer contributes to several possible contamination problems. Case histories have shown nitrate poisoning of livestock which have consumed forage high in nitrate. Plants which have been killed for a variety of reasons continue to absorb nitrate for a period of time without assimilating the nitrogen. The animal consuming the

forage may die due to the excess of plant nitrates (Garner, 1958).

For citizens, especially in the rural sectors, nitrate accumulation in groundwater can have negative health implications. The primary illness occurring from drinking water containing large levels of nitrate is that of methemoglobinemia (Olson, 1985). Gastric cancer, nervous system impairment and birth defects have also been connected with excess nitrate (Olson, 1985). Methemoglobinemia is largely a problem with infants, especially a child suffering from diarrhea. Contraction of this illness can result in the 'blue baby' syndrome; death from asphyxiation. It must be noted that not all users of contaminated groundwater will become ill. A risk factor exists when defining the probability that an individual will develop negative side effects from drinking high concentrations of nitrates.

INSTITUTIONAL SETTING FOR GROUNDWATER POLICY

Groundwater management has been very slow to develop. Groundwater supply and quality data are expensive to acquire and contamination occurs underground, out of sight of those affected. Public awareness of groundwater in the United States began in the 1800's as the population expanded westward and the need for tapping groundwater increased. As the demand grew, the need for policy arose. Slowly a system of private rights has evolved to deal with management controversies.

Rights to Groundwater

Michigan employs the riparian doctrine which, in the case of surface water, grants water rights to those individuals who own land adjacent to a watercourse. The riparian doctrine originated from English common law guaranteeing that water owned by the riparian would not be diminished in either quantity or quality. This has been modified in the United States to include the rule of reasonable use, which permits some change in quantity or quality if the diminishment is deemed reasonable (Meyers and Tarlock, 1980).

For groundwater, the rule of reasonable use grants restricted rights to the overlying landowner. The water must be put to purposes of beneficial enjoyment of the land from which it was taken (Meyers and Tarlock, 1980). Thus, all neighbors have equal rights to the use of the water found under their land as long as the use is "reasonable". A landowner's right to the underlying groundwater is restricted to the quantity necessary for use on the land. Transporting water off the land from which it was pumped is generally not allowed and water withdrawn and used on the land must not be wasteful or malicious (Rota, 1985). One of the fundamental tenets of the riparian doctrine is that the amount of water a riparian may use depends on the purpose and amount that others are using (Meyers and Tarlock, 1980). Hence, there is a strong necessity for the riparian owner to understand how the use of the water will affect others.

In Michigan, the basic law of groundwater is nuisance litigation. "Reasonable use" is applied as the basis for declaring a nuisance. The court's decision is determined by case law and the cost of litigation to pursue a claim of unreasonable use is very high (MSU, 1985). A distinction is made between intentional or unintentional damages. Reasonableness is based on four determinants; (1) the physical characteristics of the land; (2) conflicting uses of the water; (3) the economics of the surrounding community; and (4) local politics (MSU, 1985). Hence, with the basic law of groundwater being dependent on defining "reasonableness", the law inevitably has elements of both science and politics.

Local Government Role in Michigan Groundwater Policy

Local governments are granted a variety of powers by federal and state authorities. The general law controlling water pollution for Michigan is the Water Resources Commission Act, Act 245, P.A. 1929. It has three main provisions which are implemented by local authorities;

(1) Permits are required for all dischargers of waste into water systems in order to control water pollution;
(2) The collection of fees from regulated dischargers; and
(3) Compliance enforcement of dischargers with permit requirements (MDNR, 1985, p.21).

The use of Act 245 as a monitoring device over agricultural pollution is restricted. The controlled application of agricultural fertilizers for normally accepted uses does not require a permit and also does not require groundwater monitoring (MDNR, 1983). Thus, the township does not keep records of the amount of fertilizers applied to the land and

monitoring of groundwater is only done randomly, unless by the private individual (Kirkpatrick, 1986).

Local authorities can assist in groundwater protection in a variety of ways, depending on the amount of funding and staff allocated to this goal. The assistance can come in forms of; (1) data collection, analysis, and dissemination; (2) land use planning and zoning; (3) development of local groundwater protection programs; (4) educational programs; (5) technical assistance to businesses; and (6) cooperation with state programs (CCEP, 1984). The Cabinet Council on Environmental Protection (CCEP) recommended that the local government role emphasize land use zoning as a technique for isolating high-risk activities from drinking water sources (MDNR, 1986). CCEP also stated the importance of close contact between local health departments and the public, for often this type of authority is the first to be notified in cases of groundwater contamination (CCEP, 1984).

State of Michigan Role in Groundwater Protection

The state policy of groundwater quality is directed toward the fulfillment of three main goals; (1) prevention of future pollution and protection of public health; (2) maintenance of high quality groundwater supplies; and (3) provision for the opportunity of economic development (CCEP, 1984). To achieve these goals the actions of the state are based on the following policies:

(1) protection of drinking water aquifers;
(2) limiting human exposure to critical materials;
(3) encouraging economic development by assisting developers in locating where there is a low risk to drinking water

supplies and by developing regulations that do not overly burden commerce;
(4) considering future groundwater needs; and
(5) coordination of inter-agency programs with state goals for groundwater management (CCEP, 1984).

The authority for the groundwater quality program in Michigan is derived from a conglomeration of several state laws. These are summarized in Figure 3.1. There is no comprehensive legislation governing the regulation, utilization, and administration of Michigan's groundwater resource.

Federal Role In Groundwater Protection

State rules of water law define the nature and limit of

Act 64 of 1979 - Hazardous Waste Management Act
Specifies the engineering of hazardous waste landfills and provides for the licensing and regulation of individuals engaged in the use of hazardous waste.

Act 127 of 1970 - Michigan Environmental Protection Act
Provides methods to protect the air, water, and other natural resources through judicial proceedings regarding environmental standards.

Act 243 of 1951 - Servicing of Septic Tanks, Seepage Pits, or Cesspools
Regulates the licensing and bonding of the servicing and cleaning of septic tanks, seepage pits, or cesspools.

Act 245 of 1929 - Water Resources Commission Act
General water pollution law regulating discharges to groundwater and grants permitting for certain discharges.

Act 307 of 1982 - Environmental Response Act
Michigan's version of the federal "Superfund" program.

Act 368 of 1978 - Part 127, Groundwater Quality Control
Authority for monitoring water supply and quality through the Public Health Code.

Act 399 of 1976 - Michigan Safe Drinking Water Act
Protects public health by providing for supervision and control over public water supplies.

Act 423 of 1984 - Underground Storage Tank Registration
Requires the registration of particular underground storage tanks.

Act 641 of 1978 - Solid Waste Planning and Management Act
Regulates the management of solid waste.

Figure 3.1: Major State Laws Affecting Groundwater

water rights, however the federal role in water resources should not be ignored. Federal policies in the late 1980's clarifying the responsibility of the state in protecting groundwater have increased. There are numerous programs within the federal government to deal with groundwater quality protection, and federal powers can take precedence over water use rights created by the state. Yet, no explicit, comprehensive national mandate exists to protect groundwater quality.

Federal laws and programs do not address all sources which contaminate groundwater or have the potential. Non-hazardous, non-waste, and nonpoint sources have much less stringent requirements than point sources, especially hazardous wastes (OTA Study, 1984). Further, there is no concentrated federal effort to collect, analyze, and use groundwater quality data (CEQ, 1984). Protection efforts for groundwater quality are fragmented and there is no single agency or organization responsible for all groundwater programs.

There are approximately sixteen federal statutes which address groundwater protection. Regulatory authority is granted to two federal agencies, EPA and the Department of the Interior. Federal statutes which provide authority to control groundwater contamination, and could affect agricultural contamination, are summarized in Figure 3.2.

POLICY ALTERNATIVES

There has been increased political pressure on governments to deal with groundwater contamination episodes. People seek

Federal Water Pollution Control Act of 1972 (FWPCA)
Contains: Amendments by the 1977 Clean Water Act, Section 208 area-wide planning program, Section 303 water quality standards and implementation plans, and the National Pollutant Discharge Elimination System (NPDES).

Safe Drinking Water Act of 1974 (SDWA)
Groundwater management is covered by: the Underground Injection Control Program, the Sole Source Aquifer Provision, and national water quality standards.

Resource Conservation and Recovery Act of 1976 (RCRA)
Enables the supervision of municipal solid waste and hazardous waste disposal.

Toxic Substance Control Act (TSCA)
Regulates toxic substances in the manufacturing, use, and disposal cycles.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA, "Superfund")
Provides immediate response to hazardous substances in the environment.

Figure 3.2: Major Federal Laws Affecting Groundwater

reasonable, enforceable, and active groundwater quality policy that changes current user behavior. Several policy options have been designed to deal with groundwater quality, ranging from regulatory tools to education. Each method defines differently the rights of various individuals, has a range of distributional consequences, and has varying performances outcomes. Each alternative will imply certain consequences for the members of society who use the groundwater.

The rules discussed in this section vary by whose rights to the resource are protected and what variation of that right is enforceable. The boundaries between the rules are not strongly defined and will depend upon societal preferences, political power, and information about the rights. As society becomes more environmentally conscious, the rights

farmers have over the quality of the resource change. The boundaries are being redefined.

Permitting and taxes

If permits or taxes were required as agricultural chemicals are applied to a field, the farmer would essentially be obtaining permission to use the groundwater. The public must agree upon the price the farmer pays in order to use the water. Both taxes and permits make the farmer pay the price which the public finds acceptable for jeopardizing the clean water. That special tax could then be earmarked for groundwater renovation efforts.

In Jefferson County, Wisconsin, for example, local governments have been active in regulating the location and management of animal feeding operations. The county requires a permit for feedlots and poultry farms over an established size. To be granted the permit the farmer must agree to comply with the applicable restrictions (DiNovo and Jaffe, 1984). Thus, the feedlot operations continue by consent of the community.

The burden borne by the farmer from permitting arises from the costs incurred in obtaining the permit. The farmer is required to buy a "license" which specifies the amount of fertilizers legally spread on the ground. With taxes, the burden would be shared between the users of nitrogen fertilizer, the fertilizer industry, and consumers of agricultural products. However, if the tax applies only to those farmers who need to use nitrogen fertilizer, it will not necessarily

be passed evenly among consumers. Agriculture exists in a competitive economy making it difficult for those farmers using nitrogen fertilizer to increase the price of their product and still be competitive in the market with other farmers. The burden would be on the farmer to either pay the tax, or decrease the amount of nitrogen fertilizer applied, thus passing the costs to the fertilizer industry.

Problems in implementation arise with both taxes and permits. A tax may not adequately represent the demand for groundwater protection. Who pays the costs will depend upon the elasticity of demand for fertilizer. The goals of decreasing contamination practices may not be met evenly across all farmland. Further, there is no assurance that the most vulnerable areas would receive adequate attention.

High costs of monitoring a tax program would be small, whereas a permitting program would have high policing costs. Administering and monitoring the use of permits would require large amounts of time and money. The transaction costs would be borne by the state. Kansas, for example, spent $10 million in 1984 for staff to support their groundwater permitting and compliance regulations (NRC, 1986, p.174).

Zoning

Zoning has often been used as a method to separate incompatible land uses on the local level. This alternative can also be used for groundwater protection. By placing restrictions on how the land can be used, protection of groundwater recharge areas is encouraged. Special use restrictions can be

added to existing land use laws, increasing protection to particular recharge areas (Libby, 1986). As sensitive areas are protected, these ordinances actually create varying degrees of ownership over the use of groundwater. Persons living within zones allowing degradation will have ownership opportunities whereas those living in regions zoned for extra protection will not.

In Michigan, these types of ordinances have rarely been implemented, though the authority exists. As of late 1986, two townships in Michigan have used local zoning ordinances to protect the groundwater. Springfield township in Oakland County has established a zoning ordinance to regulate development over sensitive recharge areas. The ordinances are based on extensive mapping of the physical characteristics of the township. "Site plan review criteria" have to be adopted by new developments within particular zones (Walls, 1986).

Meridian township in Ingham County has established protection of groundwater recharge areas as a declared public purpose of land regulation. Overlay zones have been established to protect the groundwater supply in a time when the area is experiencing major development pressures (Harlowe, 1986). Consequently, zoning can be used to (1) prohibit uses which cause groundwater contamination, (2) allow certain activities under particular conditions, (3) limit the intensity of an activity, and (4) establish locations for certain uses (Yanggen, 1984). Zoning will be the most beneficial when

the land use activity can be easily monitored, thus decreasing policing costs.

Classification System

A classification system for groundwater aquifers is similar to zoning, yet on a larger scale. As defined by the E.P.A., those aquifers, or portions of aquifers, highly valued by society would be identified and the actions of individuals restricted to protect the water. Differential protection of the aquifers occurs by tailoring regulatory requirements to the class of the groundwater (Raucher, 1986). Thus, it becomes more expensive to use highly sensitive aquifers for waste disposal rather than aquifers of lower quality.

Two basic controversies arise. First, it is questionable whether an aquifer serving a small population will be considered of equal value to one which is the drinking water source for an urban area. Agricultural communities may bear the burden. Second, designating the type of aquifer use expected in the future may actually determine future use (Dycus, 1984). The changing needs of the populace may be difficult to accommodate once designations have been made.

Connecticut has implemented a statewide groundwater classification system. The entire state has been mapped and classified according to four classes of groundwater. As a result, there is a shortage of areas for waste disposal, and public resistance to the classification of areas for waste disposal or landfill activities has risen. However, if the program goes as planned this public resistance will turn into

an incentive for encouraging development of resource recovery facilities (NRC, 1986, pp.46-47).

Liability

Farmers polluting the groundwater may be held responsible for damages caused by a contaminant. Compensation for the public's loss of clean water would have to be paid by the farmer. This is very similar to the institutional structure presently in Michigan. The public cannot force the farmer to stop polluting practices, yet the public can sue the farmer to pay for the damages imposed.

Controversies arise with this type of property right rule, especially in deciding how much damage has been done, who caused it, and what should be the payment. There are large impediments to placing monetary values on health and in valuing the negative impacts to the resource. The difficulties with the present institutional structure in Michigan include; (1) delay in dealing with specific contamination situations; (2) continuing damage during litigation; (3) difficulty in identifying the polluter; and (4) conflicting local and state interests.

Penalties

Regulations are imposed as a policy tool to change or redefine the options facing groundwater users. For regulations to be effective they must be enforceable. How these costs are distributed within society will depend on the objective of the regulation, where funding originates, and what level of government is involved (Libby, 1986).

There are situations where regulation would be advisable; such as a groundwater contamination case where the source of the pollution is fully known and regulation is easily enforced. However, this is not the case for fertilizing practices. Continual monitoring of fertilizer use is very difficult and expensive. The enforcement agencies in Michigan lack sufficient staff to monitor all farmers at all times (Kirkpatrick, 1986). Farmers would have to be accountable for their own actions, which in other pollution situations has proven ineffective. The penalties imposed would have to be substantially significant to encourage farmers to comply with the regulations. There would be no guarantees. Hence, the possibility of effectively decreasing the amount of fertilizer appears minimal and the taxpayers would bear the burden.

Market bargaining

With market bargaining the farmer could be given the right to use the groundwater in the manner he chooses. If he is creating an externality, such as groundwater contamination, then those opposed to the externality have to bid away those rights. Thus, a market price would be put on clean groundwater.

One way market bargaining has been used in land use planning, which may applied to groundwater protection, is through the purchase of development rights. A community purchases the development rights to property with the purpose of restricting intensive development of the land while allowing other specified uses such as recreation. The

property is still under private ownership, subject to property taxes.

Development rights acquisition has been used in many cases to preserve agricultural lands. In Suffolk County, New York, for example, farmers sold the development rights to the county in return for a payment and the right to retain title to the land (TCRPC, 1984, p.13). The land continues to be actively farmed and the community retains open space. However, there is no evidence that this type of program has been utilized to preserve groundwater recharge areas (TCRPC, 1984, p.13).

The use of subsidies involves the public offering a market bid to farmers to stop contamination, such as has been used to stop soil erosion through the Conservation Reserve Program. A subsidy could be offered to farmers to decrease the amount of nitrogen fertilizers applied to their land. There are obvious enforcement problems. Initially the rules of the subsidy may be followed, but as the individual realizes that increasing the amount applied by a minimal margin will most likely go unnoticed, the amount of fertilizer applied may slowly increase.

Programs could be established to educate the farmer on how the use of fertilizers will affect the groundwater. However, it is still questionable whether the rules of the subsidy would be followed. A farmer may question whether he is the only person following the guidelines of the subsidy. Further, he may feel that his water is being polluted by his

neighbors, not by his own actions. The rationale for continuing the nonpolluting practices has disintegrated.

Acquisition

Through the use of eminent domain, authority is given for the public to spend funds to acquire land for public purposes, such as to protect a groundwater recharge area. The landowner is compensated for the rights transferred by acquisition.

Schenectady County, New York has used the public purchase of lands to protect critical recharge areas. The cost to the County to purchase these areas was estimated in 1980 to be $167,000 to $207,000. This represents a cost of approximately $4.85 to $5.85 for each home served by the protected water supply (DiNovo and Jaffe, 1984, pp.101-102).

Education

Educating the populace to the effect of private and public actions should be an element of any policy strategy for protecting groundwater. To effectively reduce groundwater contamination episodes, the public needs to understand why the problem exists, its causes and how can they be decreased. This is a very important facet to increasing the public's understanding to how their activities are harming the environment. A Nebraska Cooperative Extension program, for example, was the catalyst for reducing water usage by an estimated 1.5 million acres of water in 1983 by teaching farmers about irrigation scheduling (CES, 1986, p.30). Wisconsin attributes the success of its groundwater quality program in part to its strong information and education emphasis (NRC, 1986, p.73).

The community needs to be aware of existing and future pollution. It is imperative to convince the farmer of the environmental problems imposed by misuse of nitrogen fertilizer. A survey of Michigan Cooperative Extension programs identified education as an important asset for having a positive impact on alleviating groundwater contamination. Education in the proper management of fertilizers and pesticides was found to be the most important element in efforts to decrease contamination (CES, 1986).

Education should bring the health concerns of society to a personal level, and alleviate much of the uncertainty which engulfs this issue. The intentions of an educational program should be to impress upon the farmer that:

1. A groundwater quality problem does exist with detrimental private and public consequences.
2. The problem can be directly correlated with the farmer's current behavior.
3. Feasible solutions, both economically and agronomically, are available.

By changing the individual's perception of the problem, information can be used to encourage public participation in groundwater protection policy. Yet, increased education will not solve the problem of free riders. The opportunities of these individuals must be altered by the other incentives.

RECOMMENDATIONS

Efforts to decrease groundwater contamination episodes can vary greatly across the spectrum of policy tools. Each method has a different set of costs and benefits, placing the costs of the policy on differing groups of individuals. A

policy system must effectively deal with the given properties of groundwater, while recognizing the transaction and distributional costs involved. The various tools discussed previously should be chosen on the basis of their effectiveness for a community.

Presently groundwater protection in Michigan is based on an unfocused collection of laws and regulations. Better coordination between those designing groundwater policy would aid in establishing a solid protection program. To meet groundwater quality goals an institutional system must be developed where individual choices producing contamination become more expensive.

In developing protection programs for groundwater, nondegradation alternatives should be emphasized; focusing on preventive versus reactive methods. This form of policy has proven to be the most cost effective in cases of nonpoint source pollution. Yet, discretion is necessary to make a non-degradation groundwater policy politically and economically feasible. Minnesota's Pollution Control Agency, for example, has the discretion to consider certain social and economic factors in decision making (GLWRPC, 1986, p.33). The State of Wisconsin originally established a policy of non-degradation. They have since then noted, "In recent years...the state has moved toward the recognition that some contamination of groundwater is almost inevitable in modern, industrial society" (Yanggen and Webendorfer, 1984, p.12-13).

Hence, a pure nondegradation policy may not be possible, yet due to the extreme costs and time consuming measures for the aquifer to be cleansed a preventive pollution strategy should be emphasized. The Great Lakes and Water Resources Planning Commission has recommended that Michigan implement a policy of nondegradation (GLWRPC, 1986). This would be even more effective nationally.

Regional Land use Planning

Land use planning on the regional or local level can be a significant asset to groundwater quality control. Groundwater recharge zones ignore political boundaries, thus contamination problems are often confronted regionally. Coordination among all levels of government is imperative. Yet, the policy tools regulate land use exist predominantly on the local level.

Regional boundaries for groundwater protection are economically logical. Decision units remain small and the population is more homogeneous, transaction costs and information costs will be reduced in obtaining majority decisions. The National Research Council reports that in many states local authority has been more effective in controlling groundwater pollution problems than state authority. County and municipal ordinances controlling underground storage of gasoline were in place in Cape Cod, Massachusetts, Long Island, New York, Dade County, Florida, and Santa Clara County, California, one to five years before state or federal laws were enacted (NRC, 1986).

Groundwater quality should be identified as the specific objective of policy programs, and the public should be included in developing and implementing protection programs. Since nearly all activities affecting groundwater quality are tied closely to land use it is important to achieve public recognition of the problems and methods which can decrease contaminating episodes.

Cross-Compliance

An effective policy program to combat agricultural source contaminants should focus on the relationship between agricultural policy and groundwater policy. The economic and political climate in the U.S. over the last decade has pushed large numbers of American farmers to cultivate their land as intensively as possible. While farm policy works in the short run, with the on-going effort to stabilize farm income, environmental quality is inherently a long term project. There is a significant need to develop compatibility between the two. This could be done by establishing cross-compliance between the policy areas. Two national programs could be used concurrently; a Groundwater Reserve and a Groundwater Buster Program.[2]

The objective of the Groundwater Reserve Program would be to establish a protection system for groundwater. Those aquifers which are vulnerable to contamination from agricultural practices would be identified and monetary incentives

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[2] An easy comparison can be made between these programs and the Conservation Reserve and "sodbuster" programs contained in the 1985 Food Security Act.

(ie. cost-sharing) provided for lands above the aquifer to be taken out of production. Basically, government would lease production rights from the farmer for a specified period. Removing the land from production would allow the natural waste assimilating capacity of an aquifer to occur. The incentive for farmers to set aside land would be established through a bidding system, with ownership granted to the farmer while the public is paying for reduced risk of contamination. The Groundwater Reserve would alter the options facing farmers, by bringing long term groundwater protection goals into the short run attention span of the farming community.

The objective of the Groundwater Buster Program, which would be implemented in conjunction with the Groundwater Reserve, would be to restore the water quality of contaminated aquifers. The program would provide a strong incentive for farmers to discontinue the use of polluting farm practices above a contaminated aquifer until the aquifer recleanses itself.[3] Farmers would become ineligible for benefits of certain USDA programs, such as price supports, crop insurance protection, or FmHA loans, if they planted particular crops known to need high levels of nitrogen fertilizer on designated lands.

Enforcing these two programs should not be a problem; aerial photographs could be used. Pictures of the landscape could be routinely taken to monitor the development of the

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[3]The time needed would be decided on a case-by-case basis, perhaps being infinite, depending upon the extent of contamination and the hydrological conditions of the aquifer.

land as is currently done with other farm programs. Agriculture production on the designated land would be easily noticed. This enforcement characteristic is a significantly positive aspect of the programs, for many policy recommendations for nonpoint source contaminants are extremely difficult to effectively monitor.

These programs would improve consistency between groundwater policy and farm policy. If the government is paying the farmer for crop reductions, in the form of subsidies, externalities to the environment should not be part of the package also. Government needs to change the bidding process so it is paying for what is desired. By paying a price higher than the farmers reservation wage the government is actually creating a problem with one incentive, commodity programs, and trying to solve it with another, groundwater policy programs. The two should be linked. An incentive should be given for agricultural producers to consider the external effects of their management practices. The Groundwater Buster and Groundwater Reserve Programs would begin to set needed priorities for groundwater protection.

APPLICATION: MONTCALM COUNTY, MICHIGAN

Throughout this report groundwater contamination has been discussed on a broad base level, yet the issues are relevant to the more specific problems of individual regions. Analyzing information on nitrate contamination of groundwater in Montcalm County provides a working example for applying the

analysis to a particular region. The purpose of this study is not to provide specific prescription for the county, but instead to provide useful information to those decision-makers designing policy to meet the goals of the community.

Montcalm County

Montcalm County is located in the west-central part of the Lower Peninsula of Michigan (Figure 6.1). The total area of the county is 710 square miles, with a population of approximately 50,000. The primary industry of the area is agriculture, with potatoes, dry beans, oats, barley, and wheat as principals (Espie, 1985). Montcalm County is Michigan's leading producer of potatoes, producing more than one-fifth of Michigan's entire potato crop (USDC, 1986, p.1).

Concerns for high nitrate levels found in the ground-water have increased over the last five years. Approximately 50% of the county is situated over unprotected aquifers,

Figure 6.1: Map of Michigan with Montcalm County highlighted

and an estimated 80% of the population depends upon the groundwater for their drinking water supplies. Public Health officials are concerned that these drinking water supplies will be disrupted as nitrate levels increase within the county. In mid 1986, Montcalm County Public Health has reported over 250 wells with nitrate levels higher than the public health standard of 10 parts per million (ppm) (Selden, 1986). The largest percentage of these contaminated wells are located in areas where the soils have sandy loam and loamy sand characteristics.

In Montcalm County, nitrate contamination is being attributed to extensive agriculture activities, where the aquifers are vulnerable and nitrogen fertilizers are used in amounts greater than needed (Smucker, 1986; Selden, 1986). In 1984, a Michigan State University study analyzed three locations within Montcalm County for the probability of fertilizers leaching into the groundwater. All three locations showed a pattern that indicated the potential to lose nitrate from the soil (Ellis, 1984). High quantities of nitrate were found late in the growing season when plant uptake of nitrate is greatly diminished, indicating that the soils will allow the nitrate to move down to the groundwater during the fall and winter months (Ellis, 1984).

A second Michigan State University study has used computerized mapping to illustrate potential and present groundwater

contamination areas within Michigan.[4] The maps show increasing areas and levels of contamination over time, centering around the northwestern corner of the county. These maps confirm concentration levels up to 7 ppm, yet County health employees have reported instances of nitrate levels much higher. Of the wells sampled nitrate levels range within the county from 0 ppm to 31.9 ppm, with an estimated average of 4-6ppm (Selden, 1986). These levels have all been increasing; not a single case has been reported where nitrate levels have decreased between samplings (Selden, 1986).

By comparing maps of contamination with soils and land use maps, one can see that the aquifers with high nitrate levels are primarily underlying agriculture land consisting of sandy soils. These aquifers are also those most vulnerable to contamination. This supports the hypothesis of both the Cooperative Extension Service and the District Health Department that agricultural practices upon vulnerable areas are one of the leading causes of nitrate contamination of groundwater within the county (Smucker and O'Donnell, 1986; Selden, 1986).

Human health effects. Concern for protecting groundwater in Montcalm County arises from the possible ill-health effects associated with contaminated water. Within the county there have been several suspected cases of methemoglobinemia, or "blue baby" syndrome. Health officials are confident two

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[4] These maps are included in the parent study for this report. See: Kovan, Jessica Trumbull An Analysis of Selected Policy Alternatives to Alleviate Groundwater Contamination in Michigan, unpublished Master's thesis, Michigan State University, 1986.

cases can be highly correlated to excessive levels of nitrate in the drinking water (Selden, 1986; Finkbeiner, 1986). In both of these cases, one reported in Howard City and the other in Fenwick, the children were reported to have turned blue within an hour after birth (Finkbeiner, 1986). Due to the uncertainty involved in establishing direct causation, methemoglobinemia has been cited as a possibility but health officials are not saying so with certainty.

Concern for negative human health effects within the county appear to be increasing (Selden, 1986). Any public establishment with nitrate levels between 10 ppm and 20 ppm must post notices stating the situation. If the nitrate level is greater than 20 ppm the water supply will be shut down until a new well is drilled and nitrate levels decrease. This has occurred in three places within the county (Selden, 1986).

Economic effects. In 1986, mortgage companies and the Veterans Association require water samples from wells to be taken before loans, or a certification of guarantee, can be given for purchasing new homes. If nitrate levels above 10 ppm are found, the loans are rejected until a new well is dug or the existing well is drilled deeper; thus yielding nitrate levels less than 10 ppm. Often the individual will choose not to purchase the home due to the high cost of drilling the new well (O'Donnell, 1986). These costs usually averages approximately $2,000 (Selden, 1986). Consequently, land values are affected when sampled wells show high nitrate levels.

There are other economic costs to the community and county residents which arise due to groundwater contamination. There are increased costs to the Public Health Department for the enlarged number of well samplings and posting of notices not to drink the water. When notices are posted in public establishments there may be a loss in revenues to the service industry, depending upon the public reaction and the type of establishment. How these costs are passed along to the consumer will be determined by the producer. The state at this time is launching a county wide research study involving a computer analysis of the area (Yordanich, 1986). The costs for this program will be distributed to Michigan taxpayers.

Public concern. Individual awareness within the county in regards to high nitrate levels and the possible negative effects to the individual varies by community. At this time there are no organized interest groups focusing on nitrate contamination (Smucker and O'Donnell, 1986). Two agencies dealing with community concern over groundwater contamination are the Cooperative Extension Service and the Mid-Michigan District Health Department. These agencies have differing roles within the community and thus relay information to the public differently. The Cooperative Extension Service serves the community as an educational source, conducting programs in agriculture, marketing, natural resources, public policy, family living, nutrition and 4H Youth development. These programs are diversified, however the main philosophy remains

to educate the individual in order to create better communities in which to live and work (CES, undated). In regards to groundwater quality in Montcalm County, the Extension Service recognizes there is a nitrate contamination problem stemming from agricultural production practices. They have chosen to emphasize minimizing public concern by not elaborating water quality problems within the region. Instead focus is placed upon the economic justification for farmers to practice best management practices when applying fertilizers and how this will benefit the underground water (Smucker and O'Donnell, 1986).

The Mid-Michigan District Health Department assumes a contrasting role within the community. As regulators rather than educators, their clientele consists of both rural and urban communities. Health officials grant permits for new wells and close down water supplies which show high nitrate concentration (Selden, 1986). In regards to groundwater quality, the objective of Health Department officials is to increase public awareness of contamination problems by continually sampling wells and reporting negative side effects of drinking the water (Selden, 1986). They believe this has enhanced community awareness.

Institutional Setting

There is not an established groundwater protection program in Montcalm County. County officials follow the guidelines of the Groundwater Quality Control Act, Part 127 of Act 368 P.A. 1978, the Michigan Safe Drinking Water Act, Act 399

P.A. 1976, and the Environmental Health Code established by the Mid-Michigan District Health Department. Through a combination of Act 368 and 399 the District Health Department is given the enforcing responsibility over water supply quality.

The Public Health Code deals with location, construction and maintenance of wells (MDPH, 1983). The two clauses dealing specifically with groundwater quality regulate the distance wells can be drilled from pollution sources and require notifying the public about pollution (R325. 1673 and R325.1673). In regards to notification of pollution, it is stated, "An owner or occupant using a polluted water supply or a supply which, in the judgment of the health officer, represents an immediate health hazard shall be notified by the health officer of the health hazard" (Act 368 P.A. 1978, Part 127, R 325.1673). The public health officer will at that time give advice to the well owner on actions which can be taken to protect human health, such as drilling a deeper well (Selden, 1986). Whether to follow the advice is left to the discretion of the landowner.

The indirect yet primary control which public health employees have over agricultural practices comes from Act 368, which establishes the requirement of permits for irrigation wells (Selden, 1986). This gives public health employees control over how and where wells can be drilled. Thus, if contamination is evident on a farm, new wells can be regulated in an effort to alleviate some of the problems.

A second indirect control is through Act 245, the Water Resources Commission Act, in which limited control is granted over concentrated animal feeding operations through permits. These operations are declared to be a "point source discharge," including it in the requirement that those individuals discharging wastes into groundwater obtain a permit. However, Act 245 does not define what constitutes a concentrated animal feeding operation.

The Environmental Health Code regulates water supply, sewage disposal, refuse disposal, and housing. Authority is given to the District Health officer to enforce the regulations. However, agricultural practices are not mentioned in the Health Code.

There are no local zoning ordinances to protect sensitive groundwater areas within the county. For these to be developed local opposition would have to be confronted. The Montcalm County Cooperative Extension Service is not enthusiastic about the use of zoning for this purpose. It is felt the large amount of government involvement already in agriculture makes the use of further restrictions prohibitive (Smucker and O'Donnell, 1986).

Consequently, education and random well sampling are the primary tools used within the county to decrease the occurrence of contamination episodes. The Cooperative Extension Service develops brochures which are sent to farmers regularly discussing such topics as fertilizer and pesticide usage. Meetings are held focusing upon the economic aspects of proper

fertilizer management. Soil testing is recommended, and approximately 700 samples per year are taken; 627 samples were analyzed from July 1984 to July 1985 (CES, Nov. 1985). Each soil test is sent to Michigan State University (MSU) for recommendations on the use of fertilizers and irrigation. However, MSU is not the only source used for sampling soil. Fertilizer industries also will sample soil and make recommendations for farmers. Their recommendations often are incompatible with those of MSU. Despite the educational effort, farmers continue to apply more nitrogen than needed for crop growth (Smucker and O'Donnell, 1986). Extension agents feel that even more education is necessary to break this natural reaction to the uncertainty and risk involved with crop production.

The costs inherent in trying to relay convincing information about the groundwater is very high. Collecting full data about the groundwater and land use, and applying those data to a groundwater protection program are not a top priority for the county (Smucker and O'Donnell, 1986). Relying upon education and well sampling to alleviate the uncertainty and reduce the contamination will most likely not protect the resource.

Although conflicts between groundwater users have already been verified within Montcalm County, effective policy has not been established to eliminate the incompatible uses. Monitoring wells for contamination will not prevent the pollution. The contamination results from the daily activities of farmers; the pollution is not intentional. While the Public

Health Department chooses to point fingers at agriculture, the individual farmer will not feel that he is to blame. Thus, voluntary action to reduce the amount of fertilizers used in order to protect groundwater quality should not be expected.

Suggestions

Montcalm County leaders need and want to design policy to have a positive influence upon protection of the resource.[5] To protect groundwater in Montcalm County, action is needed at federal, state, and local levels. In general, the state sets the rules for local government action (TCRPC, 1984). The county itself has more limited powers than the state, yet there are options which can be taken by county government to protect the health of its citizens. The necessary first step is to formulate a groundwater recharge area protection strategy. Without an established strategy, conflicting uses of the groundwater may result.

Groundwater and Land-use Data. Groundwater data and land use information are needed to fully assess groundwater threats and to provide reasoning for supporting rational groundwater regulations. The collection of information about the groundwater resource is necessary to identify recharge areas. The information can be collected through well maps, topographic maps and on-site observation (TCRPC, 1984). Once this information has been accumulated potential recharge sites should be identified. Recognizing the potential for ground-

[5] More detailed recommendations which would apply to the county are developed in the larger study (Kovan, 1986).

water contamination will aid in identifying the problem before it occurs and support preventive programs. Though collecting the data may be costly to the community, the information is a necessity for the county to decrease the contamination in the long run.

Once this information has been collected, land use planning can be formulated in the context of local conditions and needs. Planning can be an effective tool to deal with the costs individuals will impose upon one another now and in the future. Incompatible land uses should be confronted before there are negative impacts upon health.

Public Acquisition. For Montcalm County, the high concentration of nitrate in the groundwater is the primary contamination concern. Thus, a protection strategy needs to concentrate on a preexisting problem, fertilizer use. The principle focus of the strategy should be on discontinuing polluting activities over sensitive recharge areas. An effective method for accomplishing this on the local level is through the full fee simple purchase of the areas of interest. Eminent domain power may be exercised since the purpose of acquisition is to protect the health, safety and welfare of the community (TCRPC, 1984). Due to the high enforcement costs for requiring decreased use of fertilizers, public acquisition of lands over the most sensitive recharge areas may be the most reasonable method for groundwater preservation.

The benefit of public acquisition is in its ability to isolate high risk activities from local drinking water

sources. It is, perhaps, the most secure method for protecting groundwater recharge areas and can be implemented on the local level. A second advantage is the compensation provided to the owner for the value of the land rights taken. The Tri-County Regional Planning Commission has recommended public purchasing as an effective management technique to protect the health of the community (TCRPC, 1984).

On the other hand, public acquisition is initially one of the most costly methods. The costs will depend upon the size of the recharge area, and its present land use. The costs may be reduced once the land is purchased if it can be used for other noncontaminating activities, such as recreation, artificial recharge or a future well site location (TCRPC, 1984). As costs are discounted over time, community expenditures may be justified. Montcalm County officials would have to weigh the discounted benefits and costs of such a program to decide whether it is worth implementing.

Development Rights. A second alternative would be for the county to purchase specific development or production rights for the particular agricultural land. The farmer retains title to the land, yet is restricted in the types of land use which could be undertaken. Thus, a form of market bargaining would take place to protect the resource. It would be possible to monitor the types of crops grown and protection of the groundwater would be enhanced. However, at times the recharge area may be the most productive farmland, thus the bidding price the farmer would demand for the rights to the

land may be very high. The county would have to again decide whether in the long run the benefits exceed the costs. In addition, there is always the possibility of exercising eminent domain for partial rights.

The transfer of development rights is also an alternative for local government. Officials would have to find land within the county where development would be permitted, while controlling development in sensitive areas. To stop the production on land over a recharge area, the county would designate land elsewhere that could be used for the production. A transferring of rights occurs from one land parcel to another through an administered market. Essentially, the landowner, in an area where production is permitted, must acquire an additional right from an owner of land important to a recharge area. In that way, while land use opportunities are forsaken in the interest of protecting a groundwater aquifer, the landowner is compensated by other owners who retain the right to produce the sensitive crop.

The transfer of development rights has been effectively used to alter development within a county, in order to protect historic or agricultural land (TCRPC, 1984). It has also been used in New York and Florida to move development away from a groundwater recharge area (TCRPC, 1984). However, cases have not been found where the transferring of rights has involved agricultural production. For Montcalm County, it is questionable which land not already in agricultural production could be used to transfer production or development rights.

Costs versus benefits. The purchase of development rights, public acquisition, and collection of data all impose large initial costs upon the county, thus officials will have to weigh long run costs and benefits. There may be a point where it is less expensive for individuals to buy bottled drinking water than for the county to protect the resource. This is an important point. In Montcalm County, where farmers are polluting their own drinking water, bottled water may be the least costly local alternative. A local committee could, perhaps, be established to investigate providing bottled water publicly to those in need.

Other land use controls previously discussed will not be effective in Montcalm County due to high exclusion costs or legal constraints.[6] However, acquisition of the land or the purchase of development rights may be insufficient protection if surrounding lands still have activities which will contaminate the recharge area.

Consequently, there will be situations where state and federal levels of government have more effective means to deal with nonpoint sources of pollution. Implementing a program such as the suggested Groundwater Reserve would provide outside aid to Montcalm County in protecting the resource. The county itself has a limited number of choices

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[6] Zoning is a land use control which could be effectively monitored. However, it will not be effective in protecting groundwater in an agricultural area because preexisting land uses do not have to conform to the new zoning ordinance (Wyckoff, 1986).

in dealing with preventing this type of contamination, and cost versus benefits must be weighed.

Education. As Montcalm County officials recognize, education is a very important asset to a protection strategy. Groundwater common sense should be taught on all levels, from grade school children to the officials of the county. Teaching individuals to take groundwater protection into account in making day-to-day land use decisions would be beneficial to changing behavior in the long run.

Implementation. A regional emphasis is often very important to protect the water quality of an entire aquifer. With Montcalm County, the unprotected aquifer regions extend through the surrounding counties of Mecosta, Newaygo, Kent, and Ionia. The need for a multi-county regional strategy is obvious. Development of Groundwater Management Districts in Michigan could be an implementable strategy capable of protecting a regional aquifer. These management districts would be locally managed special purpose subdivisions defined by the aquifer boundary. Each district would have a management board made up of a variety of individuals representing the region. Such a strategy has proven effective in Kansas, where five such management districts have been delineated. Each district is charged with managing the groundwater resource within its boundaries (NRC, 1986, p.56). The management board should include representatives from Cooperative Extension, Department of Public Health, and Soil

Conservation Service, as well as public officials, experts in groundwater management, and citizens of the region.

To mobilize and maintain support for the Groundwater Management Districts both leadership and funding are important. Strong dedicated leadership will be essential in achieving support for the programs. In both Wisconsin and New Jersey, Governors have led their states in developing strong environmental protection programs (NRC, 1986, p.182). Leadership could also be provided by knowledgable scientists.

Montcalm County is but one example of the groundwater quality management challenge facing Michigan. Timely response to existing contamination episodes and, more importantly, effective protection programs that are sensitive to the economic and political diversity of the issue are absolutely essential to Michigan's economic future. Clean water is more than an environmental amenity; it is fundamental to the future of the state.

BIBLIOGRAPHY

Bedell, D.J. and R.L. VanTil "Irrigation in Michigan," Michigan Department of Natural Resources, Water Management Division, 1979.

Bedell, D.J. "Municipal water withdrawals in Michigan," Michigan Department of Natural Resources, Water Management Division, 1982.

Cabinet Council on Environmental Protection (CCEP) "Groundwater Protection Initiatives," A Report to the Governor's CCEP, Lansing, MI, Sept. 1984.

Cooperative Extension Service (CES) "The Cooperative Extension Service: A Guide prepared for County Boards of Commissioners," Michigan State University, E. Lansing, Michigan, undated.

------ "Median Soil Test Value for Mineral Soils in Michigan Counties," Department of Crops and Soil Science, Michigan State University, File: 32.82, November 1985.

------ Groundwater Education: A Challenge for the Cooperative Extension Service, Extension Committee on Organization and Policy, Michigan State University, 1986.

Council for Agricultural Science and Technology (CAST) Agriculture and Groundwater Quality, Report No. 103, Library of Congress Cataloging in Publication Data, May 1985.

Council of Environmental Quality Annual Report (CEQ) Environmental Quality - 1984, U.S. Government Printing Office, Wash D.C., 1984.

DiNovo, Frank and Martin Jaffe Local Groundwater Protection: Midwest Region, American Planning Association, Chicago, IL, 1984.

Dycus, J. Stephen "Development of a National Groundwater Protection Policy," Boston College Environmental Affairs Law Review, Vol. 11, No. 2, January 1984.

Ellis, Boyd "Nitrate Contamination of Groundwater," Department of Crop and Soil Science, Michigan State University, unpublished paper, undated.

Espie, Margaret (ed.) Michigan Agricultural Statistics 1985, Michigan Agricultural Reporting Service, Lansing, Michigan, 1985.

Finkbeiner, Betty Nurse, Mid-Michigan District Health Department, interview, September 1986.

Freeze, R.A. and J.A. Cherry Groundwater, Prentice-Hall, Englewood Cliffs, N.J., 1979.

Garner, G.B. "Learn to live with nitrates," MO Agricultural Experiment Station, Bulletin #708.

Great Lakes and Water Resource Planning Commission (GLWRPC) "Committee D: Groundwater Protection and Management," State of Michigan Government, Lansing, MI (Preliminary draft, August 1986).

Harlowe, Rich Director, Meridian Township, Ingham County, Michigan, telephone conversation, October 14, 1986.

Kirkpatrick, Robert, Department of Agriculture, Telephone interview, June 19, 1986.

Libby, Lawrence W. "Groundwater Quality: A Policy Perspective," Paper prepared for North Central Public Policy Education Committee, Michigan State University, May 1986.

Kovan, Jessica T. An Analysis of Selected Policy Alternatives to Alleviate Groundwater Contamination in Michigan, Unpublished Masters thesis, Department of Agricultural Economics, Michigan State University, 1986.

Madison, R.J. and J.O. Brunett "Overview of the Occurrence of Nitrate in Ground Water of the United States," National Water Summary 1984 - Water-Quality Issues, 1984.

Meyers, Charles J. and A. Dan Tarlock Water Resource Management, Foundation Press, Inc., Mineola, New York, 1980.

Michigan Department of Natural Resources (MDNR) "Local Roles in Groundwater Protection and Management," Local Groundwater Advisory Group, 1985.

------ Michigan Permit Requirements for Natural Resource Development, Environmental Protection Bureau, Community Assistance Division, February 1986.

Michigan Department of Public Health "Groundwater Quality Control: Part 127 of Act 368 P.A. 1978, as amended, and rules," Lansing, Michigan, 1983.

Michigan State University Legal-Institutional Issues in Michigan Water Planning and Inventory of Current Statutory Laws, Department of Natural Resources, 1985.

National Research Council Groundwater Quality Protection: State and Local Strategies, National Academy Press, Wash. D.C., 1986.

O'Donnell, Jill Extension Agent, Montcalm County Cooperative Extension Service, Telephone conversation, September 1986.

Olson, R.A. "Nitrogen Problems," Presented at the "Plant Nutrient Use and the Environment" Symposium, Kansas City, Missouri, Oct 21-23, 1985.

Porter, K.S. "Agricultural Practices: Policy Implications," Public Policy on Groundwater Protection, ed. W.R. Kerns, Proceedings of a national conference at Virginia Polytechnic Institute and State University, Blacksburg, VA, April 13-16, 1977.

Pye, Veronica I., Ruth Patrick, and John Quarles Groundwater Contamination in the United States, University of Pennsylvania Press, Philadelphia, 1983.

Quissenberry, Dwight Agronomist, Soil Conservation Service, State of Michigan, telephone conversation, Sept. 22, 1986.

Raucher, Robert S. "Regulating Pollution Sources under a Differential Ground-water Protection Strategy," presented at the AAEA meetings, Reno, Nevada, July 1986.

Rota, Sue An Assessment of Federal and State Groundwater Quality Protection Efforts, Research Paper, Department of Natural Resources, Michigan State University, 1985.

Selden, Barry Sanitarian, Mid-Michigan District Health Department, Interview, September , 1986.

Smucker, Donald County Extension Director, Montcalm County, Michigan, Meeting, Michigan State University, January 16, 1986.

Smucker, Donald and Jill O'Donnell Extension agents, Montcalm County Cooperative Extension Service, Interview, September, 1986.

Stiglitz, J. E. "A Neoclassical Analysis of the Economics of Natural Resources," Scarcity and Growth Reconsidered, V. Kerry Smith , ed., The Johns Hopkins Press, Baltimore, Maryland, 1979.

Tri-County Regional Planning Commission (TCRPC) Implementation of Local Groundwater Recharge Area Management Strategies: An Administrative Guide, Lansing, Michigan, 1984.

U.S. Office of Technology Assessment (OTA) Protecting the Nation's Groundwater From Contamination, Vol. 1, U.S. Government Printing Office, Wash D.C., 1984.

Walls, Collin Township Supervisor, Springfield Township, Michigan, telephone conversation, Sept. 19, 1986.

Wyckoff, Mark Public Consultant, Lansing, Michigan, telephone conversation, October 14, 1986.

Yanggen, Douglas A. and Bruce Webendorfer "Groundwater Protection Through Local Land Use Controls," Department of Agricultural Economics, University of Wisconsin, Madison, WI (preliminary draft 1984).

Yordanich, Dan Student intern, Mid-Michigan District Health Department, interview, Stanton, Michigan, September 29, 1986.