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Guide to Local Groundwater Protection in Florida

Volume I
The Decisionmaking Process

Prepared for

St. Johns River Water Management District

Southwest Florida Water Management District

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Chapter I Introduction

INTRODUCTION

Groundwater is the principal source of fresh water for public supply, rural, industrial and irrigation purposes in Florida. Average groundwater withdrawals total over 7.5 billion gallons per day. Approximately 92% of the state's population depends on underground sources for its drinking water supply, with approximately 20% of the population drinking untreated well water drawn directly from private wells. In many parts of the state, natural protection is lacking for potable aquifers. Population and development pressures are also so high that both the quantity and the quality of the resource are under increasing stress. There are many potential sources of groundwater contamination, which can be either acute or chronic. Spills and ruptures of storage tanks for hazardous materials are examples of acute sources which can rapidly introduce any of a number of toxic contaminants into an aquifer or wellfield. Slower leaks from storage tanks and nonpoint discharges from many sources, or the regular infusion of septic tank effluent and untreated stormwater can also accumulate to eventually contaminate an aquifer. Once contaminated by toxics, it may be difficult if not impossible to restore a potable aquifer to its former condition. The costs associated with such efforts can be extremely high, ranging well over several million dollars in some cases. Thus, the most efficient approach to groundwater protection is one which prevents contamination by controlling land uses over sensitive aquifers.

By necessity and by statute, Florida's local governments are at the forefront of efforts to prevent the contamination of potable aquifers. The necessity of the effort is related to the fact that the primary responsibility for protecting local sources of drinking water falls to the local government. The duties and responsibilities associated with its local police powers require a local government to pass regulations protecting the health, safety and welfare of the public. At the same time, Florida's Local Government Comprehensive Planning and Land Development Regulation Act (Growth Management Act) includes a statutory requirement that local governments implement plans and land development regulations which protect potable aquifers and wellfields.

Several factors tend to make local groundwater protection a complicated undertaking in Florida. First, the hydrogeology of much of the state is fairly complex, making it difficult to accurately characterize the nature of the resource to be protected. Additionally, many of the state's most attractive areas for development overlie underground sources of potable water, or are important recharge zones to local and regional potable aquifers. Development pressures in the state are strong, and the increased numbers of potential pollution sources that accompany developed areas usually coincide with those areas' needs for more potable water. The technical issues associated with groundwater protection can also be complicated. Determining what types of technological or operative controls constitute a stringent approach under a given set of circumstances requires careful analysis. From the legal standpoint, a welter of federal and state laws supply a jigsaw approach to groundwater protection that may not provide adequate protection at the local level.

USE OF THE MANUAL

The purpose of this manual is to provide guidance in the choice and development of local aquifer protection strategies in Florida. The manual is in three volumes. Volume I contains summaries of basic information on the primary potential sources of contamination, summaries of the aquifer protection tools available to local governments, and a chapter on the decisionmaking process. Planning and decisionmaking guidance are included to help direct the process of gathering, analyzing and using data, and developing effective strategies.

Volume II of the manual includes more detailed planning and regulatory information on some of the most important potential sources and pathways of contamination, and the tools available to local governments to help prevent the contamination. Types and sources of groundwater planning data, methods of analyzing such data, and methods of delineating protection zones are also explained. Summaries of many applicable state and federal laws are offered, to provide a basic understanding of the approaches being taken and the level of protection offered by those regulations. Volume II concludes with explanations of suggested regulatory strategies addressing the primary groundwater threats based on high, medium or baseline stringency standards. Volume III of the manual contains appendices of representative model ordinances and adopted local ordinances, dealing with many of the potential pollution threats facing local governments. It also includes appendices containing references and sources of additional information.

A recommended approach is to read Volume I for an overview of the primary threats to potable aquifers, a summary of the tools available to local governments to create aquifer protection programs and a discussion of the planning and decisionmaking process. Tables and notes throughout Volume I refer to materials in Volume II and Volume III which provide expanded treatment of the topic or examples of the approach being suggested. Where necessary, reference can be made to these sections of the manual for additional information.

As explained in Chapter IV of this volume, the aquifer protection planning process requires research and analysis of several types of data. Volume II, Chapter I supplies an explanation of the sources of such data and methods of analyzing the data. The understanding of a community's potable aquifers, groundwater use patterns, land use patterns and groundwater threats that emerges from this research allows a community to evaluate the potential applicability and usefulness of existing regulations. Volume II, Chapter II provides summaries of most of the applicable rules addressing protection of groundwater, including notes on the weaknesses and strengths of the more important regulations.

It is likely that existing regulatory authorities will not provide the coverage or level of protection required to meet the groundwater protection goals of many local governments. In cases where existing regulatory authorities do not provide adequate protection, it will be necessary to adopt an aquifer protection strategy using the regulatory and non-regulatory tools available to local governments. Volume II, Chapter III includes an explanation of these tools and a discussion of ordinance structure and legal considerations, providing a better understanding of the potential organization of a protection strategy. Volume II, Chapter IV suggests high- and medium-stringency regulatory requirements addressing the primary groundwater threats. Volume III, Appendix A includes a number of protective ordinances adopted by local governments, providing examples of approaches that may be modified for application in other localities. Appendix B supplies technical and planning references. Appendix C gives the user the addresses and phone numbers of additional sources of information.

GUIDE TO LOCAL GROUNDWATER PROTECTION IN FLORIDA

Volume I The Decisionmaking Process

Chapter 1 Introduction: Short explanation of how this manual may be used, and some of the more important hydrogeological concepts.

Chapter 2 Summary: Sources and Pathways of Contamination: Summary explanation of the primary potential threats to groundwater in Florida.

Chapter 3 Summary: Aquifer Protection Tools: Summary explanation of the regulatory and nonregulatory tools available to local governments in structuring aquifer protection programs.

Chapter 4 <u>The Decisionmaking Process</u>: Explanation of the planning and decisionmaking process by which aquifer protection programs are created. Topics include: management and technical advisory groups, collection and analysis of data, establishing goals and objectives, interim control measures, technical data collection and analysis, developing aquifer protection strategies, implementing aquifer protection strategy, monitoring and evaluation.

Glossary

Volume II Planning and Regulatory Information

Chapter 1 <u>Planning Data Collection and Analysis</u>: More detailed treatment of the data collection process, including: types and sources of groundwater data, sources and pathways of contamination, ranking of groundwater pollution threats, designation of protection zones.

Chapter 2 <u>Applicable State and Federal Law</u>: Summaries of the requirements of federal, state and water management district regulations related to groundwater threats, for use in evaluating effectiveness and potential use as baseline approach in local programs, and determining need for additional local regulations addressing aquifer protection. Summary of the Growth Management Act requirements.

Chapter 3 <u>Review of Aquifer Protection Tools</u>: Explanation of the regulatory and non-regulatory approaches available to local governments, including: ordinance structure, legal considerations, regulatory techniques--zoning, subdivision controls, health regulations.

Chapter 4 <u>Suggested Regulatory Strategies</u>: Presentation and explanation of suggested low, medium and high stringency regulatory approaches to the primary groundwater threats, with emphasis on high stringency approaches. Topics include: introduction, on-site sewage disposal, hazardous materials storage and management, stormwater runoff, agricultural activities, underground injection and drainage wells, landfills.

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Volume III Appendices

Appendix A: <u>Representative Ordinances</u>: Model ordinances and adopted groundwater protection ordinances from Florida and other states, for potential adaptation by local governments.

Appendix B: <u>Planning and Technical References</u>

Appendix C: <u>Sources of Information</u>

HYDROGEOLOGICAL CONCEPTS

A few basic concepts are important for a general understanding of the groundwater resource, how it may be threatened and how it may be protected. Potable water wells draw groundwater from the state's underground aquifers. ***Aquifers*** are geologic formations which contain sufficient saturated permeable material to yield significant quantities of groundwater. Groundwater is that which is found below the unsaturated subsurface zone known as the ***vadose zone***. Aquifers can be characterized by the types of subsurface material in which the groundwater is found. Most of Florida's primary aquifers are composed of saturated sand and gravel deposits, carbonate rock or fractured rock. These materials can be deposited as consolidated or unconsolidated aquifers. ***Unconsolidated*** aquifers appear as formations of sand and gravel with complex interspersed layers of clay, silt, sand and gravel. ***Consolidated*** aquifers in Florida include extensive sedimentary rock formations of limestone or dolomite. Such aquifers are particularly susceptible to ***karst formations***, created as infiltrating water slowly dissolves the limestone, enlarging existing faults and bedding planes into fissures, caves and sinkholes.

Aquifers are also characterized by the degree of natural protection or confinement. ***Confined aquifers*** are those with layers of overlying, relatively impermeable geological strata. The groundwater in these aquifers is under pressure, and the height to which the water will rise in a tightly cased well tapping a confined aquifer is known as the ***potentiometric (piezometric) surface*** for that aquifer. ***Unconfined aquifers*** are those with no clays or other overlying low permeability geologic formations. They are also known as ***water table aquifers***, and their upper surface is known as the water table. When at or near the land surface, they are called ***surficial aquifers***. Aquifers can also be ***semi-confined*** (or ***leaky confined***), indicating that the aquifer has few overlying geologic strata, or that the strata have more permeability than that of a true confining layer. ***Recharge areas*** are those areas hydrogeologically connected to an aquifer, which contribute significant amounts of water to the aquifer. An unconfined aquifer receives recharge from the entire land surface overlying the aquifer. The recharge areas for shallow aquifers are often fairly nearby. Generally, the deeper the aquifer, the farther away are its recharge areas and the longer it takes for percolating water to travel to the productive zone of the aquifer.

Florida's principal aquifers consist of sand at land surface and limestone and dolomite at depths of less than a few hundred feet. Their locations at or near the surface in many areas make them vulnerable to contamination from various activities and land uses. The state has four major aquifer systems, including the Biscayne Aquifer, the Sand and Gravel Aquifer, the Unnamed Surficial and Intermediate Aquifers, and the Floridan Aquifer System. The ***Biscayne Aquifer*** is a surficial carbonate aquifer in the southeastern part of the state which supplies water to most of the Gold Coast area, and which is under tremendous stress. It underlies all of Dade and Broward counties and adjoining parts of Palm Beach and Monroe counties. The ***Sand and Gravel Aquifer*** is the major source of water supply in the western part of the Florida panhandle. It consists of surficial sediments that exceed 700 feet in northwestern Escambia county, and that thin out to the south and east. The water is under both confined and unconfined conditions, with the deep production zone being semiconfined.

Unnamed Surficial and Intermediate Aquifers are present over much of rest of the state, and where deeper aquifers contain nonpotable water, they are important sources of supply. The surficial deposits consist of sand and shell with minor limestone beds. The aquifers are used for public supply in areas southwest of Lake Okeechobee and in various localities along the east coast from Palm Beach county northward. In other areas, they are used mainly for rural supplies. The ***Floridan Aquifer System*** is one of the most productive systems in the United States, and extends across all of Florida, southern Georgia and parts of Alabama and South Carolina. It is the lowermost part of the groundwater reserve in Florida, consisting of very deep beds of limestone and dolomite, which are interconnected hydraulically to varying degrees. The Floridan Aquifer is at or near the surface in the western part of the peninsula that extends from Wakulla to Pasco counties and in most of Holmes and Jackson counties. In other areas it is buried to depths of 1,100 feet below sea level in southern Florida and 1,500 feet below sea level in the western panhandle. It is unconfined in about one-fourth of the state, and confined to varying degrees elsewhere. The Floridan Aquifer is a major source of drinking water for many public supply systems.

Chapter II Summary: Sources and Pathways of Contamination

SUMMARY: SOURCES AND PATHWAYS OF CONTAMINATION

Several types of land uses have significant potential impact on groundwater resources. Proper planning of an aquifer protection program requires understanding of the existing and potential threats within the jurisdiction of the local government. The following section summarizes information contained in Volume II, Chapter I concerning the primary sources of groundwater contamination in Florida.

ON-SITE SEPTIC SYSTEMS

Discharge from septic systems and cesspools has been identified as a significant source of groundwater contamination. Typical contaminants associated with septic systems are disease causing organisms (pathogens), nitrates, phosphorus, and toxic materials. Pathogens such as salmonella, hepatitis, and hookworm can survive for significant periods of time under conditions readily obtainable with septic tanks and drainfields. Nitrogen is commonly found in septic tank waste and is converted to nitrates in soil. Nitrates are linked to methemoglobinemia, a condition leading to asphyxiation in infants. Other suspected health effects are nervous system impairment, birth defects, and cancer. Nitrates are readily transported through coarse soils with little or no attenuation. In watershed areas, nitrogen and phosphorus can increase eutrophication of surface waters. Most toxic materials disposed of in septic systems are not effectively treated by the attenuative mechanisms in septic tanks and drainfields.

Septic systems depend on biological processes within the septic tank and in the soil column underlying the drainfield to attenuate waste products. Solids in the waste settle to the bottom of the tank, where some breakdown occurs. Normally, solids must be pumped out on a regular basis to avoid clogging of the system. Suspended wastes in the effluent receive partial treatment within the tank, then are carried through piping systems from the tank to the drainage field. The drainfield allows the effluent to percolate through the soil beneath the drainfield, receiving additional biological treatment before reaching groundwater. Problems may result from improper siting of septic tank systems, excessive densities, system failure, and unsafe disposal.

Septic tank systems should be sited in areas where the soil has sufficient permeability and attenuation capacity to treat the waste before entering the groundwater. Satisfaction of this criterion will depend on the density of septic systems as well as soil characteristics. Systems should be placed in areas of low groundwater to promote drainage and prevent flooding. In high groundwater areas, treatment efficiency is reduced due to heavy saturation of the soil and can lead to flooding of drainage field areas increasing the potential for human exposure to waste contaminants.

Major factors leading to system failure are improper system design or installation and lack of maintenance. If not properly designed for the volume of waste disposal, a septic system may clog or force effluent to "breakout" to ground surface without sufficient subsurface treatment. Disposal of wastes other than those for which a system is designed can result in more rapid degradation of the system, reduced operating effectiveness, or leakage. Failure to properly maintain septic systems with periodic pumping and inspections allows solids to accumulate, eventually clogging the system and reducing or halting the waste treatment process.

Improper installation procedures can jeopardize the integrity of the septic system. Scratches or dents in the tank or piping material can weaken the system and lead to rapid deterioration. Compaction of drainage field soils during construction can reduce or prohibit percolation, damaging the ability of the system to properly treat the effluent. Where compaction is severe, system backup or flooding can occur.

Preventive Technologies and Practices

Proper system siting, design, installation, operation and maintenance are important to protecting groundwater from septic tank system contaminants. Since many sewage contaminants cannot be effectively treated by attenuation or uptake, siting systems away from public or private drinking water supplies is advisable. Density restrictions should also be applied to ensure adequate dilution of these contaminants occurs to minimize their potential cumulative effects. Maximum recommended densities for residential on-site systems are normally set at two per acre, though soil and groundwater conditions in an area may require lower densities. Other siting considerations include adequate soil conditions to support the system and waste volumes, and low groundwater conditions to promote drainage of waste water.

Proper operation requires an understanding of the limits and capabilities of the septic system. Only materials and quantities anticipated by the system design should be deposited in the system. Routine maintenance is also a critical factor in the long-term operation of a system. Routine inspection and pumping are recommended every three to five years to avoid clogging from waste solids. Cleaning products claiming to dissolve clogging solids without pumping may destroy beneficial bacteria that aid in the breakdown of waste. The overall effectiveness of these products is questionable and many contain suspected carcinogens. Many municipalities promote maintenance by requiring certifications of inspection prior to property transfers or allowing local tax credits for proper tank maintenance activity. Other municipalities contract with septic cleaning services to provide discounted rates to residents.

Alternative technologies are available for areas where geological or hydrological conditions are not suitable for conventional septic systems. These technologies include mound or fill systems, sand filters, and evapotranspiration. Treatment system designs should be selected based on type and volume of waste as well as environmental conditions.

HAZARDOUS MATERIALS STORAGE AND MANAGEMENT

One of the most serious potential pathways for contaminant migration is leakage from improper storage and management of hazardous materials. Contaminants from leaks, spills or accidents can migrate into groundwater and severely impact potable water supplies. An effective potable aquifer protection strategy will necessarily include careful regulation of aboveground and underground storage tanks for liquid hazardous materials, and management programs for hazardous materials usage.

Storage Tanks and Integral Piping

Three primary causes of storage tank leaks are: corrosion of tanks and piping, improper design and installation, and poor operating practices. Corrosion can occur in either fiberglass reinforced (FRP) plastic or metal storage tank systems. FRP storage tank systems may deteriorate if materials being stored are incompatible with the materials forming the tank and piping. FRP tanks are also subject to deterioration by effects of the surrounding environment, such as extreme temperatures, unstable foundations or fill materials.

Metal tanks and pipes corrode through an electrochemical process which leads to oxidation or rusting of the tank. Environmental conditions such as extreme temperatures or elevated levels of salt, sulfide, bacteria, or moisture can cause corrosion of metal tanks and piping. The process may also be initiated when tanks are placed too near outside electrical sources, or when two tanks constructed of dissimilar metals are placed near each other, or if a new steel tank is placed near another older, rusty tank. A metal tank may also corrode on its own due to variations in the metals used to construct the tank. These variations, when placed under stress or in water, tend to become corrosion sites.

Improper design and installation are also causes of storage tank leakage. Design considerations should include appropriateness of tank size and construction material for the type and volume of material to be stored. Design considerations for underground storage systems should include the compatibility of the fill material placed around the tank with the storage system materials. Incompatible fill can lead to deterioration of underground storage tanks. Poor site selection and fill placement can lead to installation of tanks on unstable foundations, placing stress on the tank and increasing the likelihood of corrosion or rupture.

Preventive Technologies and Practices

The risk of leaks or spills from aboveground and underground storage tanks can be minimized through proper equipment selection, installation practices and operating practices. The following briefly describes appropriate types of equipment, proper installation procedures and operating practices.

A variety of tank and piping materials and system design options exist to reduce the potential for corrosion, rupture, or accidents. Tanks and pipes may be constructed with reinforced materials, cathodic protection, or corrosion resistant coatings. Secondary containment of tanks and pipes is the most effective form of leak protection. Double-walled tanks and pipes provide pre-engineered secondary containment. Special piping joints, such as expansion or swing joints, provide additional flexibility to a system, reducing the risk of leakage.

Storage tanks and piping should be designed with monitoring and alarm systems. To guard against overfilling, a storage system may be equipped with gauges, automatic shut-off valves and/or alarms. To reduce spill risks while transferring stored materials to or from the tank, storage systems may be designed with spring-loaded couplings to prevent stored material from running out of the transfer hose after the receiving tank is full. To detect leaks once the system is installed, monitoring systems to measure liquid levels in the tank may be included in the system design. In double-walled tanks, a monitor of the interstitial space between the inner and outer tank walls should be able to detect breaches of either wall.

Aboveground systems should include a containment area surrounding the tank to hold storage tank contents in case of spill or leakage. Aboveground tanks should not rest directly on the ground, but should be placed on an impervious surface, with secondary containment provided by an impervious dike or wall. The containment system for outdoor tanks should be capable of holding a designated quantity of rain water in addition to the contents of the tank. When it is not possible to install impervious containment under an existing tank, internal lining may, under certain circumstances, provide some protection for that portion of the tank in contact with the ground.

Proper installation practices are critical to the long-term safe operation of a storage tank system. Attention should be given to proper siting and careful handling of equipment. In the installation of underground storage tanks, there are additional concerns about backfilling, and anchoring. Selecting the appropriate site requires an understanding of the geology, hydrology and previous land uses of an area. This understanding will help avoid areas of corrosive soils, unstable soil foundations, existing older or abandoned tanks, and areas of electrical activity. Tanks must be handled properly during installation to avoid scraping or denting which could impact the integrity of the tank or increase the potential for corrosion.

Where potentially high groundwater conditions are unavoidable, anchoring of an underground tank will be necessary. Anchoring requires that the tank be strapped to concrete pads laid alongside the tank, to prevent it from floating, which can damage the storage system. Backfill material should be chosen for compatibility with the storage system and should provide adequate support for underground FRP tanks.

Hazardous Materials Management

Hazardous materials management plans allow development of comprehensive approaches to the use and handling of hazardous materials. It is important to have a complete understanding of the types and quantities of hazardous materials being used in a particular business and the processes through which these materials go. Operating practices must be developed with attention toward personnel safety and protecting and monitoring the integrity of storage and processing systems. Accidents resulting in spills may be minimized by thorough training of operations personnel and careful attention to operating procedures. Operating procedures should be documented and should, at a minimum, address identification of all system components, procedures for measuring liquid levels, loading and unloading of stored materials, and emergency prevention and preparedness plans.

STORMWATER RUNOFF

The adverse impacts of stormwater runoff can include erosion, flooding and contaminant migration into surface water and groundwater. Stormwater management has long focused on flooding and erosion control, however recently, stormwater contamination of groundwater has become an important concern. In developed areas, impervious surfaces such as concrete foundations, sidewalks, asphalt parking lots and roads cause stormwater to accumulate rather than seep naturally into the soil. Pollutants resulting from the associated land use can be washed into surface and ground waters with stormwater. In addition, biological processes for attenuating many stormwater pollutants are lost when the natural ground cover is paved. Volume II, Chapter II of this manual provides an expanded discussion of the types of stormwater runoff pollutants and basic principles of stormwater management. The chapter also explains several types of best management practices that may be incorporated into stormwater management plans.

Stormwater Runoff Pollutants

Typical stormwater runoff pollutants include sediment, oxygen demanding substances, heavy metals, bacteria and nutrients. Sediment is solid material made up of disintegrated rock, eroded soil or organic material. Sedimentation in runoff is not associated with any particular land use, but may be found in areas where is erosion is not effectively controlled.

Oxygen demanding substances are generally organic materials, such as grease and oils, which are decomposed by microorganisms requiring oxygen to live. As the volume of these substances increases, the amount of oxygen required to digest them also increases. The more oxygen taken in by these organisms, the less that is available for existing plant or fish life. Oxygen demand is measured by two types of tests, biological oxygen demand (BOD) or chemical oxygen demand (COD). Levels of oxygen demanding substances are usually higher in areas of residential or roadway land use. To handle elevated BOD or COD levels, a stormwater system should include aerators or fountains or should be designed to promote wind mixing so that sufficient oxygen is available.

Heavy metals, such as lead, zinc, copper, and cadmium are found in runoff from highway areas. These metals result from degradation of highway materials and the operation of motor vehicles. Stormwater systems should be designed with aquatic plants which will aid in the uptake of dissolved metals. In addition, design should allow for sufficient distance between stormwater discharge points and the receiving inlet in order to promote settling of sediments and uptake of the metals. One popular response is the use of grassed swales, in combination with settling ponds and retention ponds.

Nutrients, such as nitrogen and phosphorus, are most often found in runoff from residential areas. The primary sources of these nutrients are fertilizers and detergents. Nutrients cause the accelerated growth of algae and other aquatic plants. These plants consume oxygen and deplete the available dissolved oxygen for other existing plant and fish life. Stormwater systems should be designed to promote settling of the particulate forms of the nutrients and should have areas of aquatic plants near the discharge point to assimilate dissolved nutrients.

Principles of Stormwater Management

The goal of stormwater management for new development should be to assure that the volume of stormwater, rate of discharge, and pollutant loading after development is similar to the conditions prior to development. Addressing that goal, the Florida Department of Environmental Regulation (DER) has developed several principles for stormwater management in its publication, "The Florida Development Manual: A Guide to Sound Land and Water Management."

The principles suggest that comprehensive stormwater management begins with sound land use planning decisions. Land use plans should include stormwater management plans that take advantage of natural drainage features which slow runoff and promote infiltration. The management plans should also consider the impact on the entire drainage basin in which the development is located rather than focusing on the boundaries of the development. The design of the system should adequately address need for settling, infiltration and storage areas.

To decrease sediment clogging and maintain the operating efficiency of a stormwater management system, the principles recommend system stabilization prior to the first use of the system. This reduces the likelihood that re-vegetation or regrading will be required after startup. Following startup, regular inspections and maintenance should be performed to maintain system efficiency.

Representative Best Management Practices

An efficient, integrated stormwater management system will employ a "treatment train" approach using various "best management practices" (BMPs) to handle the first flush of runoff, in which about 80-90% of the pollution load is carried. Generally, BMPs control erosion, sedimentation, flooding, and pollution loading through infiltration and detention. Infiltration BMPs decrease pollution loads by filtering stormwater back into the ground through various natural or man-made systems. These systems treat the storm water by providing pathways for assimilation or settling of pollutants as the water seeps into underlying aquifers. Common infiltration BMPs are vegetated waterways, retention areas, exfiltration trenches and underground percolation systems. These systems retain stormwater allowing it to flow through vegetation or percolate through permeable soils or underground filtration systems.

Detention BMPs hold and treat stormwater for later release. Detention BMPs include detention areas, detention ponds with soil filters, and wetland systems. These systems may also use vegetation to absorb pollutants, soil filters to trap particulate pollutants attached to sediment, and indigenous microorganisms to break down organics.

In existing developed areas, the installation or modification of a stormwater management system may be difficult. For these areas, low cost retrofit BMPs include curb cuts, inlets within grassed areas, turf blocks, porous paving material and filter trenches. These BMPs treat stormwater by filtration through grassed areas, gravel filled collection trenches with underlying filter material, or filtration through porous concrete or asphalt, reducing flooding and runoff from road surfaces.

AGRICULTURAL LAND USES

Agricultural activities such as improper or excessive use of agricultural chemicals, or improper management of animal wastes can result in groundwater and surface water contamination. An aquifer protection program in agricultural areas should address the handling, storage and use of chemicals, such as pesticides and fertilizers, and wastes from concentrated livestock operations.

Agricultural Chemicals

Modern agricultural operations are extremely dependent on various types of chemical pesticides, including insecticides, herbicides, and fungicides. The fate and transport of many pesticides is not clearly understood. The two characteristics most important to determining a pesticides's potential to contaminate groundwater are its persistence and mobility. Persistence refers to the ability of a chemical pesticide to survive in soil while mobility refers to how far the pesticide can move in the surface and subsurface environment. Key properties are solubility, volatility, soil sorption ability, and degradation rate. Soil conditions such as temperature, moisture, precipitation, and groundwater flow also affect the likelihood of pesticide migration into groundwater.

In addition to pesticides, nitrogen containing chemical fertilizers and manures threaten groundwater when the application amount exceeds the amount taken up by the crops. In the subsurface environment, residual nitrogen is converted to nitrates, which are soluble and do not readily adhere to soil particles, thus making them more likely to migrate to groundwater. Nitrates have been linked to methemoglobinemia, "blue baby syndrome," a condition which causes asphyxiation in infants. Other suspected health effects are impairment of the nervous system, cancer, male sterility, and birth defects.

In addition to nitrate leaching, irrigation activities can threaten groundwater when pesticides and fertilizers are mixed with irrigation water for simultaneous application, a process known as chemigation. If it is improperly mixed or its application is poorly timed to coincide with rain events, chemigation water can force more of a chemical below the crop root zone and into the groundwater. Trench, or furrow, chemigation is more likely to result in leaching of chemicals to groundwater. Both the quantity and quality of irrigation water applications can be more carefully controlled with the use of drip irrigation techniques. Other general measures for protecting groundwater from agricultural chemicals include the use of appropriate storage containers, proper mixing practices and containment of mixing areas, proper container disposal, and installation of antisyphon devices on chemigation equipment.

The best approach for groundwater protection purposes is to avoid the use of agricultural chemicals in sensitive aquifer protection areas. Pesticides should not be applied in areas where, due to geologic or soil conditions, they are likely to migrate to groundwater. The application of fertilizer should be based on realistic crop yield expectations and should be limited to the amount necessary to meet projected crop needs. The method, rate and timing of agricultural chemicals should be aimed at maximizing crop uptake and minimizing losses to groundwater.

Additional protective pesticide management techniques include those such as the practice of rotating crops in order to take up residual nitrogen in soil and disrupt insect life cycles and plant diseases. These types of strategies are basic to integrated pest management (IPM), an developing system of pest management which uses biological and other less intrusive methods to control pests, with only minimal use of pesticides. Though not yet widely adopted, IPM reduces the need for pesticide application by the use of techniques such as natural pest predators, changing planting times to avoid peak pest populations, trapping male insects, and development of resistant crop varieties, among others. Its promotion is important to groundwater protection efforts in Florida.

Animal Feedlots and Livestock Operations

Under normal conditions, animal wastes can be readily assimilated by crops and soil. However, in intensively used areas where waste loads are high and groundwater is closer to the surface, or soil is more permeable, manure creates a contamination problem for surface water and groundwater. Animal waste contains nitrogen which promotes algal growth in surface water and can lead to eutrophication. In soil, nitrogen is converted to nitrates which are soluble and can easily migrate to groundwater, creating the potential for various human health problems. Animal wastes also contain bacterial pathogens which can transmit viruses and diseases. The use of hormones, antibiotics and chemical feed additives in livestock production raise concerns about the impact of these compounds on groundwater and human health.

The most effective approach to groundwater protection is to prevent siting of intensive livestock operation in areas with insufficient soil attenuation capacity, and to control animal densities in less sensitive areas. Even in less sensitive areas, a manure management plan should be developed to address waste collection, adequate containment and treatment methods, carefully timed applications of treated wastes based on crop nutrient needs, monitoring programs, and odor and surface runoff control measures.

INJECTION AND DRAINAGE WELLS

The injection of treated waste water into nonpotable aquifers is a method of effluent disposal. Underground injection wells are drilled through several geologic layers and water-bearing zones, and waste water is pumped under pressure into a brackish water zone typically beneath a low permeability clay or rock layer (confining layer). Failure of well casings or leaks through the confining layer can result in contamination of overlying aquifers. Typical contaminants associated with injection wells are industrial wastes, organic chemicals, acids, and brines.

State law divides injection wells into five classifications. Class I wells are used for disposal of hazardous wastes and other industrial or municipal wastes beneath the lowest geologic formation containing an underground drinking water source within one quarter mile. Injection of hazardous waste through wells in this class are prohibited as of July 1, 1983. Class II wells inject brine from oil and gas production or are used to enhance recovery of oil and gas through the injection of water. Class I and Class II wells cannot inject into or above a potable aquifer but may be installed through the aquifer. Class III wells provide injection for the extraction of minerals or solution mining of minerals. Class IV wells are designated for injection of hazardous or radioactive waste, but have been prohibited in Florida since April 1, 1981. Class V wells are the most common and include drainage wells, connector wells, recharge wells, cooling water return wells, and other injection wells not identified in Classes I through IV. Generally, these wells may inject into drinking water aquifers, if the injected fluids meet drinking water standards. Volume II, Chapter II includes an expanded summary of the state administrative rule regulating injection wells.

Preventive Practices

Underground injection and drainage wells should be prohibited in karst areas, recharge areas, other wellfield protection areas, and where subsurface conditions cannot provide adequate confinement of injection or drainage fluids. Safe design considerations for well construction include testing the waste for compatibility with the well equipment and with other wastes to be injected into the zone. In addition, if the waste is incompatible with the material forming the confining layer, the layer may be breached and allow leaking into potable aquifers. Care should be taken in installing injection well casing to ensure integrity of the casing and to prevent possible leakage of fluids before they reach the injection zone. Monitoring of drinking water aquifers in the vicinity of the disposal well should be conducted to ensure the effectiveness of the disposal system.

LANDFILLS

In most areas of Florida, landfills pose an inherent threat to groundwater. Leachate is produced from precipitation or moisture in landfill waste and seeps to the base of the landfill taking with it soluble waste materials. Leachate volumes tend to be higher in humid areas, where precipitation exceeds evaporation. EPA's Office of Solid Waste has estimated that a 17-acre disposal site with annual precipitation of 10 inches can generate 4.6 million gallons of leachate a year.

The contaminants generated by landfills vary according to the type of waste. The typical municipal landfill contains primarily paper, food waste, yard trash, glass, metal, and plastics. This includes potentially toxic materials such as household containers with cleaning products, solvents, paint, pesticides, oils and acids. The contaminants generally associated with sanitary landfills include disease causing organisms (pathogens), organic chemicals, and heavy metals. Pathogens carried by insects or vermin often survive in soil conditions beneath landfills and are not adequately treated by attenuation processes. Organic compounds tend to be more mobile and less likely to degrade through biological interaction. These compounds are linked to impairments of the central nervous and circulatory systems. Heavy metals do not degrade through biological interaction and tend to accumulate in the body, contributing to central nervous system disorders, gastrointestinal disturbances, birth defects, and cancer.

The level of risk associated with landfills depends largely on the type of waste, site conditions, and facility design and operation. Siting of landfills on unstable soil foundations can cause landfill liners to fail under waste loads. High groundwater areas are also unsuitable, since the likelihood of groundwater contamination is greater in the event of a liner breach.

In Florida, landfills are classified into three categories. Class I sanitary landfills receive an average of 20 tons or more of solid waste per day and receive an initial cover at the end of each working day. Class II sanitary landfills receive an average of less than 20 tons per day and must be covered once every four days or more frequently if they receive sewage or industrial sludges, dead animals, or other nuisance wastes. Class III landfills receive only trash and yard trash, including vegetation, debris, cardboard, cloth, glass, street sweepings, and vehicle tires. Construction and demolition debris landfills accept such materials as asphalt, concrete, wallboard, glass, shingles, lumber, tile and other materials from the construction or demolition of a property.

Liners are required for landfills accepting more potentially hazardous materials, though many older existing landfills are not lined. Liners may be constructed of synthetic materials or soil (clay). Material selection depends on the type of waste disposed and site conditions. Synthetic liners are required to meet certain design and performance standards specifying thickness, durability, and stress resistance. Soil material selected for liners must meet certain standards of impermeability and be free of fractures, roots, or other potential contaminant migration pathways. If soil liners are not sufficiently thick, leachate may seep through the liner through intervening soils and into groundwater.

Landfills accepting more potentially hazardous materials are required to have a leachate collection system constructed of a network of perforated pipes at the base of the landfill, connected to sumps. Beneath the leachate collection system is a protective liner constructed of soil or synthetic material. If the containment and collection system materials are incompatible with the waste, the system is likely to function less efficiently or fail entirely. Leachate collection systems should be inspected regularly to ensure constant operating efficiency.

Preventive Technologies and Practices

Though probably impossible to eliminate entirely, the numbers of landfills can be drastically reduced by other measures such as recycling, composting, and waste-to-energy processes. Such approaches can increase the lifespan and reduce the risks posed by landfills by reducing the amount of waste disposed in landfills.

Proper siting is the most important approach to preventing groundwater contamination from landfills. It is vital that no landfill be located within hydrogeologically vulnerable areas for existing or future public wellfields, or near higher concentrations of shallow private wells. The most suitable areas for landfills are those with low groundwater, providing the greatest distance between the landfill liner and underlying aquifers. Also, due to concerns about runoff and leachate migration, landfills should be prohibited within fairly large distances of surface waters.

Adequate design and performance of the liner and leachate collection system are critical to groundwater protection, since these components serve as the primary preventive technologies for contaminant migration. Materials used for construction of the liner and leachate collection system should be compatible with the type of waste anticipated. Care should be taken during installation to ensure that these systems are not damaged and will function as expected. Inspection and testing should be performed prior to any waste disposal. Landfills should also have a monitoring program to detect the presence of leachate in groundwater. Leachate production can be reduced by requiring cover materials to be installed, including use of a compacted clay cap for purposes of landfill closure.

Chapter III   Summary: Aquifer Protection Tools

SUMMARY: AQUIFER PROTECTION TOOLS

A number of tools are available to local governments to assist in the implementation of an aquifer protection program, including both regulatory and non-regulatory approaches. Among the regulatory controls exercised by local governments are zoning ordinances, subdivision controls and health regulations. Non-regulatory techniques are characterized by local government control of protected lands, careful coordination with other public planning efforts and by development of public awareness. These tools include purchasing land or development rights, acquiring easements or options, developing contingency plans, organizing county-wide hazardous waste collection events, and developing public education programs. A more complete discussion of the following approaches is provided in Volume II, Chapter III. See Table 1 for a summary of the potential application of local government tools to primary groundwater threats.

REGULATORY TOOLS

A key regulatory tool available to local governments is zoning. ***Traditional zoning*** limits land uses in an area to those considered compatible with other uses. The approach is most useful for aquifer protection in areas with little or no development. In areas of existing development, land uses may not be consistent with the sensitive nature of the underlying aquifers. Attempts to rezone such areas may meet stiff resistance, and if successful, normally must allow pre-existing nonconforming uses to be grandfathered in. In these areas, options do exist, such as the removal or gradual phasing out of nonconforming uses, but under traditional zoning analysis, may be subject to legal challenge.

Another very important tool, on which most of the other tools may be based, is known as overlay zoning. ***Overlay zones*** are mapped districts, corresponding to the boundaries of one or more areas of aquifer vulnerability, which set other restrictions on land use, in addition to those of the existing zoning classification. Overlay zoning may be applied to protect sensitive aquifer zones that do not correspond to existing zoned areas or which require more stringent protection than is provided by existing zoning regulations. Based on the sensitivity of the underlying aquifer, additional restrictions may include prohibitions on certain land uses, reduced densities, limits on impervious surface, hazardous materials controls, and strict stormwater and waste disposal requirements. Many of the representative ordinances included in Appendix A of this manual employ an overlay approach to controlling land uses over sensitive areas.

Overlay zones must be based on sound hydrogeological information, or they may be subject to constitutional attack. Generally, regulations must have a reasonable relationship to a valid governmental objective. Protection of the public health and safety through groundwater protection is well accepted as a valid governmental objective, thus the primary focus will be on whether a local ordinance bears a reasonable relationship to that objective. To avoid charges of arbitrary and capricious governmental action, there should be a substantive showing of a rational basis for the delineation and classification of the protected areas based on the best available information. The information may come from local staff studies, hydrogeological consultants, agencies such as the Florida Department of Environmental Regulation (DER), the United States Geological Survey, Florida Geological Survey, water management districts, or from permit applicants.

Several regulatory techniques can be combined to control land uses and densities in overlay zones. One of the more common approaches to aquifer protection is the application of ***land use prohibitions*** on the most threatening land uses in sensitive areas. This approach may also specify certain other potential land uses as ***conditional uses*** (also known as ***special exceptions*** or ***special uses***), and require applicants to submit special use permit applications (see, for example, Palm Beach County Ordinance No. 88-7).

Careful specification of acceptable uses under the special permit section is important to ensure that an ordinance is not interpreted as allowing activities which could endanger potable aquifers. The conditions under which special permits are granted should also be carefully specified in the ordinance, in order to ensure that potable aquifers will be effectively protected from permitted activities. One approach to the permitting of special uses is provided in Sections 4.3.8--4.3.10 of the Acton, Mass. zoning bylaw. A ***variance*** is a form of relief from the requirements of a zoning ordinance, typically considered at the discretion of an appointed board such as a zoning board of appeals or board of adjustment, on a finding that application of the ordinance places a clear and unnecessary hardship on the applicant and that granting the variance will not impair the intent or effectiveness of the ordinance in protecting the public health and safety. If some form of relief mechanism is determined to be necessary, for groundwater protection purposes, the use of special exceptions is preferable to use of variances, since special exceptions may only be granted under certain conditions which must be carefully stipulated in the ordinance.

Subdivision regulations are another form of aquifer protection tool that can be used to control factors such as drainage patterns and stormwater management, street construction, impervious surfaces, utility placement and traffic patterns. Under Florida's Local Government Comprehensive Planning and Land Development Regulation Action (LGCPLDRA), all local governments are required to regulate the subdivision of land to ensure consistency with land use planning and other goals, including the sewer, water and drainage element and the conservation element. Subdividers must submit plat maps for approval before any land can be subdivided. A local subdivision control ordinance may, for example, specify required stormwater management practices or limit areas of impervious road surfaces (see, for example, Section 4.3.4 of the Acton, Mass. zoning bylaw and Winter Park Code, Chapter 23A). ***Site plan review*** is not limited to subdivision plat maps, and may be required for any type of development, whether or not lots are being subdivided. Though not intended to allow the imposition of style or design preferences, site plan review can be used to carefully review and control elements of the plan dealing with surface water drainage, environmental concerns, traffic effects, pedestrian safety, utility services, and disposal of wastes. In reviewing site plans, local boards can determine if the engineering design of the proposed development adequately addresses aquifer protection.

Large lot zoning can be required in aquifer protection areas, to reduce the potential intensities of land use by regulating the minimum lot size. Increasing lot sizes reduces the potential number of septic systems within a development, and reduces the number of buildings and amounts of paved area, thus decreasing the impacts of stormwater runoff and enhancing groundwater recharge. The overlay bylaw of Holliston, Mass. controls lot sizes and impervious surfaces for various categories of land use in each of three aquifer protection zones.

Under its police power authority, a local government may adopt and implement ***health regulations*** protecting the health and safety of the community. One of the most important of these types of regulations is the control of hazardous materials storage and use. Working in coordination with DER, local governments may adopt regulations to control the use, storage and handling of hazardous materials. Though the state currently preempts control of underground storage tanks for certain regulated substances, including motor vehicle fuel, local governments may contract with DER to administer the state regulations for two years, then adopt more stringent standards. In sensitive zones, such uses are often prohibited or subject to very strict permit conditions. Representative ordinances addressing hazardous materials storage and use include those of Austin, Tex. (Ordinance No. 84), Broward County (Chapter 27-12), and Pinellas County (Ordinance No. 90-2).

TABLE 1
Potential Application of Aquifer Protection Tools by Local Government

	On-Site Septic Systems	Haz. Mat. Storage and Mgt.	Storm-water Runoff	Agric. Land Uses	Inj. and Drainage Wells	Landfills
Traditional Zoning	•	•		•	•	•
Subdivision Regs./ Site Plan Review	•	•	•		•	•
Health Regs.	•	•				
Overlay Zoning	•	•	•	•	•	•
Land Use Prohibition	•	•			•	•
Density Controls	•					
Impervious Surface Controls		•	•			•
Containment Standards		•		•		•
Operation/ Maintenance Regs.	•	•	•	•	•	•
Best Management Practices		•	•	•		
Contingency Plans		•			•	•
Hazardous Waste Collection		•				
Acquisition			•		•	•
Public Education	•	•	•			

Local governments may also enact health regulations controlling the use of septic systems and small-scale sewage treatment plants known as package plants. Septic tank siting and density controls are important to limiting groundwater loading rates in sensitive areas. Package plants are often proposed for developments too far removed from central sewer lines, in areas considered unsuitable for conventional septic systems. Most package plants use pre-engineered designs and processes which may not be adequate to the needs of the development. The potential health threats posed by poor maintenance or plant failure require control of package plants in aquifer sensitive areas. The requirements of Dade County Code (Section 24-13) and the Panhandle Health District No. 1 address septic tank siting, density and operating controls.

Cluster zoning and ***planned unit development (PUD) zoning*** operate to preserve as much as possible the natural uses of the land. Development in these zones is placed in smaller areas for easier monitoring and more careful approaches to reducing sources of contamination. Cluster zones permit closely grouped residential developments, allowing expanses of open space or common areas, and protecting environmentally sensitive areas, including recharge areas. PUDs generally contain multiple uses, such as residential and commercial, but apply the same concept of close grouping and open space. Cluster and PUD zones may also exist as "floating zones." These zones are not mapped but the required conditions such as allowable uses, densities, and lot sizes are specified in the zoning text. In appropriate areas, the developer may petition to have the zone applied.

Local governments may also create ***transfer of development rights (TDR)*** programs with protected "sending areas" from which landowners may transfer development rights permitted by zoning to other areas known as "receiving areas." In exchange for protection of a sending area, the developer is granted a density bonus in the receiving area. Receiving areas must be capable of tolerating a much higher development density without adversely impacting potable water supplies. By transferring development rights out of the sending area, protection is increased for the aquifer over which the sending area is located. Such programs require substantial administrative resources.

NON-REGULATORY TOOLS

There are a wide variety of non-regulatory tools available which can supplement regulatory controls in sensitive areas, or serve as the primary protection strategy in less sensitive areas. ***Acquisition of land or other interests in land*** is an important protective tool for local governments. A municipality may purchase land overlying sensitive aquifers from willing landowners. It may also obtain private land by exercising eminent domain. An outright sale can take several forms including fair market value sale, installment sale, or sale with a reserved life estate. Rather than purchasing the property in fee simple, a municipality may opt to purchase only a partial interest, since these are typically less expensive than fee simple purchases. With a partial interest, the local government may not exercise full control over the property, but may restrict certain activities or land uses. Generally, the local government is not required to maintain the property, and may still collect property taxes from the owner.

Capital improvements planning is another important non-regulatory component of an aquifer protection approach, given the role that local government infrastructure plays in fostering development. Capital improvements planning, planning for future development, transportation planning and conservation and open space planning all play a role in whether and how a community will develop. Local governments can further aquifer protection goals by carefully coordinating the policies and objectives of these comprehensive plan elements with potable aquifer protection goals. ***Contingency planning*** is another local activity which identifies how a community will deal with water supply disruption and contamination events. In developing a contingency plan, potential threats to ground water should be identified along with appropriate response and remediation actions.

Toxic household wastes such as cleaning products, pesticides, paints, pool chemicals, and solvents are often disposed with other household trash, increasing the risk of groundwater contamination at municipal landfills. Wastes discharged into sewer or septic systems may also jeopardize groundwater quality. ***Hazardous waste collection programs*** allow a local government to collect such materials before they enter the waste stream. Typically, a local government will contract with a hazardous waste management company to transport and properly dispose of the collected wastes. The Florida Department of Environmental Regulation may be able to supply grant funds to help establish local hazardous waste collection centers.

A local government may initiate its own ***groundwater monitoring program***, possibly in conjunction with the monitoring networks of the DER, HRS or water management districts. Implementation of a monitoring program requires documented sampling procedures and certified laboratory analyses. The information gathered from sampling can be useful in modifying local groundwater protection programs.

Chapter IV The Decisionmaking Process

THE DECISIONMAKING PROCESS

INTRODUCTION

Creating effective, defensible aquifer protection programs requires careful planning, research and analysis. Proper treatment of the technical, legal and administrative issues associated with groundwater protection may require the efforts of several local government departments. The planning process should include establishing a management team and technical advisory group, determining the goals and objectives of the effort, selecting options and developing an appropriate strategy, and implementing the selected strategy. Critical tasks will include collecting and analyzing information on hydrogeology and water use patterns, assembling technical data, delineating protection zones, analyzing the applicability of existing regulations, and developing ordinances. The following discussion on decisionmaking examines issues in this process, and is structured around a planning model published by the Southwest Florida Water Management District.[1]

MANAGEMENT TEAM AND TECHNICAL ADVISORY GROUP

An important first step is to assemble a management team and a technical advisory group. The management team, composed of staff from planning, engineering, public works and environmental departments, will guide the processes of gathering information, setting goals and objectives, and selection of appropriate strategies to achieve the goals and objectives. It is advisable to select team members capable of explaining to the public and local governing board the many technical and planning issues involved in creating an aquifer protection program.

A technical advisory group should help guide the process through technical issues concerning information gathering and evaluation, and the development of appropriate standards such as setbacks and design criteria. A particular standard may, or may not, be appropriate in a given situation, depending on the vulnerability of the aquifer and the degree of threat posed by the land use in question. The technical advisory group will help in determining what types of technological or operation controls should be considered an appropriate level of protection, whether an existing regulation provides the control required, and whether a low, medium or high stringency technical requirement is necessary in a given case. Where possible, such a group should include a qualified hydrogeological consultant, as well as representatives of the appropriate water management district, the DER, HRS, the U.S. Geological Survey, and possibly, representatives of other local governments, the U.S. EPA, the Florida Geological Survey, local university department members (including geology, civil engineering, soil science, environmental engineering), a regional water supply authority, and citizens with expertise.

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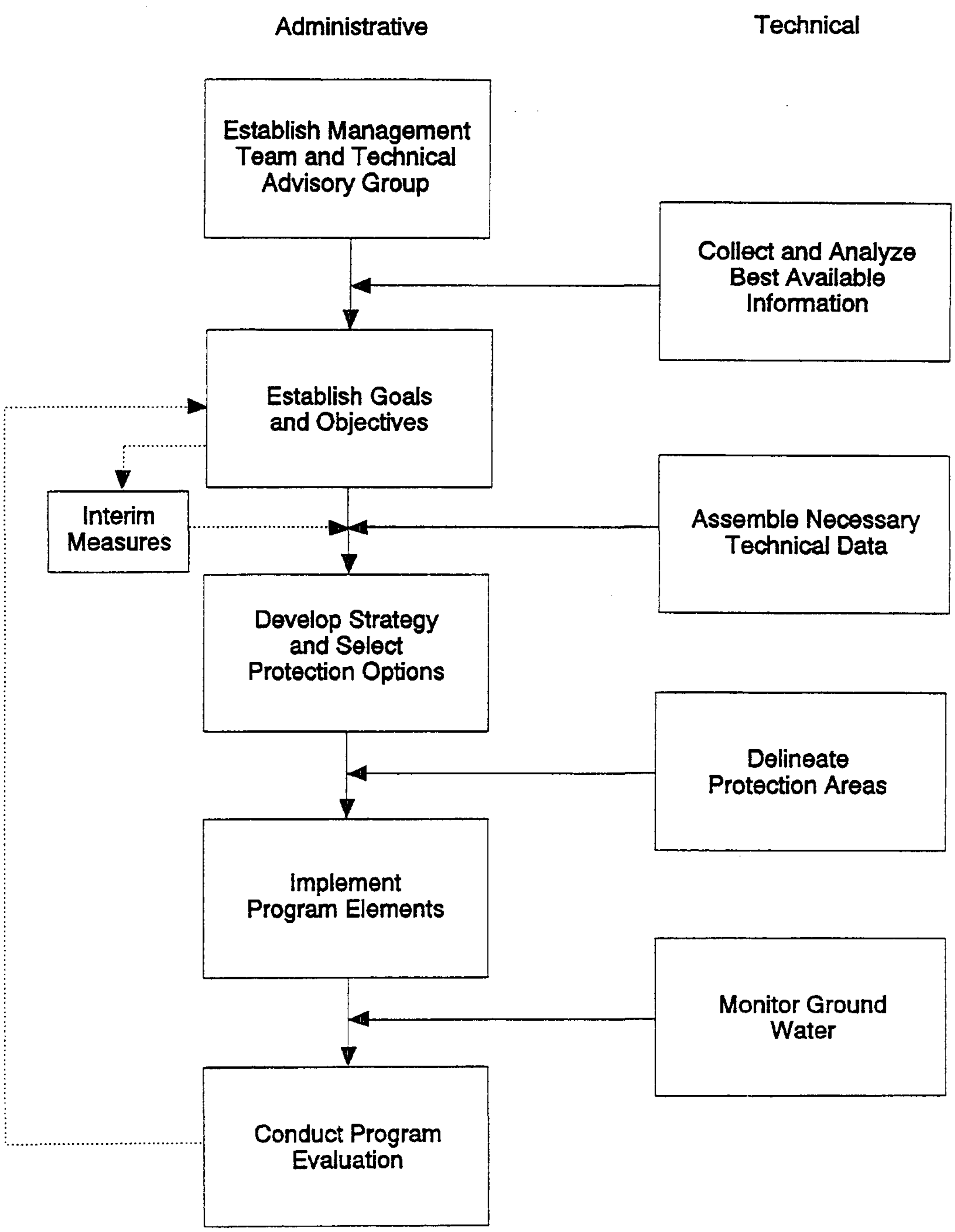
[1] See Frahm, R., "Ground-Water Supply Protection," Technical Information Planning Series, No. 88-4, Southwest Florida Water Management District, Brooksville, Fl. (1989); see also, Canter, Knox & Fairchild, Ground Water Quality Protection 525-547, Lewis Publishers (1988); see generally, Page, G. (ed.), Planning for Groundwater Protection, Academic Press (1987); Blatt, D., "From the Groundwater Up: Local Land Use Planning and Aquifer Protection," 2 J. Land Use and Envtl. Law 108 (1986).

FIGURE 1
Initiating a Local Ground-Water Protection Program



COLLECTION AND ANALYSIS OF EXISTING DATA

The next step in the decisionmaking process involves the collection and analysis of existing information. Establishing a local data base is necessary to the creation of any regulatory program, but particularly so in planning for groundwater protection, because the vulnerability of underground aquifers is not easily determined, and many of the potential sources and pathways of contamination are not readily apparent. Information gathering occurs in two phases. The initial phase includes research and analysis of the best available data concerning local conditions. Staff should be able to perform most of this research, with assistance from the technical advisory group. There are several types of information important to this process. First, the ***hydrogeologic characteristics*** of the area must be determined. The basic types of hydrogeological data include: 1) aquifer mapping (location and extent of important aquifers), aquifer characteristics (degree and extent of confinement, consolidated or unconsolidated, transmissivity and yield, and saturated thickness of deposits; 2) groundwater flow; and 3) groundwater quality.

Basic planning needs also require understanding of ***groundwater use patterns***, including location of existing and future public wells, community and non-community wells and areas with higher concentrations of private wells. Finally, there must be an inventory ***of groundwater threats***, including the locations of existing, historic and future land uses associated with various types of potential contamination. Some form of data management program will be necessary to sort and evaluate the different types of data coming, allowing them to be assembled into a coherent picture of the area.[2] The goal is to be able to see where potable aquifers are vulnerable, where development exists and where it is going, where water is being or will be withdrawn for potable use, and how threatening existing and projected land uses are to groundwater supplies. Overlay maps of the data will help indicate where aquifer protection zones should be located and how stringent land use controls should be in those areas. Where available, geographic information system (GIS) computer capability will be important to the data management effort.

Data is available from a variety of sources, including the local government planning, environmental, health and utilities departments, the water management districts, the Florida Department of Environmental Regulation, the U.S. Geological Survey, U.S. Environmental Protection Agency, the regional planning councils, the U.S. Soil Conservation Service, various departments and research centers within universities, and several professional organizations. Volume II, Chapter I of this manual includes an expanded discussion of the collection and analysis of data on hydrogeology, hydrology, groundwater use and groundwater threats.

ESTABLISHING GOALS AND OBJECTIVES

Using data from the initial phase of information gathering, the planning process can focus on establishing the goals and objectives of the groundwater protection program. This phase of the process is aimed at determining what general areas of the community need protection and what levels of protection should be applied. Overall direction for the local groundwater protection effort can be found in the State Comprehensive Plan (Chapter 187. F.S.), regional policy plans, available from the appropriate regional planning council, and the state water use plan.[3] Since local comprehensive plans and development regulations must be consistent with state and regional plans, the local groundwater protection program should use these plans for guidance. The local

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[2] The U.S. Environmental Protection Agency is currently funding several "Wellhead Protection Data Management Pilot Projects" around the country. Information gathered through these pilot projects can be requested from the EPA Office of Ground-Water Protection.

[3] See Ch. 17-40, Fla. Admin. Code (1990).

program will be based not only on the groundwater threats and aquifer characteristics of the area, but also on the purposes and objectives established in the sewer, solid waste, drainage, potable water and natural groundwater aquifer recharge element, and the conservation element of the local comprehensive plan. The level of service standards for water, sewer, drainage and potable water set by the plan should serve as more specific guides for establishing the goals of an aquifer protection program.

The administrative and enforcement capabilities, and the political will of the local government have a role in determining appropriate goals and objectives. These are discussed in a later section. Full integration of the groundwater protection program into the comprehensive plan will require coordination with the future land use element, the traffic circulation element, and the capital improvements element, since policies and goals established in each of those elements will also have effects on groundwater quality.

INTERIM CONTROL MEASURES

Creation of a full-scale aquifer protection program may take many months of research and development. Based on the severity of existing threats and the aquifer vulnerability as determined by the initial information gathering process, the local government may need to adopt interim protection measures while a more detailed and technically defensible program is being developed. There are simple protection zones and short-term protection strategies that can be adopted quickly, to provide a certain level of protection, while more effective and defensible approaches are developed. The EPA describes several simplified methods for delineating protection areas in its publication titled, "Guidelines for the Delineation of Wellhead Protection Areas."[4] These include reasonable fixed radii circles, calculated fixed radii zones, and simplified variable shapes. Volume II, Chapter I of this manual contains an expanded discussion of protection area delineation methods. Basic protective measures can include prohibitions of threatening land uses, design standards addressing primary threats such as hazardous materials storage, operating standards and emergency plans. Local governments which have adopted interim protection ordinances include Hillsborough County and St. Lucie County, Florida.

TECHNICAL DATA COLLECTION AND ANALYSIS

Aquifer protection strategies must be based on site-specific considerations indicating a knowledge of hydrogeological conditions, types of potential pollution sources, their relative risks and their cumulative level of threat to drinking water supplies, as well as the administrative and enforcement capabilities of the local government. Information gathered during all phases of the planning effort will be important in the formulation of an effective strategy.

Data collection occurs in two phases. After existing information has been gathered and analyzed, and the goals and objectives of the local groundwater protection program established, a second, more technically oriented data gathering effort can be undertaken. The broader study will serve to indicate the general parameters of sensitive areas, potentially threatening land uses and areas of existing and future groundwater use, allowing more concentrated research efforts to be focused in these areas. The technical advisory group and a hydrogeological consultant will be important to guide this phase of the process. The goals of this phase are to generate as much specific data as possible on the hydrogeologic and hydrologic characteristics of the region, the locations of existing and potential groundwater threats, the degree of threat they pose, development trends, and the existing and anticipated patterns of water use in the area. Such

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[4] U.S. Environmental Protection Agency, Office of Ground-Water Protection, Guidelines for Delineation of Wellhead Protection Areas, Washington, D.C. (1987).

data will serve an important function in establishing the technical bases for delineation of aquifer protection zones, and for setting adequate regulatory standards to control groundwater threats in those zones. Limited economic and administrative resources may reduce the area which can be studied. A minimum approach will include study of areas of groundwater withdrawal, and areas upgradient of groundwater withdrawals, to the groundwater drainage divide. Important recharge areas for existing and future public water supply wells should also be examined.

DEVELOP AQUIFER PROTECTION STRATEGY

When technical data gathering and analysis have been completed, a local government is in position to develop a protection strategy. The relationship between a community's protection zones, pollution sources, water use patterns and aquifer protection goals will be reflected in the management strategies it adopts. Management strategies include not only the levels of stringency adopted for land uses in particular zones, but also the types of aquifer protection tools utilized by the local government. Developing a strategy will require analysis of several factors, including: the size, sensitivity and relative importance of the areas which have been identified as protection zones; the types of existing and future groundwater hazards and the aggregrate level of threat they represent; the level of protection afforded by existing regulatory and non-regulatory programs; and the political will and administrative resources of the local government. Determining what combination of conditions will mandate use of stringent approaches, or will allow use of more moderate approaches, requires evaluation of all factors. The technical advisory group plays an important role in evaluating this data and developing appropriate levels of protection.

The chosen strategy not only will require consideration of the goals and objectives that have been established for the groundwater protection program, but must also be related to the administrative resources and political will of the local government. Applicable state, federal and regional regulations should be analyzed to determine the level of protection they offer and the degree to which they satisfy the goals and objectives of the local program. The creation of local management programs should also reflect careful consideration of the capabilities and weaknesses of other regulatory authorities, and the potential use of non-regulatory approaches. The most effective strategies will combine regulatory and non-regulatory techniques, and will coordinate the aquifer protection program with policies and goals in other elements of the local comprehensive plan. All prohibitions and regulatory requirements should be based on evidence and planning analyses which support the approach taken, indicating the level of threat represented by the regulated or prohibited land use, and how the approach taken is necessary to adequately protect the drinking water supply.

Delineate Protection Zones

One of the most practical and defensible approaches to groundwater protection involves establishing aquifer protection overlay zones, defining areas within which threatening land use activities are prohibited or are subject to more restrictive permitting conditions. There are several approaches possible to defining protection zones.[5] The two most important types of areas to be protected are potable aquifer recharge areas and zones of contribution to existing and future public supply wellfields. A minimum approach should delineate zones around areas of significant groundwater withdrawal (including major public wells, community wells and areas with higher use of private wells), and areas upgradient of groundwater withdrawals, to the groundwater drainage divide or to a designated groundwater travel time boundary that will allow adequate time for detection and cleanup of contamination events. Where financial constraints make it impossible to

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[5] See U.S. Environmental Protection Agency, Office of Ground-Water Protection, Guidelines for Delineation of Wellhead Protection Areas, Washington, D.C. (1987).

perform exhaustive hydrogeological studies, a local government may minimize the likelihood of legal challenges to its location of the lines defining protection zones by allowing applicants to submit data based on additional studies concerning the location of zone boundaries. Volume II, Chapter I contains a section explaining the various approaches to delineation of protection zones, including analysis of their strengths and weaknesses.

Most local governments will have designated protection zones that include a certain number of areas based on travel time or drawdown contours extending out from existing and future wellfields, and/or the zones of contribution to such wellfields, and/or areas of significant recharge and direct connection to the potable aquifer feeding the wellfields. In some cases, it may also be necessary to designate areas with high concentrations of private wells as protection zones. The geographic extent and hydrogeological sensitivity of protection zones are important considerations in determining where a control strategy will be focused and how strict it should be. Clearly, more sensitive areas will require stricter approaches to the siting, construction and operation of potentially polluting land uses. The sensitivity of a zone is a function of the directness of its connection to a potable aquifer and its proximity to either a public wellfield or to areas with higher numbers of private wells. Information from the DRASTIC site rating methodology, and other measures of hydrogeological sensitivity, should be utilized in determining relative sensitivities of zones (see Volume II, Chapter I for summaries of several methodologies used to rank sites and groundwater threats).

The size of the local government's protection areas will to some extent, also influence the types of aquifer protection strategies it may undertake. It is more difficult to implement and oversee a permitting program in large areas than in smaller areas. For communities with the resources to administer a permitting program, it may be possible to impose strict permit requirements for a wide range of threats over a large area, but economic and administrative realities make this infeasible for many local governments. Smaller protection zones may allow for easier implementation of a permitting system, since the smaller area enables the local authority to more easily determine appropriate standards and to monitor how well the standards are being met. Where such zones are closer to drinking water wells or to other sensitive areas, the permitting standards for allowed uses should be more stringent, while farther away from wells and sensitive areas, the standards may be appropriately relaxed. Small critical zones may also be targeted for acquisition under the capital improvements planning element and potable water elements of the local comprehensive plan.

For local governments without the extensive resources necessary to conduct a wide-ranging permit program, consideration should be given to prohibiting threatening land uses in critical aquifer protection overlay zones. Where protection zones are small and have a direct relationship to the maintenance of drinking water quality, the prohibition of any threat to groundwater is clearly appropriate. Such zones may include the areas immediately adjacent to a wellfield, zones around sinkholes or areas of karstic limestone with direct connections to a potable aquifer, and relatively small zones with higher concentrations of shallow private drinking water wells. Land use prohibitions in larger zones have also been adopted by local governments in cases where such an approach was determined to be necessary to adequately protect drinking water supplies (see Pinellas County Ordinance No. 90-2).

Very sensitive and important aquifer protection zones can occur over larger areas, such as those underlain by karst limestone. Where a direct threat to drinking water supplies is substantial and local administrative resources limited, prohibiting that land use in sensitive zones of any size may be appropriate, but especially so in sensitive areas containing few of the offending land uses. For the most highly toxic or widespread threats in critical aquifer protection zones, it may be necessary to take this approach in order to adequately protect the community's drinking water. If applied farther away from wellfields, prohibitions may become less defensible. If applied to every potential threat across broad geographical areas however, the legal and administrative difficulties of this approach are apparent.

Where conditions require prohibition of, for example, facilities using hazardous materials in a protection zone, but threatening uses of that type are present in the zone, it may be possible to close the facilities, paying certain costs associated with the closures (see Palm Beach County Ordinance No. 88-7), or to amortize such facilities on a schedule which allows the owners to recoup the cost of the investment. Monitoring should be required during the amortization period, to assure no contaminants are being released to groundwater. With some less threatening land uses, where these approaches are not feasible, a retrofit schedule can be implemented which requires the existing facilities to upgrade their design and operations to meet strict control standards, with monitoring required at the start of the process.

Where larger protection zones are not considered as critical to the quality of a drinking water supply, permitting standards can be appropriately relaxed farther away from wells and recharge areas. In general terms, the smaller the protection zone and the greater the potential threat to drinking water wells (based on the sensitivity of the zone and the threat to it), the more likely it is that prohibitions of threatening land uses or application of strict permitting and retrofit standards will be considered reasonable. At the other end of the continuum, combinations of conditions that include larger protection zones, lower levels of sensitivity, and potential threats that are low toxicity and low density, may require only baseline regulatory approaches or non-regulatory approaches, such as educational pamphlets and bill stuffers.

Evaluate Level of Threat from Existing and Future Land Uses

The degree of threat posed by existing and future land uses in a community will have a significant effect on the choice of aquifer protection strategies necessary to control those hazards. Information from local surveys and analyses of potential pollution source ranking systems should be used to locate and prioritize critical land uses. The local comprehensive plan capital improvements element, housing element, future land use element and potable water element will provide information on the types and locations of anticipated potential groundwater threats throughout the community. Volume II, Chapter I includes a section detailing the primary threats to groundwater, methods of ranking threats, and the protective technologies and practices applicable to each.

Severe threats, especially in or near critical areas, will require stringent controls such as prohibition and removal, or very strict design, construction and operation standards. Prohibitions and closures of existing facilities should be based on analyses which show the threat to be substantial and immediate. Potential threats such as hazardous materials storage, on-site septic systems and package plants can be addressed by health regulations, which allow for stringent and retroactive controls on such land uses. For local governments facing severe threats to groundwater, but lacking the resources to implement a strict permitting program, protection of the community's source of drinking water may require simple prohibitions on such land uses within critical areas. Where administrative resources allow a permitting strategy, serious groundwater threats that do not warrant closure should be controlled with more stringent setback distances, containment standards, construction standards, monitoring standards, and operational safeguards, shorter permit durations, stricter variance and special exception standards, lower application rates, longer retention times and lower densities, among others. Low-level threats, such as land uses with reduced densities and less potential toxicity may be addressed with non-regulatory or baseline regulatory approaches, especially for zones which are less critical and farther away from drinking water supplies.

The planned locations of future wellfields should be factored into this analysis, to allow strict controls on uses and development standards to be put into place well before any development pressure occurs in those areas. Future protection zones with little existing development may be rezoned to reflect the sensitive nature of the underlying aquifer, with threatening land uses and materials prohibited. Permitted land uses in these zones can be kept at low densities, with design, construction and operation standards that are appropriate to protection of the area.

Evaluate Effectiveness of Existing Regulations

Aquifer protection needs will depend on the sensitivity of the protection zones and the types of potential threats. In order to adequately protect sensitive areas, it will be necessary to evaluate the effectiveness of existing regulations addressing the particular threats in those areas. Comparing the adequacy of existing regulatory controls to aquifer protection needs in the community's designated protection zones will indicate where local controls must be developed or upgraded to protect the drinking water supply. There are several federal, state and district regulations dealing with the primary threats to groundwater. These include rules of the U.S. EPA, Florida's Department of Environmental Regulation, and Department of Health and Rehabilitative Services, the applicable water management district, and the state Department of Agricultural and Consumer Services.

Summaries of the applicable laws and rules administered by these agencies are contained in Volume II, Chapter II of this manual (see Table 2 below for page number references). For a full accounting of all requirements, reference should be made to the text of the rules. Staff in the various departments of DER, HRS, and DACS, the regional EPA office, national EPA office of groundwater protection, and the applicable water management district can also be contacted for specific information on the requirements of the rules. The technical advisory group, hydrogeological consultant and local legal staff will be able to help in evaluating the strengths and weaknesses of those regulatory approaches, and determining whether the permit criteria are appropriate given the sensitivity of local protection zones and the level of threat posed by the particular land use.

When evaluating the sufficiency of state and federal rules, important criteria to consider include: threshold values at which permit conditions are imposed, numbers of exemptions, criteria for variances, setbacks from wellfields, surface waters and other sensitive areas, containment standards, monitoring standards, operation and maintenance standards, closure requirements, reporting requirements, contingency planning requirements, retention standards, and density standards. Additional factors to consider in evaluating existing regulatory authorities are whether they provide adequate review of new and existing threats within the particular protection zone, whether they can maintain adequate overview of permitted systems over time, and whether they have the necessary commitment to enforcing permit conditions. In many cases, the regulatory standards administered by state, regional and federal agencies should be considered baseline requirements, appropriate in situations where there is considerable natural protection or where the potential threat is relatively low.

Based on this evaluation, it may be necessary to adopt an independent local ordinance that more carefully addresses conditions in the area. Other potential approaches may rely on the appropriate state or water management district rule to control a particular threat in a particular area, or a mix of local regulations addressing certain protection zones and state or district rules addressing other areas. The analysis will depend on the vulnerability of the zone, the threat posed by the particular land use, and the adequacy of the existing regulatory authority. In evaluating the effectiveness of existing rules, a major consideration is the level of oversight and enforcement that federal, state and regional authorities can provide for the numbers and types of potentially polluting facilities in an area. In many cases, local governments may be better capable

TABLE 2
Applicable State Rules: Baseline Regulatory Scheme

On-site Septic Systems

Ch. 10D-6, F.A.C.: Standards for Onsite Sewage Disposal Systems (Vol. II, p.139)

Package Plants

Ch. 17-600, F.A.C.: Domestic Wastewater Facilities (Vol. II, p.117)

Hazardous Materials Storage and Management

Ch. 17-761, F.A.C.: Underground Storage Tank Systems (Vol. II, p.130)

Ch. 17-762, F.A.C.: Aboveground Storage Tank Systems (Vol. II, p.137)

Ch. 17-150, F.A.C.: Hazardous Substance Release Notification (Vol. II, p.113)

Stormwater Runoff

Ch. 17-25, F.A.C.: Regulation of Stormwater Discharge (Vol. II, p.105)

Title 40, F.A.C.: Applicable Water Management District Rules

St. Johns River Water Management District (Vol. II, p.146)

Southwest Florida Water Management District (Vol. II, p.147)

Agricultural Land Uses

Chs. 17-3, 17-28, Part VII, F.A.C.: Permitting of Discharges to Groundwater (Vol. II, p.94)

Ch. 17-660, F.A.C.: Industrial Wastewater Facilities (Vol. II, p.119)

Ch. 17-670, F.A.C.: Feedlot and Dairy Wastewater Treatment and Management Requirements (Vol. II, p.122)

Ch. 5E-2, F.A.C.: Pesticides (Vol. II, p.144)

Ch. 5E-9, F.A.C.: Pesticide Applicators (Vol. II, p.145)

Underground Injection and Drainage Wells

Ch. 17-28, F.A.C.: Underground Injection Control (Vol. II, p.109)

Chs. 17-3, 17-28, Part VII, F.A.C.: Permitting of Discharges to Groundwater (Vol. II, p.94)

Landfills

Ch. 17-701, F.A.C.: Solid Waste Facilities (Vol. II, p.125) of gauging the ongoing status of a permitted facility. Where the permitting standards of, for example, a state agency are considered sufficient to adequately regulate a type of land use in a delineated protection zone, the local government should consider taking an oversight role. One possibility is requiring operating permits to be renewed on a regular basis, contingent on satisfactory monitoring records and continuing compliance with state (or additional local) standards.

Some of the more relevant DER rules are those regulating stormwater discharge, aboveground storage tanks, industrial wastewater facilities, and permitting of discharges to G-I and G-II groundwater. Though the DER's new underground storage tank rule may not be as stringent as necessary to adequately protect the drinking water resources in a particular locality, the rule is preemptive. Local governments wishing to adopt stricter approaches may contract with DER to implement the rule for two years, then replace it with a local ordinance. Applicable water management district rules include those for management and storage of surface waters and regulation of stormwater management. The state Department of Health and Rehabilitative Services administers rules controlling the location, design, construction, and maintenance of on-site septic systems.

Develop Regulatory and Non-Regulatory Strategy

No single regulatory approach to groundwater protection is applicable in all circumstances. Differences in hydrogeology, land use patterns and administrative capabilities require that local programs be individualized to serve local needs. Several techniques will probably be necessary in a local protection program, with successful programs including a balance of regulatory and non-regulatory components. Some of the most applicable regulatory tools available to local governments for groundwater protection include: overlay zones, source prohibitions, health regulations, tank containment standards, housing and septic tank density controls, and subdivision regulations (drainage controls, impervious surface controls). Potentially useful non-regulatory tools include: acquisition of fee or development rights, hazardous waste collection programs, spill contingency planning, capital improvements planning, monitoring programs, and public education programs. Volume II, Chapter III contains an expanded discussion of the aquifer protection tools available to local governments. Volume II, Chapter IV includes suggested regulatory approaches addressing the primary threats to groundwater. Table 3 indicates the potential use of selected regulatory and non-regulatory tools in high, medium or low stringency applications.

Regulatory Approaches

The location of existing land use zoning boundaries and classifications should be reviewed to determine how well they protect the community's aquifer sensitive areas. In certain cases, it may be possible to rezone parts of potable aquifer recharge areas or zones of contribution to public wells. Sensitive areas with inappropriate zoning can be addressed by an overlay zoning scheme, if traditional rezoning of such areas is infeasible. Within the aquifer overlay zones, potential threats to groundwater should be either prohibited or regulated at varying degrees of stringency, depending on the degree of aquifer sensitivity in that zone.

A baseline level, low stringency ordinance would simply require proof that an applicant had obtained the appropriate state or water management district permit before a local development order could be issued. This approach may be sufficient for areas of the community with no impact on potable aquifers, or with adequate levels of natural aquifer protection. In certain cases, state or district requirements may provide adequate control of land uses in protection zones. A slightly more restrictive approach could involve additional permit data requirements or permitting conditions imposed by the local government, and continuing oversight of permitted facilities. Since, in many cases, the local government will be in better position to maintain oversight of local land uses, this approach should be seriously considered. It also is potentially applicable for areas with little or no potential impact on potable aquifers. In very sensitive aquifer protection zones, a high stringency approach would involve creation and implementation of a local ordinance that imposed prohibitions, or very restrictive permitting standards addressing concerns such as densities, siting, design, construction, installation, operation, monitoring and closure of regulated activities.

TABLE 3
Selected Aquifer Protection Tools: Representative Levels of Stringency

	High	Moderate	Low
Regulations	Prohibitions; strict local permit conditions. (Vol. II, pp.175 - 257).	Local compliance monitoring of activities permitted under state or water management district rules.	Local development orders conditioned on approval of activity under state or district rules.
Direct Management Activities	Local hazardous waste collection; local contingency plans. (Vol. II, p.171).	Inventory of existing and historic land uses with groundwater pollution potential.	Inventory of new and future land uses with water pollution potential.
Acquisition	Local acquisition of wellhead protection zones and recharge areas (existing and future). (Vol. II, p.170).	Local acquisition of lands within, ie., ten year ground water travel time of larger public wells.	Recommendations to state and district agencies for acquisition priorities; local acquisition of single acre easements around existing and future public wells.
Education	In-school programs. (Vol. II, p.171).	Public service announcements; media events.	Utility bill stuffers.

Non-Regulatory Approaches

A primary goal for the groundwater protection program should be to assure that the program is carefully coordinated with the local government's future land use plans, capital improvements plans, transportation plans, and conservation and open space plans. The policies and objectives of these elements are an essential non-regulatory consideration in developing an effective aquifer protection strategy, since implementation of the objectives in these elements will have direct effects on the potential for groundwater contamination. Aquifer sensitive areas should not be considered for infrastructure extensions that would allow or tend to encourage inappropriate development. The future land use and transportation elements should be carefully evaluated and coordinated with aquifer protection goals, to assure that policies in those elements will not increase the pressure to develop sensitive areas. Conservation and open space plans should incorporate the goal of protecting sensitive areas by encouraging acquisition and/or passive, low impact uses.

In addition to fee acquisition, the purchase of development rights or conservation easements can provide important protection to sensitive areas. Other non-regulatory tools include hazardous waste collection programs, local contingency plans addressing potential spills and accidents, various types of public education programs, and development of monitoring networks, possibly coordinated with the efforts of DER, HRS or the applicable water management district.

Determine Administrative Resources and Political Will

The form of any aquifer protection strategy will be influenced by the administrative capabilities and level of commitment of the local government. Political will is a measure of the support for an effective groundwater protection strategy, based on four primary factors: awareness that the problem is serious or imminent and that existing approaches are inadequate; executive pressure from officers of the local government; internal pressure from the agencies that will have responsibility to manage the strategy; and external political pressure such as state level growth management requirements.[6] Measures of political will include the level of commitment to creating or upgrading necessary departments in order to administer an in-depth strategy, and the degree of protection and level of protective detail provided in the local comprehensive plan.

Creating local aquifer protection strategies will require realistic evaluation of the community's aquifer protection goals, its commitment to these goals, and its ability to implement a particular approach. The administrative resources of a local government will be reflected in the presence, size and technical sophistication of health departments, planning departments, environmental departments, and codes enforcement departments. The resources available to, and the sophistication of each of these types of departments will affect the ability of a local government to implement more detailed and wide-ranging strategies.

Greater administrative resources combined with higher levels of political will should allow for more detailed permitting programs, stricter protective provisions and a stronger oversight role for local government. Though considerations such as these will play a role in shaping a protection strategy, the overarching concern must always be how well the strategy serves to protect the public health and safety. When local political will and aquifer protection needs are greater than the administrative resources of the local government, permitting programs may not be feasible, especially over larger protection zones. If necessary to protect the community's drinking water supply, a local government with fewer resources can clearly adopt protective provisions. In these

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[6] Canter, Knox and Fairchild, Ground Water Quality Protection, 529-532, Lewis Publishers, Inc., Chelsea, Michigan (1988).

cases, the local government's police power responsibilities may require that it simply prohibit many threatening land uses in critical zones, if it is otherwise unable to strictly regulate such uses through a permitting program.

IMPLEMENTING THE AQUIFER PROTECTION PROGRAM

Once protection zones have been established and a protection strategy has been developed, it will be necessary to determine how the program should be implemented. Implementing a groundwater protection strategy can be a challenge, depending on the complexity and scope of the program and the administrative resources available to the local government. The new functions associated with a groundwater protection program can either be accommodated within an existing administrative framework, or with the creation of a new department. Utilizing the existing administrative structure will probably be the least expensive alternative, though a separate department allows flexibility and continuity in the establishment and operation of the program. If sufficient resources are not available to implement all program elements, it may be preferable to take an incremental approach by assigning priorities and implementing the elements on an appropriate schedule.

A second factor in formulating and implementing a local program involves sound fiscal planning. Though most of the funding will necessarily come from the local government itself, the water management districts, DER, and EPA are potential sources of funding and technical assistance, especially for water modeling and planning purposes. Rule 9J-29, Florida Administrative Code, contains information on funding assistance for governments which must adopt land development regulations on or before March 1, 1991. Rule 9J-30 contains the allocations for local governments which must adopt such regulations between April 1, 1991 and Dec. 1, 1991. These funding sources are administered by the Department of Community Affairs. An EPA publication titled "Local Financing for Wellhead Protection"[7] contains information on a large number of potential funding sources and options for local governments.

MONITORING AND EVALUATION

One of the last steps in the ongoing process of creating more effective programs is to ensure that monitoring is performed and evaluated on a regular basis. Groundwater monitoring serves as an important feedback mechanism, aiding in program evaluation and refinement, and providing early warning of problems such as contamination, saltwater intrusion or declining water levels. The monitoring program should follow the priorities of the groundwater protection program itself. A local government will want to coordinate with the appropriate water management district, the DER and the USGS in designing a monitoring program, since these agencies may have monitoring networks which meet some the needs of the local government.[8] The local groundwater program itself should require careful monitoring of certain land uses as a permitting condition. Periodic evaluation of an aquifer protection program is necessary, in order to assess how well program objectives are being met. It will also promote efficient use of local resources and allow for modification of the program as necessary, based on possible changes in hydrogeological conditions, groundwater levels, water quality, water use patterns or land use patterns.

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[7] U.S. Environmental Protection Agency, Office of Ground-Water Protection, Local Financing for Wellhead Protection, Washington, D.C. (June 1989).

[8] See, eg., Florida Department of Environmental Regulation, "Florida's Ground Water Quality Monitoring Network," Tallahassee, Fl. (1990).

Glossary

GLOSSARY

Aquifer: geologic formation which contains sufficient saturated permeable material to yield sufficient, economical quantities of groundwater.

Cone of depression: a depression in the groundwater table or potentiometric surface that has the shape of an inverted cone and develops around a well from which water is being withdrawn. It defines the **zone of influence**, which is the area surrounding a pumping well within which the water table or potentiometric surface has been changed due to groundwater withdrawal. (See figures, Vol. II, pp. 67, 68)

Confined (artesian) aquifer: an aquifer bounded above and below by confining units (geological strata) of distinctly lower permeability than the aquifer media; contains groundwater under pressure. (See Figure B)

Confining unit (layer): a hydrogeologic unit of relatively impermeable material, bounding one or more aquifers; same as **confining bed.** (See Figure B)

Consolidated aquifer: an aquifer made up of consolidated rock that has undergone solidification or lithification; in Florida, sedimentary rock formations of limestone or dolomite.

Drawdown: the vertical distance groundwater elevation is lowered, or the amount pressure head is reduced, due to removal of groundwater; a lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping of groundwater from wells. (See figures, Vol. II, pp. 67, 68, 72)

Hydraulic gradient: slope of a water table or potentiometric surface. Change in hydraulic head across a defined distance in a direction that gives the maximum rate of head decline.

Hydraulic head: measure of the height to which groundwater will rise above a datum, most often sea level; groundwater moves in direction of decreasing head.

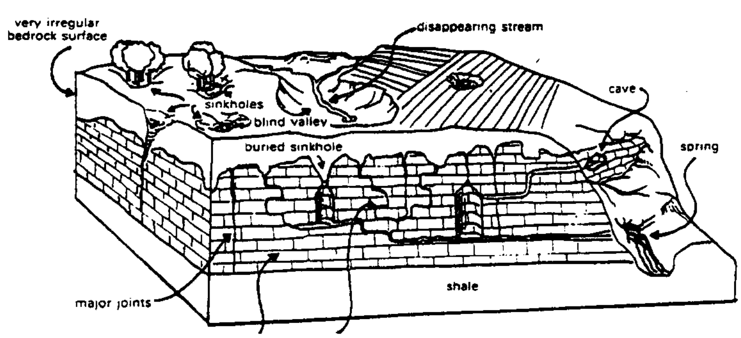
Karst aquifer (formation): class of consolidated limestone aquifer characterized by fissures, caves, sinkholes, and springs. (See Figure A)

Leaky aquifer: an artesian or water table aquifer that loses or gains water through adjacent semipermeable confining units.

Perched water: unconfined groundwater separated from an underlying main body of groundwater by an unsaturated zone.

Permeability: capacity of porous rock, sediment or soil to transmit fluids; a measure of the relative ease of fluid flow under unequal pressure.

Figure A: Karst Topography

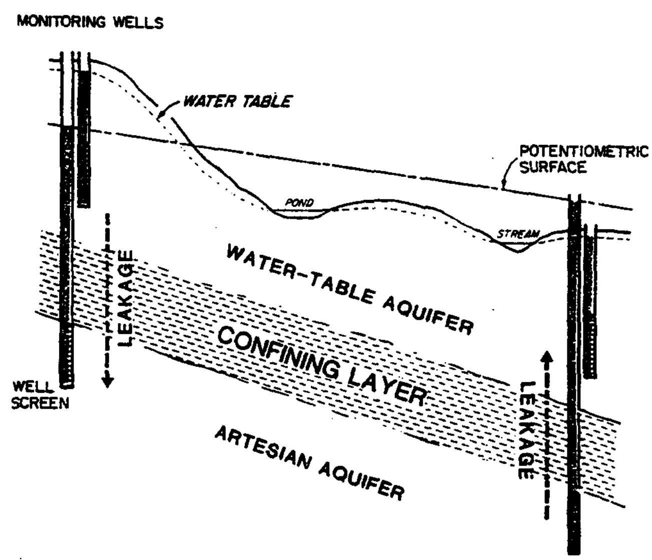


Porosity: ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment. **Effective porosity** is the amount of interconnected pore space through which fluids can pass, expressed as a percent of bulk volume; effective porosity is less than total porosity.

Potable: suitable for human consumption as drinking water.

Potentiometric (piezometric) surface: a surface representing the level to which water will rise in tightly cased wells piercing a confined aquifer. (See Figure B)

Figure B: Potentiometric Surface



Recharge area: area from which water reaches the zone of saturation through infiltration; fluids move downward into an aquifer through the subsurface underlying recharge areas.

Saturated zone: the subsurface zone in which the voids in the rock or soil are filled with water at a pressure greater than atmospheric; the water table is the top of the saturated zone in an unconfined aquifer.

Semi-confined (leaky confined) aquifer: aquifer which has a leaky confining unit and displaying characteristics of both confined and unconfined aquifers; an aquifer which loses or gains water through adjacent semi-permeable confining units.

Time of travel (TOT): the time required for a contaminant to move in the saturated zone from a specific point to a pumping well.

Unconfined aquifer: an aquifer not overlain by a geological confining unit; the upper surface of the saturated zone is known as the **water table**; also known as **water table aquifer**; when close to the land surface, also known as **surficial aquifer**. (See Figure B)

Unconsolidated aquifer: aquifer composed of loose sand and gravel in complex interspersed layers of clay, silt, sand and gravel.

Vadose zone (unsaturated zone): unsaturated subsurface zone between the soil surface and the deepest groundwater (saturated zone). Saturated bodies, such as perched groundwater, may exist in the unsaturated zone.

Water table: upper surface of a zone of saturation, where that surface is not formed by a confining unit; the surface between the vadose zone and the groundwater; that surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.

Zone of contribution (ZOC): the area surrounding a pumping well that encompasses all areas of features that supply groundwater recharge to the well. (See figures, Vol. II, pp. 67, 68)

Zone of influence (ZOI): the area surrounding a pumping well within which the water table or potentiometric surface has been changed due to groundwater withdrawal. (See figures, Vol. II, pp. 67, 68)