TECHNICAL EVALUATION OF TITLE 5 THE STATE ENVIRONMENTAL CODE 310 CMR 15.00

PREPARED BY
DEFEO, WAIT & ASSOCIATES, INC.
FOR THE
COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Technical Evaluation of Title 5
The State Environmental Code
310 CMR 15.00

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FOREWORD

DeFeo, Wait & Associates, Inc. was selected by the Massachusetts Department of Environmental Protection to evaluate the provisions of Title 5 of the State Environmental Code: "Minimum Requirements for the Subsurface Disposal of Sanitary Sewage" (310 CMR 15.00). The agreement between the Commonwealth of Massachusetts and DeFeo, Wait includes a detailed scope of services specifying the key tasks for this project. It provides for the submittal of four interim or progress reports, a draft final report which summarizes the entire project and addresses the Department's comments on the four progress reports, and a final report incorporating the Department's review comments on the draft report.

Interim Reports were submitted to the Department in September, October, November and December, 1990. The present document is intended to satisfy the requirements for a draft report. It includes a complete integration of the material included in the four previously submitted documents and addresses comments received from the Department as of the date of this printing.

This draft report was prepared under the direction of Mr. Mark K. Pare, Vice President of DeFeo, Wait & Associates, Inc. It represents the collective thought and expertise of many individuals including employees of DeFeo, Wait and its subcontractors. The following individuals made significant contributions essential to the completion of this project:

Kevin P. Klein	DeFeo, Wait & Associates, Inc.
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Special recognition is also extended to Mr. Michael H. Frimpter of the U. S. Geological Survey who participated in the review of the sections dealing with ground water elevation determinations and offered helpful suggestions for improvements.

The Department of Environmental Protection's review committee includes Department staff and an advisory committee comprised of representatives from select special interest groups. The following individuals participated in the review and provided comments on the Interim Reports:

Department of Environmental Protection Review Committee

Bryant J. Firmin	DEP Bureau of Resource Protection DWPC
Thomas Clougherty	DEP Northeast Regional Office
Leo Lessard	DEP Central Regional Office
Brett Rowe	DEP Southeast Regional Office
Christopher Stevens	DEP Bureau of Resource Protection DWS
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Department of Environmental Protection Advisory Committee

Marcia Benes	Mass. Association of Health Boards
Garen Bresnick	Mass. Home Builders Association
Steven Calichman	Cooperative Bank of Concord
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Richard Dolan	Mass. Association of Sewage Pumping Contractors
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Gregory Erickson	Mass. Health Officers Association
Walter Ericksen	Mass. Home Builders Association
Donald Hickman	Mass. Audubon Society
Barbara Kern	Mass. Association of Health Boards
Elizabeth Kline	Executive Office of Environmental Affairs
Maureen McGovern	Representative Stephen Angelo's Office
Paul McNaulty	Mass. Environmental Health Association
Richard Nylen	National Association of Industrial & Office Parks
Allan Rodenhiser	Mass. Association of Sewage Pumping Contractors

Input and suggestions made by Department personnel and the advisory committee members helped identify those issues deserving additional attention and detail in this draft report. The advisory committee, in particular, has expressed some reservations concerning the recommendation sections of the four Interim Reports. Some modifications have been made to address the concerns raised by the committee.

Unfortunately, it is virtually impossible to mitigate all of the apprehensions that were expressed. In some instances there was a wide disparity in opinions among the various reviewers. Given the diversity of interests represented by the advisory committee, it is extremely doubtful that unanimity among reviewers could ever be achieved.

This document is intended to present the underlying scientific and engineering principles upon which a sound regulatory program could be based. Suggestions on alternative regulatory approaches are also provided as directed by the terms of the scope of services for this project. It should be emphasized that the conclusions and recommendations presented in this document do not necessarily reflect those of the Department of Environmental Protection. The Department's position on the various issues will not be finalized until the completion of the comment period on this draft document.

The report's recommendations are expected to stimulate discussion on the different approaches for regulating the installation and use of on-site sewage disposal systems. Readers are encouraged to express their views and opinions in writing to the Department of Environmental Protection. The Department has indicated that it will fully evaluate all comments prior to formulating any amendments to the Code.

EXECUTIVE SUMMARY

Subsurface sewage disposal systems are utilized at approximately 27 percent of the housing units in Massachusetts. These systems include a variety of components and configurations, the most prevalent being the septic tank/soil absorption system commonly referred to as the septic system.

Septic systems, when designed, sited, installed, operated and maintained properly can offer an effective means of sewage disposal. Under appropriate environmental circumstances, and with proper management, they provide a safe and reliable method of wastewater disposal, especially in areas of relatively low housing density where municipal sewerage systems are not available or feasible. If used indiscriminately, however, they can result in a significant threat to public health and/or have an adverse affect on the quality of the environment.

Title 5 of the State Environmental Code, administered by local boards of health on behalf of the Massachusetts Department of Environmental Protection, was promulgated to regulate site evaluation, design, installation, and use of individual subsurface sewage disposal systems. The Code was last updated in 1978 during a period when the subsurface environment was considered a safe and convenient depository for many of society's waste products. At that time, impacts of sewage disposal practices on ground water quality were not immediately obvious and were generally overlooked as national attention focussed primarily on the more conspicuous pollution problems of our surface waters and air.

It was not until the early 1980's that the topic of ground water protection emerged as one of considerable significance in Massachusetts. Major advances in the analytical chemistry field provided the capability to detect both naturally occurring chemicals and synthetic compounds quickly and accurately, even when present in minute concentrations. As the ability to detect pollutants improved, incidents of ground water and surface water contamination that can be traced to septic systems became more prevalent. Technological advances within the past decade have also contributed to an increased knowledge concerning the physical, chemical and biological processes occurring within the unconsolidated deposits of the earth's surface. The result has been a heightened awareness of the limitations on the capacity of natural soil processes to render contaminants in discarded wastes harmless before reaching the ground water.

Armed with this knowledge, improved regulations can be developed to assure that septic systems are designed as effective land treatment and disposal units incorporating adequate provisions for the protection of public health. Equally important, it is now recognized that subsurface sewage disposal and associated land uses must be properly managed through the implementation of new design and operational standards in combination with siting restrictions in order to effectively protect and preserve valuable ground and surface water resources.

This document is designed to provide officials responsible for developing and implementing the Commonwealth's septic system management program with a comprehensive summary of the various interrelated science and engineering principles concerning subsurface sewage disposal. The report provides ideas, alternatives, and real-world examples for modifying the existing subsurface sewage disposal code.

There is no single approach to septic system management that will ensure protection of public health and the environment in all circumstances. The type of program selected by the Commonwealth will depend on a number of factors including the jurisdiction and level of regulatory authority provided in the existing regulations, the availability of resources at the state, regional and local levels, the impacts on other related building and environmental protection regulations and the variability in conditions within specific geographic areas of the state.

Probably the most significant factor to be considered in updating the existing regulatory program is whether the responsibility for developing and implementing modifications to the on-site sewage disposal regulations should be focussed at the state or local level, and to what extent any new state requirements should influence existing local health regulations. The present Code was promulgated to provide minimum statewide standards. Most cities and towns have adopted more stringent requirements, many of which provide an excellent compliment to Title 5. Some local regulations, however, are ill-conceived and, as a result, contradict the very intent and purpose of the state regulations.

Several professional organizations have produced model codes and ordinances for use by local officials in promulgating supplemental health regulations or ordinances. Unfortunately, many local governments have adopted the model language without gaining an accompanying appreciation for the rationale behind the regulatory provisions. Since this has, in certain instances, resulted in inadequate or inappropriate regulations, this project has been designed to take a different approach. The study is intended to provide information necessary to gain a better understanding of the workings of on-site wastewater treatment and disposal systems by providing a comprehensive discussion of the large body of technical information that has been published on this subject. The underlying basis for the imposition of regulatory controls should become clear as the reader reviews the information presented and gains an appreciation of the important role each item plays in the overall regulatory context.

Whether the Commonwealth selects to draft an entirely new set of on-site sewage disposal regulations or revise portions of the existing Code, the changes should be made as part of an comprehensive land-use and water resource protection plan. This plan should integrate various public safety, public health, environmental protection, and zoning programs to effectively regulate sewage disposal system installation and use, along with other activities affecting the quality of the environment. Careful deliberation needs to be given to zoning changes or other means of imposing minimum lot size requirements, as controlling septic system density may be the only effective means of maintaining or attaining stated water quality objectives. Special limits on septic system design and placement should also be considered as a means of protecting the most sensitive environmental receptors such as potable water supplies and surface water bodies in critical resource areas.

Local environmental conditions and current subsurface sewage disposal practices need to be given special attention when developing the strategy for changes to the existing program. The program needs to combine strong technical guidelines governing siting, design, operation and maintenance, with enough flexibility in evaluation and implementation procedures to accommodate differing conditions and circumstances.

Some of the other states have done away with rigid one-dimensional design and location standards and have begun using performance standards or allowable waste effluent concentrations to guide the choice and assessment of appropriate treatment technologies for individual sites. While it is recognized that some of the elements of septic system management and control programs proven to be successful elsewhere in the country may not be applicable here in Massachusetts, there are certain components of these programs that have nearly universal applicability and these should be given serious consideration for adoption into the Massachusetts Code.

The Commonwealth's subsurface sewage disposal program must be effective in its ability to protect the environment and public health, and manageable for the regulators as well as the regulated community. It must be both efficient and consistent with related building and environmental protection regulations. The program must include exacting procedures necessary for ensuring full compliance.

Compliance can be monitored in a variety of ways, including requiring thorough technical reviews, permits, site inspections, technical training, certification, and financial incentives, or by utilizing a combination of these techniques. The most effective management programs reportedly include construction, and installation permits which require detailed permit application reviews, and individual site inspections by the approving authority.

The Commonwealth's septic system management program should also incorporate aggressive provisions to secure proper operation and maintenance of septic systems once they are installed. The issuance of operating permits which require routine inspections and septic tank pumping is one means of regulating septic system use. The requirements could be supplemented with financial incentives encouraging compliance with the applicable regulatory requirements. As an example, this could involve assessing administrative penalties for poor system maintenance or incumbering the sale of a house if its septic system does not adequately comply with the prevailing regulations. Some form of financial assistance to those who could otherwise not afford to upgrade their existing inadequate system might also be considered.

The professional involved in the siting, design, installation, and maintenance of septic systems must maintain a high standard of integrity and practice in order to safeguard life, health and property. They should be required to possess certain minimum experience and qualifications deemed necessary to fulfill these obligations. A demonstration of technical competence is generally provided through proof of professional registration. Additionally, thought should be given to providing special training and certification for the technical reviewers to ensure that the approving authority understands and correctly enforces all of the regulatory provisions.

Septic systems work best under a specific set of environmental conditions and may not function properly under other circumstances. Since these systems depend on the soil for wastewater treatment and disposal, consideration of soil and site conditions are crucial elements in the design of an effective septic system. The regulations should clearly specify site evaluation techniques. Parameters that must be considered for inclusion in the evaluation criteria include: soil classification, structure, texture, depth, drainage and permeability, ground and surface water location and seasonal high elevation, and geology, topography, and climate. Each of these factors plays a role in the proper treatment of effluent from a septic system, and if not considered appropriately, can contribute to improper or incomplete treatment. Additionally, the hydraulic conductivity and the hydraulic gradient at the disposal site should be appropriately assessed to determine whether the site is capable of transmitting the volume of water that will be discharged from the system.

The conventional septic system may not be appropriate for sewage disposal in certain soil types and under some environmental conditions. Restrictions and in certain instances prohibitions on their use have to be carefully considered and coordinated with other regulatory programs to effectively protect the interest of the present and future residents of the Commonwealth.

The existing regulations are rigidly tied to conventional septic system designs and allow only minor variances. The revised Code should provide specific procedure for considering the use of innovative or alternative systems without having to invoke variances. Non-conventional systems may, under certain conditions, provide improved treatment capabilities. These systems may provide the only viable option for replacing failing conventional systems. Available technologies need to be selected based upon the unique requirements of an individual site.It must be recognized, however, that innovative and alternative on-site systems are generally more complex than conventional septic systems and therefore there are increased opportunities for error in their design, installation, and operation. The users of these systems have to be made aware of the special operation and maintenance requirements for these types of systems. This awareness must also be passed along to future system users should ownership of the property change. The regulations for these systems must be well designed to carefully control and monitor their use and to address the specific considerations for the particular application.

A two tier approach which clearly distinguishes repairs and replacement from the construction of new subsurface sewage disposal systems should be developed and less cumbersome standards should be considered for upgrading existing failures. Solutions such as community septic systems and small regional sewage treatment plants should be evaluated as potential options for septic system repairs where adequate security can be provided to guarantee successful operation and maintenance. The revised Code also needs to specifically address the means by which existing inadequate non-conforming systems will be brought into compliance with the regulations.

Education and public relations should be an important aspect of the selected septic system management program. Septic system controls are most effective when the public understands the relationship between ground water protection and proper septic system siting, design, installation, use and maintenance.

Many hazardous chemicals, because they are resistent to biodegradation, pass through septic systems and contaminate ground water. These chemicals originate from a variety of sources including septic tank cleaners and additives. They are also contained in household products used for cleaning, painting, or maintaining automobiles and appliances. Toxic chemicals may also be discharged by commercial and industrial businesses which utilize septic systems for the wastewater disposal. Consideration must be given to measures designed to control the sale and use of septic system cleaning and additives, prohibiting discharge of toxic organic chemicals to the ground water, limiting the commercial and industrial waste disposal into septic systems and educating the public on potential ground water contamination problems associated with improper disposal of certain household products.

Analysis of a wide range of septic system sizes has revealed a significant trend towards poor performance with higher design and operating flows. A primary cause of the elevated failure rate of large systems is the inadequacy of the current site investigation procedures originally developed for single user on-site domestic systems. As system size increases, maintaining conservative loading rates and utilizing suitable soils become increasingly important factors. Along with changes in technical guidance and criteria, new regulatory strategies need to be developed for larger systems. These systems need more thorough technical review and stricter oversight during the permitting process. The regulatory requirements should include a high degree of individual review by the regulating authority.

Septage disposal needs to be viewed as an important component of any comprehensive septic system management program. Several factors have led to problems with improper septage disposal in Massachusetts. Probably the most important of these has been the lack of readily accessible approved disposal facilities. Regulating septage and sludge disposal adds to the enforcement and administrative costs for governmental agencies. However, a program addressing only septic tank installation and use and not accompanying disposal of the residual wastes neglects a substantial source of potential ground and surface water contamination.

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BACKGROUND

CHAPTER 1

INTRODUCTION

1.1 Background

Man's carelessness in the management of his own excreta can result in a number of diseases as pathogens from an infected person find their way by water, food, or soil to another human being. The first line of defense would appear to be simple; manage our waste so that none of it reaches our drinking water or food supplies and isolate it from the ground surface where it is accessible to animals, including insects and birds, which can be direct carriers of pathogens.

The septic tank/soil absorption system was first developed as a method of achieving these basic hygienic objectives. Based in part on research conducted by Louis Pasteur and Robert Koch on the germ theory of disease, the "fosse septique" was developed in France in the 1860's through a collaborative effort of Louis Mouras and a fellow countryman Abbe Moigno (Chanlett, 1973).

Septic tank systems first appeared in the United States in the 1880's (Cotteral and Norris, 1969). The Lawrence Experiment Station (LES)[1] conducted studies on two-compartment septic tanks as early as 1899 (Chanlett, 1973). These early studies at LES demonstrated 47 to 60 percent removal of organic matter from the wastewater as measured by the oxygen-demand test.

Since their introduction, septic tank systems have become the most widely used method of on-site sewage disposal. It is estimated that there are over 22 million septic tank/soil absorption systems in the United States, serving approximately one-third of the nation's population (USEPA, 1986b). Although the concept and design of the septic tank/soil absorption system are relatively simple, the system involves complex physical, chemical and biological processes. Performance is essentially a function of the design of the system components, construction techniques employed, characteristics of the wastes, rate of hydraulic loading, climate, areal geology and topography, physical and chemical composition of the soil mantle, and care given to periodic maintenance (USEPA, 1977).

During the past two decades, numerous technical studies have been undertaken in response to the growing concern regarding the effect of land disposal practices on ground water quality. This increased awareness and understanding of the subsurface environment has caused attention to be focused not only on basic hygienic principles but also on the septic tank/soil absorption system's overall capacity to render the contaminants in discarded wastes harmless to the environment. Technological advances made during this time have increased our knowledge of many of these complex physical, chemical and biological processes and altered our viewpoint concerning the capabilities, and limitations, of septic tank systems.

1 The Lawrence Experiment Station is now a Division of the Massachusetts Department of Environmental Protection.

The septic system's recent reputation as a major contributor to environmental pollution is not the result of the system's inadequacies, but rather the result of a misuse of this disposal practice. The septic tank system is a combination of unit processes which were initially intended for rural farm families. Its widespread use in suburban areas has resulted in many installations where the septic system has been squeezed onto small lots, in soils of limited suitability and has been neglected by the home owner. The septic tank/soil absorption system has demonstrated to be ill-fitted under these adverse circumstances, particularly when used in conjunction with on-site water supplies.

1.2 Regulatory History

In the early 1940's, the U.S. Public Health Service published a set of standards governing the design and use of subsurface sewage disposal systems. These initial standards served as the basis for early sanitary sewage codes throughout the country. The Massachusetts Department of Public Health adopted minimum requirements for the disposal of sanitary sewage in 1962. This code, which became known as Article XI of the State Sanitary Code, was amended four times throughout the 1960's.

Authority for the control of sewage disposal in Massachusetts was transferred in July 1975 from the Department of Public Health to the newly created Department of Environmental Quality Engineering (now known as the Department of Environmental Protection). The Department of Environmental Quality Engineering, empowered with the authority to develop a State Environmental Code, promulgated "Title 5 - Minimum Requirements For The Subsurface Disposal of Sanitary Sewage" in 1977. Title 5 of the State Environmental Code replaced Article XI of the State Sanitary Code and became the official regulation for the statewide control of individual subsurface sewage disposal systems.

In 1978, in direct response to a growing need for greater environmental protection, a task force of environmentalists, builders, engineers, and local board of health officials set out to revise Title 5. The task force worked to prepare a comprehensive set of regulations that would provide a greater degree of health and environmental protection and would lessen the need for local supplemental restrictions. The task force researched available literature to corroborate the proposed revisions. The resultant revised regulations, substantiated by a thorough research of available literature, reflected the state of science at that time period.

The effects of septic tank/soil absorption systems on groundwater and surface water quality has been studied extensively in the past 13 years. Scientific advances in chemistry, hydrogeology and biology have altered our basic perceptions concerning the subsurface environment as a safe disposal media. In addition, the ability to determine water quality parameters in parts per billion is a technology that was not available in the early 1970's. It is on the basis of these and other significant scientific advances that a decision has been made to re-examine the current Title 5 regulations with the goal of modifying the Code to reflect recent technological advances in science and engineering.

1.3 Septic Tank/Soil Absorption System Components

The conventional septic tank/soil absorption system has two primary components, a water tight compartment (septic tank) and a provision for liquid effluent discharge to the subsoil (soil absorption). The septic tank serves simultaneously as a separation unit and as a storage and digestion unit for the retained scum and sludge. The solids storage and digestion functions dictate the tank's volume, dimensions, and structure. The greater the depth, the less the velocity currents caused by the incoming and exiting wastewater disturb the sludge and scum. Baffling, and the use of multi-compartment tanks, has been shown to increase detention times and improve scum and sludge retention.

A leaching structure is used to dispense the liquid septic tank effluent into the soil, and therefore must be constructed in soils capable of accepting and dispersing the liquid. There are several types of leaching structures currently used including: leaching pits, leaching galleries, leaching chambers, leaching trenches and leaching fields/beds. Some of these structures provide temporary retention area for the liquid above the infiltrative surface, while others contribute minimal storage volumes.

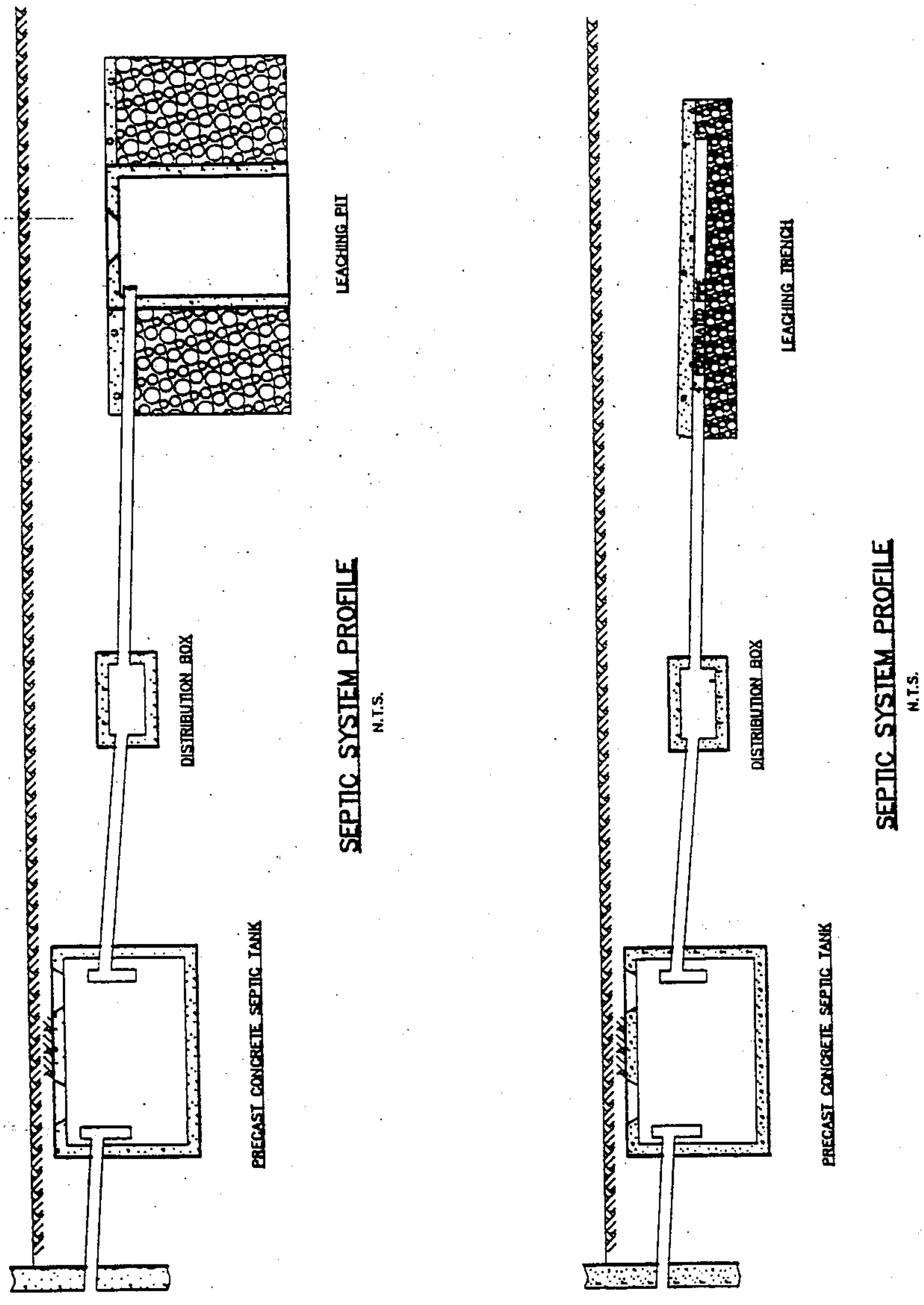
Once the septic tank effluent reaches the leaching structure, it percolates through a gravel (washed stone) layer into the surrounding soil. With time, a biological mat, consisting of facultative (aerobic/anaerobic) bacteria and bacterial products, forms at the soil-gravel interface. The mat serves to break down organic matter, to immobilize inorganic compounds, and to effectively reduce the effluent infiltration rate thereby maintaining unsaturated soil conditions in the underlying soils. Pathogenic organisms and other pollutants are removed from the liquid as it passes through the mat and the unsaturated soil.

The installation of a leaching pit involves a large excavation which is lined in a cylindrical fashion with brick, perforated concrete, or interlocking concrete blocks. A manhole is constructed at the top and the lining of the pit is generally surrounded with a layer of various sized washed stone. The interior of the leaching pit provides a reservoir which supplies temporary storage of the septic tank effluent until it is dispersed into the soil through the bottom and the open-jointed and rock filled sides.

Leaching chambers and galleries are similar to leaching pits in that they provide a large interior volume which enables visual observation to ensure proper function. Chambers and galleries are of a square or rectangular design and are usually constructed in shallower sections than are leaching pits. Galleries and chambers have open joints and are often surrounded with washed stone. The sewage which enters is dispersed within the interior of the structure and in the spaces surrounding the stones before seeping into the soil.

Leaching fields and leaching trenches are the most commonly used designs for on-site wastewater treatment and disposal systems. They differ from the other types of leaching systems in that they have no cavernous interior for the temporary retention of the liquid effluent. These types of leaching systems consist entirely of gravel and a distribution system, usually perforated pipe. The sewage is retained within the pore spaces of the washed stone prior to absorption by the surrounding soil.

FIGURE 1.1.1


LEACHING PIT
DISTRIBUTION BOX
PRECAST CONCRETE SEPTIC TANK
SEPTIC SYSTEM PROFILE
N.T.S.
LEACHING TRENCH
DISTRIBUTION BOX
PRECAST CONCRETE SEPTIC TANK
SEPTIC SYSTEM PROFILE
N.T.S.

Trenches are long narrow stone filled excavations which utilize both bottom and sidewall surface areas for infiltration. Beds differ from trenches in that they are wider, may contain more than one distribution pipe, and effectively utilize only the bottom area for infiltration.

The septic tank/soil absorption system may also have a number of ancillary components depending on the specific application. The most common ancillary component in the typical septic tank/soil absorption system is the distribution box which is located between the septic tank and the leaching structure. The distribution box is a small watertight chamber with a removable cover to facilitate inspections and cleaning. Its purpose is to divide the incoming wastewater equally between each lateral of the leaching structure. In order to achieve this objective, the outlet inverts must be at exactly the same elevation with the inlet invert slightly elevated.

A dosing chamber or tank is frequently utilized in situations where a septic tank discharges to large leaching structures and intermittent dosing of the soil absorption area is desirable. The surge from the dosing tank aids in equally distributing flow to the extremities of the leaching structure particularly when small diameter pipe is used. Dosing tanks are usually constructed of concrete or other durable material and are vented through the building sewer or other similar outlet. The tanks are commonly designed with a capacity sufficient to discharge a volume of effluent capable of covering the soil absorption area to a depth of at least one inch in under 15 minutes.

Siphons, located in the dosing tank, are sometimes used if the dosing chamber is at a higher elevation than the leaching structure. They retain liquid within the dosing tank and intermittently release it to the leaching structure as the volume within the tank reaches a predetermined level. Pumps are also used with dosing tanks, particularly when the dosing tank is at an elevation lower than the leaching structure.

Grease traps are used as a pretreatment device for waste waters containing high amounts of oils and grease. Grease traps are flotation chambers which enable the grease to rise to the liquid surface where it is retained, allowing the clarified liquid below to exit the tank. Design and sizing requirements for grease traps is usually very similar to that of the septic tank. Grease traps are generally installed on a separate building sewer exclusively serving food preparation areas.

1.4 Septic Tank/Soil Absorption System Treatment Processes

For most people, a septic system represents a simple means of disposing of waste; flush the toilet and forget it. What happens in the septic system doesn't matter as long as it continues to work. This lack of knowledge about the processes which occur, and the optimum conditions under which they take place, has lead to problems in the design, management and operation of septic systems and the soil and ground water contamination which they can create.

In considering potential contamination from septic tank/soil absorption systems, attention must be focussed on the transport and fate of pollutants from the system through the underlying soils and into the ground water. A number of complex waste reduction mechanisms occur in both the soil and ground water environments.

As septic tank effluent moves through the soil pores beneath the soil absorption system, suspended matter is removed by filtration. The depth at which removal occurs varies with the size of the particles, soil texture, and rate of water movement. The higher the hydraulic loading rate and the coarser the soil, the greater the depth of particulate penetration.

Adsorption, ion exchange, and chemical precipitation are the most important chemical processes governing the movement of dissolved constituents in septic tank effluent. These chemical processes occur at different rates depending upon the characteristics of the soil. A key soil parameter is the cation exchange capacity. The cation exchange capacity of soils varies significantly depending on the humus and clay content.

The biological reactions that take place in the soil include organic matter decomposition and nutrient assimilation. Most of the biological activity takes place in the upper layers of soil underneath the soil absorption system.

The efficiency of waste strength reduction is dependent upon many factors including septic system design, loading rate, depth to ground water, the presence of limiting soil horizons, soil characteristics (texture, morphology, pH, organic content, etc.), and wastewater characteristics (pH, temperature, the organic strength, measured by Biochemical Oxygen Demand and Chemical Oxygen Demand, and the concentration of suspended solids, volatile organics, refractory organics, dissolved inorganic solids and heavy metals). Domestic septic system waste contains a great deal more than just human excreta and water. Metals, minerals, oils and grease, miscellaneous solids, detergents and soaps, cleaning fluids and household chemicals and disinfectants find their way to the subsurface environment via discharge through the septic system. Once in the subsurface, a complex combination of removal processes begins. Many of the removal processes are either reversible (temporary removal which can be undone if the conditions change) or step-wise reactions (removal occurs due to two or more operations which depend upon the successful realization of the preceding step for completion). Some of the processes which would occur separately have been found to be competing reactions with only the preferential reaction actually occurring.

The principal component of domestic wastewater is biodegradable organics composed principally of proteins, carbohydrates and fats. The human body, through a complex mixture of chemical and biological processes, serves to break down food stuff exacting energy and emitting digested waste. Enteric bacteria, naturally present in the human intestines, serve a necessary purpose in this digestion process. They break down certain hydrocarbons allowing the host to utilize the newly created form. The host-enteric bacteria relationship is symbiotic, neither can survive without the other. The host requires the presence of bacteria for digestion, whereas the enteric bacteria cannot reproduce outside of the human body.

The digestion process is not completed in the body. Undigested or partially digested organic matter, no longer in a form most easily utilized by humans, is discharged from the body as waste. This waste stream also contains high concentrations of bacteria, the majority of which are not pathogenic. Once ejected from the body with the waste stream, the enteric bacteria and the microorganisms naturally present in the soil environment continue to act in much the same manner as in the human body, exacting energy through the oxidation of the remaining organic matter. In addition to organic matter, food is provided to the microorganisms through the destruction of other microorganisms. In this manner the majority of pathogenic bacteria are destroyed by the microorganisms present in the properly functioning septic system.

CHAPTER 2

WASTEWATER CHARACTERISTICS

The characteristics of wastewater from individual households and related establishments, such as hotels, restaurants, offices and mercantile buildings, can have a profound effect on the performance of a subsurface sewage disposal system. Various water use events within these buildings create intermittent waste discharges that vary widely in strength and volume. Although sewage is usually greater than 99 percent water, the small portion of solids in suspension and in solution has an important affect on subsurface treatment and disposal processes.

Human waste is only one component of domestic sewage. Wastewaters generated as a result of personnel hygiene, household cleaning, and food preparation also contribute to the composition and concentration of the waste. Discarded material from kitchens, bathrooms, lavatories, toilets and laundries add human excrement, paper, soap, dirt, food wastes and other substances to the mineral and organic matter already present in the water supply. Some of the wastes are suspended in the liquid, some go into solution, and others are, or become, so finely divided that they acquire the properties of colloidal particles. Much of the waste substance is organic matter that can be metabolized by saprophytic microorganisms, which breakdown and decay the waste.

Domestic sewage is unstable, bio-degradable, and putrescible. Under certain environmental conditions, domestic sewage may generate offensive odors. Additionally, sewage contains significant quantities of enteric organisms which create a potential threat to human health. A list of the contaminants commonly found in strong, medium, and weak strength domestic sewage is provided in Table 2.1.

The concentration of the constituents of wastewater may vary considerably, depending upon the percentage and type of waste present and the amount of dilution water added. The composition of wastewater from a given source may change on a seasonal basis, reflecting different water use patterns. Additionally, daily fluctuations in quality and quantity are also observable.

The most significant components of sewage are suspended solids, biodegradable organics, and pathogens. Suspended solids are primarily organic in nature and are composed of some of the more objectionable material found in sewage. Body waste, food, paper, rags, and biological cells form the bulk of the suspended solids load. Even inert materials such as soil particles may become fouled by absorption of organic material to their surface. Removal of suspended solids is essential prior to the discharge of the wastewater.

Table 2.1

TYPICAL ANALYSIS OF DOMESTIC SEWAGE[1]

Constituent, mg/l[2]	Strong	Medium	Weak
Total Solids	1,200	720	350
Dissolved Solids	850	500	250
Fixed	525	300	145
Volatile	325	200	105
Suspended Solids	350	220	100
Fixed	75	55	20
Volatile	275	165	80
Settleable Solids ml/l	20	10	5
5-Day BOD	400	220	110
Total Organic Carbon	290	160	80
Chemical Oxygen Demand	1,000	500	250
Total Nitrogen (as N)	85	40	20
Organic	35	15	8
Free Ammonia	50	25	12
Nitrites	0	0	0
Nitrates	0	0	0
Total Phosphorous (as P)	15	8	4
Organic	5	3	1
Inorganic	10	5	3
Chlorides	100	50	30
Alkalinity (as $CaCO_3$)	200	100	50
Grease	150	100	50

1 Adapted from Metcalf and Eddy, Inc. (1979)

2 Milligrams per liter except as noted.

Although suspended organic solids are biodegraded through hydrolysis, the majority of the biodegradable material contained in sewage is in the form of soluble organic compounds. The soluble organics contained in domestic sewage are composed chiefly of proteins (40 to 60 percent), carbohydrates (25 to 50 percent), and lipids (approximately 10 percent) (Metcalf & Eddy,Inc., 1979).

Proteins are primarily amino acids, while carbohydrates are complex compounds such as sugars, starches, and cellulose. Lipids include fats, oil, and grease. All of these materials contain carbon that can be biologically converted to carbon dioxide, thus exerting an oxygen demand. Proteins also contain nitrogen, and thus additional oxygen may be required to satisfy the nitrogenous oxygen demand of the waste.

All forms of waterborne pathogens including bacteria, viruses, protozoa, and helminths may be found in domestic sewage. These organisms are discharged by persons infected with disease. Although the pathogens causing most diseases rarely survive outside of the host organism for any length of time, sufficient number of pathogens are present in all untreated sewage to represent a substantial health hazard.

Sewage treatment systems are generally designed to reduce the concentration of suspended solids, biodegradable organics, and pathogens to acceptable levels. Additional treatment processes are required to reduce levels of nutrients when the sewage is discharged to delicate environmental systems. Processes to remove refractory organics and heavy metals, and to reduce the level of inorganic dissolved solids, are required whenever the sewage is discharged to areas where the water serves as a potable water supply.

A number of laboratory analyses can be performed to determine the nature of domestic sewage. Laboratory tests vary from precise quantitative chemical determinations to qualitative measurements performed for many of the physical and biological parameters. Due to the interrelated nature of the parameters, a whole battery of tests is necessary to fully characterize the waste.

Physical Analyses

Physical characteristics commonly used to describe sewage quality include temperature, odor, and color variations. A measurement of the waste's temperature is useful in indicating the effects on biological activity, the solubility of gases and temperature gradients within the tank. The normal temperature of sewage is slightly above that of the water supply because heat is added during the utilization of water for a number of domestic purposes.

Normal fresh domestic sewage has a distinctive somewhat disagreeable odor. Rotten or putrid odors, such as hydrogen sulfide and other products of anaerobic decomposition, indicate stale waste devoid of oxygen. Fresh sewage generally has a grayish color. Black, or a dark color generally indicates a stale or septic sewage, particularly if accompanied by offensive odors.

Chemical Analyses

The chemical characteristics of wastewater are determined by the chemical properties of the suspended, colloidal, or dissolved organic and inorganic materials and their relative concentrations. Approximately 75 percent of the suspended solids and 40 percent of the filterable solids in sewage are organic in nature. They are derived from both animals and plants. Organic compounds are normally composed of a combination of carbon, hydrogen, and oxygen, and in some cases nitrogen. Other important elements such as sulfur, phosphorous, and iron, may also be present. Urea, the prime constituent of urine, is another important organic compound contained in sewage.

Along with proteins, carbohydrates, fats, oils, and urea, sewage may contain small quantities of synthetic organic compounds. Examples of these include surfactants, phenols, agricultural pesticides, and chlorinated hydrocarbons. Sewage also contains various inorganic components such as arsenic, boron, cadmium, chlorides, chromium, copper, iron, lead, manganese, mercury, nickel, nitrogen, phosphorous, potassium, silver, sulfur, and zinc. Some of these inorganic constituents are necessary for growth of biological life, and absence of sufficient quantities could limit beneficial processes. Excessive quantities on the other hand, may be toxic to plants and animals or otherwise interfere with the natural environmental balance.

Biological Analyses

A wide variety of microorganisms can be found in sewage. Most are free-living single or clustered cells capable of independently carrying out the life processes of growth, metabolism, and reproduction. The smallest are viruses and phages, too small to be seen with a microscope. Next in size are bacteria. These may be identified with the aid of the microscope supplemented by observations of the reactions to their environment. Others, slightly larger, are known simply as microscopic organisms because the species can be identified by the aid of a microscope alone.

Organisms in sewage may be harmful, harmless, or helpful. The organisms that are harmful to humans are the pathogenic organisms. Their presence in sewage is usually abnormal and, in general their existence in this environment is shortlived. Even these short durations , however, may be sufficient for the transmittal of diseases.

CHAPTER 3

CONTAMINANT TRANSPORT AND FATE

3.1 Waste Strength Reduction

Bacterial oxidation, the biological conversion of carbonaceous organic waste into energy and stable emission products, provides the major process by which septic system effluent is broken down and removed from the environment. Biochemical Oxygen Demand, BOD, is the parameter most widely used to characterize the strength of an organic pollutant. The BOD of a waste is a measure of the oxygen required by microorganisms for the biochemical oxidation of organic matter, leading to waste stabilization and elimination.

In a septic tank/soil absorption system, bacterial growth is provided as a direct result of the introduction of carbonaceous material. Food and energy, in the form of carbon and oxygen, are used by the bacterial cells to survive and to reproduce, thereby creating new cell material and allowing for additional wastewater treatment (Gaudy, 1988). A properly functioning soil absorption system must first allow for the growth of bacteria to reduce the organic strength of the waste, and subsequently allow the bacteria to expire and to be filtered from the effluent flow before introduction to surface or ground waters (Gaudy, 1988).

Biochemical oxidation rates are dependant upon many variables including waste strength and type, bacterial population density, dissolved oxygen concentration, moisture content, and detention time (Zaghloul et al., 1988, Gaudy, 1988). The pathway, rate and extent to which bacterial oxidation occurs is dependent upon a number of factors including the waste strength and characterization, bacterial population and the availability of oxygen and nutrients. Bacterial growth transpires at its greatest extent during the first 1 - 7 days and is assumed to follow the Monod equation which relates the concentration of a limiting nutrient with the growth rate (Corapcioglu and Haridas, Matthes and Pekdeger, 1982).

Depending upon the environmental system, the growth limiting nutrient may be carbon, oxygen, nitrogen, phosphorous or a micro-nutrient such as calcium or magnesium. In a surface water environment the limiting nutrient is usually nitrogen or phosphorous (Walker et al., 1973, Sawhney, 1977, Reneau, 1977). In the anaerobic septic tank, a deficiency of both free and combined forms of oxygen generally limits the treatment efficiency. In a subsurface soil absorption system, although complete nitrification may be accomplished, nitrogen removal is usually unable to proceed due to the inadequate supply of carbon required to fuel the anaerobic denitrification reactions (Lamb et al., 1988).

As a waste stream is conveyed through a septic tank/soil absorption system it is subjected to a variety of different operating conditions. The initial treatment processes occur in the septic tank which acts as an anaerobic biological reactor encouraging waste equalization and bulk solids removal. The septic tank promotes settling of solids and the floatation of grease and scum thereby allowing the discharge of a clarified liquid effluent.

The anaerobic biodegradation processes which occur in a septic tank progress in the absence of free oxygen through the utilization of combined forms of oxygen, derived from nitrates and sulfates. The resulting degradation process utilizes nutrients, organic carbon and combined oxygen to form carbon dioxide, methane, new bacterial cells, nitrogen gas, and hydrogen sulfide gas.

$$\text{Organic Carbon} + \text{Nutrients} + NO_2 \xrightarrow{\text{Anaerobic Bacteria}} CO_2 + N_{2(g)} + \text{New Cells}$$
$$+ SO_4 \rightarrow CO_2 + H_2S_{(g)} + \text{New Cells}$$

Anaerobic biodegradation is a slow and inefficient treatment process. This is especially true in a septic tank where both free and combined sources of oxygen are scarce. This lack of oxygen limits the effectiveness of the septic tank to only a 30 - 50 percent reduction of the influent BOD (Hagedorn et al., 1981).

Aerobic biodegradation, the biotransformation of nutrients (nitrogen, phosphorus, and micro-nutrients - calcium and magnesium), organic carbon and free oxygen into carbon dioxide, water and new bacterial cells, is a much more efficient mode of treatment.

$$\text{Organic Carbon} + \text{Nutrients} + O_2 \xrightarrow{\text{Aerobic Bacteria}} CO_2 + H_2O + \text{New Cells}$$

The efficiency of aerobic biodegradation is controlled, in part, by the rate at which oxygen can be supplied to the bacterial cells. In a soil absorption system, bacterial respiration rates and soil reaeration potentials are both enhanced by the preservation of unsaturated soil conditions. Unsaturated soils promote aerobic conditions and, by prompting filtration and adsorption onto the surface of the underlying soil particles, provide the extended transport times necessary for adequate wastewater purification (Anderson et al., 1982).

3.2 Biomat Formation

Studies have shown that shortly after leaching is commenced, the hydraulic conductivity at the gravel-soil interface of a soil absorption system is greatly decreased by the formation of a 2 - 5 cm (0.8 - 2 inches) thick biomat clogged zone (Anderson et al., 1982). The majority of the waste strength reduction of a properly operating septic tank/soil absorption system is accomplished in this clogging mat which allows bacterial cells to amass, providing a highly concentrated treatment zone which contributes to the physical and biological cleansing activity and induces favorable unsaturated flow conditions in the underlying soils (Anderson et al., 1982).

Clogging mat formation is the result of physical, chemical and biological processes leading to a combination of the disintegration of soil aggregates, bio-clogging of soil pores with microbial cells and their synthesized products (slimes and polysaccharides), and the dispersion of soil aggregates due to the attack of microorganisms on the organic binding materials of the soil. The extent of the decrease in infiltration rate is a function of the depth of the ponded liquid above the clogging mat, the thickness and hydraulic conductivity of the biomat, and the underlying soil moisture tension (Anderson et al., 1982).

Although the exact mechanism by which clogging mat formation occurs is not completely understood or agreed upon, it has been shown to occur in all types of soils except possibly very coarse sands and gravel (Otis, 1985). Under aerobic conditions, clogging mat formation has been described as progressing in three distinct phases. The first phase is a rapid clogging to approximately 25 percent of the initial hydraulic conductivity. This has been credited to structural changes occurring in the soil, such as swelling and dispersion, and a surficial accumulation of organic materials (Otis, 1985). During subsequent phases a slow fluctuation to approximately 10 percent of the initial hydraulic conductivity, followed by a sharp drop to 1 - 2 percent can be expected. Anaerobic soil clogging occurs 3 - 10 times faster than under aerobic conditions (Brown et al., 1979) and may lead to an increased thickness and reduced hydraulic conductivity of the biomat due to reduced bacterial destruction of the deposited organic material, the additional growth of slimes and the deposition of ferrous sulfide (Canter and Knox, 1985).

Many studies have been conducted in order to investigate the mechanisms involved in clogging mat formation and to determine methods by which its formation could be eliminated or controlled. Most of the studies conclude that the clogging mat formation will occur in all types of soils (with the possible exception of the coarsest grained sands and gravel) and that this less permeable layer is essential to effect the desired degree of treatment (Anderson et al., 1982).

3.3 Potential Pollutants From Septic Tank/Soil Absorption Systems

Pathogens

The reduction/destruction of pathogenic microorganisms (bacteria and viruses) is a major governing constraint in the design, construction and operation of septic tank/soil absorption systems. The bacterial contaminants of concern are enteric bacteria, found in the human intestines and emitted with the feces. The most important pathogenic bacterial strains, capable of transport in the groundwater and surface water pathways, include Salmonella sp., Shigella sp., Vibrio cholera, Yersinia enterocolitica, Y. pseudotuberculosis, Leptospira sp., Francisella tularensis, Dyspepsia coli, and Escherichia coli (Matthes and Pekdeger, 1982).

Because E. coli is present in wastewater in high concentrations (septic system effluent contains E. coli in the order of 10^6/100 ml) and exhibits long survival times in the aquifer system, it has been used as an indicator of bacterial contamination. The state's drinking water standards[1] (310 CMR 22.00) do not permit any E. coli to be detected in a 100 ml sample of potable water. Attaining this standard requires that total treatment be accomplished between the source of the bacteria, the septic system leaching facility, and drinking water wells. Surface water bodies used for bathing or recreational use, are limited to concentrations of no more than 200 E. coli per 100 ml (314 CMR 4.00).

Most of the waste strength reduction that occurs in a soil absorption system is the result of biodegradation by bacteria. The endogenous bacterial population, naturally present in small numbers in the soil, is primarily responsible for the bio-oxidation of influent organic waste and the partial destruction of the pathogenic fecal bacterial population. With time, the biological activity results in the development of a biomat clogged zone at the gravel-soil interface which contains the highest concentration and variety of bacteria, providing the most concentrated treatment zone. The lag time in the production of the large amounts of bacteria needed to reduce the strength of the incoming wastes and to destroy the associated enteric bacterial populations may result in temporary increases in fecal coliform levels in the groundwater underlying previously unused soil absorption systems (Gaudy, 1988).

The bacteria required for waste treatment in the biomat, and the surviving enteric pathogenic bacteria, must be captured before the effluent is released to the environment. Bacterial removal in the unsaturated soils underlying the biomat is accomplished by chemical reactions, physical adsorption and filtration by the soil (Hagedorn et al., 1981). Filtration is prevalent due to the relatively large size of bacteria in relation to soil pore size. Bacteria range in size from 0.25 to 30 micrometers (μm - 10^{-6} meters) with only those larger than 3 μm efficiently removed by physical trapping (Canter and Knox, 1985). Adsorption and retention of bacteria by the soil, which may be the first step in the biodegradation process, has been found to be increasingly effective in clay and silty soils, with retention efficiency inversely proportional to soil particle size (Hagedorn et al., 1981).

Viral contamination is similar to bacterial contamination in that the infectious agent is introduced to the environment from improper disposal of human wastes. Enteric viral contaminants, emitted from infected individuals, are unable to multiply in the aquatic environment, but may live for extended periods, upwards of one hundred thirty days and travel with the groundwater for great distances, up to one mile, depending upon the groundwater flow velocity (Yates, 1989). Pathogenic viruses are not generally a part of the normal microbial flora of healthy individuals, but may be present in significant numbers due to infection or disease (USEPA, 1977). There are over one hundred pathogenic viruses which have been found in domestic septic system wastes including; hepatitis A virus, poliovirus, coxsackie virus, Norwalk agent(s), adenovirus, rotavirus and ECHO (enteric cytopathogenic human orphan) virus (Matthes and Pekdeger, 1982), (Gerba, 1977). Common viral related illnesses and symptoms include paralysis, gastroenteritis, hepatitis, meningitis, and eye infections (Gerba, 1977).

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1 The Maximum Contaminant Levels listed in the 310 CMR 22.00 are based in part on the National Interim Primary Drinking Water Standards under the Federal Safe Drinking Water Act.

Viruses are the smallest, least easily detected, and hardest to treat of the human pathogens. Viruses differ from bacteria and cellular organisms in that they have no metabolic enzymes, use no nutrients and produce no energy. Viruses are made up of only two essential components, a protein and a nucleic acid. In order to reproduce, a virus infects a host cell with the viral nucleic acid. The host cell, which may be either plant, animal or bacterial, then replicates the viral protein and reassembles the virus. Since viruses are dependent upon host cells for reproduction, simple antibiotic treatments and disinfection techniques are not sufficient and extensive disease outbreaks are possible (Gaudy, 1988).

A typical septic system effluent contains a viral count of approximately 10^4 viruses per liter (10^7 viruses per 1000 liters). As the World Health Organization recommends that concentrations of viruses not exceed one per 1,000 liters, a reduction of more than seven orders of magnitude is necessary (Yates, 1989). The small size of viruses, approximately 20 - 2000 nanometers (1 nm = 10^{-9} meters), and long survival time, makes removal from the environment a difficult task (Gaudy, 1988). This, coupled with the fact that very low doses (possibly a single virus) are needed for infection, makes viral removal or inactivation an important consideration in septic tank/soil absorption system design.

The fate of microorganisms in the environment is determined by the ability of the organism to survive and the degree of retention by the soil particles. These two variables are determined by the climate, the nature of the soil and the nature of the microorganism (Gerba, 1977). Removal of viral contamination can be accomplished through either inactivation, caused by a disruption of the DNA, or RNA, core of the virus particle, or adsorption onto soil particles. Viruses are amphoterically charged, colloidal sized particles, exhibiting a net charge of zero at their isoelectric point and a negative charge at most soil pH values. This means that adsorption of viruses can be accomplished by either anionic or cationic resins, depending upon the soil pH, the particular virus and the ionic strength of the solute (Burge and Enkiri, 1978). Most viruses are readily adsorbed onto soils at a pH of 7.4 or lower (Cantor and Knox, 1985).

Virus adsorption to soil surfaces is governed by electrostatic double-layer interactions and van der Waals forces (Gerba, 1977) (weak molecular level attractive forces effecting otherwise ideal gasses) with adsorption rates described as following the Freundlich Isotherm. The first order, diffusion controlled, adsorption rate increases with increasing cation exchange capacity, specific surface area and soil clay content, along with decreasing pH and organic carbon content (Burge and Enkiri, 1978). Viruses have been shown to adsorb onto the surface of particles of clay, glass, and oxides of iron, silica and aluminum. Different viruses, or different strains of the same virus, have been shown to display marked differences in adsorption potential. This has been attributed to the variability of the protein configuration on the outer capsid of the virus. It is this outer layer which influences the net charge of the virus, thereby changing the electrostatic potential and degree of interaction between the virus and soil (Gerba, 1977).

Reducing the incidence of viral contamination of the groundwater is especially important in preventing the transmission of infectious disease. As viral populations can survive for extended periods in the saturated aquifer system, septic systems must be designed to promote complete immobilization and inactivation of viruses in the unsaturated zone of the soil absorption system. Unsaturated flow, resulting in low flow velocities, promotes the formation of the thin soil-water contact layers and extended detention times necessary for viral contaminant removal. For a given virus and soil, the amount of virus adsorbed is linearly related to the square root of the detention time (Burge and Enkiri, 1978).

Heavy Metals

Heavy metal concentrations are oftentimes an important consideration in the handling and disposal of commercial and industrial wastewaters. Heavy metals are toxic to microorganisms, plants and animals, with arsenic, and mercury being the most toxic to humans. Although not a major component of domestic sewage, trace concentrations of heavy metals may be present in both the sludge contained by the septic tank (septage) and the liquid effluent discharged to the soil absorption system. Heavy metals, such as arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc, and trace inorganics, such as cyanide, are added as pigments and dyes in inks, paints and plastics or used in the manufacture of cleaning solutions, batteries, topical antiseptics and astringents, pharmaceuticals, cosmetics, and herbicides and insecticides. Significant concentrations of copper, in addition to lead and cadmium in older systems, can also be introduced to waste waters through the dissolution of metal ions into the waters contained in household pipes.

Metals are removed from wastewaters through a number of processes including neutralization/precipitation, sorption, ion exchange and complexation. Of these mechanisms, adsorption appears to be the most important for the fixation of heavy metals (Canter and Knox, 1985). All of the above listed metals, with the exception of the trace inorganic cyanide (CN^-), are positively charged cations (eg. mercury, Hg^+), capable of binding with the negatively charged ions present in soils. Competition for sorption sites comes from the much more prevalent, although less toxic, metals including iron, calcium, sodium and manganese.

Removal of metals by precipitation can occur only to the equilibrium solubility of the metal at the current water pH. Precipitation reactions in soil systems usually result in metal carbonate precipitates, although metal sulfide and metal hydroxide precipates may also occur. Precipitation reactions are concentration and pH controlled. Since most metal hydroxides are amphoteric they exhibit the lowest solubility concentration at an optimum pH value, usually in the range of 8 - 11.

In the complex mixtures comprising septic system wastes, diminishing the metals content to the equilibrium solubility concentration is usually not possible. This may be due to inadequate detention time available for completion of the precipitation process, insufficient filtration of the colloidal sized metal precipitates, or the formation of soluble organic or ligand complexes. Many ligands, such as CL^-, NH_3, S^{2-}, and OH^-, are naturally present in ground waters and waste waters (Sawyer and McCarty, 1978). Organic and ligand complexes tie-up metals and compete with the removal processes thereby altering the mobility and equilibrium solubility concentration of the metals.

Significant accumulations of metals occur at the gravel-soil interface (Brown et al., 1977). These metals may be bound in organic complexes, capable of being redissolved with organic breakdown or changing conditions. System upsets which may lead to desorption of metals include the onset of anaerobic reducing conditions or a lowering of the pH.

Suspended Solids

Suspended solids, ranging from colloidal to particulate size, contribute turbidity and color to wastewaters. Examples of suspended solids found in sewage include clay, silt, microorganisms, algae, organic debris, and complexed metals. Suspended solids may be either hydrophilic (water loving, easily mixed with water) or hydrophobic (water hating, eg. oils). Most suspended solids present in waste water have negative charges, and are therefore not attracted to the predominantly negatively charged unsaturated soils. Removal of suspended solids is accomplished through filtration, adsorption and ion exchange processes, both in the unsaturated and the saturated environment.

Dissolved Inorganic Solids

Inorganic solids are the major components comprising most soils and are therefore found in varying concentrations dissolved in natural ground waters. Dissolved elements and molecules, exhibit a net charge and contribute to the color found in some waters. Examples of dissolved materials include positively charged ions such as sodium, potassium, calcium, magnesium, manganese, iron, copper, hydrogen, and heavy metals and negatively charged ions including carbonate, bicarbonate, sulfate, chloride, phosphate, nitrate, and hydroxide. While dissolved inorganic solids are naturally present in aquifer systems, increased loads due to septic systems, especially when used in conjunction with water softening units, may lead to a degradation of the quality, both aesthetically and health wise, of the aquifer and may lower the permeability of the receiving soils.

Trace Organics

Trace organic contamination may be introduced to the aquifer through natural sources, such as plants and animals, or through spills or the discharge or accidental release of contaminated wastewaters. Trace organic pollutants can be found in domestic sewage due to the improper handling or disposal of petroleum products such as gasoline, oil and grease, or petroleum based products and solvents including, cleaning fluids, adhesives, lubricants, soaps and detergents, degreasers, thinners, paint and varnish removers, moth repellents, pesticides, fungicides, and insecticides.

Some, but certainly not all, of the trace organics undergo some degree of biodegradation in acclimated ground waters. The microorganisms naturally present in soils and groundwater, and introduced with domestic sewage can slowly, and oftentimes over great distances with ground water movement, break down most of the volatile organic compounds inadvertently released. Refractory organic compounds including surfactants (the agents which provide the cleansing power of detergents by making the stain prefer to be bound to the surfactant rather than to the soiled material), phenols, and pesticides are of particular concern due to their resistance to biological degradation.

Even those volatile organic compounds which are biodegradable are of concern. The slow rate of the biodegradative process oftentimes results in detectable levels of volatile organic contamination being present in downgradient wells. Additionally, in the subsurface environment, released organic pollutants undergo significant changes not the least of which may be halogenation. Halogenation, most commonly with chlorine, results in chlorinated hydrocarbons many of which have been found to contain carcinogenic properties.

Acids/Bases

The addition of large concentrations of acids or bases to a waste water stream can have a great impact on the degree of treatment afforded by the system. Viral adsorption and metal precipitation are two processes in which pH plays an important role. Viruses are adsorbed onto the surface of soils which exhibit a pH below their isoelectric point, and therefore low pH waste waters are preferred. Metals exhibit their lowest solubility in basic solutions, thereby providing for the greatest degree of precipitation in alkaline environments. Viruses and metals, previously removed by the soils underlying a septic system, can become resuspended in a waste water that is either too alkaline or too acidic, respectively.

Improper control of the pH of a waste water can also dramatically affect the rate and extent of the biological activity occurring in a septic system. Acids commonly found in domestic waste waters include, vinegar, nitric acid and hydrochloric acid. Common bases include laundry bleach, ammonia and lye. Although microorganisms are sensitive to small changes in pH, drastic swings are buffered by the septic tank, which contains a volume large enough to dilute most small, one time incidents which may occur in a domestic system. The effect of acids and bases is much more important for commercial and industrial systems for which the extensive use is much more prevalent.

Nitrogen

After carbon and oxygen, nitrogen is the most abundant element, by weight, in organic matter. Nitrogen, and nitrogen containing compounds, are a major component of proteins and nucleic acids. The average influent to a domestic septic system contains 42 mg/l of nitrogen, of which 75 percent is ammonia-nitrogen and 25 percent is organic nitrogen (Magdoff et al., 1972). The organic nitrogen is largely contained in the fecal proteins whereas the inorganic ammonia-nitrogen is derived from urine.

Nitrogen elimination is a two step process, aerobic nitrification followed by anaerobic denitrification. The first step, nitrification, is the bio-oxidation of reduced forms of nitrogen; ammonia and organic nitrogen, to nitrite and nitrate using elemental oxygen as the energy source. This is accomplished readily under aerobic conditions by autotrophic nitrifying bacteria such as Nitrosomonas, which converts ammonia to nitrite, and Nitrobacter, which converts nitrite to nitrate (Willman et al., 1982).

Nitrosomonas

$$NH_4^+ + 1.5\,O_2 \rightarrow 2\,H^+ + H_2O + NO_2^-$$

Nitrobacter

$$NO_2^- + 0.5\,O_2 \rightarrow NO_3^-$$

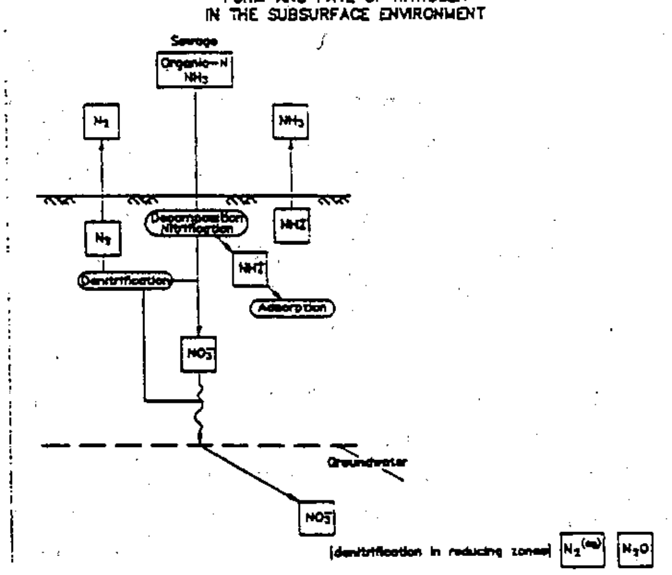
Overall Nitrification Reaction

$$NH_4^+ + 2\,O_2 \rightarrow NO_3^- + 2\,H^+ + H_2O$$

Denitrification is the conversion of nitrate to elemental nitrogen gas under anaerobic conditions. In this environment, anaerobic bacteria use combined forms of oxygen (nitrate and sulfate); to convert organic carbon into carbon dioxide and new bacterial cells. The combined oxygen molecules are transferred to the carbon, and nitrogen is removed from the system as nitrogen gas. Oxygen, usually present in unsaturated soils and dissolved in groundwater, is pathogenic to anaerobic bacteria, thus precluding the occurrence of appreciable amounts of denitrification under aerobic conditions (Gaudy, 1988).

FIGURE 3.3.1

FORM AND FATE OF NITROGEN IN THE SUBSURFACE ENVIRONMENT



Extensive nitrogen removal is not accomplished by a conventional septic tank/soil absorption system. In these systems, especially those installed in sandy soils, an anaerobic environment containing the proper concentration of nitrate, anaerobic bacteria, and organic carbon sources does not exist. Conventional systems rely on the limited degree of removal of ammonia-nitrogen in the septic tank and on ammonium adsorption and fixation occurring on the surface of the clogging mat and soil, for a short term nitrogen reduction (Reneau, 1977). This limits the effectiveness of most conventional systems to only a 5 percent removal of the influent nitrogen (Lamb et al., 1988).

The molecular form of the discharged nitrogen has a great effect on its fate, mobility and impact. Small amounts of the reduced forms of nitrogen, (e.g. ammonia), may be adsorbed onto negatively charged soil particles. The remaining nitrogen, primarily in the form of nitrates, can be transported for long distances with the saturated groundwater (Lamb et al., 1988; Walker et al., 1973). In surface water, nitrogen can be incorporated into the microbial biomass promoting algal blooms, contributing to diminished dissolved oxygen concentrations in the bottom sediments of rivers and estuaries, leading to accelerated eutrophication and decreased aquatic viability (Reneau, 1977). Algal growth is an autotrophic reaction in which the carbon source is non-organic carbon dioxide.

$$\text{Carbon Dioxide} + \text{Nutrients} + \text{Light} \xrightarrow{\text{Algae}} O_2 + \text{New Algal Cells}$$

Nitrate, the form of nitrogen largely emitted from a conventional leaching system has potentially harmful health effects. Nitrate levels of 45 mg/l have been found to cause significant health risks (Peavy and Groves, 1977) such as the onset of methemoglobinemia in infants who ingest excessive amounts of nitrate and nitrite contaminated water (Reneau, 1977). This has resulted in prescribing the Recommended Maximum Contaminant Levels for nitrate and nitrite in drinking waters at 10 mg/l and 1 mg/l respectively.

Nitrate, due to its anionic character and high solubility, is very mobile in the saturated aquifer (Lamb et al., 1988). Lateral nitrate movement through the saturated zone is unlimited with little soil attenuation and concentration reduction only occurring through dilution (Peavy and Groves, 1977). Groundwater contamination by nitrates is usually limited to the uppermost 30 cm (1 foot) of the saturated zone with little naturally induced mixing occurring (Walker et al., 1973). Reducing the threat of nitrate contamination in drinking waters can be accomplished by lowering the septic system density or through the use of deeper wells, with well points installed below the upper, most highly contaminated groundwater layer (Walker et al., 1973).

The Wisconsin mound system is a leaching system which has been found to provide some degree of denitrification. A Wisconsin mound system utilizes an aerobic absorption and initial treatment zone constructed above the existing topsoil which is plowed or furrowed to promote infiltration (Bouma, 1972). This less permeable layer detains water, promoting anaerobic conditions, and thereby providing an appreciable degree of denitrification of the previously oxidized effluent (Bouma, 1972).

Phosphorus

Domestic wastewater contains an average of 20 - 25 mg/l of phosphorus, with approximately 65 percent in the organic form and 35 percent in the inorganic orthophosphate form. Settling of suspended solids in the septic tank removes a portion of the phosphorus resulting in an effluent containing 15 - 20 mg/l of phosphorus, 85 percent of which is in the soluble inorganic orthophosphate form (Canter and Knox, 1985).

The major phosphorous removal processes involve adsorption and precipitation reactions, many of which may be somewhat reversible or have finite loading limitations (Hill, 1981). Phosphate removal follows a two step process - the adsorption of the negatively charged phosphate ions onto the positively charged cations present in the minerals of the soil followed by precipitation of phosphorus as hydroxyapatite (Witt et al., 1974; Sawhney, 1977).

The extent of phosphate adsorption is affected by the amount of adsorption sites available, a function of soil type and pH, and appears to be dependant upon temperature and effluent phosphate concentration (Sawnhey, 1977). The adsorption is actually a chemisorption onto the surface of iron, aluminum or calcium minerals (Canter and Knox, 1985). This adsorption reaction is rapid, independent of flow velocity and detention time, and proceeds until all of the sorption sites are filled (Witt et al., 1974). It may be somewhat reversible, through periodic flooding of the soil which reactivates the adsorption sites but may also result in the redissolution of phosphates (Sawhney, 1975). Additional phosphate mobility can be induced by the onset of anaerobic or reducing conditions which lower the phosphate sorption capacity of the soil and lead to phosphate desorption (Hill, 1981).

As the phosphate adsorption sites quickly become saturated, the second most important step in the removal process, a precipitation reaction, resulting in hydroxyapatite begins (Witt et al., 1981). Additional phosphorus removal may be achieved due to the formation of iron phosphate and aluminum phosphate precipitates (Sawhney, 1977). These precipitation reactions are time dependent, with phosphate removal efficiency proportional to the infiltration rate (Witt et al., 1974).

Under proper conditions, these reactions may provide for 75-80 percent removal of the influent phosphorus load (Witt et al., 1974). Once in the ground water, the remaining phosphorous continues to be adsorbed as it moves downgradient of the system. As adsorption sites on the silts and clays in the saturated zone become filled, the active treatment sites migrate in the direction of ground water flow. Complete phosphorus removal can never be obtained as predicted from Freundlich Isotherms. Long term phosphorus concentrations below septic tank/soil absorption systems have been found to be in the range of 6 - 7 parts per million. Once in the groundwater, the phosphorous can be transported, essentially unchanged, to a surface water discharge point (Peavy and Groves, 1977).

Phosphorus from septic systems is not directly harmful to humans, but if it is discharged to lakes or other fresh water bodies, it may act as a fertilizer stimulating plant and algae growth. As the nutrient balance between phosphorus and nitrogen becomes tipped, some species become predominant and the environment becomes unfavorable for many others. This increase in nutrients and productivity is generally referred to as eutrophication.

PART II

SITE EVALUATION

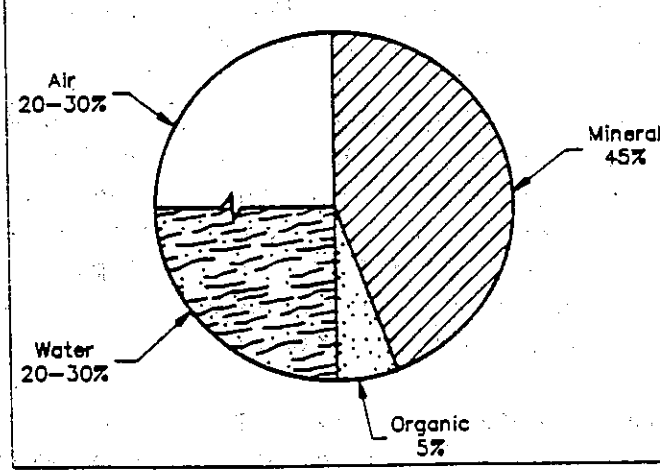
CHAPTER 4

SOIL ANALYSIS

Consideration of soil conditions is a critical factor in the design and siting of an effective on-site sewage disposal system. Ground water contamination occurs when constituents in septic tank effluent enter the ground water without being adequately treated or retained by the soil. This may be a result of soil or geologic characteristics such as high permeable gravel layers, clay layers with major macropores caused by shrinking and swelling, or other formations that allow partially treated septic tank effluent to bypass soil layers and enter the ground water prematurely.

A site suitability assessment is performed to evaluate a particular area for on-site sewage disposal. A suitable site must contain soils capable of accepting the expected hydraulic loads while providing adequate treatment to safeguard both the environment and the public health. When designing and siting an on-site sewage disposal system the soil characteristics of the site where the system will be installed must be fully evaluated. This site characterization is a complex process, typically involving a systematic field investigation to assess landscape positioning and soil taxonomy. Ideally, the site suitability analysis should also include a comprehensive evaluation of the soils, including an examination of the soil characteristics and an identification of the soil profile. The geologic parent material and mode of material emplacement should be evaluated in order to identify appropriate design modifications necessary to overcome site specific limitations.

FIGURE 4.1.1
COMPONENTS OF SOIL



4.1 Literature Review

Soil is the upper weathered and biologically molded part of the earth's crust. The average soil consists of 45 percent mineral solids, five percent organics and 50 percent air and water (see Figure 4.1.1). The solid portion is composed of weathered rock material, whereas the organic portion is comprised of decayed and synthesized plant and animal residue.

Soil formation has been active in Massachusetts since the most recent retreat of the glaciers approximately 12,500 years ago. Physical and chemical weathering, a function of climate, topography, time and vegetation, affects the parent material forming unique environments which result in the formation of distinct horizons. These horizons can be described by digging an observation pit and inspecting the texture, structure, color, layering, consistence, mottling, and drainage class of the soil. The standards used to describe and evaluate soil profile characteristics were developed over a fifty year period and are described in detail in the Soil Survey Manual (Soil Survey Staff, 1981).

The soils in Massachusetts are similar to other glacially derived soils found in the New England States, New York, Michigan, Ohio, Indiana, Michigan, Wisconsin, Minnesota, North Dakota and parts of South Dakota, Montana, Illinois and Iowa. The Massachusetts soils are taxonomically classified as spodosols (Foth, 1984) which form in humid climates from sandy siliceous parent material. Related soils can also be found in parts of Florida and Georgia.

The following criteria used in soils evaluation has been adopted from the Maine Department of Human Services, Division of Health Engineering manual entitled "Site Evaluation for Subsurface Wastewater Disposal Design in Maine", second edition, dated August 1983.

Parent Material

The parent material of a soil dictates many of its physical, chemical and biological characteristics. Major parent materials include glacial outwash and till, glacio-lacustrine (lake) deposits, marine sediments, wind blown materials and floodplain deposits.

The glacially derived materials include tills and stratified drift oftentimes intermixed with large boulders. If the till was laid down at the bottom of a glacier it is referred to as a basal till. Basil till is usually fine grained and compacted to an almost cement-like consistence. Tills deposited by melt water are loose and sandy and are oftentimes associated with stratified drift. Stratified drift, as the name implies, was laid down by melt water with some degree of stratification. Classifications of stratified drift include: kames, eskers and outwash plains. Soils derived from these deposits are generally coarse textured and well sorted by size.

The glacial deposits in Massachusetts are principally stratified drift, found in the outwash deposits of the southeastern part of the state and the glacial valley aquifers located throughout the remainder of the state. Tills are found in the moraine deposits of southeastern Massachusetts and blanketing bedrock throughout the state. Till deposits are usually exposed when the bedrock is close to the surface.

Water derived soil materials include marine, lacustrine and alluvial deposits. Marine deposits are mostly clay and become denser with increasing soil depth. Soils derived from these deposits can be silty clay loam and silty clay. Lacustrine deposits are associated with lake bottoms. They tend to be less fine than marine sediments and include fine sandy loam and silt loams. Alluvial deposits are found along modern rivers and are generally young poorly developed soils. Texture varies depending on the depositional environment. Organic soils are found in swamps, bogs and marshes.

Soil Wetness

Knowledge of the times and depths at which a soil is very wet is very important in using the soil for subsurface wastewater disposal. Free water is very influential on the biological, chemical and physical processes.

Soil characteristics, climate, slope and landscape position influence soil wetness. Precipitation, runoff, infiltration, and permeability also affect the degree and duration of wetness. A soil at a higher elevation may have a deeper water table or have a shorter duration of wetness than the same soil at a lower elevation downslope. Although the depth to ground water table changes greatly during and between years, most soils usually have typical times and depths of saturation.

Soil morphology is used to infer moisture conditions in a soil. Soil color, texture, structure and consistence will enable the skilled and experienced observer to characterize soil wetness.

Soil Drainage

Natural drainage refers to the conditions of saturation or near saturation that exist in a soil and the frequency and duration of the periods of saturation. There are six drainage classes listed below in increasing order of saturation.

> Excessively drained. Water is removed from the soil very rapidly. Excessively drained soils are commonly very coarse textured, stony, or shallow. Some are steep. All are free of the mottling related to wetness.
>
> Well drained. Water is removed from the soil readily, but not rapidly. It is available to plants throughout most of the growing season, and wetness does not inhibit growth of roots for significant periods during most growing seasons. Well drained soils are commonly medium textured. They are mainly free of mottling.

Moderately well drained. Water is removed from the soil somewhat slowly during some periods. Moderately well drained soils are wet for only a short time during the growing season. They commonly have a slowly permeable layer within the substratum or periodically receive high rainfall, or both.

Somewhat poorly drained. Water is removed slowly enough that the soil is wet for significant periods during the growing season. Wetness markedly restricts the growth of some plants unless artificial drainage is provided. Somewhat poorly drained soils commonly have a slowly permeable layer, a high water table, additional water from seepage, or a combination of these.

Poorly drained. Water is removed so slowly that the soil is saturated periodically during the growing season or remains wet for long periods. Free water is commonly at or near the surface for a long enough period during the growing season that most plants cannot be grown unless the soil is artificially drained. The soil is continuously saturated in layers directly below plow depth. Poor drainage results from a high water table, a slowly permeable layer within the profile, seepage, or a combination of these.

Very poorly drained. Water is removed from the soil so slowly that free water remains at or on the surface during most of the growing season. Unless the soil is artificially drained, most plants cannot grow. Very poorly drained soils are commonly level or depressed and are frequently ponded.

Soil Color

Soil color is a very useful property for soil identification and appraisal because many important characteristics can be inferred from soil color and patterns. Soil color is influenced by mineralogy, wetness, organic matter content, and genetic processes. Soil color does not have any known direct influence on the functioning of soil other that effecting absorption of heat at the soil surface. However, it is extremely important in the clues that it provides toward understanding other physical, chemical and biological soil properties.

Commonly, dark colors in the upper horizon suggest more organic matter than light colors. Organic matter decomposes slower in saturated soils that in freely draining soils, all other factors being equal, since microbial activity is slower in saturated soils with its anaerobic environment that in freely draining soil with its aerobic environment. Very dark soil surfaces usually indicate poorly drained conditions.

The Munsell Soil Color Chart is a tool used to assist in determining the soil color. Soil color is measured by comparison with approximately 200 different color chips systematically arranged according to their Munsell notation of hue, value and chroma. Hue is the dominant spectral color (wavelength of light). Value is the amount of light (lightness of color). Chroma is the strength of the color and increases with decreasing grayness. A color of light brownish gray for example is denoted as 2.5Y 6/2 meaning that the color is of a 2.5Y hue, value of 6 and a chroma of 2.

Soil Drainage Mottles

Iron is one of the main coloring substances of soil. The color of the iron in soil is closely related to the amount of oxygen derived from the air that is present. Air is absent or in short supply when soils become saturated or nearly saturated with water. When air is absent in the soil, iron exists in the ferrous or reduced state which is gray in color. When there is an air supply as in well drained soils, the iron is in ferric or oxidized state which is yellowish and reddish in color. If, over a long period of time, a soil has been alternately wet and dry a combination of both ferric and ferrous iron are found. This produces a mottled condition.

Mottling is defined as spots or blotches of different color, or shades of color, interspersed with the dominant background color. Oxidation (bright colors) and reduction (dull colors) are caused by alternating aerobic and anaerobic conditions attributable to a seasonally fluctuating groundwater table, or the intermittent presence of a perched water table.

Mottles can be described in terms of quantity and contrast. Quantity can be indicated by one of three classes based on the percentage of the observed surface that is occupied by mottles:

Few	Less than 2%
Common	2 to 20%
Many	More than 20%

Contrast can be described as faint, distinct, or prominent based on the visual distinction that is evident between associated colors.

Faint	Evident only on close examination.
Distinct	Readily seen, but contrast only moderately with the soil matrix background color.
Prominent	Contrast strongly with the soil matrix background color.

Following are the major soil drainage groups used in the Subsurface Wastewater Disposal Rules. The different drainage conditions are caused by variations in ground water levels, seepage, rate of surface runoff and soil permeability.

Well drained soils: Well drained soils have bright subsoils which are free of mottling to depths greater than 48 inches; indicating that water drains freely from the profile. Colors of the surface soil vary widely but are generally less dark than those of poorly drained soils.

Moderately well drained soils: Moderately well drained soils exhibit drainage mottling between 15 and 48 inches beneath the mineral soil surface. Water is removed from these somewhat slowly; the profile is wet for a short but significant part of the year. Moderately well drained soils commonly have a restrictive layer, seepage water, or a seasonal high ground water table at a soil depth of 15 to 48 inches. Colors of the surface and upper subsoil are relatively uniform within each layer. Mottling becomes noticeable in the lower subsoil and may appear as yellow-orange spots and blotches mixed with the natural brownish color.

Poorly drained soils. Poorly drained soils have a seasonal high groundwater table 15 to 6 inches beneath the existing mineral soil surface. Poorly drained mineral soils have a dark (black) surface layer underlain by a gray subsoil which may contain some yellow-orange mottles. These soils usually occur at the base of long slopes in low depressions and near flat seepage areas. If these soils have been cultivated, the plow layer will have disturbed soil horizonations to usually about 9 inches. Evaluation of the seasonal high ground water table when mottling ends at the base of the disturbed plot layer will require an evaluation of the color of the plow layer and appraisal of organic matter accumulation.

Very poorly drained soil: Very poorly drained soils have ground water at or within 6 inches of the soil surface for a significant period of time. These soils are very dark throughout the profile from organic matter accumulation.

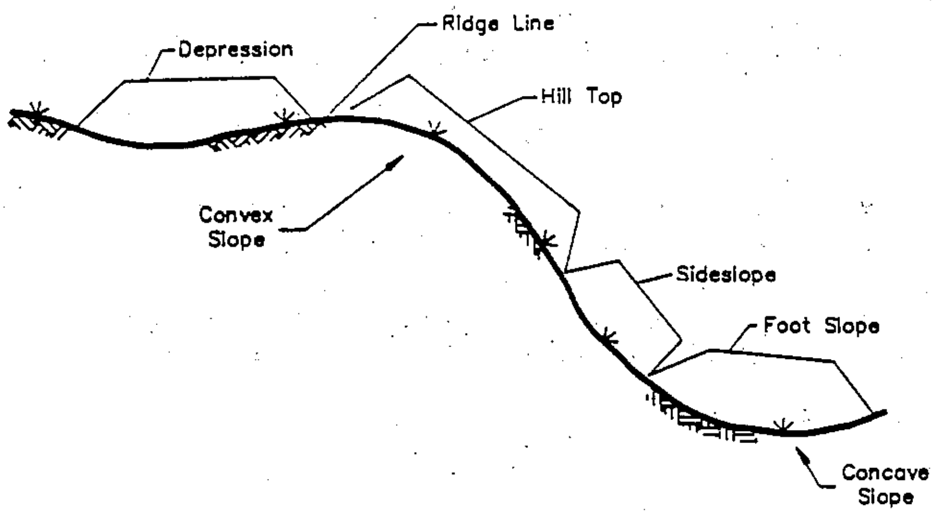
Position in Landscape and Soil Characteristics Affecting Drainage

The natural drainage of a soil depends on how much of the water falling on the land enters the soil and how well it passes through the soil. The position of the soil in the landscape, slope, and size of upslope watershed all influence the drainage..

Flat land and depressional areas have very little runoff and may receive additional runoff from higher ground; most of which must drain through the soil. Poorer drained soils generally occur in these positions. Undulating or rolling land has more runoff and less water passing through the soil. Soils on upland knolls or on a side slope with a very limited watershed are usually well or moderately well drained unless there is a restrictive layer perching the ground water. On steep slopes, most of the water runs off and excessively drained soils result because relatively small amounts of water enter the soil.

Texture of the soil also influences the natural drainage. Coarse textured soils usually drain better than fine textured soils. Whether the subsoil is "heavy" or "light" textured may influence the natural soil drainage. Fragipans, claypans, and bedrock all influence the natural drainage because they restrict the downward movement of water.

FIGURE 4.1.2
LANDSCAPE POSITIONS



<u>Soil Structure</u>

Soil structure is the natural organization of soil particles into units separated by surfaces of weakness. An individual natural unit is called a ped. Soil can have simple structure, compound structure or no structure at all. Simple structure is structure comprised of one type of ped while compound structure exhibit large peds composed of smaller peds within. Several basic shapes of peds are recognizable in Maine soils:

Granular:	Approximately spherical peds.
Blocky:	Blocklike or polyhedral peds.
Platy:	Peds are flat, platelike, and oriented horizontally.
Prismatic:	Peds with flat or slightly rounded vertical faces. Longer vertically than horizontally. Tops of prisms are normally flat.

Observation of soil structure is important in determining internal soil water permeability for subsurface wastewater disposal design consideration. Granular structure is favorable to air and water movement in all directions and is usually found is upper soil horizons. Blocky structure allows for soil water movement in all directions, but commonly to a lesser degree than granular peds. Platy structure inhibits downward movement of soil water to various degrees and soil water movement is generally forced laterally. Platy structure is usually associated with "restrictive layers" for subsurface wastewater disposal design consideration. Prismatic structure is usually associated with the finer textured soils. There is very little internal soil water movement within prisms so that soil water movement generally is restricted to channels between prism faces or perhaps laterally across the top of the peds.

<u>Consistence</u>

The cohesion among soil particles and adhesion to other substances is described by soil consistence. Soil consistence may be described in terms of soil strength which is the degree of resistance to breaking or crushing when force is applied. When evaluated at field moisture capacity, the terms of loose, very friable, friable, firm, very firm, extremely firm, or cemented can be used.

Restrictive Layer

A restrictive layer is a horizon in the soil that is resistant to downward movement of water and root penetration, and a cause of perched water tables. Lateral movement of water over the layer is common on steep slopes. Restrictive layers may exhibit platy or prismatic structure and firm, very firm, extremely firm or cemented consistence. Restrictive layers in Maine soils are found in firm basal till, fine textured sediments, or perhaps genetically formed in sandy loam or loamy sand horizons.

4.2 State Regulations

A survey of state regulations found that forty-one states (and Guam) use observation holes to obtain soils related information such as soil morphology, soil color, mottling, structure and texture (Table 4.2.1). Twenty-eight states (and Guam) use soil mottling to indicate the highest ground water level. In New England, Maine, New Hampshire and Vermont include soils information in leaching structure design. Sizing of domestic leaching structures in Maine is done entirely on the basis of soils data.

It appears that the majority of states use a combination of percolation test results and soils information in the site suitability process. The minimum required observation hole depth varies from two to three feet below the soil surface in Georgia and Mississippi to twelve feet in Rhode Island. A number of states require test holes to be excavated to a depth at least three (Minnesota) to six feet (Alaska, New Mexico, and New York) below the bottom of the proposed leaching structure.

Seven states, including Massachusetts and Rhode Island, limit site suitability assessment for on-site sewage disposal to a certain time period. The great majority of states, including all other New England states allow site suitability assessments to be completed throughout the year.

4.3 Local Regulations

Seventy-one towns have instituted regulations on the minimum number of test holes to be excavated on each lot. Many of the towns require two deep holes, one in the primary area and one in the reserve area. Several towns, such as Topsfield and Boylston, require two test holes in the primary area supplemented by two in the reserve area. The town of Sherborn requires a minimum of three test holes. If ledge is encountered, a minimum of five test holes must be excavated.

A total of 32 towns have set requirements on the minimum depth of the test pit. A majority of these towns have set the depth at either 10 or 12 feet. The town of Rehoboth requires a minimum depth of 14 feet. Several other towns, such as, Westwood and Amherst require the depth to be four to six feet below the leaching field.

FIGURE 4.1.3
SOIL TEXTURAL TRIANGLE

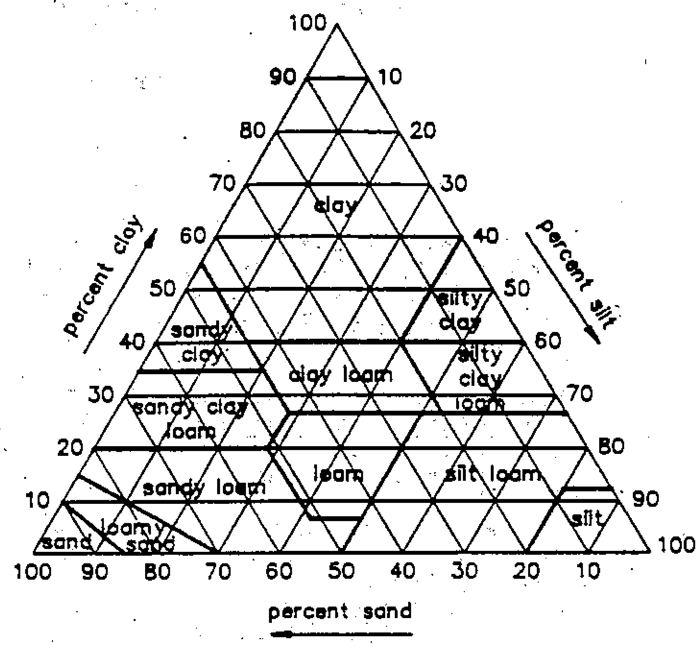
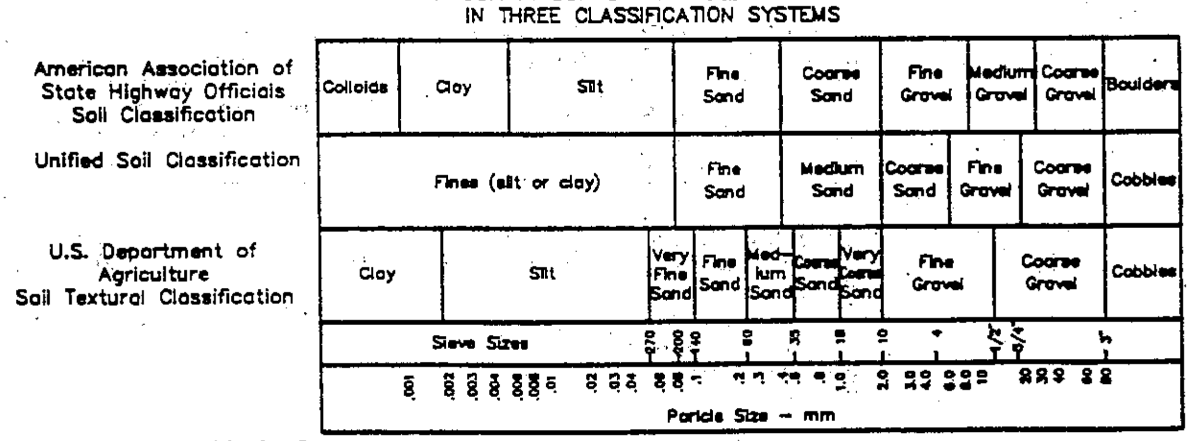


FIGURE 4.1.4
A COMPARISON OF PARTICLE SIZE LIMITS
IN THREE CLASSIFICATION SYSTEMS



Modified from PCA Soil Primer

PARTICLE NAME	PARTICLE SIZE RANGE, IN mm	SIEVE NUMBERS
VERY COARSE SAND	2.0 – 1.0	10 – 18
COARSE SAND	1.0 – 0.5	18 – 35
MEDIUM SAND	0.5 – 0.25	35 – 60
FINE SAND	0.25 – 0.10	60 – 140
VERY FINE SAND	0.10 – 0.05	140 – 270

TABLE 4.1.1

CHARACTERISTICS OF SELECTED SOIL TEXTURAL CLASSES COMMON IN MASSACHUSETTS

Texture and Appearance

Soil Textural Class	Dry Soil	Moist Soil
Sand	Loose, single grains which feel gritty. Squeezed in the hand the soil mass falls apart when the pressure is released.	Squeezed in the hand it forms a cast which crumbles when lightly touched. Does not form a ribbon between thumb and forefinger.
Loamy Sand	Loose, single grains which feel gritty but enough fine particles to stain finger prints in palm of hand.	Squeezed in the hand it forms a case which crumbles when touched and only bears very careful handling.
Sandy Loam	Aggregates are easily crushed. Very faint, velvety feeling initially, but as rubbing is continued, the gritty feeling of sand soon dominates.	Forms a cast which bears careful handling without breaking. Doesn't form a ribbon between thumb and forefinger.
Loam	Aggregates are crushed under moderate pressure; clods can be quite firm. When pulverized, loam has a velvety feel that becomes gritty without continued rubbing.	Cast can be handled quite freely without breaking. Very slightly tendency to ribbon between thumb and forefinger. Rubbed surface is rough.
Silt Loam	Aggregates are firm but may be crushed under moderate pressure. Clods are firm to hard. Smooth, flour-like feel dominates when soil is pulverized.	Cast can be freely handled without breaking. Slight tendency to ribbon between thumb and fore-finger. Rubbed surface has a broken or rippled appearance.
Silty Clay Loam	Aggregates are very firm. Clods are hard to very hard. Tendency to ribbon between thumb and fore-finger with some flaking, greasy feeling, moderately sticky.	Cast can be handled very firmly without breaking.
Silty Clay	Squeezed with proper moisture content into a long ribbon, sticky feel.	

TABLE 4.2.1

SOIL CRITERIA USED IN SITE SUITABILITY ASSESSMENTS

	SOIL CLASSIFICATION	PROFILE	COLOR	MOTTLING	STRUCTURE	TEXTURE	CONSISTENCY
Alabama		X		X			
Alaska							
Arkansas		X			X	X	
Arizona	X	X	X	X	X	X	X
California	X			X		X	
Colorado							
Connecticut	X	X	X	X	X	X	X
Delaware		X	X	X	X	X	X
Florida	X	X	X	X	X	X	X
Georgia(1)							
Hawaii							
Idaho	X	X	X	X	X	X	X
Illinois	X						
Indiana		X	X	X	X	X	X
Iowa	X						
Kansas(1)							
Kentucky	X	X	X	X	X	X	X
Louisiana(1)							
Maine		X	X	X	X	X	X
Maryland	X		X	X	X	X	X
Massachusetts		X		X			
Michigan	X	X					
Minnesota	X			X			
Mississippi	X		X			X	
Missouri	X	X	X	X	X	X	X
Montana	X	X	X	X	X	X	X
Nebraska	X	X				X	
Nevada			X	X			
New Hampshire	X	X	X	X	X	X	X
New Jersey	X	X	X	X	X	X	
New Mexico	X						
New York	X	X	X	X	X	X	X
North Carolina	X	X	X	X	X	X	X
North Dakota							
Ohio	X				X	X	
Oklahoma							
Oregon		X	X	X	X	X	X
Pennsylvania	X	X	X	X	X	X	X
Rhode Island		X					X
South Carolina	X					X	X
South Dakota		X	X	X	X	X	
Tennessee	X			X	X	X	X
Texas	X						
Utah	X	X		X			
Vermont		X					
Virginia(1)							
Washington	X					X	
West Virginia		X		X	X	X	X
Wisconsin	X	X	X	X	X	X	X
Wyoming				X		X	
Guam	X						
TOTAL	29	27	21	28	23	29	21

(1) Regulations unavailable

4.4 Conclusions and Recommendations

Soil survey identification procedures for most of the parameters discussed above can be learned during a few days of training, although under certain conditions greater expertise may be required. Site suitability assessment and evaluation of the sewage disposal potential of a site is greatly enhanced by the use of these soil parameters.

Present deep hole observation procedures can be improved significantly without a great deal of effort by the site evaluator or increased costs for the property owner. It is proposed that the current Title 5 requirements for the deep observation hole be maintained. In addition, the site evaluator should be required to prepare a profile description using standard soil terminology (Soil Survey Staff, 1981). The profile description should be formally documented on a standardized data form and include, as a minimum, the following:

Landscape position - identify the sites topography to avoid siting the system in depressions or at the base of slopes which may effect the sites runoff or infiltrative capacity.

Color - bright uniform colors (yellow, browns and reds) indicate aerated well drained soils, while dull grey soil indicates saturated anaerobic conditions.

Mottling - dark colored lines and blotches indicate intermittent periods of aerobic or anaerobic conditions cased by saturation from a fluctuating water table or changes in permeability.

Texture and Structure - dependent on the amounts and types of sand silt and clay present and can give a better understanding of the soils ability to accept the effluent.

Parent Material - the origin of the soil helps define its texture, structure and consistence. Inclusion of this parameter can help other trained persons visualize the sites characteristics.

We recommend that the Department of Environmental Protection adopt the SCS classification system and the Munsell Color Chart as the standards for describing soil characteristics and completing the above form. Further, we recommend that a standard guide for site evaluation be prepared by the Department of Environmental Protection for distribution to boards of health and system designers. This guide should describe the interrelation between soil evaluation and site conditions as they pertain to the design of subsurface sewage disposal systems. It should provide details on soil classification and morphology as well as ground water elevation determinations.

CHAPTER 5

DETERMINATION OF GROUND WATER ELEVATION

Ground water levels can fluctuate several feet due to varying weather and climatic conditions. During the arid summer months when precipitation is minimal and evapo-transpiration rates are high, water levels decline. Lowest levels are generally reached in late fall. The level usually begins to rise again in the winter commonly reaching its peak in March and April after the snow and ice has melted. Extended droughts or above average precipitation may result in ground water deviations of several feet from normal seasonal levels.

Hydrologic location also affects ground water fluctuations. Generally the smallest variation is observed near the ocean, its bays, estuaries, or salt marshes, increasing with distance from the ground water discharge boundary. The hydraulic characteristics of the geologic material also influence the water level range.

A single water level measurement will rarely represent the maximum ground water level. Despite this fact, Title 5 only requires one measurement of the depth to water at the test site with no provision included for estimating the highest level to which ground water can be expected to rise.

Recognizing the seasonal variations in ground water elevations, many local boards of health have decided to only accept measurements completed during early spring for septic system permit applications. While this may improve the likelihood of obtaining higher than average ground water readings, it does not necessarily provide an accurate estimate of the maximum high ground water elevation.

High ground water levels are a major cause of septic system failure. The aerated soil between the bottom of the leaching facility and the water table provides physical, chemical, and microbial treatment of the sewage converting the various constituents in the septic tank effluent into less noxious forms. Seasonal flooding of the unsaturated zone beneath the leaching system results in a decreased treatment efficiency and in severe instances causes the sewage to back-up into the plumbing and/or breakout onto the land surface.

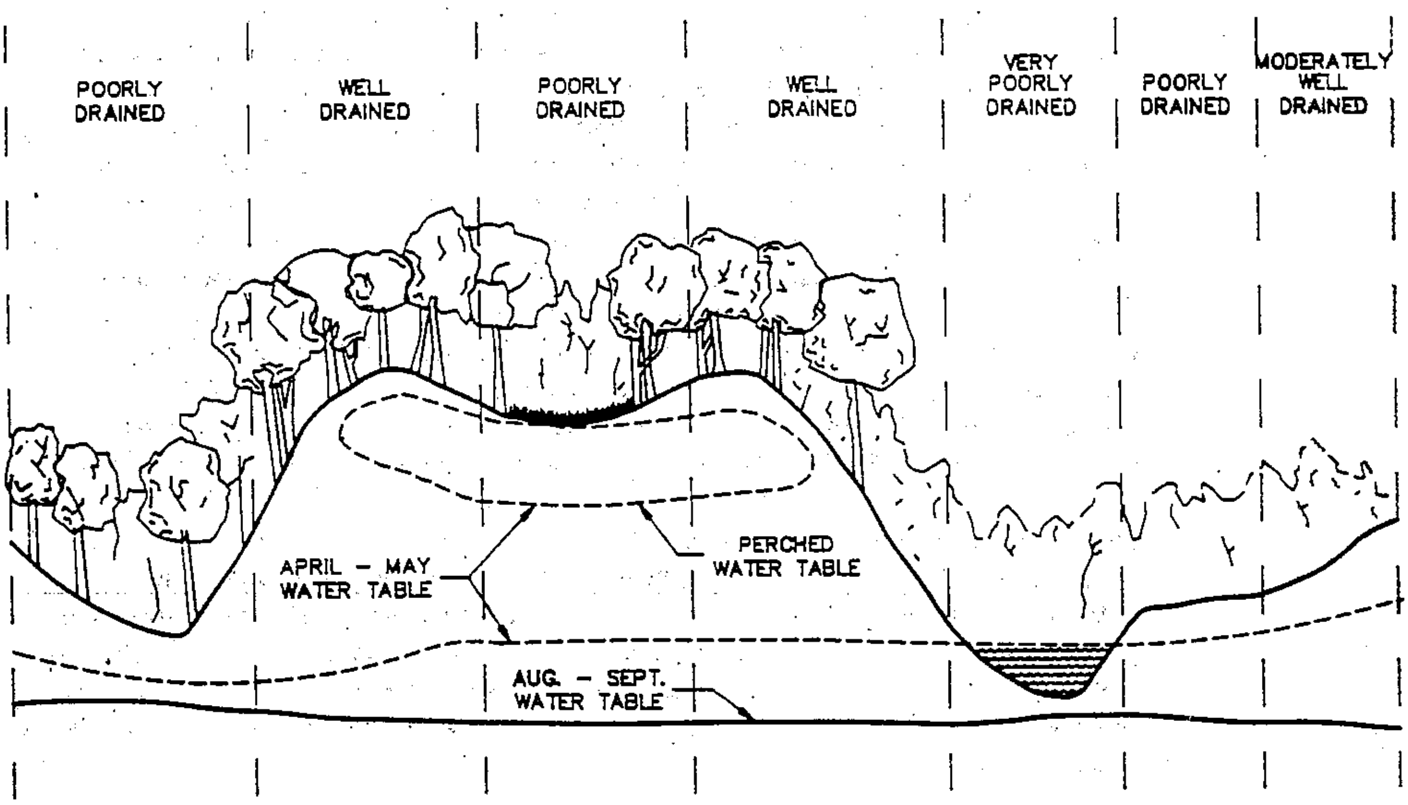
5.1 Literature Review

Proper design and an accurate assessment of the seasonal high water table is required to ensure that aerated soil is available throughout the year and that the soil horizon is of adequate thickness and type to properly disperse the effluent (Cantor and Knox, 1985). The maximum ground water elevation is currently established through visual observations completed during an historically established "wet period". 310 CMR 15.01 defines the maximum ground water elevation as "the height of the ground water table when it is at its maximum level or elevation. This level is usually reached during the

months of December through April". A review of statistical information based on long-term ground water well measurements in Massachusetts reflects the strong seasonal trends in groundwater elevations. Most often the highest ground water elevations are recorded during the spring (March, April, May). However, August has been the wettest month on record during at least one particular year (M. Frimpter, 1981). Therefore, a total reliance on "wet-period" observations may lead to erroneous results during dry or non-typical years. Limiting the site assessment season to the "wet period" also overlooks the need to promptly perform system repairs even when failures occur during non-wet periods.

FIGURE 5.1.1

TOPOGRAPHY, DRAINAGE, AND VEGETATION OF A SOIL ASSOCIATION



For determinations of ground water levels in Deep Observation Holes to be meaningful, they need to be compared to a permanent reference point. The validity of the one-time measurement can only be ensured when it is evaluated in context to long-term measurements. For example, March 1989 was a dry month. Water table levels throughout Massachusetts were within the lowest 25 percent recorded for that month. In contrast, April and May were wet months and well levels taken during this period fall within the highest 25 percent of data ever collected for those months. Observations conducted during March of 1989 resulted in a significant underestimation of water table levels (in some towns as much as 4 feet below the "normal" maximum level), whereas measurements taken during April or May were more representative of the maximum ground water elevation.

Several Massachusetts municipalities (e.g. Shrewsbury) employ a network of wells to determine when high ground water elevations are present and when deep hole observations can be made. While this approach ensures that the observation period occurs during a wet month, there is no guarantee that this time interval represents the maximum ground water elevation. Furthermore, this approach requires great flexibility by landowners and consultants which at times may be unrealistic.

The U.S. Geological Survey (USGS) in cooperation with the Office of Water Resources of the Department of Environmental Management completes monthly monitoring on a network of about 90 observation wells throughout Massachusetts. Additionally, about 60 wells on Cape Cod are cooperatively monitored by the Cape Cod Commission and the USGS. Any state, county, regional or municipal agency is eligible to enter this program with the USGS which can match local governmental funds, (dollar for dollar) with Federal funds. Many of the wells in the current network have been monitored continuously for several decades resulting in the compilation of an extensive historical record. The resultant computerized ground water level data base allows for a comparison of present on-site measurements with the historical record of USGS wells in the area to determine whether the on-site measurements represent maximum ground water levels. When statistical analysis of the water levels from the USGS wells indicates that ground water levels are within the upper 20 percent (or within any other specified limit) of all measurements ever taken, observations in the general area of that indicator well should reasonably reflect the actual maximum ground water level.

The USGS has developed mathematical models for the prediction of ground water elevations in Massachusetts (Frimpter, 1981, 1983). Based on historic well data, and considering topographic differences and variations in permeability of various soil strata, maximum ground water levels at a particular site can be approximated from current groundwater measurements. This procedure is especially suited to deep unconfined aquifers in large outwash deposits and in sandy materials (M. Frimpter, personal communication). The method can be defined with the following mathematical formula:

$$S_h = S_c - S_r \frac{(OW_c - OW_{max})}{OW_r}$$

where:

S_c	=	measured depth to groundwater at the site;
S_h	=	estimated depth to probable high water level at the site;
OW_c	=	concurrent depth to water in the observation well which is used to correlate with the water levels at the site;
OW_{max}	=	depth to historical maximum water level at the observation well which is used to correlate with water levels at the site;
S_r	=	range of water level where the site is located. (refer to Frimpter, 1983)
OW_r	=	recorded upper limit of annual range of water level at the observation well which is used to correlate with the water levels at the site.

Values of OW_{max} and OW_r for the USGS observation wells are given in Table 5.1.1. Values for Ow_c can be obtained from "Current Water Resources Conditions in Central New England" distributed monthly by the USGS free of charge.[1] Values of S_r can be selected from Figures 5.1.2, 5.1.3 and 5.1.4 taken from Frimpter (1981).

For a more complete and in-depth explanation the reader is referred to "Probable High Ground-Water Levels in Massachusetts" published by the U.S. Geological Survey as OFR 80-1205. This methodology does require a certain level of expertise to be displayed by the consultant as well as the regulatory personnel.

5.2 State Regulations

The U.S. Environmental Protection Agency, in a review of state regulations, recognized three types of state control ranging from a rigid application of uniform state-wide standards to a detailed analysis of site specific limiting factors allowing for a "custom" system design for each individual lot. The present Title 5 regulations are an example of the former type, while the regulations in Maine are an example of the latter. Research indicates that site specific designs require greater expertise by site evaluators and designers; however, long-term performance generally is greatly enhanced by this procedure.

1 For subscription to this monthly report contact: U. S. Geological Survey, Water Resources Division, Suite 926, 10 Causeway Street, Boston, Massachusetts 02242-1040.

TABLE 5.1.1

VALUES OF OWr and OWmax[1]

OBSERVATION WELL	OWr	OWmax
Acton 158	5.40	14.98
Andover 26	9.00	3.47
Andover 462	3.55	11.72
Attleboro 83	2.72	1.98
Barnstable 230	4.84	20.51
Barnstable 247	4.80	20.73
Becket 12 *	2.06	2.56
Billerica 363	10.45	1.13
Blandford 9 *	1.25	2.11
Boston 925	6.78	17.49
Bourne 198	4.80	29.88
Brewster 21	4.91	6.90
Brewster 22	4.76	28.13
Chatham 138	4.64	20.71
Chelmsford 68	6.38	3.83
Chelmsford 385	3.42	13.83
Cheshire 2	12.80	0.09
Chicopee 95 *	2.23	19.40
Colrain 8	7.74	14.62
Concord 165	4.67	35.50
Concord 167	4.72	4.47
Cummington 13 *	3.08	3.04
Dedham 231	9.88	2.45
Deerfield 44	4.26	1.42
Dover 10	5.37	29.95
Duxbury 79	3.77	6.10
Duxbury 80	3.27	19.53
East Bridgewater 30	13.25	2.40
Edgartown 52	5.41	12.93
Foxborough 3	3.90	16.24
Freetown 23	4.63	8.72
Georgetown 168	3.61	2.42
Granby 68	5.83	4.25
Granville 5	5.99	28.06
Granville 6	5.64	2.49
Great Barrington 2	9.07	3.99
Halifax 97	2.62	2.30
Hanson 76	3.23	2.50
Hardwick 1	7.71	9.21
Hardwick 31 *	1.12	10.54
Haverhill 23	7.97	4.96
Hawley 8 *	1.75	3.80
Lakeville 14	10.45	9.28
Lexington 104	2.26	1.22
Mashpee 29	3.63	5.62
Middleborough 82	15.26	1.50
Montague 5	6.55	0.41

OBSERVATION WELL	OWr	OWmax
Montgomery 19	4.70	0.57
Nantucket 228	4.13	21.45
New Bedford 116	2.71	2.31
Newbury 27	9.09	1.48
Norfolk 27	2.96	4.20
Northbridge 54 *	-----	3.33
Norton 37	7.40	2.35
Orange 63 *	3.05	5.20
Otis 7	5.61	4.55
Pelham 23 *	3.64	9.44
Pelham 24 *	3.66	2.74
Petersham 16 *	10.74	4.71
Pittsfield 51	12.12	12.30
Plymouth 22	6.82	19.82
Plymouth 494 *	-----	27.24
Sandwich 252	1.88	45.88
Sandwich 253	4.52	45.78
Seekonk 275	2.60	5.02
Sheffield 58 *	2.12	11.95
Southwick 95 *	3.78	0.66
Sterling 1	11.96	1.66
Sunderland 7	12.86	6.25
Sunderland 68	2.69	1.75
Taunton 337	5.95	5.96
Templeton 3	2.11	2.45
Topsfield 1	11.74	5.22
Townsend 13	4.38	9.55
Truro 1	1.90	9.28
Truro 89	2.20	10.20
Wakefield 38	4.64	4.51
Ware 43	4.07	5.17
Wareham 51	5.85	3.34
Wayland 2	3.02	13.96
Webster 1	5.28	10.28
Wellfleet 17	4.63	7.27
Wenham 76	3.83	0.39
West Brookfield 2	3.25	15.79
West Brookfield 10	10.15	1.57
Westhampton 20 *	4.92	5.30
Westfield 62	8.27	3.70
Westfield 152 *	4.28	2.20
Weymouth 2	14.81	5.25
Weymouth 3	13.61	2.91
Weymouth 4	4.60	3.64
Wilbraham 55	14.62	30.56
Wilmington 78	5.94	4.19
Winchendon 13	10.07	1.86
Winchester 14	11.02	4.03
Worcester 274	2.22	22.23

1 Source: U.S. Geological Survey

Site suitability assessments in most states include the excavation of observation holes to determine ground water elevation as illustrated in Table 5.2.1. Some states (California, Kansas, New Mexico, Rhode Island and Vermont) use piezometers, wells, and ground water contour maps in estimating the depth to ground water. Three states (Hawaii, Texas, and Missouri) have no formal procedure to assess the depth to the water table.

Site suitability assessments are limited to a certain time period in seven states, including Massachusetts and Rhode Island. The great majority of states, including all other New England states, allow site suitability assessments to be performed throughout the year (Table 5.2.2).

FIGURE 5.1.2 – – Probability of water-level range in till

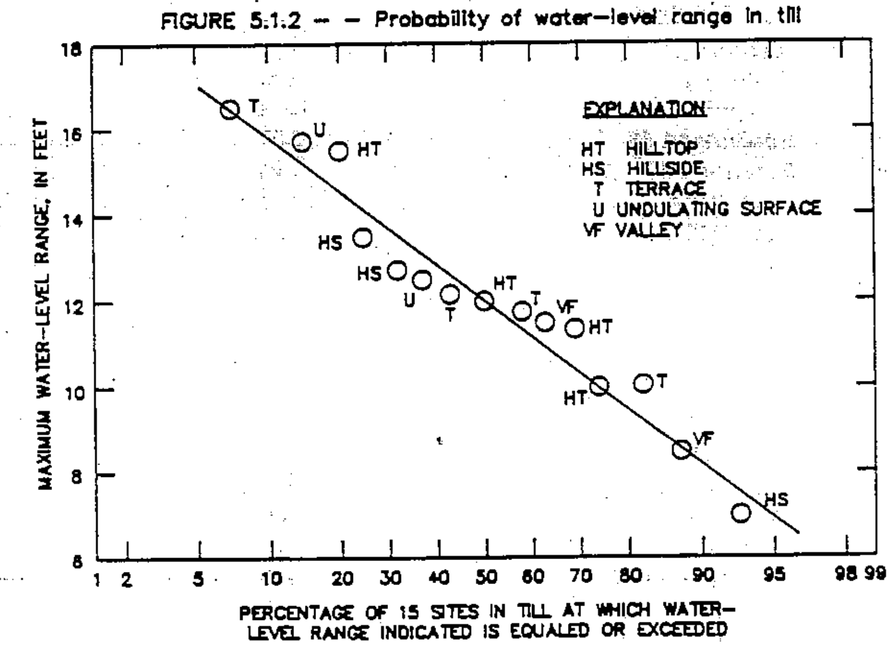


FIGURE 5.1.3 -- Probability of water-level range in sand and gravel on terraces

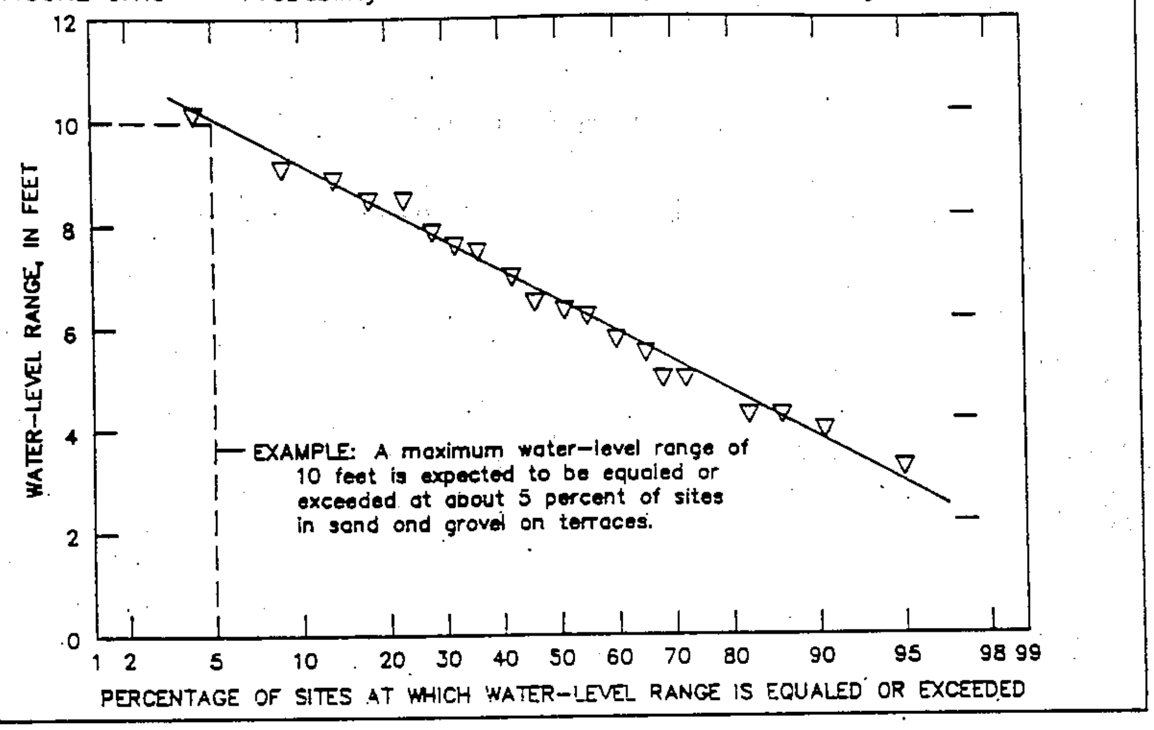


FIGURE 5.1.4 -- Probability of water-level range in sand and gravel in valley flats

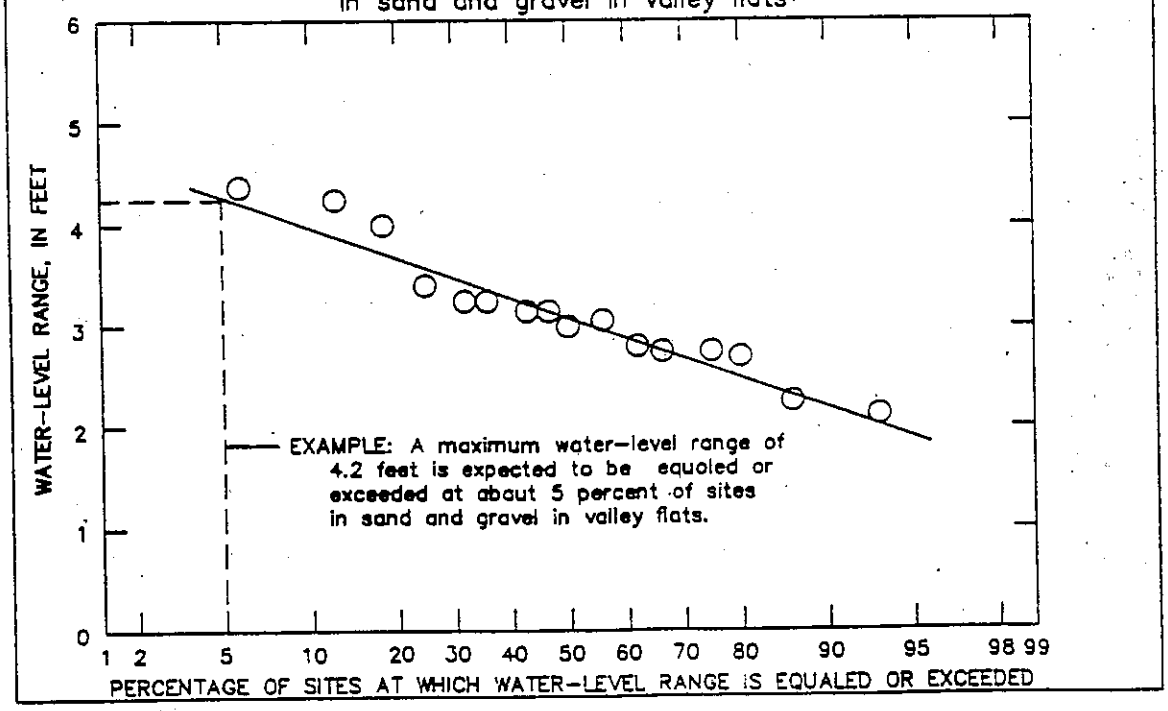


TABLE 5.2.1

METHOD FOR MEASURING DEPTH TO GROUNDWATER

	NONE	MOTTLING	OBSERVATION HOLES	ON-SITE VEGETATION	SOIL SURVEY REPORTS	LOCAL KNOWLEDGE	OTHER
Alabama		Y	Y(1)				
Alaska		Y	Y			Y	(15)
Arkansas			Y(2)				
Arizona			Y(2)				Y(3)
California							(11)/(17)
Colorado			Y				
Connecticut		Y					Y(4)
Delaware		Y					
Florida		Y(5)		Y	Y		
Georgia		Y					
Hawaii	Y(23)						
Idaho			Y(6)				
Illinois						Y	
Indiana		Y					
Iowa			Y		Y		
Kansas						Y	(17)/(18)
Kentucky		Y					
Louisiana						Y(19)	Y(7)
Maine		Y	Y(24)				
Maryland			Y				
Massachusetts			Y				
Michigan		Y					
Minnesota		Y					
Mississippi			Y		Y		
Missouri	Y(20)				Y		
Montana			Y(9)				
Nebraska		Y				Y	Y(8)
Nevada		Y(21)	Y(21)			Y(22)	
New Hampshire					Y	Y	
New Jersey			Y(9)		Y		Y(10)
New Mexico		Y	Y		Y		(11)/(12)
New York			Y				
North Carolina		Y					
North Dakota		Y					
Ohio		Y(13)			Y		
Oklahoma			Y				
Oregon		Y	Y(14)				
Pennsylvania		Y	Y(15)				
Rhode Island			Y(9)				Y(11)
South Carolina		Y					
South Dakota		Y				Y	
Tennessee		Y					
Texas	Y						
Utah		Y					Y(16)
Vermont		Y	Y				
Virginia		Y					
Washington		Y	Y(9)				
West Virginia			Y				
Wisconsin		Y					
Wyoming		Y	Y				
Guam		Y					
TOTAL	3	28	24	1	7	8	11

NOTES:

Y = Yes

(1) 5' soil bore-observations of 24 hour standing water
(2) Backhoe excavation
(3) Historic groundwater level over the last 10 years is used in areas with a history of flooding
(4) Standpipes until USGS indicates high conditions (when there is doubt)
(5) "Soil indicators"
(6) Highest water level maintained for one week is considered maximum
(7) Crayfish burrows, concretions, free groundwater (occasionally)
(8) Depth of roots
(9) Monitored during high groundwater season
(10) Soil Morphology
(11) Well Data
(12) Piezometers in sensitive or irrigation influenced areas
(13) "Soil profile"
(14) In salt affected soils, high groundwater observations are made
(15) Observed for standing water
(16) Piezometers used occasionally
(17) Groundwater contour maps
(18) Soil probe for shallow groundwater tables
(19) In general the groundwater is very shallow. It is approximately 2' in most of Southern LA.
(20) Where regulated by the county
(21) Site assessments are conducted by environmental health specialists when there are grounds for suspecting the site conditions. Mottles may be deceptive due to flood irrigation.
(22) Trouble spots: high water table, fractures, clay areas are known. Otherwise easy-desert soils and low population.
(23) In accordance with their underground injection control program, subsurface disposal is only permitted in certain areas where groundwater is not potable (brackish) and traditionally there has been little concern for groundwater measurement in these areas (this is changing)
(24) When mottling is considered a relic of changed conditions.

* Observation holes may be dug or bored

TABLE 5.2.2

FIELD ASSESSMENT PERIOD

	PERIOD LIMITED	PERIOD NOT LIMITED
Alabama		X
Alaska	X(1)	
Arkansas		X
Arizona		X
California		X
Colorado	X	
Connecticut		X(2)
Delaware	X	
Florida		X
Georgia		X
Hawaii		X
Idaho	X(3)	
Illinois		X(4)
Indiana		X
Iowa		X
Kansas		X
Kentucky		X
Louisiana		X
Maine		X
Maryland	X	
Massachusetts	X(5)	
Michigan		X
Minnesota		X
Mississippi		X
Missouri		X
Montana		X
Nebraska		X
Nevada		X
New Hampshire		X(6)
New Jersey		X(7)
New Mexico		X
New York		X
North Carolina		X
North Dakota		X
Ohio		X
Oklahoma		X
Oregon		X
Pennsylvania		X
Rhode Island	X(8)	
South Carolina		X
South Dakota		X
Tennessee		X
Texas		X
Utah		X
Vermont		X
Virginia		X
Washington		X
West Virginia		X
Wisconsin		X
Wyoming		X
Guam		X

(1) On soils with high water table (HGWT) or expected perc rates of less than 60 min./inch tests are conducted in December-April.
(2) Generally not but subject to evaluator's discretion.
(3) Limited to the seasonal high water table period.
(4) Prohibited in soils that have been filled within the last year.
(5) State recommends that it be done during high ground water period.
(6) Generally unrestricted but additional measurements may be made in the spring in cases of major disagreement.
(7) Limited to January-April if direct measurement of HGWT is used to measure maximum ground water elevation (if soil morph. or soil surveys are used the assessment dates are unrestricted.
(8) Generally limited to January-April although there are criteria for dry season calculations.

5.3 Local Regulations

There are 78 towns that require deep hole testing at specific times of the year. Many of these towns require testing between March and June, some only March and April, while the town of Burlington allows deep hole testing only in April. Other towns, such as Uxbridge and Sutton, allow testing between November and May. The Nashoba Associated Boards of Health annually establishes the period when deep hole testing may be performed. The town of Marion also determines the testing time which, in areas of tidal influence, must be conducted one to three hours after an astronomical high tide.

There are 20 towns that limit the length of time that the test results are valid. Most of these towns have set this limit at two years; while the town of Seekonk has a four year limit and the towns of Spencer and Millis impose one year limits.

5.4 Conclusions and Recommendations

There is no single method which ensures an accurate estimate of the maximum ground water elevation at all times. The "wet period" approach limits assessment of the ground water elevation to certain times of the year regardless of the actual ground water conditions. Limiting site suitability assessments to periods when the ground water level is within a certain range also presents problems. Conceivably, during dry years it is possible that the water table will never approach the established maximum ground water level range, thereby prohibiting site assessments during the entire year.

Although every method has its limitations, we propose a multi-parameter approach which will allow a more accurate, year-around assessment of the ground water elevation than is currently possible with the Deep Observation Hole test. First, we propose that the term "Maximum High Ground Water Table" be replaced with the term "Mean Annual High Ground Water". The "Mean Annual High Ground Water should be defined as:

> "the level of the ground water table which is not exceeded eight out of ten years. This level commonly, but not always, is reached during the months of December through April."

This definition permits water table elevation predictions based on statistical evaluation of long-term data, allows estimation of the mean highest ground water level from soil morphology, and by recognizing climatic variability, provides a more realistic approach to ground water level observations.

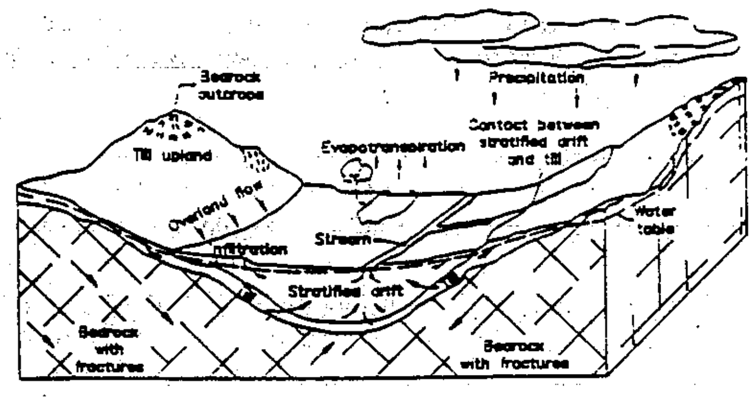
The multi-parameter approach will permit a more reliable means of predicting the ground water level using scientifically sound estimations in conjunction with a comprehensive soil analysis. The first parameter is a modification of the existing procedure of using the months of March to May. Regulatory officials need to know in a timely fashion when ground water levels in the area under their jurisdiction are typical of the mean highest ground water level. It is proposed that information regarding measured elevations in the USGS wells be made available on a more frequent basis during historically wet periods. Funds need to be made available to the USGS to enable the collection of well measurements on a more frequent basis during wet periods and to develop methodology (e.g. toll-free information number or frequent mailings) for distribution of this information, in a timely fashion, to regulatory officials.

Once it has been established that water levels are within 20 percent (or any other desired level) of the maximum values ever recorded for that area, actual deep hole observations can be performed. This approach, in its proposed format, requires expenditures of public funds which may not be possible at this time. It is possible that a state-wide fee for on-site sewage disposal permits could provide the necessary funds, as long as these fees are placed in a dedicated account.

In certain instances, additional restrictions should be imposed on the periods during which ground water elevation determinations are conducted to account for localized conditions. For example, in areas experiencing tidal influences, ground water elevation readings should be taken between one hour before and two hours after an astronomical high tide.

The second approach utilizes the availability of USGS observation well data to allow mathematical correlations to predict ground water elevations (Frimpter, 1981; Frimpter and Fisher, 1983). Based on historical well data, and considering topographic differences and soil type (sand or till), maximum ground water levels at a particular site can be approximated from current measurements. This procedure is especially suited to unconfined aquifers in sandy outwash deposits typical of Cape Cod, and stratified glacial drift common to valleys throughout New England. This method tends to predict higher than actual levels in tills which exhibit wide ranges of water level fluctuations and is not applicable to silty marine and glacio-lacustrine deposits which may contribute to perched ground water conditions (Frimpter, personal communication). For the correlation method to be applied, proper selection of the representative observation well requires that the well and site be in the same type of soil. Accuracy is further enhanced by selection of a representative well which is in the same topographic setting and in geographic proximity to the test site.

FIGURE 5.4.1



Recharge, Discharge and Generalized Groundwater Flow Patterns in a Stratified Drift Aquifer

The third approach to estimating maximum high ground water levels is based on soil morphology. Deep Observation Hole profile features such as soil color, mottling and texture permit an estimation of the mean maximum ground water level. It is proposed to expand the present Deep Observation Hole test to enable assessment of the ground water elevation using the standard soil morphology approach.

As indicated by the survey of state regulations, most states do not use a "wet period" approach but instead rely on soils information for prediction of seasonal high ground water elevations. This procedure works well in areas where soils have developed soil structure due to the presence of clay, such as in tills, terraces, and marine and glacio-fluvial deposits. While this method does not determine the maximum ground water level that will occur at a site, it does provide a reproducible indication of the mean highest ground water level as previously defined.

Use of soils information permits a year round completion of site suitability assessments, resulting in a better work load distribution for regulatory officials and assessment professionals. Use of this technique is essential in repair situations where at present no formal procedure exists for assessing the water table, even though high water levels may have contributed to the initial failure.

The morphology approach provides a low cost, time proven test to estimate mean annual high ground water levels. Soil scientists have used this method in Massachusetts for over 90 years, ever since the first soil survey in this state was conducted. This method requires some expertise of regulatory officials and consultants. However it is fairly easy to learn and, if properly executed, provides reliable year round estimates of ground water levels in most soils, with the exception of coarse sandy soils.

CHAPTER 6

PERCOLATION TEST

The percolation test, often simply called the perc test, is the most widely used method in the country for determining the suitability of a specific soil to accept septic tank effluent. In Massachusetts, the state code prohibits use of soils with percolation rates above 30 minutes per inch. A number of local governments have adopted lower maximum percolation rate limits.

Percolation test results have little relation to final infiltration rates in the leaching facility. In fact, tests conducted in the same soils can vary by 90 percent or more (U.S. EPA, 1978; Bouma, 1971; Healy and Laak, 1973). This variability is due to the differences in test procedures, the natural soil variability, and soil moisture conditions at the time of the test. At best, the test measures whether or not the soil at a site will accept water. Experience gained through the years has led to much lower design loading rates than the leaching rate actually measured with the percolation test. Alternative, more scientific tests require considerable expertise and take much time to perform. Hence the use of percolation test results in the design of on-site sewage disposal systems has continued with appropriate margins of safety.

Increasing concern with environmental and public health issues has focused attention towards the on-site sewage disposal system as a possible source of contaminants and pathogens. The current code allows relatively high application rates (2.5 gallons per day per square foot (10 cm/day)) which may permit pathogen movement through the soil.

Title 5 does not put a time limit on the duration of the validity of percolation and deep observation hole test results. Some municipalities have adopted regulations limiting the duration to two or sometimes one year, or provide that such test results become invalid upon a change in ownership of the building site.

This section of the report will review the scientific basis of the percolation test and discuss the test's limitations. An evaluation of procedures in other states and those imposed by boards of health will be provided, and possible modifications to the existing procedure will be discussed.

6.1 Literature Review

The effectiveness of the percolation test as a site suitability design standard has been studied extensively (Clark, 1981, 507; Canter and Knox, 1985). The test originally was designed by Henry Ryon in 1926 in order to estimate the permeability of the soil near failed leachfield systems (Winneberger, 1974).

The original percolation test, and even the refinements of the method made by the Public Health Service in 1949, raised many questions about which soil characteristics are measured by the test. Percolation test procedures, in general, are not standardized and often are inconsistent between and within states. Despite the recognized shortcomings, many of the original methods were incorporated into the "standard" percolation test procedures published by the Public Health Service in 1957, and by the EPA in 1980 (Kaplan, 1987).

The basic method of conducting the percolation test is to dig or auger a hole in the soil 6 to 12 inches in diameter to the depth of the proposed soil absorption system. Water is poured into the hole to a depth greater than 12 inches and allowed to drain. This procedure is repeated until the rate at which the water level drops is more or less constant. The hole is then refilled to a depth greater than 12 inches and the amount of time it takes for the water level to drop one inch is determined (Healy and Laak, 1973). The percolation rate, reported in minutes per inch, is used as a determination of the suitability of the soil for absorbing septic tank effluent and for determining the size of the leaching structure.

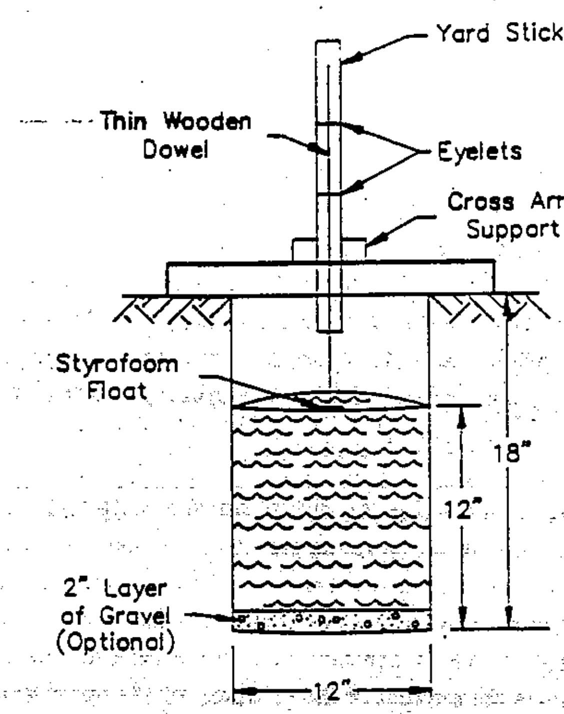
The permeability or hydraulic conductivity of the soil is the rate at which a known volume of water will move through a volume of soil under a measured hydraulic gradient. Permeability and hydraulic conductivity are often used interchangeably. Assuming that the fluidity of the liquid is constant, the intrinsic permeability of a soil is synonymous with the hydraulic conductivity. The hydraulic conductivity is a characteristic of the soil which is constant at a given moisture content. The percolation test, on the other hand, measures the amount of time it takes for the water level in a hole to drop one inch. It is often referred to and used as if it were a measure of the ability of the soil to conduct water or effluent. Numerous factors which can influence the amount of time it may take for the level of water to drop one inch in the hole are not accounted for in the standard percolation tests or in the amendments made since its conception.

There are practical and theoretical questions raised when evaluating the ability of the percolation test to measure the soil's hydraulic characteristics. Not only are there differences in operator variability (Winneberger, 1974), but saturated-unsaturated flow theory indicates that the rate at which the level of water will fall one inch in a cylindrical test hole, depends on many factors besides the permeability of the soil (Healy and Laak, 1973, Bouma, 1971, Barbarick et al., 1976, Elrick and Reynolds, 1986). The most significant of these are:

1. The Diameter of the Test Hole;
2. Level of Water in the Hole; and
3. The Soil Moisture Content.

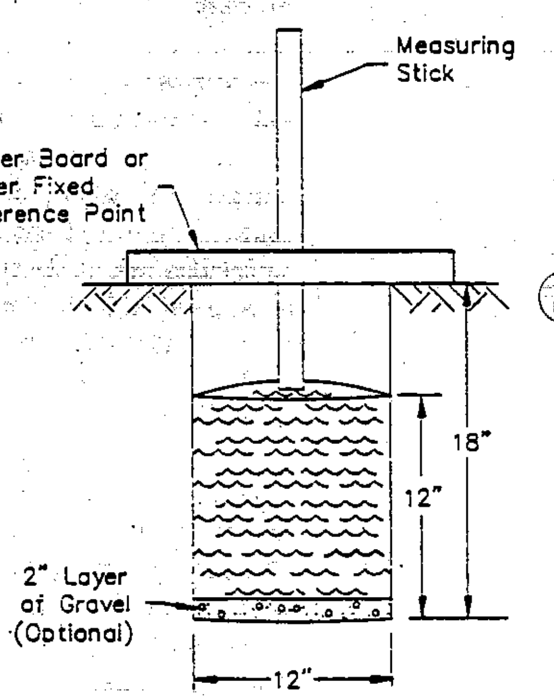
FIGURE 6.1.1
STANDARD PERCOLATION TEST HOLE

(a) Floating Indicator



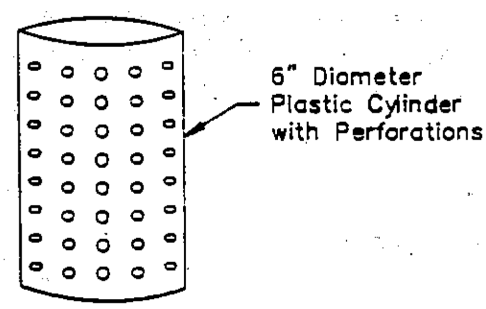
(a) Precise measurement of suface head with the help of a float.

(b) Fixed Indicator



(b) Less precise measurement of surface head with a stick (or steel tape).

(c) Insert



(c) Plastic cylinder sometimes used in place of gravel layer.

Diameter of the Test Hole

The diameter of the test hole must be standardized. Water will "disappear" much more quickly in a smaller diameter hole due to a large surface area to volume ratio (Winneberger, 1974; Kaplan, 1987). Healy and Laak (1973) ran comparative percolation tests using different diameter holes and determined that the percolation rate is equal to the flow rate divided by the circular area of the hole, and that a 6 inch diameter hole will demonstrate a percolation rate approximately 6 times that of a 15 inch diameter hole.

Barbarick, Warrick, and Post (1976) used a randomized site layout with four replications of 10, 20, 25, and 30 cm (4, 8, 10, and 12 inches) diameter test holes to determine the relationship between percolation rates and test hole diameter. A significant linear relationship between percolation rate and hole diameter was found and approximated by the equation:

$$Y = 5.55 - 0.12\,X$$

where X is the test hole diameter in centimeters and Y is the percolation rate. Using the average infiltration rate, i, over the soil water interface, the relationship was also expressed mathematically as:

$$i = 1\,dV/Adt = r\,dh/(r + 1)\,dt$$

where A is the area of the side walls, dt is the increment of time, dV is the change in water volume, dh is the change in hydraulic head, and r is the radius of the test hole. Assuming that the infiltration rate is independent of test hole diameter, the relationship between two test holes of different diameters in the same soil was given as:

$$PR1 = [(1+2h1/r1)/(1+2h2/r2)]PR2$$

where the percolation rates in the two holes are represented by PR1 = dh1/dt1 and PR2=dh2/dt2. The mathematically determined percolation rates for changes in test hole diameter were comparable to the experimental values. The same relationship between test hole diameter and percolation rate as expressed by Healy and Laak (1973) and Warrick et al. (1976), was obtained using the following steady-state flow equation of Elrick and Reynolds:

$$t = a^2\,CdH/(2\,Kfs\,H^2 + a^2\,Kfs\,C + H\,\phi M)$$

where a is the radius of the hole, C is a dimensionless parameter, H is the hydraulic head, Kfs is the field saturated hydraulic conductivity, and ϕM is the matrix flux potential.

Level of Water in Test Hole

Another source of inconsistency in the percolation test is the height of the water in the test hole (Winneberger, 1974; Peterson, 1980; Elrick and Reynolds, 1986). "Water is absorbed fastest when the hole is filled highest. Later, if water is allowed to recede toward the bottom of the hole, it is absorbed more slowly. Water fall decelerates as the hydraulic head lessens" (Winneberger, 1974).

Elrick and Reynolds (1986) found that the percolation rate in a saturated soil is 2.7 times higher with an initial head of 30 cm (12 inches) than it is with an initial head of 15 cm (6 inches). This is comparable with the work of Healy and Laak (1973) who predicted an increase of 2.5 inches in the initial hydraulic head would increase the percolation rate by a factor of 2.4. It should also be noted that the water level is allowed to fluctuate throughout the test, which could also result in variable percolation times due to alterations in the head (Kaplan, 1987; Peterson, 1980). Bouma (1971) found that a constant head percolation test, performed by maintaining a constant level in the test hole and measuring the volume of water added over a given period of time, was more accurate, and exhibited less variability, than the falling head method.

Presoaking the Hole

Presoaking of the hole is another procedure which, if not standardized, can lead to discrepancies in test results. Presoaking the test hole was first introduced by Weibel et al. (1954) in order to minimize the effect of swelling clays on the percolation rate. It was suggested that the hole be kept filled with water for at least four hours and preferably overnight before the percolation test is conducted, but that the procedure was not essential and need not be followed in soils containing little or no clay. Since this procedure is only occasionally followed, the capillary forces in the soil will vary as will the results of the tests (Kaplan, 1987).

An unsaturated, or partially saturated soil will exhibit a faster percolation rate than a saturated soil. In dry soils, with the exception of sands and gravels, the percolation rate also is affected by the matrix potential[1], in addition to the gravitational potential. The percolation test will yield a wide range of results as the matrix potential decreases and the soil approaches saturation (Healy and Laak, 1973). This may not be a problem if the test is repeated until the percolation rate has stabilized.

Barbarick et al. (1976) presoaked each test hole until steady infiltration was obtained (24 hours for moderately coarse textured soils and 48 hours for finer textured soils) and reported that the recommended periods of 6 to 20 hours would not have appreciably changed the rates. It was also noted that finer textured soils required a longer soaking period than coarser textured soils in order to obtain steady state conditions.

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1 Water molecules at the water table are subject to an upward attraction due to surface tension of the air-water interface and the molecular attraction of the liquid and solid phase. This is known as the matrix potential or capillarity.

It has been found in numerous studies (Hill, 1966; Chan, 1976; and Elrick and Reynolds, 1986) that even though steady flow out of a test hole can be attained rather quickly, field saturation adjacent to the hole is not achieved for a much longer period of time. Elrick and Reynolds (1986) found that upon achieving steady state the capillarity of the soil, as governed by texture, structure and soil tension, retains the same effect on the flow rate regardless of the duration of the test or soaking period. The steady state flow rate, Qs, from an uncased cylindrical hole was determined experimentally and theoretically and is represented by the following equation (Reynolds and Elrick, 1985; Reynolds et al. 1985; Elrick and Reynolds, 1986):

$$Qs = [2\pi Hs^2/C]\ Kfs + \pi a^2 Kfs + [2\pi Hs/C]\ \phi m$$

where Hs is the steady depth of water in the hole, Kfs is the field saturated hydraulic conductivity, a is the radius of the test hole, ϕm is the matrix flux potential of the soil, and C is a dimensionless parameter. This supports the theoretical analysis of Healy and Laak (1973) who found that long term soaking would not eliminate the effect of capillarity.

Percolation Test Compared with Soil Permeability

Studies have been conducted to evaluate the relationship between the permeability of the soil and the percolation test (Bouma, 1971; Healy and Laak, 1973; Winneberger, 1974; Fritton et al., 1986; Elrick and Reynolds, 1986; Barbaric et al., 1976; Kaplan, 1987; Bicki et al., 1988; and others). Many of the studies have failed to demonstrated a clear relationship between the measured hydraulic conductivity of a soil and the flow rate determined by the percolation test (Derr et al., 1969; Healy and Laak, 1973; Barbaric et al., 1976; Conta et al., 1985; Fritton et al., 1986).

Flow rates determined by the percolation test are greatly influenced by the capillarity or matrix potential of the soil, which in turn is a function of the water content of the soil, position of the water table, and weather conditions (Healy and Laak, 1973; Elrick and Reynolds, 1986). Bouma (1971) compared percolation rates with measurements of the saturated and unsaturated hydraulic conductivity. Percolation rates were found to be much higher than the hydraulic conductivity values measured in the soil horizons. The percolation rates are determined by flow with undefined boundary conditions, while the saturated conductivity values are well defined physical constants of the soil when the hydraulic gradient is one.

Healy and Laak (1973), used mathematical analysis in comparing the percolation test to permeability studies, as well as assuming ideal isotropic conditions in conducting laboratory and field tests. The calculations of flow rate from a cylindrical hole based on both capillarity and gravity were approximated by the following equation:

$$Q = C1\ b\ K\ Hcap + C2b^2K$$

where b is the diameter of the hole, and C1 and C2 constants depending on the shape of the hole. Using the approximate relationship between capillary head and permeability given by Taylor:

$$Hcap = 0.07/K^{1/2}$$

where K is permeability and Hcap is the maximum capillary potential, it was found that the flow rate given by the percolation test is governed primarily by the capillary potential of the soil. The relationship between permeability and percolation rates was defined as:

$$\text{percolation rate} = 25\ k + 8.9\ Hcap/b$$

where b is the size of the hole and k is the permeability. Field test results showed percolation rates much less than those predicted by the model. It was hypothesized that this is due to the large variations in capillary potential in the soils.

Statistical techniques have been used to correlate percolation results with laboratory measurements of the permeability of soil cores (Winneberger, 1974). Using an approximation of the permeability determined in the lab, it was found that the correlation coefficient varied from -0.359 to 0.746 (all statistically significant) with a mean regression line of:

$$\log k = -4.86 + 1.69 \log p$$

The permeability tests also showed a large variation in results, which the investigators attributed to operator variability.

6.1.2 Dewatered Percolation Tests

Title 5 specifies that subsurface sewage disposal systems must be located in areas where there is at least four feet of naturally occurring pervious soil below the entire area of the leaching structure. This four feet of naturally occurring soil is necessary to ensure that sufficient undisturbed soils are present to accept the effluent and allow a zone of passage for the flow to exit the site.

Separately, the regulations require a minimum of four feet of pervious soil between the bottom of the leaching structure and the maximum groundwater elevation. This four foot zone is required to provide the desired treatment of the septic tank effluent. This zone may be comprised of either naturally emplaced soils or fill materials brought in from another location. When fill materials are used to provide the specified separation distance above high ground water, at least four feet of naturally occurring, pervious soil must be present below the fill in order to demonstrate the appropriate zone of passage.

While percolation tests may be performed at any time of the year, it is not possible to perform the percolation test when the soils are saturated with ground water. In some instances, the percolation test may be postponed until the groundwater elevation recedes sufficiently to allow the test to be conducted. In cases where high groundwater persists throughout the year, it may be necessary to artificially lower the groundwater table to allow the required testing of the soils. This is commonly referred to as a dewatered percolation test.

The purpose of the dewatered percolation test is simply to demonstrate that there is a sufficient zone of passage for the septic tank effluent to allow the system to be constructed in fill. A number of concerns arise regarding the validity of results obtained when dewatered percolation test are used. Some individuals feel that lowering the groundwater table creates a vacuum, causing the water in the percolation hole to be suctioned toward the dewatering pump or drain. In actuality, as long as the ground water level is below the bottom of the percolation test hole, gravitational forces will control the flow of water out of the test hole.

The dewatered percolation test provides some of most accurate information about the soils percolation rate. Some soils contain expanding clays of the smectite family (montmorillonite, bentonite, kaolinite). Such clay particles immobilize layer upon layer of water molecules around them, and push away from each other. This results in a swelling which restricts water flow through the soil pores, lowering the overall permeability. Presoaking the percolation test hole was design to saturate the soils allowing the soils to swell prior to testing. Generally only the soils immediately surrounding the test hole are adequately wetted during the short presoak period specified in the percolation test procedures and may lead to extremely variable results. In a dewatered percolation test the soils are completely wetted prior to the test so that optimal conditions exist.

The standard methodology for the dewatered percolation test is as follows:

1. A trench is excavated with a backhoe, several feet below the water table, on either side of the test area forming a "V".

2. The area inside the "V" is then sloped towards the vertex of the "V" to the elevation of the soil to be tested. In some instances this procedure is all that is necessary to dewater the test area.

3. A percolation hole can then be excavated on the slope inside the "V" and the test performed.

4. In other cases, when the platform inside the "V" does not dewater during steps 1 and 2, it may be necessary to bail or pump the water out of the trench.

6.2 State Regulations

A survey of state regulations indicates a shift from uniform application of design standards to a site specific evaluation. Thirty-six states (and the territories of Guam and Puerto Rico) base leaching facility design almost exclusively on the percolation rate, whereas 14 states use soils-based evaluation methods.

Maximum acceptable percolation rates vary from 30 minutes per inch in Massachusetts and Maryland to 120 minutes per inch in Delaware, New York, Vermont, Washington, and Wisconsin. Most states, including New Hampshire and Connecticut, have 60 minutes per inch as the upper limit of the percolation rate. Some states also have a minimum percolation rate requirement. Minnesota requires at least 0.1 minutes per inch, some states have a 1 minute per inch minimum, whereas some even have a minimum of 10 minutes per inch.

Although most states have standardized the percolation test to some degree, there appears to be considerable variation in test procedures from one state to the next.

6.3 Local Regulations

Of the towns that have filed more stringent regulations with the Department of Environmental Protection, the majority of these additional or supplemental requirements have been related to the percolation test or setback requirements. The additional percolation test requirements can be divided into several categories: (1) when percolation testing is allowed; (2) more stringent limits on percolation rates; (3) the number of percolation tests required per lot; (4) the time limit for percolation test validity; and, (5) special percolation testing requirements including de-watered percolation tests and presoak requirements.

There are 69 towns that have set certain times of the year during which percolation testing can be performed. Several towns including Sutton and Northbridge allow percolation testing year round; others like Harwich decide on the testing period annually. The majority of towns allow percolation testing sometime between December and June. The town of Dracut allows percolation testing between June and February only so that it does not interfere with the deep hole testing period.

Approximately 61 towns have decreased the maximum percolation rate from 30 minutes per inch to a lower maximum rate. Forty-five of these towns have decreased the maximum percolation rate to 20 minutes/inch, nine towns have decreased the maximum rate to 15 minutes/inch. Other towns have required a minimum percolation rate. An example of this is the town of Gloucester which requires a minimum percolation rate of at least two minutes per inch or the addition of fill to increase the rate to two minutes per inch.

Seventy towns have set a minimum number of percolation tests per lot ranging from two (one in the primary and one in the reserve) to four (two in the primary and two in the reserve). The town of Shirley requires a minimum of two tests for a single family home and three or more for multiple family dwellings.

Forty-one towns have set a length of time that the percolation test results are valid. This time period usually ranges from one to five years, with an average of two years. The town of Marshfield has determined percolation tests are valid indefinitely.

Thirty towns have special requirements for conducting percolation tests. Grafton does not allow percolation testing in holes that have been left open overnight. Bedford and Billerica require overnight presoaks. Several towns, including Fairhaven and Millis, do not allow dewatered percolation tests. The town of Carver does not allow dewatered percolation testing or any presoaking.

6.4 Conclusions and Recommendations

Given the long history of use of the percolation test procedure in Massachusetts, it is recommended that the percolation test be retained as it represents the most practical method for evaluating a site's ability to accept septic tank effluent. However, based on our review of scientific and engineering literature, we conclude that in order to provide the best safeguard for the environment and the public health, the test procedures must be consistently applied and the results must be supplemented with additional information on soil morphology.

At the present time, only minor modifications of the existing percolation test are recommended. To reflect current practice, the current section 15.03(5)(a) should be amended to read:

> (a) Prepare a test hole located within the proposed leaching strata, including any strata which upon visual inspection appears most limiting. The test hole shall have a minimum diameter of 12 inches with vertical sides 18 inches deep.

Based on review of the literature and practices in other states, there is no compelling reason to limit design percolation rates to 30 minutes per inch and less. Slower percolation rates reflect soils higher in fines (clay) which may have potential problems with construction, particularly during adverse weather conditions. But if the system is properly designed and constructed, these soils can provide consistently higher degrees of treatment than soils with faster percolation rates, providing a higher degree of protection to public health and the environment. In view of this, it is recommended that the maximum allowable percolation rate be increased to 60 minutes per inch.

Research indicates that coarse sands provide adequate treatment of pathogens provided that actual flow rates through the soil are low (<1.0 cm/day (0.25 gpd/sf)) and/or sufficient depth to the limiting layer (impermeable material, high ground water table) is present. The clogging layer essential for wastewater treatment, may not form adequately in gravels and very coarse sands. In these materials the lack of phosphorus fixation may also pose a potential environmental threat. Since the literature appears to be inconclusive regarding the appropriate safeguards to be employed in these instances, we suggest that further evaluation be directed towards the need for more stringent requirements, such as increased separation distances and/or minimum acceptable percolation rates, for areas comprised of coarse grained sands and gravels.

No studies on the duration of validity of percolation test results or deep observation hole test results have been reported. We do not know of any scientific or engineering reason to limit the results of these tests to any particular time period since they are based on basic physical and morphological soil properties which change little with time. Therefore, we do not believe that restrictions on the duration of the validity of the percolation test results are necessary. However, additional testings should be required if the site and soil conditions have been altered or the system is sited in an area different from the location originally tested.

Percolation tests can be conducted anytime during the year provided the test is not performed in frozen soil. Testing during the winter months must be conducted with care to assure that the soil which is being tested is below the frost layer. Caution should also be exercised during drought conditions when additional presoaking may be necessary to adequately swell the clay and silt particles.

The percolation test is presently used as the standard method for assessing the suitability of a soil for an on-site sewage disposal system. However, due to variations within the method itself, as well as a multitude of other factors, it can produce highly variable results. The percolation test is not solely a measure of the permeability of the soil. Operators and evaluators of the results should be cognizant of the factors which influence the test results and interpret them accordingly.

If the percolation test is to be a viable method for assessing the suitability of a soil for on-site sewage disposal, the procedure must be standardized and conservative limits set in order to evaluate the results. Operators should understand how variables such as the diameter of the hole, height of the water, and presoaking of the test hole can alter the test results.

CHAPTER 7

TRAINING AND CERTIFICATION OF SITE EVALUATORS

The purpose of having an environmental code that provides for protection of public health and the environment is defeated when the people assigned the job of applying the principles of site selection and design are not properly trained in the basic theories and lack the knowledge necessary to properly site, design, and construct on-site septic tank/soil absorption systems. An improperly designed or constructed system does not provide the degree of public health and environmental protection intended by Title 5. This report makes recommendations on improvements to the Code in order to increase the treatment performance and reliability of septic tank/soil absorption systems. Hand-in-hand with these changes should be the requirement that those responsible for the application of these regulations have some type of training or certification stating that they are familiar with the concepts of wastewater treatment and subsurface disposal.

Some of the principles of wastewater treatment and disposal are independent of the magnitude of the design flow, whereas other aspects are more applicable to either small, medium or large systems. For example, medium and large systems require more detailed analysis of the hydraulic impacts, such as ground water mounding, that effluent applications have on the ground water resource. Small systems, serving residential or small commercial buildings, generally do not require such a detailed analysis. Hence, the professional requirements, as well as the level of training for designers of these systems, may be different. Regardless of the level of expertise of the personnel presently permitted to design septic tank/soil absorption systems, additional training, particularly pertaining to improved siting techniques, should be required for everybody involved in the design process.

A number of state regulations contain training requirements for septic system designers, installers and even septage haulers. For example, during the last 15 years Minnesota has required that new designers and installers take a multi-day course in various aspects of septic system design. This course includes a field and classroom exam. Attendance at annual one-day refresher sessions is required as well. This mechanism not only provides solid training in the basics of septic system design and siting but also ensures that those working in this field are keeping abreast of the latest regulatory changes and the most recent design standards and techniques.

The following sections outline the need, and describe the proposed methods, for ensuring that all regulatory officials (state and local) and designers are aware of the various aspects and interpretations of the regulatory code, the technical requirements of both site evaluation and design, and the requirements for the proper operation and maintenance of septic tank/soil absorption systems.

7.1 Literature Review

The design of small systems is currently performed by both registered sanitarians and registered professional engineers, whereas larger systems require the stamp of a registered professional engineer. Many of these professionals have had no formal training in site evaluation and septic tank/soil absorption system design. Most, if not all of their training, is obtained on the job supplemented with voluntary attendance of seminars, workshops, and training sessions.

While most of these designers are dedicated to doing the best job possible, many are just not familiar with the basic principles of septic system design and do not have the proper background to properly evaluate certain design criteria. Additionally a mechanism for regularly apprising these individuals of regulatory revisions and the latest technical advances is lacking. With the exception of occasional conferences and workshops, and the Department of Environmental Protection's 2-day Title 5 training program, there is no formal opportunity for most designers, or maintenance personnel, to become familiar with the most up-to-date information.

It would also be beneficial to require that all state and local officials responsible for the approval and inspection of these systems be certified as well. State and local officials have the responsibility of enforcing the provisions of Title 5. It seams reasonable that they should possess a working knowledge of these regulations and an understanding of septic tank/soil absorption system design. This would ensure that substandard designs will be recognized prior to construction.

The existing Title 5 training program implemented by the Department has successfully taught the principles of septic system design and operation to a number of state and local officials, designers, and installers. The course objectives of these training sessions should be the same for a continuing education program. These are:

- To present information for the understanding, application and enforcement of Title 5 - The State Environmental Code - Minimum Requirements For The Subsurface Disposal of Sanitary Sewage.
- To provide technical information on plan review, system siting, soils, ground water, bedrock, percolation tests, deep hole evaluations, system components and materials for the construction and maintenance of subsurface sewage disposal systems.
- To minimize inconsistencies in the interpretation of Title 5.
- To demonstrate to trainees, the application of Title 5 requirements and technical information, through case studies and problem solving activities.

At the end of the training session, each trainee should be familiar with, and capable of at least the following:

- Interpreting and enforcing the provisions of Title 5;
- Conducting a percolation test and interpreting the results;
- Evaluating soil, water and bed rock elevations in a deep observation hole;
- Reviewing and understanding a site plan;
- Evaluating a site and reserve area for a subsurface sewage disposal system including topographical features of the building lot and the potential effects of the proposed sewage disposal system on drainage, water supplies and wetlands;
- Determining the appropriate components for a subsurface sewage disposal system;
- Computing the size of all components of a subsurface sewage disposal system; and,
- Understanding the responsibilities involved in designing, installing, and maintaining a subsurface sewage disposal system.

It is clear from other sections in this report that a much higher level of expertise will be required once the recommended changes are implemented. The present format of training, or perhaps the lack thereof, does not allow for proper dissemination of this information.

7.2 State Regulations

The states that have progressive regulations reflecting a greater awareness of the complexity of septic system design and operation also have training and/or certification requirements. Designer certification is mandated by a number of states. Other states, as illustrated in Table 7.2.1, conduct workshops on a regular basis, but do not require any certification other than professional registration.

In New England; Maine, New Hampshire, and Vermont have formal certification programs for septic system designers and field personnel assessing site suitability (site evaluators). These programs involve multi-day training sessions concluded by field and class examinations. New Hampshire allows special courses to be taken in lieu of the formal training session, but the candidate is still required to pass an examination and possess minimum qualifications. These special courses are offered by various agencies, including the state's land grant institutions. In Connecticut, training for small septic system designers is provided by the Department of Engineering Services. In this state the designers are tested chiefly on their knowledge of the state code.

A number of states offer training in cooperation with sister agencies, federal agencies like the Soil Conservation Service, professional organizations, or state educational institutions. Minnesota has the longest continuously running program, offered by the Minnesota Pollution Control Agency in cooperation with the University of Minnesota Extension Service.

TABLE 7.2.1

REQUIRED QUALIFICATIONS OF FIELD EVALUATORS

	ENGINEER	SOIL SCIENTIST	SANITARIAN/ SITE EVALUATOR	SOIL TRAINING	STATE CERTIFICATION
Alabama	Y	Y	N	Y(1)(2)	N
Alaska	Y	N	N	Y(7)	N
Arkansa	Y	N	N	N	Y(1)
Arizona	Y	N	Y	Y(3)	Y(3)
California	Y	N	N	N	N
Colorado	N	N	N	N	N
Connecticut	Y	Y	Y	*	*
Delaware	N	Y	N	Y(2)*	N
Florida	Y	N	Y	Y(2)(3)*	Y(3)(2)*
Georgia	N	N	N	Y(1)	N
Hawaii	Y	Y	Y	N	Y(1)
Idaho	Y	N	Y	Y(1)	N
Illinois	N	N	N	N	N
Indiana	N	N	N	Y(1)	N
Iowa	N	N	N	Y(4)	N
Kansas	Y	N	N	N	Y(3)
Kentucky	N	N	Y	Y(1)*	Y(5)*
Louisiana	Y	N	Y	Y(1)	Y(1)
Maine	Y	N	Y	N	Y(2)*
Maryland	N	N	N	Y(10)	N
Massachusetts	Y	N	Y	N	Y(1)(2)
Michigan	N	N	Y	Y(9)	N
Minnesota	N	N	N	Y(6)	Y(6)
Mississippi	Y	N	N	Y(3)	N
Missouri	N	N	N	Y(10)	N
Montana	Y	N	Y	Y(2)(1)	N
Nebraska	N	N	N	N	N
Nevada	Y	N	N	Y(12)*	Y(1)
New Hampshire	N	N	Y	Y(2)(1)	Y(2)(1)
New Jersey	Y	N	N	N	N
New Mexico	N	N	N	Y(1)	N
New York	Y	Y	N	N	N
North Carolina	N	Y	Y	Y(1)	Y(1)
North Dakota	N	N	Y	Y(14)	Y(14)
Ohio	N	Y	Y	Y(1)(2)	N
Oklahoma	Y	N	Y	Y(10	N
Oregon	N	N	N	Y*	N
Pennsylvania	N	N	Y	Y*	Y*
Rhode Island	Y	Y	Y	Y(7)	Y(7)
South Carolina	N	N	Y	Y(12)*	Y*
South Dakota	Y	N	N	N	N
Tennessee	N	Y	N	Y(1)	N
Texas	N	N	Y	N	N
Utah	Y	N	N	Y(1)	N
Vermont	Y	N	Y	N	Y*
Virginia	N	Y	N	Y(1)	N
Washington	N	N	Y	Y(10)	Y(3)
West Virginia	N	N	Y	Y(1)(2)	Y(1)(2)
Wisconsin	N	N	Y	N	Y(2)*
Wyoming	N	N	N	Y(8)	N
Guam	Y	N	N	N	N

* Specialized training or certification testing about soils and on site evaluation for state or local agency "site evaluators."

(1) Generalized environmental health training or certification testing for state locate agency "sanitarians" or "environmental health officers."

(2) Private evaluators included.

(3) Presently being developed.

(4) Occasional short courses for Health Department Sanitarians.

(5) Provisional certification for first 6 months, then full.

(6) Pollution Control Agency in conjunction with U of MN Extension Services offer training and certification.
(7) For installers only (private groups offer workshops for designers regulators).
(8) Informal optional training program.
(9) Some programs offered in coordination with other agencies - voluntary.
(10) Occasional courses offered.
(11) Private certified soil testers are licensed.
(12) Informal field training.
(13) Voluntary certification program offered.
(14) State has conducted voluntary training program.
(15) Each county has its own form.

Y = Yes
N = No

7.3 Local Regulations

None of the towns that have filed local regulations with the Department of Environmental Protection have specific requirements pertaining to training or increased qualifications. Some towns, like Norton, have in the past attempted to require that persons conducting percolation tests and designing sewage disposal systems obtain a separate license from the Board of Health. These towns have been notified by the Department that the requirement of additional testing of Registered Engineers and Sanitarians is inconsistent with State statutes.

7.4 Conclusions and Recommendations

The Department should seriously consider developing and instituting a formal training program to provide instruction on proper site evaluation techniques, septic tank/soil absorption design and regulatory requirements.

The training program should include, at a minimum, the following topics:

- principles of on-site sewage treatment and disposal; including basic system components, function of these components, and the potential impact of these on public health and the environment.
- site suitability assessment; including actual field work, percolation test, proper monitoring well installation, and the preparation of soil profile descriptions.
- engineering design principles including septic tank design, specifications, and installation; effluent distribution systems, and soil absorption systems.
- regulatory aspects of septic system design; training in all sections of the revised Title 5, variances, and administrative responsibilities.
- alternative designs; including fill systems, mound systems, serial systems using drop boxes, and pressure distribution.

Course instructors should be individuals well acquainted with septic system design, operation and maintenance. Courses should be provided by a multi-disciplinary team of engineers, hydrologists, pubic health experts, regulators, and soil scientists.

The courses could easily be established, at no cost to the Department, by using existing Continuing Education programs at the various educational institutions. These programs could be operated on a competitive basis at the various colleges and universities. All course offerings, however, should be subject to approval by the Department.

Course participants should be given continuing education credits. Although these specific courses should not be mandatory for licensed professionals, all septic system designers should be required to demonstrate that they have obtained a minimum of six hours of continuing education in on-site sewage disposal each year.

Regulatory Officials and Septic System Inspectors who do not possess professional registration (either as a Registered Sanitarian for systems less than 2,000 gallons per day or as a Registered Professional Engineer for all size systems) should be encouraged to take the course as well. These individuals should be required to pass a certification examination administered by the Department. Upon passing the examination, which should include a class and a field component, the Department should issue a certificate of completion. This certificate should state that the candidate has demonstrated basic skills in site evaluation requirements and septic system reviews and fully understands the basic operation and maintenance requirements. Issuance of this document should not be construed as certification of the competency of a particular individual, just that the person has attained certain basic skills to perform the required reviews.

Only individuals with the prerequisite professional registrations and the appropriate continuing education credits should be allowed to design septic systems. Septic tank/soil absorption systems with design flows exceeding 2,000 gallons per day should be designed by a Registered Professional Civil/Sanitary Engineer.

Given the current fiscal situation in Massachusetts, it is not likely that additional funds or personnel will be available for training and certification. We therefore suggest that the Department seek the assistance of state's higher education institutions, the state Board of Registration of Professional Engineers and the State Board of Registration of Sanitarians in the implementation of this program.

PART III

LOCATIONAL STANDARDS

CHAPTER 8

UNSATURATED TREATMENT ZONE

The vertical distance between the gravel bottom of the leaching structure, and the maximum groundwater elevation or impermeable bedrock layer, is one of the most important variables in preventing the transmission of disease. The vertical separation distance along with the effluent loading rate and soil properties determines the soil moisture content, soil tensional forces and the detention time available for contaminant removal. Constituents removed or altered by soil absorption systems include: organic compounds, biological contaminants such as bacteria and viruses, and inorganic contaminants such as phosphorus, nitrogen and metals.

Currently, Title 5 of the State Environmental Code prohibits the siting of leaching structures in areas where the maximum ground water elevation is less than four feet below the bottom of the leaching structure. This chapter will explore groundwater and impermeable layer depths as they relate to hydraulic conditions and contaminant removal efficiencies.

8.1 Literature Review

Transport of certain pollutants have been found to be effectively limited by unsaturated effluent transport through a soil profile of sufficient depth with adequate amounts of clay, silts, fine sands, and organic matter (Gerba, 1977). It is unsaturated flow conditions that allow the soil absorption system to provide treatment of the septic tank effluent. Under unsaturated, aerobic, soil conditions, the effluent travels through the soils in a tortuous path, increasing the detention time and providing increased interaction between contaminants and the soil.

The saturated hydraulic conductivity approximated by the percolation test, does not predict system performance under the unsaturated soil conditions present in properly operating soil absorption systems. Unsaturated flow proceeds at a much slower rate than does saturated flow due to the increased effects of soil matrix tension (Peavy and Groves, 1977).

Soil grain size distribution and soil moisture content are two factors influencing unsaturated flow rate. The large pores of sandy soils drain abruptly at relatively low tensions; whereas the very fine pores in clayey soils release a small volume of water over a wide range of tensions. Soils do not have one unsaturated hydraulic conductivity but rather a range of values dependent upon the soil moisture content (Jarret, 1982).

Unsaturated flow has been described as progressing in three stages, or ranges, depending upon the water content of the soil. The first stage, occurring at very low water contents, is typified by the formation of discontinuous pendular water rings around the soil grain contact points. Water flow is discontinuous and air-water and soil-water interactions readily proceed along a very thin, almost molecular, film present on the solid surfaces (Bear, 1979). As the moisture tension declines, the water content progresses towards an equilibrium with the interstitial air. At this point, a continuous water phase is formed permitting flow, albeit at a very low rate.

Above the equilibrium point, water flow is described by the final two stages, funicular and insular. During funicular conditions, both the air and water phases are continuous. As the water flow progresses to the insular stage, the gaseous phase is no longer continuous resulting in trapped bubbles and the restricted flow of air. When all of the entrapped air is driven out of the soil pores, the water flow proceeds under saturated conditions (Bear, 1979).

Capillary Rise

Soil moisture tension retards the downward flow of water through soil pores and results in a suction force which causes the water above the phreatic surface of a water table aquifer to be pulled up into the so-called capillary fringe (Bear, 1979). The lower portion of the capillary fringe, located just above the aquifer, may approach saturated conditions thus diminishing the efficiency of the soils for treating contaminants contained in the septic tank effluent (Ver Hey and Woessner, 1988) Coarse sandy soils which are mainly comprised of large pores have a limited capillary rise, whereas clayey soils display a considerable capillary fringe.

The extent of the capillary rise is dependent upon the soil grain size distribution with numerical estimates based upon the effective particle diameter and porosity. Estimations by Silin Bekchurin (1958) suggest a total capillary rise of 2 - 5 cm (0.06 - 0.16 feet) in coarse sand, 12 - 35 cm (0.4 - 1.15 feet) in sand, 35 - 70 cm (1.15 - 2.3 feet) in fine sand, 70 - 150 cm (2.3 - 4.9 feet) in silt, and 2 - 4 meters (6.6 - 13.1 feet) and more in clay (Bear, 1979).

Most of the studies involving contaminant removal efficiencies of soil absorption systems have been conducted in laboratory soil columns. The majority of these tests negate the effects of capillary rise by allowing free drainage from the bottom of the soil column, i.e. no water reservoir at the base of the column. Therefore, when studies conclude that a certain depth of unsaturated soil is needed to effect a desired treatment, that reported depth correlates to the unsaturated region, or vadose zone, located between the bottom of the biomat clogged layer of a soil absorption system and the phreatic surface of the aquifer. In certain instances, the capillary rise may significantly infringe upon the vadose zone. Under these conditions, the impact of the capillary rise must be considered to ensure an adequate separation between the bottom of the leaching structure and the maximum ground water elevation.

Pathogens

Although enteric bacteria are unable to reproduce in the soil environment, they have been found to remain viable for extended times, especially under saturated soil conditions (U.S. EPA, 1978). The survival time in the unsaturated soil environment is considered a function of many variables including the physical characteristics of the particular bacteria (size, shape, surface properties, lifespan), environmental factors (rainfall, soil moisture, temperature, pH, organic content of the soil), and the concentration and makeup of the endogenous bacterial population (Gerba, 1977). Bacterial removal or decay, is accomplished by microbial activity resulting in biotransformation or inactivation. The first-order irreversible decay rate plays an important role in bacterial population density at the long detention periods associated with unsaturated flow (Corapcioglu and Haridas). The decay rate, along with growth rates and mass transfer and transport phenomena, determine the concentration of bacteria exiting in the unsaturated soil absorption zone and entering the underlying groundwater.

Bacterial populations allowed to escape into the saturated flow regime, have been shown to survive for extended periods and to move great distances with groundwater flow. Under adverse or unsuitable conditions, enteric bacteria have a limited survival rate, usually less than ten days (4-7 days in dry sandy soils), but under more favorable conditions (cold temperatures, low pH, high organic content and, most importantly, high moisture content) these same bacterial strains can be capable of surviving for more than one hundred days (Canter and Knox, 1985).

Removal efficiencies for bacteria are greatly enhanced by the development of the biomat (Hagedorn et al., 1981). After the development of the biomat four feet of unsaturated soil has been found to be more than adequate, under most soil and flow conditions, in providing attenuation and removal of the vast majority of the pathogenic bacteria introduced to the environment in septic system effluent. The required depth of unsaturated soil varies greatly depending upon the loading rate, the method of application, the soil type and consistency, the weather, and particular site characteristics.

Hagedorn (1983) found a few dozen centimeters of unsaturated soil to be adequate (Gerba, 1977), whereas Brown et al. (1977) concluded that 100 cm (3.3 feet) was adequate. Bouma et al. determined that 30 - 90 cm (1 - 3 feet) of unsaturated soil was required (Hagedorn et al., 1981) with almost total removal occurring in the first 7 cm (0.25 feet) (Corapcioglu and Haridas). Studies conducted by Stewart et al. found bacterial removal to be accomplished in less than 30 cm (1 foot) at loading rates of 3.3 cm per day (0.75 gallons per day/square feet). Further studies by Stewart and Reneau (1982) found high fecal coliform levels in perched groundwater. These perched water tables were unlikely to contaminate the underlying aquifer, but could contribute to breakout and surface contamination (Stewart and Reneau, 1982).

Following heavy rainstorms or increased loading rates, elution or saturated flow conditions may result in decreased bacterial removal efficiencies possibly prompting downward migration beyond four feet (Peterson and Ward, 1988). This effect may be magnified in very coarse grained soils and in soils with perched waters. Therefore the recommended separation distance may need to be adjusted as dictated by certain on-site conditions.

Studies on viral elimination via soil absorption systems have not been completed as frequently as have those for bacteria. Detection of viruses is difficult, time consuming and costly and is therefore not completed on a regular basis. Unlike bacteria, viruses are not appreciably removed in the biomat clogged layer. Treatment is almost totally dependent on the adsorption rate of the unsaturated soils. Specific soil, effluent and viral properties may result in vastly different rates of reduction of viral contamination.

In studying the movement of viruses through various types of soils, Brown et al. (1979) found that coliphage and fecal coliforms were removed by passage through approximately 100 cm (3.3 feet) of unsaturated soil. Some viruses were present at 100 cm, but downward movement below 120 cm (4 feet) only occurred when abnormally high concentrations were added (Hagedorn et al., 1981). This study agreed well with that completed by Dugan (1975) in which only one sample, out of twenty-eight, contained virus at 150 cm (5 feet), with all others having complete removal by 91 cm (3 feet) (Hagedorn et al., 1981).

Recent studies have shown that greater depths may be necessary for coarse permeable soils (Otis et al., 1985; Hagedorn et al., 1981; Nichols et al., 1983). In saturated soils with high hydraulic conductivities, the detention time may not be sufficient to allow adequate treatment of the septic tank effluent. Therefore, the type of soils present should be taken into consideration when determining the required thickness of the unsaturated zone (Scalf et al., 1977).

Viral adsorption and immobilization is not permanent and has been shown to be a reversible process. Elution and resuspension of viruses into the percolating water has been noted resulting in pulses of groundwater contamination following increased hydraulic loading rates or rain induced infiltration (Gerba, 1977). Studies conducted at a land application site in Florida by Wellings et al. (1974) detected viruses in wells located 3 meters (10 feet) and 6 meters (20 feet) below the surface following periods of high rainfall (Gerba, 1977). Further studies determined that viruses can be disturbed and continue further downward migration (Lance et al., 1976), and that the extent of rainfall induced elution appears to be dependent upon both the type and strain of virus (Landry et al., 1980) (Gerba, 1977).

8.2 State Regulations

Many states have adopted standards for the installation of a septic tank/soil absorption system which include establishing a minimum soil depth to bedrock or to the highest level reached by the water table. It is believed that, in some cases, state standards were selected with little information regarding the maximum depth of unsaturated soil necessary for proper treatment under the range of environmental conditions that may occur at a particular site (Hagedorn et al., 1981). A review of Table 8.2.1, which summarizes the regulations of various states regarding the minimum depth to ground water and bedrock, indicates a difference in application of design standards. The survey reveals a range of minimum depths to ground water from ½ to 12 feet from the bottom of the soil absorption system.

TABLE 8.2.1

MINIMUM DEPTH TO GROUNDWATER AND BEDROCK REQUIREMENTS

	DEPTH TO GROUNDWATER (Feet)	DEPTH TO BEDROCK (Feet)	COMMENTS
Alabama	5	5	
Alaska	4	6	
Arkansas	4	4	
Arizona	5	4	
California	5-10(1)	5-10(1)	
Colorado	4		
Connecticut	1.5	4(2)	
Delaware	3	3	
Florida	2		
Georgia			Regulations unavailable
Hawaii			No criteria given
Idaho	3-6	3-6	
Illinois			No criteria given
Indiana	3		
Iowa	3	3	
Kansas			Regulations unavailable
Kentucky	2.5-3.5	2.5-3.5	
Louisiana			Regulations unavailable
Maine	1-2(3)	1-2	
Maryland	4		
Massachusetts	4	4	
Michigan	4		
Minnesota	3		
Mississippi	4	3.3	
Missouri	2-4	2-4	
Montana	4		
Nebraska	4		
Nevada	4,2(4)	4,2(4)	
New Hampshire	4	6(5)	
New Jersey	4	10	
New Mexico	4	4	
New York	3		
North Carolina	3	3	
North Dakota			No criteria given
Ohio	4	4	
Oklahoma			No criteria given
Oregon	4	½	
Pennsylvania	5		
Rhode Island	3	5	
South Carolina	½	1	
South Dakota	4		
Tennessee	4		
Texas	4	4	
Utah	4	2	
Vermont	3	4	
Virginia			Regulations unavailable
Washington	1-3	2½-5	
West Virginia	3		
Wisconsin	3	3	
Wyoming	4		
Guam	12		

(1) For silty sand with some clay, >10 feet for fine to medium sand and silt.
(2) 10' for soils with percolation rates faster than one min/inch.
(3) Dependant upon soil type encountered.
(4) 4 feet for lots <5 acres, 2 feet for lots >5 acres.
(5) 4 feet if municipal or state approved community water supply is available.

Twenty of the states in the survey require a 4 foot separation between the bottom of the leaching facility and the maximum seasonal high ground water level. With the exception of Arkansas, Maryland, Massachusetts, Mississippi, New Hampshire, New Jersey, Ohio, and Tennessee, the states which require this depth to ground water are located in the western portion of the country (Alaska, Colorado, Michigan, Montana, Nebraska, Nevada, New Mexico, Oregon, South Dakota, Texas, Utah, and Wyoming).

The state of South Carolina, of which a great portion is below sea level, has a shallow depth to ground water, ½ foot, as does Florida which requires a separation of 2 feet. Kentucky, requires a separation of 2.5 to 3.5 feet.

The greatest separation distance required in the survey is 12 feet which is mandatory in the territory of Guam. Other states with higher separation requirements are California and Idaho which range from 5 to 10 feet and 3 to 6 feet respectively, depending upon the design soil group encountered.

The depth from the bottom of the leaching facility to the limiting layer of bedrock ranges from ½ foot in Oregon to 10 feet below the ground surface in New Jersey. The majority of the states covered by the survey have an average minimum depth to bedrock of 4 feet.

8.3 Local Regulations

Forty towns have increased the required depth to ground water by promulgating local health regulations. Of these towns, 24 have increased the distance by one foot to a total of five feet. Other towns, such as, Holden and Tyngsborough require six feet to ground water.

The town of Ipswich decides on the minimum required depth to ground water on a yearly basis, although their regulations do not provide the criteria or rationale for this determination. In some towns, such as Carlisle, an increase is only required when the percolation rate is less then 30 seconds/inch; while in Tisbury five feet is required for percolation rates greater than five minutes/inch and seven feet is required for percolation rates less than five minutes/inch.

This theme of variable distance is also present in several other towns. Some rely on the percolation rate to set the distance, such as in Mansfield, while others like Sterling set the distance based on the design flow rate.

Some towns, such as Dartmouth, have increased this distance only in Zone II's (zone of contribution to public water supply); while others like Townsend have increased the minimum by one foot townwide but require seven feet in aquifer recharge areas. Finally several towns, such as Sturbridge, require this increased distance only when water levels are not observed during deep hole tests.

In addition to setting minimum depths to ground water, ten towns have required increased depths to impervious material. Like the minimum depth to ground water the standard increase is by one foot. The town of Merrimac requires eight feet to impervious material, of which five must be naturally occurring. Merrimac defines impervious material as having a percolation rate of slower than 20 minutes per inch.

8.4 Conclusions and Recommendations

In order to properly function, a soil absorption system must be constructed and operated so as to maintain unsaturated soil conditions throughout the vertical flow regime. The U.S. Public Health Service Guidelines (1967) state that 120 - 150 cm (4 - 5 feet) of "suitable" soils are adequate for the protection of groundwater (Hagedorn et al., 1981); whereas the USEPA (1980b) determined that a 2 - 4 foot unsaturated depth was required and Peavey and Groves (1977) found that a soil absorption system located 120 cm (4 feet) above the groundwater functions adequately for all test parameters except nitrate. A thorough review of the literature indicates that the existing Title 5 standard requiring four feet of soil between the gravel bottom of the soil absorption system and the maximum groundwater elevation, is consistent with the recommendations of most authors. This separation distance is based on the premise that suitable soils are present within this four foot zone and care will be taken to ensure that the soil absorption system is installed, operated and maintained correctly.

For sandy soils exhibiting a percolation rate of less than two minutes per inch, an unsaturated zone of not less than five feet in depth should be required to provide the same degree of protection. This depth is based in part on recent research which indicates that fecal coliform bacteria and virus may be transported beyond the four foot soil depth in very coarse-grained soils under certain conditions. Published reports on this topic are limited and many of the recent studies are inconclusive. However, results of available research suggest 150 cm (5 feet) is an appropriate soil depth for coarse sands.

A four foot depth of naturally occurring pervious material has been deemed to possess the hydraulic capacity necessary to assimilate the additional liquid load imposed by a single family residential septic system. Stipulating a four foot minimum depth of naturally occurring pervious material supplants requiring additional hydrogeologic studies aimed at confirming the availability of an adequate horizontal liquid transport zone. Larger systems, generating increased hydraulic loads, require additional study of the mounding effects and transmissivity of the natural soils to document the adequacy of the available horizontal transport zone.

CHAPTER 9

SETBACKS AND ENVIRONMENTAL IMPACTS

Setback distances refer to the horizontal or lateral distance between the various components of the septic tank/soil absorption system and areas, or items of concern. For the most part, these include points of possible human contact such as wells or surface waters. Generally, the specified separation distances are intended to provide adequate transport time for the passage of the effluent through the soil where the concentrations of contaminants are expected to be reduced by filtration, straining, physical-chemical processes, biological activity, dilution and dispersion.

Approximately 100 million people in the United States depend on ground water as their primary source of drinking water. In Massachusetts, thirty-three percent of all drinking water is supplied from either public or private ground water sources. Protecting these valuable water supplies from contamination is a matter of utmost importance and a responsibility that is shared by a number of federal, state and local agencies, including the Massachusetts Department of Environmental Protection (DEP).

The Department of Environmental Protection, along with other agencies, is also responsible for assuring that sanitary wastes are properly managed so as not to pose a threat to the public health or the environment. Regulating waste disposal practices has traditionally been considered a function which is separate and distinct from water supply management, and as a result the two programs have not always been fully integrated. Now, more than ever, it is evident that the subsurface environment must be considered a single medium, and that we must properly manage both our water use and waste disposal practices if we are to reduce the potential public health risks.

In considering the possible contamination of water supplies from septic tank/soil absorption systems, attention must be focussed on the transport and fate of pollutants from the system through the underlying soils and into the ground water. A number of complex physical, chemical and biological removal mechanisms occur in both the soil and ground water. The reader is referred to earlier discussions for an overall description of the natural treatment processes occurring within the subsurface environment.

Extensive research conducted during the past decade, has clearly demonstrated that contaminants allowed to enter the ground water can travel for great distances without appreciable reductions in concentration. This information would suggest that under ideal conditions, waters used for waste disposal should not be allowed to intermix with those used for water supply. However, since we rely so heavily on the ground water both as a source of drinking water and as a receptor for our wastes, segregating the two often is not practical. Therefore, it is imperative that these two activities be appropriately managed to reduce incidents where the public health is at risk.

Title 5 regulations currently require that in siting septic tanks, leaching structures, and the other appurtenances associated with a septic tank/soil absorption system, certain minimum horizontal separation distances be maintained with respect to: wells or suction lines; water supply lines (pressure); property lines; cellar walls and inground pools; surface water supplies (reservoirs) or tributaries to reservoirs; watercourses; subsurface drains; leaching catch basins or dry wells; and downhill slopes (310 CMR 15.03(7)).

Most of the separation distances specified in the Code are based on concerns related to the protection of public health and the environment. There are, however, a number of separation distances which are intended simply to assure that adequate working space is available for the system's installation, maintenance, repair and replacement. These include setbacks from property lines, and to some degree cellar walls and inground swimming pools.

Protection of water supplies is now addressed in Title 5 through the imposition of specific separation requirements. Leaching facilities can not be constructed within 100 feet of a private water supply well or a surface water body and its tributaries used for water supply, or within 400 feet of a public water supply well. Yet, these separation distances alone or with other more stringent setbacks imposed by many local boards of health, may not be sufficient to protect water supplies in every instance. Imposing a predetermined horizontal separation distance has been found to be relatively ineffective, given that the majority of the treatment of septic tank effluent takes place in the biomat clogging layer and the underlying unsaturated soils. A better approach would include specific design modifications based upon a thorough understanding of the overall environmental setting, the area's hydrogeology and the regional housing density.

9.1 Literature Review

Saturated Flow and Contaminant Transport

A basic understanding of the hydrogeologic principles of saturated flow and how it differs from the unsaturated flow conditions of the vadose zone is a necessary prerequisite to understanding the physical, chemical, and biological processes which occur within an aquifer and, more importantly, to understanding the separational requirements necessary for proper siting of a septic tank/soil absorption system.

Ground water flow in the saturated environment is usually considered at the macroscopic scale, with reported attributes depicting average or regional characteristics. Assessing regional ground water characteristics is completed through an investigation of the mechanical, thermal and chemical energy levels exhibited at the site. Nature is constantly trying to equalize these energy differentials in accordance with the laws of physics and thermodynamics. This equalization process results both in regional ground water movement and solute transport phenomena.

Water in the saturated zone moves through the interconnected openings between the soil grains in the direction controlled by the hydraulic gradient (the slope of the water table). At the microscopic scale, ground water in the saturated environment follows a tortuous path not unlike that encountered during unsaturated conditions. A major difference is that under saturated conditions all of the voids of the porous soil medium are filled with water. This allows flow to proceed utilizing the larger pores or channels within the soil permitting increased liquid transport potentials but also lessening the available treatment options by appreciably reducing the effectiveness of filtration and adsorption.

If a pollutant, including bacteria, viruses, inorganic precipitates or organic matter, is introduced into an aquifer it is important to be able to predict its direction and rate of travel through the ground water system and the degree of treatment or removal it will undergo. Solute transport through the saturated porous medium depends on a variety of physio-chemical processes including advection, mechanical dispersion, molecular diffusion, solid-solute interactions, chemical reactions and solute decay phenomena (Bear, 1979).

Advection and hydrodynamic dispersion (the combined effects of mechanical dispersion and molecular diffusion) are the physical processes controlling the flux into and out of a given volume of water. Advection describes longitudinal solute transport due to, and in the direction of, the average ground water flow. Hydrodynamic dispersion, or miscible displacement, is the non-steady, irreversible spreading or mixing created by microscopic variations in the magnitude and direction of flow (mechanical dispersion) and solute concentration gradients (molecular diffusion) (Freeze and Cherry, 1979; Bear, 1979). Hydrodynamic dispersion causes spreading of the solute transversely (side to side), vertically, and longitudinally (in the direction of ground water flow).

Solid-solute interactions may also contribute to a loss or gain of solute mass. Typical solid-solute interactions include adsorption, deposition, solution of the solid matrix and ion exchange. Physio-chemical conditions may influence these interactions further affecting solute transport. For example, with excess calcium or aluminum aggregates may result due to changes in the particles' surface properties. These larger aggregates may then be strained or filtered from the water. Changes in the pH of the ground water may further result in a loss, or gain, of solute mass.

A decade-long study on the discharge, movement and attenuation of a sewage plume at Otis Air Force Base on Cape Cod has been conducted by the USGS. This study concluded that vertical movement of contaminated ground water was caused by vertical gradients created by the ground water mound at the disposal beds and by areal recharge from precipitation (LeBlanc, 1984). For each contaminant in the plume, the magnitude of the transport, dispersion and attenuation phenomena was found to vary. Phosphate was quickly immobilized by adsorption or precipitation as the mineral hydroxyapatite. Ammonia, upon entering zones with high dissolved oxygen concentrations, was oxidized to nitrate. Although the nitrate remained relatively unaffected by the oxidizing ground water environment, the extended duration of the sewage discharge at this location created several anaerobic zones which enabled a limited degree of denitrification. The study concluded that although dispersion was taking place along the toe and sides of the 11,000 foot plume, certain contaminants maintained high concentrations along the center of the plume as far as 8,000 feet from the source (LeBlanc, 1984).

A more recent study (Robertson, et al., 1989) included similar experiments conducted on a single septic system. This study supports many of the conclusions of the Otis study. It documents phosphate sorption in close proximity to the leaching facility, conversion of ammonia to nitrate, and the formation of a long thin plume with little transverse or vertical dispersion. This study concludes that plume attenuation is controlled by advection, biodegradation and adsorption, suggesting that mixing with background ground water and dilution from infiltrating precipitation are, for the most part, negligible.

Contaminants and Impacts on Surface Waters

The maintenance of minimum standards for the separation distances of septic systems from human contamination pathways is required due to the viability and mobility of pathogenic bacteria and viruses in the saturated subsurface environment. Unsaturated percolation of septic system wastes leading to thin water layer formation at the water-soil and water-gas interface is the best subsurface means of minimizing the risks due to pathogenic organisms. The organisms which escape soil retention or destruction, and are able to enter the groundwater, must be eliminated prior to reaching a sensitive receptor.

Saturated flow does not provide the conditions necessary for the efficient destruction or inactivation of pathogenic bacteria and viruses. While enteric microorganisms may be unable to reproduce in the aquifer environment, there is little predation available to remove them and render the water totally safe. While the minimum separation distances prescribed by Title 5 will not guarantee the total absence of pathogens at the receptor, they provide for dilution and dispersion of the contaminants of interest, thereby reducing the concentration of the contaminant at the receptors.

Bacterial and viral contamination of surface waters is becoming an increasingly important issue. Pathogens can enter the body through ingestion of water while swimming or through open cuts. While the sampling of surface waters may indicate low pathogen counts, micro-organisms are concentrated in the bottom sediments of rivers and estuaries and in the shellfish which inhabit them (Duda and Cromartie, 1982). Consumption of these tainted shellfish can lead to disease and even death. This risk of disease outbreak has led to periodic closing of numerous areas to both shell-fishing and bathing (Duda and Cromartie, 1982).

An increasing number of shellfish banks in the coastal waters of Massachusetts have been subject to restrictions or have been closed due to contamination. Outbreaks of red tide, caused by a massive growth of an algal group called dinoflagellates, can affect large areas of the sea. Algal growth is accelerated in the presence of nitrates and phosphates introduced from septic system wastes. Shellfish, which survive by eating algae, concentrate the toxins produced by these algal cells thereby rendering them poisonous to humans (Grady, 1988).

Setbacks from surface water bodies are generally considered necessary to reduce the risk of contamination by pathogenic micro-organisms and the harmful eutrophication effects instilled by the introduction of high concentrations of nitrates and phosphates. However, once in the saturated groundwater environment, very little attenuation and removal occurs. The only conventional means of protecting surface water bodies is through designs which promote proper treatment in the unsaturated zone and the maintenance of low septic system densities which allow for adequate dilution of the effluent laden groundwater before emission.

Phosphorus is usually the limiting nutrient in the surface water environment (Sawhney, 1977). Even at very low concentrations, slight increases in phosphorus content can have a dramatic effect on the quality of surface waters. Increased groundwater concentrations have been attributed to the use of septic systems, especially when phosphate rich soaps and detergents are used, and the extensive use of fertilizers. Phosphate effects are most widely found on surface waters where springtime concentrations of 0.01 mg/l have been correlated to accelerated eutrophication (Magdoff et al., 1974).

Water Supply Impacts

Information gathered through a decade long survey in the 1970's (Craun, 1984) and reinforced through an additional survey conducted in the 1980's (Yates, 1989) indicates that untreated ground water subjected to septic tank effluent is responsible for as much as 45 percent of the waterborne disease in the United States. Most of these reported disease outbreaks involve community water systems. However, it is believed that there are many additional cases of contamination occurring in individual systems which are generally not recognized, and therefore go unreported.

The surveys indicate that a large percentage of the reported illnesses have been attributed to pathogens with only 11 percent caused by toxic chemicals as summarized in the table below.

TABLE 9.1.1

Etiology of Waterborne Disease (Yates, 1985)

DISEASE	OUTBREAKS (%)
Acute gastrointestinal illness	55
Chemical poisoning	11
Giardiasis	11
Shigellosis	8
Hepatitis A	6
Salmonellosis	3
Viral gastroenteritis	2
Typhoid	2
Toxigenic E. *coli* gastroenteritis	<1
Campylobacter gastroenteritis	<1

These studies only address reported illness from contaminated wells, they do not address the low-levels of pollutants released from septic systems into the subsurface which is estimated to occur at the rate of over one trillion gallons per year (Yates, 1989). Low level contaminants could be the cause of yet undetected long-term human health problems.

Table 9.1.2 is a compilation of a number of analyses from articles that identify different contaminants that have been found in septic tanks. Many of these contaminants, if discharged without proper treatment, have the potential to adversely impact ground water and surface water used as a source of water supply.

FIGURE 9.1.1
SEWAGE TREATMENT SYSTEM
(SETBACK DISTANCES)

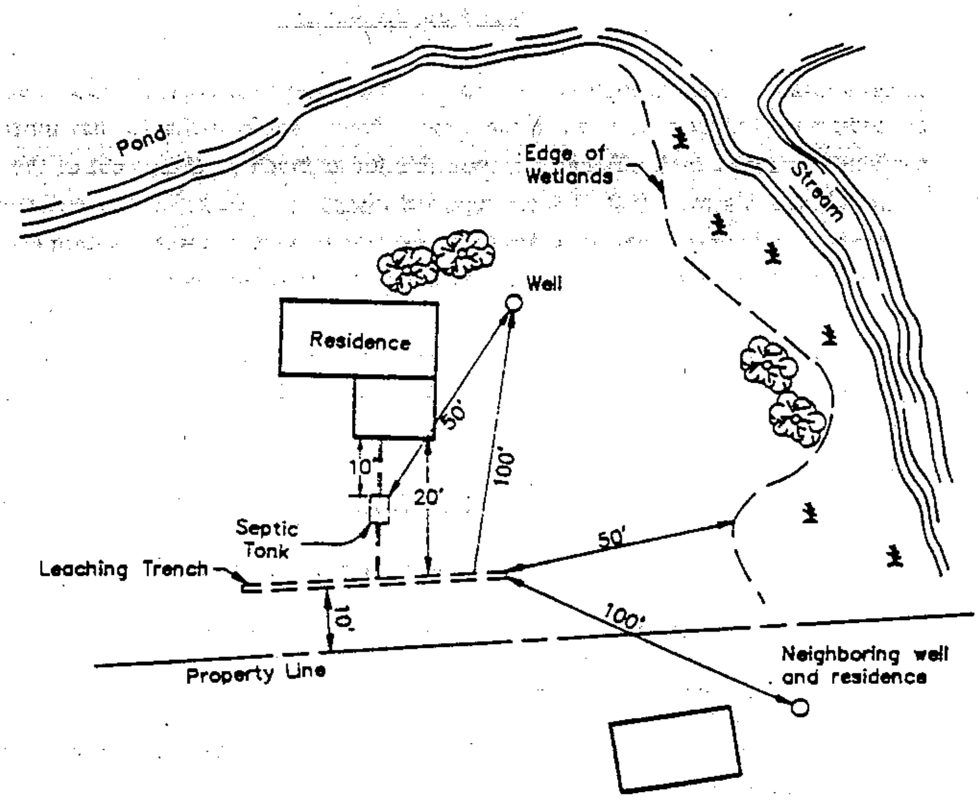

TABLE 9.1.2

CHARACTERISTICS OF TYPICAL RESIDENTIAL WASTEWATER

Parameter	Concentration mg/l
Total Solids	680 - 1000
Volatile Solids	380 - 500
Suspended Solids	200 - 290
Volatile Suspended Solids	150 - 240
BOD	200 - 290
Chemical Oxygen Demand	680 - 730
Total Nitrogen	35 - 170
Ammonia	6 - 160
Nitrites and Nitrates	<1
Total Phosphorus	18 - 29
Phosphate	6 - 24
Total Coliforms	10^{10} - 10^{12}
Fecal Coliforms	10^{8} - 10^{10}
pH	7.2 - 8.5
Chlorides	86 - 128
Sulfates	23 - 48
Iron	.26 - 3.0
Sodium	96 - 110
Alkalinity	580 - 775
P-Dichlorobenzene	.0039
Toluene	.0200
1,1,1-Trichloroethane	.0019
Xylenes	.0028
Ethylbenzene	.0004
Benzene	.0005

* Volatile Organics are the maximum concentrations.

(1) EPA 1980 "Onsite Wastewater Treatment and Disposal Systems"

(2) Brandes, 1978

(3) Greer and Boyle, 1988

Installation, Maintenance and Repair

The setback distances currently prescribed by Title 5 appear adequate for providing for the installation, maintenance and repair of subsurface sewage disposal systems without imparting adverse effects on buildings or encroachment on abutting properties. These setback distances prescribe the minimum acceptable separation to enable septic system installation and repair to be completed without undue disruption to adjacent uses. On-site conditions and the specific system design may necessitate a site specific increase in these setback distances.

9.2 State Regulations

A review of existing state regulations as shown in Table 9.2.1 indicates that most states currently do little more than impose minimum horizontal setback distances from septic systems to surface waters and wells (public and private). Setback requirements do differ in that some states impose different distances for the various components of the system while others set one distance for the system as a whole.

The states do not have uniform definitions for the various structures and topographic features, and there are exceptions to many of the requirements, thus making direct comparisons extremely difficult. An example of this would include the state of Minnesota which imposes different setbacks dependant on the river type: wild, scenic, or recreational; or the state of Maryland which has two different setbacks for water supply wells depending on whether the well penetrates a confined or unconfined aquifer.

Horizontal setbacks to surface waters are very generalized due to the great number of waters this applies to and the manner in which the particular state chooses to define a surface water. A surface water may be defined as having two or three distance requirements depending on whether the surface water is a stream, is intermittent, or is an open waterbody. The required setback distance from a surface water to a leaching system ranges from 50 feet in states such as Alabama and Colorado to a maximum of 500 feet in Vermont.

Surface drains located are upgradient of a leaching facility are required to have a minimum separation distance of 20 to 100 feet in eleven of the states surveyed, while the remainder of the states do not impose setbacks. Downgradient drains are required by seven of the states to maintain setbacks ranging from 20 to 100 feet.

Setback requirements for drainage ditch features on a site vary from 10 feet in Pennsylvania to 75 feet in New Hampshire with most states imposing a 25 foot separation distance.

Horizontal setback distances to buildings range from 5 feet in states such as Alabama and Florida to 75 feet in New Hampshire (dependent on the presence of drains in the foundation). The distance required from the system to the property line ranges from 5 feet to 10 feet.

TABLE 9.2.1

HORIZONTAL SETBACK DISTANCES TO ABSORPTION FIELDS IN OTHER STATES

	BUILDING/ PROPERTY LINE	PRIVATE/ PUBLIC WELL	SURFACE WATER	DRAIN (Upgradient/ Downgradient)	DRAINAGE CHANNEL
Alabama*	5	100	50		25
Alaska*	10	100/150/200	100		
Arkansas*	10	100/300	100		
Arizona*	10/5	100	100		
California(7)					
Colorado*	10	100	50		50
Connecticut					
Delaware	10	100/150	100		
Florida*	5	75/100/200	75		15
Georgia(4)					
Hawaii*	5		50		
Idaho	10-20/5	100	100-300		50
Illinois	10/5	75	25	10	
Indiana*	10/5	50/100/200	50		25
Iowa	10	100/200	100	10	25
Kansas(4)					
Kentucky	20/5	70	50	20/70	25
Louisiana(4)					
Maine	20/10	100/300(8)	50/100		25
Maryland*		50/100	100/300		25
Massachusetts	10/20	100	50	25	
Michigan*	15/10	50/200		25	
Minnesota	20/10	150	75-150		
Mississippi(9)					
Missouri	15-25/10	100/300	50	10/25	25
Montana	10	100	100		
Nebraska	30-40/10	100/500	50		
Nevada	20/10	100	100		
New Hampshire*	5-75/10	75/200-400	100		75
New Jersey	10/25	100	50		
New Mexico		100/200	100		25
New York	20/10	100(6)	100		
North Carolina*(10)	15/10	100	50-100	10/25	25
North Dakota*	20/10	50-100			
Ohio*	10	50			
Oklahoma*	5	50(5)	50(5)		15
Oregon	10	100	100	10/50	
Pennsylvania*	10	100	50		10
Rhode Island	15/10	100/400	50	25	
South Carolina*	5	50	50	10/25	25
South Dakota	20/10	100/150	100		
Tennessee	10	50	25		25
Texas	15/10	150	75		
Utah	5	100	100	20/100	50
Vermont(3)	25	100/125/150	50		25
Virginia(2)					
Washington	10/5	100	100	10/30	10/30
West Virginia*	10	100		10/20	20
Wisconsin					
Wyoming(2)	5/10	50	50	5	
Guam	20/5	300	300		

* Setbacks are for all components of the on-site sewage disposal system
(1) Well upgradient of system.
(2) More stringent req. for Sys >2000 GPD.
(3) ROR Sys >6500 GPD (mound systems have separate regs).
(4) Regulations unavailable
(5) 100 feet if perc <5 min./in. or ground slopes toward well or doesn't suite H20 supply.
(6) 200 feet if upgradient.
(7) Differs County to County
(8) 300 feet for >2000 GPD.
(9) No specific setbacks set
(10) For flows <3000 GPD.

Private well setback distances range from a minimum of 50 feet (Ohio, South Carolina, and Tennessee) to 300 feet (Guam). Public well setbacks range from 100 feet (Connecticut and Montana) to 400 feet (New Hampshire and Massachusetts). The majority of states use a distance of 100 feet for private wells and between 100 to 200 feet for public wells. The state of Maryland has two different setbacks for water supply wells depending on whether the well penetrates a confined or unconfined aquifer.

Several states have recognized the need to address density when siting septic systems. Minnesota requires a lot size ranging from 0.46 to 1.84 acres when constructing a septic system on lakefront property. Nevada requires 0.25 acres if the area is served by a public water supply and one acre if it has a private water supply. Other states, such as Alabama, Maine and Mississippi, also have requirements for minimum lot sizes when septic systems are to be installed.

9.3 Local Regulations

From the local regulations on file with the Department of Environmental Protection it is apparent that several towns have developed more stringent horizontal setback requirements than contained in Title 5. For the most part, the distances are double those required by Title 5. In some cases the regulations are vague, for instance the town of Pelham requires leaching facilities to be 100 feet from "an aquifer". Several towns, such as Dracut, have increased the distance from all types of wetlands, while the town of Gloucester requires a 200 foot separation from coastal wetlands and 100 feet from all others.

Some towns, such as Yarmouth and Marshfield, have included requirements for hydrogeologic studies for septic systems producing over 5,000 gallons per day.

Several towns, such as Hubbardston, have established septic tank density requirements. Most of these are modeled after the Division of Water Supply guidelines of 110 gallons per day per quarter acre.

9.4 Conclusions and Recommendations

Careful site evaluation, taking into account the environmental setting as well as the regional environmental impacts, is important for sound development. We can no longer deal with waste disposal and water supply as completely separate issues. Removal of contaminants before they enter the ground water and sound planning and design to minimize the effects of contaminants that can not be removed, are the only means of ensuring proper protection of water supplies. This requires strict conformance to the standards set for vertical separation distances and for loading rates. As previously noted, biomat clogging layer formation and unsaturated flow conditions are necessary for proper contaminant removal efficiency.

Nitrates are not effectively removed by conventional septic systems in either the unsaturated or saturated environment. Protection of surface water, as well as public and private water supplies, requires careful evaluation of the housing density and/or consideration of non-conventional systems providing denitrification. Whereas increasing lateral separation distances may theoretically aid in dilution, in practice little or no mixing occurs.

Reducing the threat of nitrate-nitrogen contamination in private water supply wells can also be accomplished through the use of deeper wells with well screens installed below the upper, most highly contaminated ground water layer (Walker et al., 1973).

Setbacks from surface water supplies and their tributaries are generally considered necessary to reduce the risk of contamination by pathogenic micro-organisms and the harmful eutrophication effects resulting from high concentrations of nitrates and phosphates. However, very little removal of contaminants occurs in the saturated zone and set-back distances therefore are not very effective. The best means of protecting surface water bodies is through system designs promoting proper treatment 2in the unsaturated zone and the maintenance of acceptable septic system densities which allow for a reasonable dilution of the effluent.

The setback distances imposed by Title 5, if coupled with the soil absorption system design changes recommended in other chapters of this report, should be adequate for the protection of the human population and the environment from the effects of contamination from small (i.e. less than 2,000 gallons per day) domestic septic systems. While dilution and a small degree of attenuation of contaminants will occur in the saturated aquifer, it occurs slowly over great distances with inconsistent results. Most of the contaminant removal is accomplished in the biomat clogging layer and the unsaturated zone of the soil absorption system. The contaminants which escape these layers and enter the aquifer are transported for great distances with little appreciable change in concentration. Therefore, increasing lateral separation distances is an ineffective method of improving the quality of aquifers or surface waters.

CHAPTER 10

DENSITY

In sparsely populated rural areas, septic systems that have been properly designed and maintained are efficient and economical alternatives to public sewer systems. Unfortunately, we have abused this treatment method has been abused so that it has become a major source of concern. This is the case particularly in areas in which the system density has exceeded the ability of the subsurface environment to receive and properly assimilate potential contaminants (Cantor and Knox, 1985).

In the past forty years, the ever increasing population has led to a steady migration to the unsewered urban fringe and rural residential areas. Much of this "suburban sprawl" proceeded with little regard to community planning and no regard to environmental impact. Some overly-developed areas, most notedly around lakes and marine embayments, are now experiencing an excessive number of septic system failures, especially among those systems which precede the current Title 5 design standards. Coupled with high septic system density, these areas pose severe long term threats to public health and the environment. These problem areas are manifested by high concentrations of nitrate-nitrogen, bacteria and viruses, and significant amounts of organic contaminants in the ground and surface water systems.

Septic system density can be defined in a number of different ways. It can be described as the average number of septic systems per square mile or the average number of septic systems per acre. It is important to understand that this number can be easily skewed depending on how one defines the limits of the area that is being analyzed.

Density is indirectly addressed in the current Title 5 regulations through the imposition of specific separation requirements or setbacks. These separational distances (or other more stringent setbacks imposed by many local boards of health) are currently the only means other than local zoning requirements of controlling septic system density.

Title 5 regulations need to include provisions which specifically address density in terms of the amount of sewage discharge per unit area. Sewage disposal alternatives need to be investigated in areas that are already over the prescribed density limit. This should include the upgrading of existing subsurface sewage disposal systems, as necessary, to prevent contamination and provide effective protection of public health and the environment.

10.1 Literature Review

Ground water pollution from septic systems has been found to be more evident in areas with high septic system density. Canter and Knox (1985) cite a 1980 Department of Commerce study listing at least four counties in the United States with more than 100,000 housing units, and at least 23 counties with more than 50,000 housing units, served by individual septic systems or cesspools. Table 10.1.1 summarizes the septic system density of several counties in Massachusetts listed in this Department of Commerce study.

TABLE 10.1.1

Septic System Densities for Counties with more than 50,000 Housing Units (adapted from Cantor and Knox, 1985)

County	1980 Pop. ($x10^3$)	1980 Units ($x10^3$)	Area sq. mi.	Subsurface Disposal(%)	Density of Septic Systems (no./mi^2)
Bristol	475	193	554	26-52	90-180
Middlesex	1367	556	825	9-18	61-122
Norfolk	607	247	394	20-40	127-254
Plymouth	405	165	654	30-61	76-153
Worcester	646	263	1509	19-38	33-66

- Housing units are calculated based on 2.46 persons per unit

It is important to note that these densities were calculated based on an assumed even distribution of septic systems throughout the county. Obviously in some parts of these counties the septic system density may be much higher than this average. In many areas across the country densities range from as low as 2 to as high as 346 septic systems per square mile. Density concentrations have been categorized by the U.S. Environmental Protection Agency (1977), as either low, intermediate or high based upon the following criteria:

low - less than 10 per square mile
intermediate - 10 to 40 per square mile
high - greater than 40 per square mile.

The Massachusetts counties listed in Table 10.1.1 all fall within the high septic system density category.

In the Long Island Comprehensive Waste Treatment Management Plan prepared pursuant to Section 208 of the Federal Water Pollution Control Act the researchers performed painstaking statistical analysis to determine the correlation between population density and the number of wells found to exceed the drinking water standard for nitrate (10 mg/l). Table 10.1.2 summarizes the relationship between the percent violations of the drinking water standard, the mean ground water nitrate concentrations and the population densities.

TABLE 10.1.2

(Adapted from Long Island 208 Report)

Violation (%)	Mean Concentration (mg/l)	Density (persons/acre)
10%	6.0	6.7
20%	7.1	8.6
30%	7.9	9.8
40%	8.7	11.2
50%	10.3	13.7

In a similar study performed on Cape Cod by the United States Geological Survey (USGS), distinct statistical relationships between the septic system density and elevated levels of nitrate and chlorides were identified (Persky, 1988).

Much of the previous work in establishing an acceptable septic system density has been conducted in relation to protection of water supplies from contamination. Traditionally, the use of setback distances has been the method most frequently used to protect water supplies from these contaminant sources. However, a higher degree of water supply protection is afforded through developing limits on housing density that reduce the total volume of wastewater discharged over a given area (NAHB, 1988).

Most attempts at establishing density formulas have been based on nitrate-nitrogen loading models used to evaluate the average impacts to ground water over large areas. Nitrate-nitrogen is generally considered because: (1) it is a contaminant of concern in drinking water; (2) its treatment in a conventional subsurface disposal system is minimal; and, (3) it is completely dissolved in the wastewater. These factors simplify the analysis of the dispersivity of nitrate-nitrogen making it much easier to evaluate than a solute that is attenuated by methods other than dilution. Using nitrogen loading as a means of determining acceptable density limits may be the most effective means of protecting the quality of water in wells or surface water bodies over the long term.

The most widely recognized approach to modelling the effect of a solute on a water body is the mass-balance method. The mass balance approach estimates the average nitrogen concentration by dividing the total mass of the nitrogen by the mass of the recharge water. This method assumes total mixing of the nitrogen with the water and therefore cannot be used for predicting nitrate-nitrogen concentration at any given point in the modelled system (NAHB, 1988).

The basic mass balance approach is represented by the following equation:

$$Z = \frac{X}{Y}$$

where:

Z	=	Nitrogen in recharge
X	=	Total weight of nitrogen ($N_1 + N_2 + N_3 + N_4$)
Y	=	Total weight of recharge water ($W_1 + W_2$)
N_1	=	nitrogen from turf fertilization
N_2	=	nitrogen from precipitation
N_3	=	nitrogen from household water
N_4	=	nitrogen from wastewater
W_1	=	recharge from precipitation
W_2	=	recharge from home water use

This basic approach was used by the Cape Cod Planning and Economic Development Commission (CCPEDC) to establish a septic system density formula (Frimpter, 1988). The National Association of Home Builders (NAHB) refined the basic formula to actually compute housing density based on nitrate-loading. The NAHB formula is presented in Table 10.1.3 at the end of this chapter.

Accuracy of a mass balance model is largely dependent on proper identification and quantification of the variables that contribute to site recharge and the total nitrogen budget. A number of researchers have determined and summarized nitrogen contributions from various sources. One of the most comprehensive summaries of this information is found in the Long Island Comprehensive Waste Treatment Management Plan. This nitrate-nitrogen summary includes many sources, including the contribution from domestic dogs and cats.

Recharge data is also reported in a number of studies. Most of the reported research includes conventional average values for home water use. Precipitation is of course site or regionally specific. This data is generally available from the national weather service.

Although the mass balance method is probably the easiest and least costly approach to evaluating density, it is important to understand its limitations. The method can only be used for solutes that are attenuated predominantly by dilution and that enter the subsurface in relatively low concentrations (Frimpter, 1988). Because this method can only deal with one solute at a time, the model assumes that all nitrogen entering the system is, or will be, oxidized to nitrate and that once in the system no denitrification occurs. It is important to note, however, that there is some nitrogen uptake by plants and that denitrification may occur when nitrate moving with the ground water encounters anaerobic conditions, such as commonly found in the soils below fresh water wetlands or other zones containing decaying organic material or peat.

Because the mass balance method relies on total mixing of the nitrate in the recharge water it can not account for individual plumes with elevated concentrations of solute. In reality, the sources of nitrate and recharge would have to be relatively uniformly distributed within the area under consideration to obtain this total mixing. Site specific models that evaluate nitrate concentrations at specific points upon actual site geology, hydrogeology and engineering are far more accurate than the mass balance method.

The CCPEDC study model was based on nitrate loads of five pounds per person per year and nine pounds per year per lawn[1], for a 3-person household. The volume of wastewater return flow was 65 gallons per person, with an annual recharge rate of 1.33 feet per year. From this, it was calculated that a lot size of 59,250 square feet would be necessary to sufficiently dilute the total nitrate load to the CCPEDC planning goal of 5 mg/l. This value was then arbitrarily adjusted to 43,560 square feet, (one acre) in order to account for roads and other open space (Frimpter, 1988).

For purposes of comparison, the input parameters used in the CCPEDC study were incorporated in the NAHB model using the drinking water standard of 10 mg/l of nitrate as the planning limit. This exercise results in a housing density of one house per 41,240 ft^2 (approximately one house per acre).

Although the actual NAHB study used slightly different values than the CCPEDC study, our review indicates that the variability is for all practical purposes insignificant. The study concluded that density should be set at 5.8 people per acre, which in accordance with Title 5 Sewage Flow Estimates (310 CMR 15.02(13)), would equate to one three bedroom house per acre. The study subsequently compared their model to those presented by others which unfortunately were not available for our review. It was reported that the Cogger and Rubin model compared favorably to the NAHB model. The study concluded that a septic system density of approximately six persons per acre is necessary to maintain an overall 10 mg/l nitrate-nitrogen concentration in the ground water.

Although not specifically designed to evaluate nitrate-nitrogen loading in the subsurface environment, the U.S. Environmental Protection Agency (1981) model for evaluating nitrate loading from sewage treatment facilities where land application is used for effluent disposal was adapted for the purpose of this study. This method calculates the maximum allowable nitrogen loading rate using the following equation:

$$L_{w(n)} = \frac{C_p (P_r - ET) + 10U}{(1 - f)(C_n - C_p)}$$

1 It is important to note that the Long Island study indicated that a majority of the nitrate-nitrogen entering the ground water system is attributed to lawn fertilization. They also found a direct correlation between the degree of fertilization and affluence; the more wealth - the more fertilizer used - the greener the lawns.

where:

$L_{w(n)}$	=	wastewater hydraulic loading rate based on nitrogen limits (in/yr)
C_p	=	nitrogen concentration (mg/l) --**10 mg/l**
P_r	=	infiltration from precipitation (in/yr) --**16 in/yr**
ET	=	evapotranspiration rate (in/yr) --**0.75 in/yr**
U	=	crop nitrogen uptake rate (lb/acre/yr) -- **0**
f	=	fraction of applied nitrogen removed by volatilization, denitrification and storage -- **0.15** (EPA)
C_n	=	nitrogen concentration in applied wastewater (mg/l) -- **35 mg/l**

The result of this calculation (using the input parameters highlighted in bold) is a wastewater loading rate of 7.17 inches per year (0.00163 feet per day). A four bedroom house with a design flow of 440 gallons per day (58.8 cubic feet per day) would require an area of 36,088 ft^2 to adequately dilute the nitrate-nitrogen entering the site from the septic system.

It is worth mentioning here that another mass-balance accounting model has been developed by Frimpter et al. (1988) for predicting possible future nitrate loading under steady-state conditions in zones of contribution to water supplies (Zone II). This model requires all of the nitrate and water entering the zone of contribution to be in equilibrium with and equal to that withdrawn for public supply. This mass-balance dilution method can be used to evaluate potential development plans and/or alternative plans within the Zone II. For example, it can be used to evaluate the impact of septic systems compared to an advanced wastewater treatment facility or to a no build option for a given development within a zone of contribution.

Other attempts have been made to propose the ideal minimum lot size required to reduce incidents of ground water contamination or to make the system easier to design, function or repair. Correral and Norris (1969) have determined that a typical minimum lot size for a single family residence should be one acre. They believe this size is necessary to take into account the area requirements for the initial septic system installation, the area for a replacement system, the setback requirements and the area for the residence itself. They recommend that the minimum lot size be increased to one and a quarter acres for sites where the terrain slopes from 5 to 10 percent, one and a half acres for sites with a slope of 10 to 20 percent, and two acres for sites with slopes greater than 20 percent. These increases are intended to account for slope limitations on the available land that can be used for the general development of the site.

The Division of Water Supply recently made changes to the Drinking Water Regulations requiring Wellhead Protection By-Laws be adopted by communities prior to final approval of new water supply sources by the Department. The by-laws, among other requirements, must prohibit the use of individual sewage disposal systems which discharge more than 440 gallons per acre. The acreage for this analysis is taken as the entire Zone II area (Michael Rapacz, personal communication).

TABLE 10.1.3

National Association of Home Builders
Nitrate Loading Model

$$h^*s = \frac{\dfrac{z[(5.2)(o)(f\text{-}r)]}{(1 \times 10^{6})} - (abc/1000) - 5.22 \times 10^{-6}(pgc)(f\text{-}n\text{-}r)}{[3.04 \times 10^{-3}(qm) + (i)(1\text{-}j)(1\text{-}k) - 3044.1(q)\left[\dfrac{z}{1 \times 10^{-6}}\right]}$$

To obtain density divide the answer by h.

N1 = nitrogen from fertilization (abc/1000)

a	=	fertilized land area (square feet)
b	=	weight of nitrogen in fertilizer (lbs/1000 sq. feet)
c	=	% of nitrogen that leaches from turf to ground water

N2 = nitrogen from precipitation 5.22×10^{-6} (pgc) (f-n-r)

f	=	total land area (square feet)
p	=	annual precipitation (in/yr)
n	=	natural land area (square feet)
g	=	nitrogen content in precipitation (in/yr)
r	=	impervious land area that runs off-site (square feet)

N3 = nitrogen from household water 3.04×10^{-3} (hqms)

h	=	number of people per dwelling
q	=	daily water use per person (gpdd)
m	=	nitrogen concentration in household water (mg/l)
s	=	number of dwellings
3.04×10^{-3}	=	conversion factor to obtain lbs/yr

N4 = nitrogen from wastewater hsi(1-j) (1-k)

i	=	annual nitrogen input per person
j	=	nitrogen loss in septic tank
k	=	nitrogen loss in soils

W1 = recharge from precipitation 5.2(f-r)(o)

o	=	annual recharge (in/yr)
5.2	=	conversion factor to obtain lbs/yr

W2 = recharge from home water use 3044.1 ghs

3044.1	=	conversion factor to obtain lbs/yr

10.2 State Regulations

There are twenty-one states that have set a minimum septic tank density. This is usually accomplished by establishing a minimum lot size for developments using subsurface disposal systems. The following list summarizes these states requirements:

Alabama - A minimum lot size of 20,000 ft^2 is required with on-site water supplies; if the lot is served by public supply, the minimum size is reduced to 15,000 sq/ft.

Alaska - Subdivision lots must have a minimum size of 40,000 ft^2. Additionally, a pollution abatement report must be generated to demonstrate that nitrate introduced by the proposed septic system will not exceed 5 mg/l at the property line.

Arkansas - A sewage justification study must be performed for new developments. This study must evaluate the level of treatment required. A key component of this study is an evaluation of the projected septic system density.

Arizona - Density is based on ambient levels of nitrate in the ground water according to the following table:

mg/l	gpd/acre
0 - 3	<1,200
3.1 - 5	<800
5.1 - 7	<400
>7	none

Delaware - A minimum lot size of one-half acre is required for residential development. A discharge of up to 500 gpd/acre is allowed for commercial developments.

Florida - A minimum lot size of one-half acre is required for residential development with on-site water supply. A minimum lot size of one-quarter acre is required where the residence is connected to a public supply. For commercial development, the discharge can be up to 1,500 gpd/acre if the water supply is on-site or 2,500 gpd/acre if a connection to a public supply is provided.

Indiana - The minimum lot size requirements vary between 10,000 and 18,000 ft^2 depending on the percolation rate. The faster the rate the larger the lot size required.

Maryland - The minimum lot size varies depending on percolation rates. The size requirements varies between 20,000 and 40,000 ft^2 for lots with on-site water supplies and between 15,000 and 30,000 ft^2 for lots serviced by public water supplies.

Montana -	A minimum lot size of one acre is required for sites with on-site water supply; 20,000 ft^2 is required for lots serviced by public water supplies.
Nevada -	A minimum lot size of one acre is required when the water supply is on-site; one-quarter acre is required when a connection to public water is provided. Commercial developments require a minimum land area of 22 square feet for each gallon of effluent generated.
New Hampshire -	New lots where subsurface disposal systems are utilized must be a minimum of five acres, with a maximum discharge of 2,000 gpd/acre.
New Mexico -	A maximum discharge of 500 gpd/acre is allowed.
N. Dakota -	A minimum lot size of 20,000 ft^2 is required and no septic system are allowed to be located within public water supply watersheds.
Oklahoma -	Percolation rates determine the minimum lot size. For lots with on-site water supplies, the lot size requirements varies between 35,000 and 40,000 ft^2; a minimum size of 22,500 ft^2 is required for lots serviced by a public water supply.
Oregon -	A maximum discharge of 450 gpd/acre is allowed. Sewage treatment facilities are required to lower nitrate level to less than 5 mg/l if this threshold is exceeded.
S. Dakota -	A minimum lot size of one acre is required when water supply is on-site. A minimum lot size of 20,000 ft^2 is required when connection to a public water supply is provided.
Tennessee -	A minimum lot size of 25,000 ft^2 is required when the water supply is on-site; a 20,000 ft^2 minimum lot size is required when a connection to a public water supply is provided.
Texas -	A minimum lot size of one acre is required when the water supply is on-site; one-half acre is required the lot is serviced by public water.
Utah -	Soil type determines the minimum lot size. If the water supply is on-site, the minimum size varies between one and 1.75 acre. If the site is serviced public water, the minimum size varies between 12,000 and 20,000 ft^2.
Washington -	Soil type determines the minimum lot size. If the water supply is on-site, the minimum size varies between one and two acres. If the site is on public water, the minimum size varies between 12,500 ft^2 and one acre.
W. Virginia	A minimum lot size of 20,000 ft^2 is required when water supply is on-site, 10,000 ft^2 is required when connected to public water.

10.3 Local Regulations

Only four of the local board of health regulations on file with the Department of Environmental Protection provide septic system density requirements. The towns of Chilmark and West Tisbury adapt their setback requirements to establish density. This is accomplished by requiring a distance of 300 feet between septic systems in the coastal zone.

The Edgartown regulations have several different requirements for new development depending upon location. In most areas they require a maximum of 110 gallons per 10,000 square feet. On the island of Chapaquidick, the maximum discharge rate is 110 gallons per day per 15,000 square feet.

The town of Hubbardston allows a maximum discharge of 440 gpd/acre. It is believed that there may be several other towns that have, or soon will adopt, density requirements in zones of contribution to public water supplies, as a result of the aforementioned amendment of the Water Supply Regulations. However, these recent regulatory amendments were not available for inclusion in this report.

It should be noted that the practice of implementing density controls has already been established in some communities by means other than board of health regulations. The towns of Norfolk and Plainville have adopted protective measures similar to those proposed in this report. Additionally, some communities establish densities by formula under aquifer or ground water protection by-laws. Examples of these include Holliston and Wayland.

10.4 Conclusions and Recommendations

The significance of density as a factor in establishing optimal criteria for siting Title 5 systems results from the analysis of other topics covered in this report. Maintaining a proper vertical distance between the ground water and the infiltrative surface of leaching systems, and applying the effluent at a rate that will allow sufficient detention for adequate treatment to be achieved are critical elements in the design of subsurface sewage disposal systems. However, some contaminants such as nitrate-nitrogen are not adequately treated by the conventional septic tank/soil absorption system. The only way to diminish the impacts of nitrate-nitrogen and other similar solutes that are not effectively removed in the subsurface environment is by allowing sufficient land area for dilution in the ground water.

In this chapter we have evaluated the land area needed to achieve dilution. The research to date suggests that proper assimilation of the sewage discharged by the inhabitants of a single family dwelling would require approximately one acre of land. Additional refinement of the input parameters may be warranted in certain instances to account for variable site conditions such reduced or increased rates of natural recharge. It may, therefore, be necessary to reduce the current septic system density in sensitive environmental areas to diminish the possibility of adverse impacts to the environment.

The ground water and surface water contamination experienced in towns across the Commonwealth is often blamed on the inadequacy of septic systems. While many subsurface sewage disposal systems in the state may be inadequate, we must also face the problem that there is simply an overabundance of septic systems, particularly along the coast and adjacent to inland waters.

A septic system density of 110 gallons per quarter acre (440 gallons per day per acre) of land controlled by the proponent should be considered as a new construction review threshold for the Department of Environmental Protection and MEPA. Alternate density limits should only be considered for projects for which the proponent has performed a detailed hydrogeologic assessment demonstrating that the effluent would be sufficiently diluted prior to reaching any downgradient receptors.

The U.S. Environmental Protection Agency and the Massachusetts Division of Water Supply have suggested that imposing minimum lot sizes in areas utilizing septic tank/soil absorption systems may be beneficial to the preservation of ground water quality and public water supplies. We see this as only a partial solution. Every effort should also be made to reduce the number of conventional septic systems in environmentally sensitive areas, areas where individual private water supplies are used, and in zones of contribution to public water supplies (Zone II's).

Defining the area over which the densities should be calculated and the manner in which specific upgrades should be addressed is beyond the scope of this project and will demand further study. However, we suggest that density controls be considered for at least the following general resource areas:

Interim Zone II's;
DWS approved Zone II's;
Sole Source Aquifers;
Areas Supplied by Private Wells;
Areas of Critical Environmental Concern; and
Coastal Areas as defined by Coastal Zone Management;

It is not our intent to penalize the individual land owner in these sensitive areas, but to focus the attention of governmental agencies on areas where, because of the concentration of septic system use, there is an increased potential of degradation of environment resources. This is a problem that extends beyond the individual homeowner and therefore must be addressed on a regional basis.

To provide focus on this issue we suggest that the Department through both the Bureau of Resource Protection, and the Bureau of Municipal Facilities; and in conjunction with the Department of Environmental Management and the Office of Coastal Zone Management, develop a uniform strategy designed to address the density problem in environmentally sensitive areas[2]. These areas should be clearly delineated and action plans developed and implemented.

An example of the type of actions that may be implemented by the Department includes requiring the computation of septic system density and developing a wastewater management plan as a condition of Division of Water Supply approval of a Zone II study. Whenever the septic system density within a Zone II area is shown to exceed 110 gallons per quarter acre, the wastewater management plan should include a timetable addressing the reduction of the septic system density through the formation of wastewater management districts. These wastewater management districts would then be charged with evaluating problem areas and investigating alternative means of wastewater disposal.

The Department's Municipal Facilities Branch, might recommend the calculation of septic system density in critical areas for projects under its review. Based upon the results of these calculations attention could be focused on the possibility of unique wastewater solutions being developed for individual areas. Higher priority might be given to projects which address sewage disposal needs within environmentally sensitive resource areas.

Possibly the best way to address the issue of existing septic system densities is through the Ground Water Classification Program. The Department is currently considering changes to this program establishing Class IV ground waters that would be allowed to meet alternative standards for remedial actions taken under the Comprehensive Environmental Response Compensation and Liability Act, the Resource Conservation and Recovery Act, the Massachusetts Oil and Hazardous Materials Release Prevention and Response Act or the Massachusetts Contingency Plan (310 CMR 40.00). It may be advantageous to establish another class of ground water (Class IA) for waters that are considered environmentally sensitive. In order to be assigned the Class IA designation, the area would have to meet the septic system density requirements (as well as other criteria, established by the Department). Sole source aquifers and areas of critical environmental concern should be given priority consideration in this reclassification effort.

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2 The term "environmentally sensitive areas" is used throughout this document to indicate valuable resource areas deserving an added degree of environmental protection. The term is purposely used in a broad sense and is intended to include resource areas such as zones of contribution to water supplies, Areas of Critical Environmental Concern, certain marine embayments and fresh water bodies. The exact definition is expected to be determined by the Department of Environmental Protection depending on the types of controls it intends to adopt.

PART IV

DESIGN CRITERIA

CHAPTER 11

SEWAGE FLOW ESTIMATES

A fairly accurate understanding of wastewater flow rates is required in order to design an effective septic tank/soil absorption system. Since the amount of sewage discharged from residential dwellings, small commercial establishments and other facilities that utilize on-site systems for the disposal of sanitary wastewaters can exhibit wide variations over time, it is important to consider not only the average daily rate of flow at these establishments but the maximum daily and peak hourly rates as well.

The wastewater flows generated at existing establishments can be determined by taking actual measurements of the discharged wastewater. Where new facilities are involved, however, the flow rates must be predicted based upon data collected from other establishments. Historically, wastewater discharge rates have been obtained by interpolating data from water supply usage for a given facility type. This information is then supplemented with actual field measurements taken at similar installations. This procedure yields reasonably accurate estimates of the average flow rates and peaking factors which can then be utilized for design purposes.

The design of septic systems is often simplified by minimizing the number of actual design parameters. For example, although wastewater strength plays an essential role in operation of the subsurface sewage disposal system, the pollutant load is typically not considered as a separate item in the design process. Adjustments to the design flow rates are made instead to account for varying wastewater strengths. An example includes discharges from restaurants which commonly exhibit high biochemical oxygen demand and suspended solids content. The design flow rate for this type of establishment is increased to accommodate the higher organic loadings. Similarly, although water conservation devices can significantly reduce the volume of water discharged to a subsurface sewage disposal system, the corresponding increase in the wastewater strength negates the benefit created by any reduction in flow.

The purpose of this section is to provide a basis for flow determinations for different types of suburban and rural developments. A detailed analysis of residential wastewater is presented first, followed by a limited discussion of wastewater flows generated by non-residential establishments, including commercial, institutional and recreational facilities. Finally the method of determining design flow rates in Title 5 is reviewed and suggestions for modifications are made where appropriate.

11.1 Literature Review

The volume of water discharged to a septic system is a key parameter utilized in the sizing of the system. Understanding flow rates from different types of facilities, not only enables proper design, but also allows the development and implementation of various water conservation and waste minimization efforts (USEPA, 1980b).

It has long been recognized that the volume of water supplied to an establishment is directly related to the quantity of wastewater generated. This is only a generalization however, as different water use practices can create flow patterns that vary significantly in both volume and contaminant strength (Siegrist et al., 1976). The flow characteristics of wastewater can have a profound effect on the performance of septic systems and therefore must be considered prior to the design and construction of a disposal system.

Residential Wastewater Flow Rates

Moderate domestic water use increases were observed during the 1960's and 1970's due in part to an increase in the utilization of modern appliances, particularly in the kitchen and laundry areas. Over the past decade, water use has remained relatively constant with slight decreases documented in certain areas. These reductions have been attributed to the national water conservation movement which resulted in the general acceptance of water saving devices such as flow restricters and low flush toilets.

There are five major ways in which the water, utilized within the home, contributes to wastewater flows. These include toilet usage, clothes washing, bathing, dish washing and water conditioning. These uses not only produce different amounts of flow, they also produce vastly different types of wastes.

Water use varies considerably between individuals depending on a number of factors including background, age, and economic status. Teenagers, for example, are notoriously high water users. The use of hot tubs or water circulating devices for therapeutic purposes is another example where substantial increases over normal water usage might be expected.

The wastewater discharged from residential dwellings, including single and multi-family households, condominiums, apartments and cottages, is comprised of a number of individual wastestreams generated through activities utilizing various plumbing fixtures and appliances. The flow and strength of the wastewater is influenced by the type of fixtures and appliances, and the frequency of their use. The type of dwelling, geographic location, and method of water supply also affect wastewater characteristics.

The U.S. Public Health Service (USPHS) conducted a detailed study for the Select Committee on Natural Water Resources of the United States Senate in 1954 and found that, on a national basis, the average water consumption was approximately 147 gallons per capita per day (Metcalf & Eddy, Inc., 1979). In a 1970 USGS survey of major public water supplies, the national average water usage rate was determined to have increased to approximately 166 gallons per capita per day (gpcd).

These averages reflected the total water use divided by the total population. Approximately 30 percent of the total water demand can be attributed to domestic use, with the remainder utilized for industrial and commercial purposes. This equates to an average daily domestic water use in 1970 of approximately 50 gpcd. Eighty percent of the per capita water use becomes sewage with the other twenty percent used for lawn watering, car washing and other consumptive uses. Therefore, using this method, the average daily sewage flow rate is on the order of 40 gpcd.

Another method for determining wastewater discharge rates is by taking actual field measurements at a representative number of installations for an extended period of time. A number of such studies have been made throughout the country. As a result of these efforts, it has been determined that the single largest component of sewage flow results from the use of flush toilets, with laundry and bathing tied for second. This is illustrated in Table 11.1.1 produced from data presented in a study by Siegrist et al. (1976).

The average daily flow per person in a normal single family residence, tabulated from these and other studies, is summarized in Table 11.1.2. This information indicates an average daily sewage flow rate of approximately 44 gpcd. Several studies indicate that the sewage discharge rates can be characterized by a base amount for the entire family plus an individual component (Orndorff, 1966).

TABLE 11.1.1

WATER USE COMPARISON, IN PERCENTAGES
(Derived from selected sources in the published literature)

Source:	1	2	3	4	5	6	7	8
Toilet	41	45	47	41	45	38	33	22
Laundry	4	5	18	19	18	12	27	25
Bath	37	30	21	26	36	34	24	23
Kitchen	6	6	9	10	13	10	16	11
Cleaning	3	4		1		3		
Drinking	5	3		3		3		
Miscellaneous	4	7	5	0	6	0		18

References:

1. "Public Water Supplies of the 100 Largest Cities in the United States", U.S. Geological Survey Water Supplies Paper No. 1812, 1962.

2. Haney, P.D., and Hamann, C.L., "Dual Water Systems,", Journal of American Water Works Association, Vol. 57, September, 1965.

3. Laak, R. "Relative Pollution Strengths of Undiluted Waste Materials Discharged in Households and the Dilution Waters Used For Each", Manual of Grey Water Treatment Practice - Part II, Monogram Industries, Inc. Santa Monica, Calif., 1975.

4. Ligman, K., "Rural Wastewater Simulation", thesis presented to the University of Wisconsin at Madison, Wisc., in 1972.

5. Wallman, H., "Should We Recycle/Conserve Household Wastewaters", 6th International Water Quality Symposium, Washington, D.C., April 18-19, 1972.

6. Besik, J.K., "Remarks", Ontario Research Foundation, Ontario, Canada, May, 1973.

7. Bennett, E. R., and Linstedt, D.k., "Individual Home Wastewater Characterization and Treatment", Completion Report Series No. 66, Environmental Resources Center, Colorado State University, Fort Collins, Colo., July 1975.

8. Siegrist, R., Witt, M., and Boyle, W.C., "Characteristics of Rural Household Wastewater", Journal of The Environmental Engineering Division ASCE, June 1976.

FIGURE 11.1.1
DAILY HOUSEHOLD WATER USE

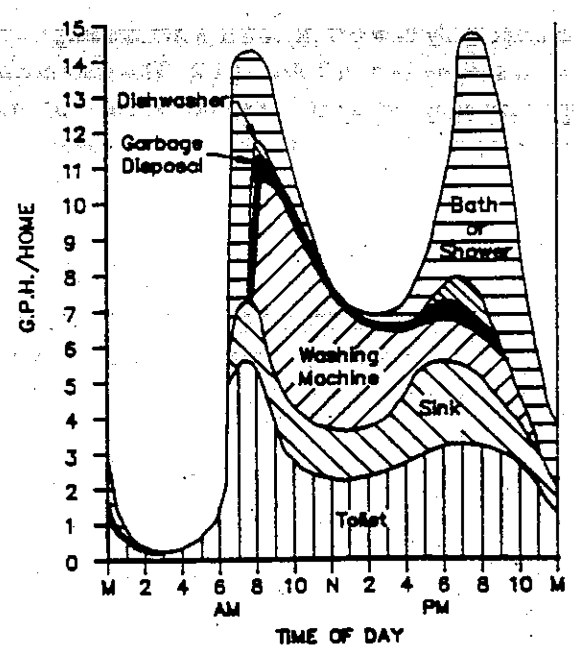


TABLE 11.1.2

SUMMARY OF AVERAGE DAILY RESIDENTIAL WASTEWATER FLOWS
(Adapted from EPA, 1980)

Study	No. of Residences	Duration of Study Months	Wastewater Flow Average gpcd	Wastewater Flow Range gpcd
Linaweaver, et al.	22	-	49	36 - 66
Anderson and Watson	18	4	44	18 - 69
Watson, et al.	3	2 - 12	53	25 - 65
Cohen and Wallman	8	6	52	37.8 - 101.6
Laak	5	24	41.4	26.3 - 65.4
Bennett and Linstedt	5	0.5	44.5	31.8 - 82.5
Siegrist, et al.	11	1	42.6	25.4 - 56.9
Otis	21	12	36	8 - 71
Duffy, et al.	16	12	41.3	-
	WEIGHTED AVERAGE		44	

The actual wastewater volume discharged from an individual dwelling on any single day is typically within the range of 50 to 150 percent of the average daily flow. Extreme values from as little as 0 to as much as 900 percent may be encountered (Anderson and Watson, 1967; Watson et al., 1967). Sewage flow rates can also vary significantly during the course of a day. Although peak hourly flows are more difficult to quantify, typical fixture and appliance usage characteristics would suggest a peak hourly rate in the order of 100 gallons/hour (USEPA, 1980b).

Since, individual water-using activities occur intermittently and the strength of the wastewater fluctuates with time, the design of septic systems must take into account both peak and sustained flows. The peak flow is a function of the characteristics of the fixtures and their position in the overall plumbing system (EPA, 1980b). Proper septic tank sizing, providing for flow attenuation, is used to offset the adverse effects that daily flow peaks would otherwise have on the soil absorption system.

Maximum daily flows, on the other hand, are estimated by multiplying a safety factor to increase the average flow rate. The general practice is to use a value of 75 gallons per person per day for sewage disposal system design. This practice is endorsed by the University of Wisconsin, Small-Scale Waste Management Project and the EPA in their Design Manual for On-site Wastewater Treatment and Disposal Systems. Using 75 gpcd as the design basis for residential dwellings provides a fifty percent increase in the actual average daily flow. This factor has been deemed sufficient for accommodating the typical maximum daily sewage flow generated at residential dwellings.

In characterizing wastewater, quantitative characteristics are often expressed in terms of other easily determined parameters. For residential dwellings the design units can be expressed on a per capita basis. Applying the per capita data to predict total residential flow characteristics requires a second parameter be considered, the number of persons living at the residence. The number of residents is often difficult to predict due to varying family size; therefore, the number of bedrooms within the dwelling is frequently used to determine the maximum occupancy potential. The average occupancy of residential units typically ranges from 1.0 to 1.5 persons per bedroom (USEPA, 1980b). In order to provide for a conservative estimate, the current practice is to assume that maximum occupancy is at least 1.5 persons per bedroom.

Some authors suggest the use of two persons per bedroom as an appropriate estimate of the occupancy of a dwelling. When this is done, the safety factor applied against the average per capita sewage flow rate should be reduced so that the design rate does not become overly conservative. Great care must be exercised in predicting wastewater flows so as not to accumulate multiple factors of safety which would yield extremely conservative estimates. One must remember that the formation of a sufficient biomat clogging layer is dependent on the hydraulic and organic characteristics of the discharged wastewater. Oversizing of the soil absorption area can adversely affect the formation of the biomat, thereby reducing the overall treatment efficiency of the system.

Non-residential Wastewater Flow Rates

There are a variety of commercial, institutional and recreational facilities which use on-site sewage disposal systems for the discharge of sanitary wastewaters. Although the sources of wastewater at these establishments are very similar to those in a residential dwelling, the mixed use of the various appliances and fixtures results in considerably different wastewater characteristics.

Characterizing typical wastewater discharges for non-residential establishments is a much more complex task than that for residential dwellings. These establishments include a diverse number of facilities such as fast food chains, convenience stores, bars, restaurants, hospitals, schools, etc. To group these diverse establishments within the same category would produce a potential for large variations in wastewater characteristics. Additionally, many intangible influences such as location, popularity and price can result in substantial differences in the volume and strength of the discharged sewage.

Physical differences in the various types of establishments also make it difficult to generalize. Different units of measurements are necessary in order to accurately estimate the total sewage discharge rate based on the type of service provided. The wastewater generated at restaurants for example is typically calculated based upon the number of seats, while square footage is used for most retail establishments.

While difficult to accurately quantify, an estimate of the average discharge rates and the magnitude of fluctuations including minimum and maximum flows on an hourly and daily basis, can be derived from the number and types of water-using fixtures and appliances at a facility, in conjunction with data on the facilities' operation.

Peak wastewater flows can be estimated utilizing the fixture-unit method (WPCF, 1976). This method is based on the premise that under normal usage, a given type of fixture exhibits an average flow rate over the period of use. An arbitrary flow of 7.5 gallons per minute has been assigned to one fixture unit. Various fixtures are then assigned a certain number of fixture units based upon their particular traits. Table 11.1.3 provides a listing of the fixture units for typical fixtures. Use of this method in conjunction with actual testing at a wide variety of establishments has resulted in the development of typical design flow rates for different commercial, institutional and recreational facilities. Typical rates adapted from the USEPA Design Manual - On-site Wastewater Treatment and Disposal Systems are presented in Table 11.1.4.

For non-residential establishments, wastewater flow characteristics can be expressed in terms of a variety of units. Per capita units are often employed as are units which represent the physical character of the establishment, such as per seat, per service bay, and per square foot. Wherever possible, wastewater characterization data specific to the particular establishment in question or a similar nearby facility, should be obtained to supplement the generic information presented in the standard tables.

Current Method of Calculating Design Flow

Wastewater flow is addressed under the current Title 5 regulations in section 310 CMR 15.02 (13) which requires; "... The volume of such flows should be based on the estimated maximum contributory population and the resultant maximum expected daily quantities of sewage as determined from the table [in 310 15.02(13)] ..." The table in 310 CMR 15.02(13) lists the minimum design criteria for a number of different types of facilities. This table takes into account the average daily flow with the appropriate margin of safety.

In addition, the regulations provide a way to establish the wastewater flow for facilities not listed using the following criteria; "... Estimated sewage flows other than those listed should be considered in relation to actual meter readings of established flows from known or similar installations. Generally, estimated sewage flows will be based on 200 percent of average water meter readings in order to assimilate maximum daily flows ..."

For the most part, the use of the table in Title 5 provides a reasonably good means for determining sewage flow estimates. However, the flow rates provided in the table need to be reviewed to update the information based on recent data that has become available since the inception of Title 5. Several rates have been particularly problematic to the Department including those for fast food restaurants, service stations without gasoline pumps, and nursing homes. The flow estimates for these facilities in particular need to be evaluated.

TABLE 11.1.3

FIXTURE-UNITS PER FIXTURE

Fixture Type	
One bathroom group consisting of tank-operated water closet, lavatory, and bathtub or shower stall	6
Bathtub (with or without overhead shower)	2
Combination sink-and-tray	3
Combination sink-and-tray with food-disposal unit	4
Dental unit or cuspidor	1
Dental lavatory	1
Drinking fountain	1/2
Dishwasher, domestic	2
Floor drains	1
Kitchen sink, domestic	2
Kitchen sink, domestic, with food waste grinder	3
Lavatory	2
Lavatory, barber, beauty parlor	2
Lavatory, surgeon's	2
Laundry tray (1 or 2 compartments)	2
Shower stall, domestic	2
Showers (group) per head	3
Sinks	
Surgeon's	3
Flushing rim (with valve)	8
Service (trap standard)	3
Service (P trap)	2
Pot, scullery, etc.	8
Urinals	
pedestal, siphon jet, blowout	8
wall lip	4
stall, washout	4
trough (each two foot section)	2
Wash sink (circular or multiple) each set of faucets	2
Water Closets	
tank-operated	4
valve-operated	8

TABLE 11.1.4

TYPICAL WASTEWATER FLOWS FROM RECREATIONAL SOURCES

Source	Unit	Range	Wastewater Flow Typical gpd/unit
Apartment,Resort	Person	52.8 - 74	58.1
Cabin, Resort	Person	34.3 - 50.2	42.3
Cafeteria	Customer	1.1 - 2.6	1.6
	Employee	7.9 - 13.2	10.6
Campground	Person	21.1 - 39.6	31.7
Cocktail Lounge	Seat	13.2 - 26.4	19.8
Coffee Shop	Customer	4.0 - 7.9	5.3
	Employee	7.9 - 13.2	10.6
Country Club	Member	66.0 - 132	106
	Employee	10.6 - 15.9	13.2
Day Camp (no meals)	Person	10.6 - 15.9	13.2
Dining Hall	Meal	4.0 - 13.2	7.9
Dormitory	Person	19.8 - 46.2	39.6
Hotel, Resort	Person	39.6 - 63.4	52.8
Laundromat	Machine	476 - 687	581
Store Resort	Customer	1.3 - 5.3	2.6
	Employee	7.9 - 13.2	10.6
Swimming Pool	Customer	5.3 - 13.2	10.6
	Employee	7.9 - 13.2	10.6
Theater	Seat	2.6 - 4.0	2.6
Visitor Center	Visitor	4.0 - 7.9	5.3

TABLE 11.1.4 CONTINUED

TYPICAL WASTEWATER FLOWS FROM INSTITUTIONAL SOURCES

Source	Unit	Range	Wastewater Flow Typical gpd/unit
Hospital, Medical	Bed	132 - 251	172
	Employee	5.3 - 15.9	10.6
Prison	Inmate	79.3 - 159	119
	Employee	5.3 - 15.9	10.6
Rest Home	Resident	52.8 - 119	92.5
	Employee	5.3 - 15.9	10.6
School, Day:			
With Cafeteria,Gym, & Showers	Student	15.9 - 30.4	21.1
Cafeteria Only	Student	10.6 - 21.1	15.9
Without Cafeteria, Gym, & Showers	Student	5.3 - 17.2	10.6
School,Boarding	Student	52.8 - 106	74.0

TABLE 11.1.4 CONTINUED

TYPICAL WASTEWATER FLOWS FROM COMMERCIAL SOURCES

Source	Unit	Range	Wastewater Flow Typical gpd/unit
Airport	Passenger	2.1 - 4.0	2.6
Automobile Service	Vehicle Served	7.9 - 13.2	10.6
	Employee	9.2 - 15.8	13.2
Bar	Customer	1.3 - 5.3	2.1
	Employee	10.6 - 15.8	13.2
Hotel	Guest	39.6 - 58.0	50.1
	Employee	7.9 - 13.2	10.6
Industry	Employee	7.9 - 17.2	14.5
Laundry (self-serve)	Machine	475 - 686	580
	Wash	47.5 - 52.8	50.1
Motel	Person	23.8 - 39.6	31.7
Motel with Kitchen	Person	50.2 - 58.1	52.8
Office	Employee	7.9 - 17.2	14.5
Restaurant	Meal	2.1 - 4.0	2.6
Rooming House	Resident	23.8 - 50.1	39.6
Store Department	Toilet room	423 - 634	528
	Employee	7.9 - 13.2	10.6
Shopping Center	Parking Space	0.5 - 2.1	1.1
	Employee	7.9 - 13.2	10.6

11.2 State Regulations

Most states utilize a method similar to the one in Title 5 for estimating sewage flow rates. Most states' septic tank regulations almost exclusively include a table of established flow rates for various facility types. Generally, these tables have been developed based upon the information presented in a text book developed by Metcalf & Eddy, Inc. entitled "Wastewater Engineering, Collection, Treatment and Reuse".

For single family residential housing the sewage flow estimates are generally based on the number of bedrooms. Arkansas sets base flow at 75 gallons per day (gpd) per bedroom, while Wyoming and Michigan use 150 gpd/bedroom. The state of Washington has established a 200 gpd/bedroom design standard.

Other states, such as Vermont have a decreasing, graduated scale for sewage flow per bedroom. For a one bedroom unit the flow is estimated at 150 gpd/bedroom, 260 gpd is used for a two bedroom dwelling, the flow estimate for a three bedroom dwelling is 325 gpd, four is 390 gpd, and five is 455. Above five bedrooms, sixty-five gallons per day is added for each additional bedroom.

Many of the sewage flow tables included similar estimates. One notable exception is the flow from mobile homes, which averages between 150 - 200 gpd for most states, while in North Dakota it is 250 gpd and Wyoming uses 350 gpd.

Some states like Michigan will accept actual flow measurements from similar types of facilities that are not included in their sewage flow estimation table.

11.3 Local Regulations

Of the towns that currently have additional regulations on file with the Department of Environmental Protection, eighteen have requirements that relate to the estimation of sewage flow. Almost all of these eighteen cities and towns have increased sewage flow requirements for residential dwellings.

Scituate reinforces the Title 5 value of 110 gpd/bedroom. The town of Natick has set design sewage flow rates at 75 gallons/person/day, with a minimum of two persons per bedroom which results is 150 gpd/bedroom. This value is also required in the towns of Mansfield and Pepperell. The towns of Norwell, Duxbury, Pembroke and Carver have set the sewage design flow rate at 200 gpd/bedroom.

East Bridgewater requires 150 gpd/bedroom for percolation rates greater than 15 minutes/inch. While the towns of Rochester and Plymouth, require a minimum design rate of 400 gallons per day per dwelling.

11.4 Conclusions and Recommendations

Predicting wastewater characteristics for different types of facilities can be a difficult task. An established procedure can help simplify this process by providing fairly accurate estimates of wastewater flow rates.

Title 5 includes a universally accepted procedure for estimating sewage flow rates for the design of new facilities. However, the table in Title 5 needs to be amended slightly to include various new types of commercial establishments. Several additional categories should be added to the table, including fast food restaurants, and service stations that do not sell gasoline. Additionally, the flow estimates for mobile homes that are now larger and contain more appliances, and for nursing homes need to be revised based on current information. Recommended changes to the table are included in bold in Table 11.4.1.

It is important to note that wastewaters other than sewage should not, under any circumstances, be discharged to septic systems. In some areas floor drains from both industrial facilities and service stations are tied into the septic system thereby presenting a potential for the discharge of non-sanitary wastewaters to the ground. These types of wastes might include waste oils and other hazardous materials listed in 310 CMR 40.300, "The Massachusetts Oil and Hazardous Materials List". In addition, embalming room wastes from funeral homes; x-ray waste from dentists offices, doctors offices, health clinics, and hospitals; photographic waste from photo developers and home dark rooms; and, laboratory waste from schools and commercial analytical laboratories should not be discharged to a septic system.

Table 11.4.1

REVISED SEWAGE FLOW ESTIMATES[1]

TYPE OF ESTABLISHMENT	UNIT	GALLONS PER DAY	MINIMUM GALLONS PER DAY
Single Family Dwelling	per bedroom	110	440
Multiple Family Dwelling	per bedroom	110	
Motel, Hotel, Boarding House	per bedroom	110	
School, without cafeteria, gymnasium or showers	per person	10	
School, with cafeteria but no gymnasium or showers	per person	15	
School, with cafeteria, gymnasium and showers	per person	20	
Boarding Schools, Colleges	per person	65	
Office Building	per 1000 sq.ft.	75	200
Retail Store	per 1000 sq.ft.	50	200
Amusement Center	per sq.ft.	2	1000
Service Station [no gas]	per bay	150	450
Gasoline Station with service bays	per island + per bay	75 125	300
Restaurant	per seat	35	1000
Restaurant, thruway service area	per seat	150	1000
Restaurant, Fast Food	per seat	20	1000
Restaurant, kitchen flow [for sizing grease trap only]	per seat	15	
Function Hall	per seat	15	
Lounge, Tavern	per seat	20	
Barber Shop/Beauty Salon	per chair	100	
Family Mobile Home Park	per site	300	
Retirement Mobile Home Park	per site	150	
Movie Theater	per seat	5	
Theater, Auditorium	per seat	3	
Bowling Alley	per alley	100	
Skating Rink	per seat	5	3000
Airport	per passenger	5	150
Country Club, dining room	per seat	10	
Country Club, snack bar or lunch room	per seat	10	
Country Club, lockers and showers	per locker	20	
Church	per seat	3	
Church, kitchen at capacity	per person	5	
Doctor Office	per doctor	250	
Dentist Office	per chair	200	
Nursing Home/Rest Home	per bed	150	
Gymnasium	per participant	25	
Gymnasium	per spectator	3	
Swimming Pool	per person	10	

Table 11.4.1 Continued

REVISED SEWAGE FLOW ESTIMATES[1]

TYPE OF ESTABLISHMENT	UNIT	GALLONS PER DAY	MINIMUM GALLONS PER DAY
Non-single family/automatic clothes washer	per washing machine	400	
Hospital	per bed	200	
Tennis Club	per court	250	
Camp, resident, washroom and toilets	per person	25	
Camp, resident, mess hall	per person	10	
Camp, day, washroom and toilets	per person	10	
Camp, day, mess hall	per person	3	
Camp Ground, showers and toilets	per site	100	
Trailer, dump station	per trailer	75	
Public Park, toilet waste only	per person	5	
Public Park, bathhouse, showers and flush toilets	per person	10	
Factory or Industrial Plant without cafeteria	per person	15	
Factory or Industrial Plant with cafeteria	per person	20	
Work or Construction Camp	per person	50	
Gasoline station	per island	75	300

(1) Estimated sewage flows other than those listed should be considered in relation to actual meter readings of established flows from known or similar installations. Generally, estimated sewage flows will be based on 200 percent of average water meter readings in order to assimilate a maximum daily flows.

NOTE: Laundromat wastes are considered industrial wastes and must be approved by the Department of Environmental Protection.

CHAPTER 12

SEPTIC TANKS

With the demise of the cesspool, the standard concrete septic tank, or variations and/or improvements thereof, has become the pretreatment option of choice for on-site wastewater disposal systems. The septic tank acts as a waste strength, temperature and flow equalization chamber designed to separate, store and diminish the quantity of floatable and settleable contaminants inherent to the liquid wastewater stream. The septic tank does not remove appreciable amounts of soluble BOD or non-settleable solids. The majority of the septic tank's organic waste strength reduction capability is accomplished by the removal of settleable biological material which accumulates on the bottom of the tank and comprises the sludge layer (Laak and Crates, 1977).

Although the septic tank does not appreciably reduce the total organic load of the wastewater, it protects the soil absorption system from excessive solids loads and minimizes the effects of shock loads and bulk solids overloading, thereby helping to prevent excessive clogging of the infiltrative surface and extending the life of the system. A properly treated septic tank effluent is essentially free of settleable suspended solids but will retain most of its non-settleable particles and soluble organic matter (Baumann et al., 1977).

12.1 Literature Review

A septic tank is separated into three distinct zones: a scum collection zone along the top, the wastewater equalization and settling zone, and a sludge accumulation zone along the bottom of the tank. In order to ensure proper function, all three zones of the septic tank must be appropriately sized. Wastewater introduction to, and effluent discharge from, the septic tank must be adequately controlled and specifically directed.

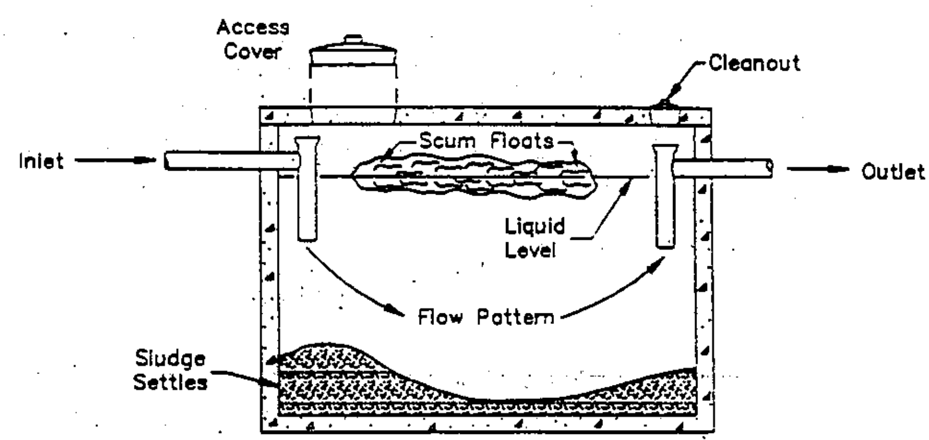
Garbage grinders have been found to result in an inordinately excessive accumulation of floatable and settleable matter within a septic tank, requiring alterations to the standard septic tank and soil absorption system design and operation. This chapter considers the only the requirements for septic tanks serving systems which are not equipped with garbage grinders.

<u>Grease and Scum</u>

The floatation zone collects and stores the floating grease and scum most abundantly contributed by kitchen wastes. This waste is not readily degradable and if not removed from the waste stream, would rapidly result in fouling and clogging of the discharge pipes and infiltrative surface of the soil

FIGURE 12.1.1

TYPICAL SEPTIC TANK (CUTAWAY VIEW)



Although not commonly present at concentrations significant enough to require the installation of grease traps, households can be expected to generate significant quantities of grease, scum and floatable solids. The installation of an inlet tee and an outlet tee enables this floatable matter to be entrapped within the septic tank. Title 5 requires that the inlet extend a minimum of 10 inches below the flow line whereas the outlet tee is required to extend below the anticipated scum floatation depth to a minimum depth of 14 inches below the flow line. This allows for the wastewater to be introduced to, and the clarified effluent collected from, the quiescent liquid settling zone which forms below the scum layer. The volume occupied by the scum is unavailable for liquid clarification, and therefore must be excluded from the calculation of available liquid detention time.

The available scum storage volume is dictated by the depth of the outlet tee below the flow line and the surface area of the tank. The floating scum will tend to dry out and harden, therefore digesting very slowly (Baumann et al., 1977). Because of this it is usually assumed that no scum digestion will occur within the septic tank and that the required floatable collection volume is only controlled by the influent concentration, capture efficiency and flow rate. A common domestic wastewater can be assumed to contain between 20 and 40 mg/l of floatable fats or grease (significantly more if garbage grinders are utilized). This concentration should result in the yearly accumulation of between 4 and 10 pounds of scum per person (Baumann et al., 1977). Typical design estimates allow for the collection of 1/3 to 2/3 ft^3/capita/yr (Laak and Crates, 1977). As the submerged scum volume in a domestic septic tank rarely exceeds 20 ft^3, a 10-inch inlet tee and 18-inch outlet tee should be sufficient to extend beyond the floatation depth (Baumann et al., 1977).

10 pounds of scum per person (Baumann et al., 1977). Typical design estimates allow for the collection of 1/3 to 2/3 ft^3/capita/yr (Laak and Crates, 1977). As the submerged scum volume in a domestic septic tank rarely exceeds 20 ft^3, a 10-inch inlet tee and 18-inch outlet tee should be sufficient to extend beyond the floatation depth (Baumann et al., 1977).

For any septic system designed to serve a facility in which the anticipated grease and scum load exceeds that normally attributed to a domestic wastewater, the use of a separate grease trap should be mandated with the floatable collection volume designed according to the influent grease, solids and hydraulic load. An increase in the design wastewater flow estimates is intended to offset the increased hydraulic, organic or suspended solids loads commonly anticipated from restaurants and many other non-domestic sources.

Sludge

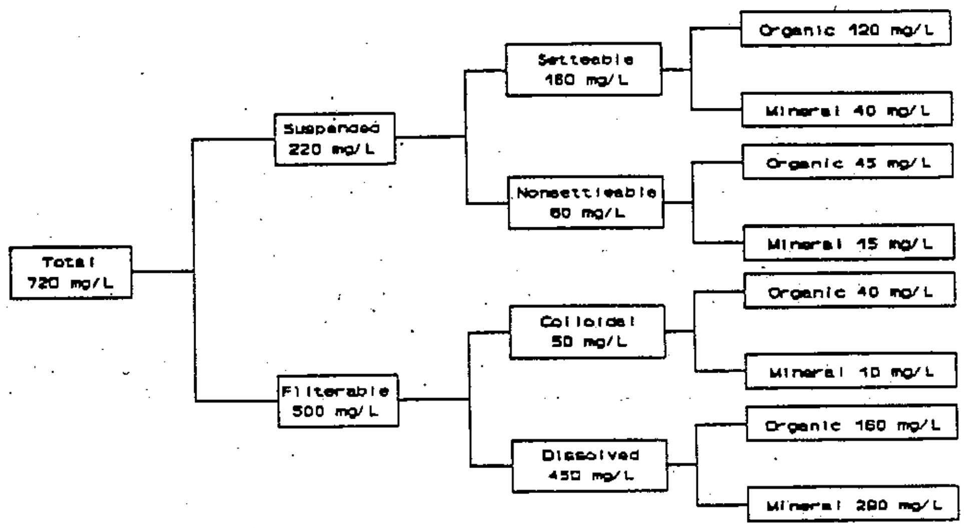
During proper operation, sedimentation contributes to the development of a sludge layer along the bottom of the tank. Under optimal conditions this organic layer would be comprised of all of the settleable solids which enter the septic tank. Upon accumulation, the captured solids undergo anaerobic biodegradation, a relatively slow degradation process which occurs in the absence of free oxygen and ultimately results in the transformation of organic matter into cellular material, carbon dioxide, methane, hydrogen sulfide, ammonia and water. This transformation of solid organic matter into liquid and gaseous matter, reduces the quantity of sludge to be disposed of (Baumann et al., 1977). The gaseous digestion products rise in the tank, hindering proper solids segregation and contributing to solids bulking and rising. This solids rise dictates the installation of a gas baffle below the outlet tee to minimize the detrimental discharge of solids to the soil absorption system.

It is important to remove solids before the sludge storage volume has been completely exhausted. Routine maintenance including a yearly pumping schedule is preferred to ensure that capacities remain and that blockage does not occur.

During most of the year the temperature within the septic tank is maintained in the mesophilic range (18 - 27°C). During the three to four month winter period the temperature within the tank is reduced to 4 - 10°C. Thermophilic bacteria become dominant and the rate of metabolic activity within the tank is decreased. This reduced metabolic activity during the winter months contributes to a lower organic removal efficiency and the discharge of a wastewater containing a relatively high concentration of BOD and suspended solids (Laak and Crates, 1977).

Bio-oxidation is much more efficient during the warmer months, but results in increased digestion gas production contributing to a rising or bulking sludge. The sludge volume, and required sludge storage depth, is increased 40 percent with a corresponding increase in the likelihood of bulk solids unloading (Laak, 1980).

Figure 12.1.2



Classification of solids found in medium-strength wastewater.
Metcalf & Eddy, 1979

Only the settleable portion of the suspended solids load of a wastewater is appreciable removed by a septic tank. The non-settleable (colloidal sized) and filterable portion of the total solids load is conveyed, essentially unchanged, to the soil absorption system. The organic settled solids undergo anaerobic biodegradation which effectively reduces the accumulated volume. The mineral portion of the settleable solids (ash) is not affected by biologic activity within the tank. This fraction, and the remaining undigested settled organic matter, comprises the sludge layer which accumulates along the bottom and requires periodic removal (Metcalf and Eddy, Inc. 1979).

Sludge accumulation has been estimated by the following simple design equation:

$$\text{Sludge Accumulation (gal/capita)} = 17 + 7.5t$$

$$t = \text{years since cleaning}$$

The required minimum sludge clear depth, (the minimum depth between the bottom of the outlet tee and the top of the accumulated sludge) is estimated by: (Laak and Crates, 1977, 798)

$$\text{Minimum Sludge Clear Depth (ft)} = 2.7 - 0.08\,A$$
$$A = \text{sludge surface area (ft}^2\text{)}$$

For design purposes 1 to 2 cubic feet of sludge can be expected to accumulate in one year from each person (Laak and Crates, 1977).

Hydraulic Detention Time

Septic tanks come in various sizes and shapes and incorporate many different design features and materials of construction. In Massachusetts, the standard septic tank consists of a simple single chamber concrete vault with an effective liquid capacity of not less than 150 percent of the design flow, but in no case less than 1,000 gallons. This size requirement results in a minimum initial liquid detention time of 36 hours (detention time = design flow + available tank volume). However, as the available solids and scum holding capacities are exhausted, the resultant detention time is very much reduced, and solids wash-out becomes more prevalent.

If there was not a minimum allowable septic tank size requirement in Title 5, a typical 3 bedroom house generating a design flow of 330 GPD would only require the installation of a 495 gallon septic tank (330 GPD x 150 percent). The 1,000 gallons minimum septic tank size enhances the liquid detention time for small system designs and results in a 72 hour initial liquid detention time. In addition to providing extended detention times, the 1,000 gallon minimum size also allows for the proper depth essential to optimize floatation, solids settling and separation (minimum depth allowed by Title 5 is four feet) while maintaining an adequate surface area for liquid storage volume, flow equalization and the minimization of short-circuiting.

With extended detention times, some of the soluble BOD interacts with digesting sludge and is converted to cellular material - measured as volatile suspended solids, VSS (Laak and Crates, 1977). Single compartment tanks exhibit a significant improvement in effluent quality as the detention time is increased from 24 to 48 hours. Effluent quality improvement is not as significant with enlargement beyond this level. Increasing the liquid detention time within the septic tank improves the BOD and volatile solids removal by promoting anaerobic digestion, whereas the construction of outlet baffles affects the suspended solids removal and settleable solids retention (Laak, 1980).

Inlet/Outlet Design

Proper configuration of the inlet and outlet devices may be the most essential component of septic tank design. The inlet must be designed in order to introduce the liquid below the accumulated scum layer in the quiescent liquid settling zone. Some mixing with accumulated solids is preferred as this will promote soluble BOD reduction and filtration of a portion of the non-settleable suspended solids.

Imhoff-type septic tanks have been promoted as being a cure for the solids unloading characteristics afflicting many septic tanks. These tanks introduce wastewater into an upper compartment which is protected from interaction with the settled sludge. While separating the liquid and solids portions of the tank improves the bulk solids unloading characteristics, eliminating influent mixing with settled sludge sacrifices the filtration step necessary for the removal of colloidal matter. This results in the production of a more turbid effluent (Laak, 1980).

The septic tank inlet should be a tee, with the bottom extending below the scum layer and the top vented and protected from obstruction. The inlet tee, and household wastewater vent, provides the septic tank with a means of releasing digestion gasses to the atmosphere. Methane production from a domestic septic tank has been estimated at approximately 10 ft^3/capita/day (Laak and Crates, 1977). Methane gas, when mixed with oxygen at the proper concentration (15 - 25 ppm CH_4) is explosive, whereas another of the prominent digestion gasses, hydrogen sulfide, is toxic. The invert of the inlet should be situated at least 1/2 pipe diameter (2 inch minimum) above the effluent invert in order to assure adequate free air space and vent capacity. Improperly installed inlet tees have been noted to oftentimes be the cause of blockage. It is therefore imperative that inlet and outlet tees be inspected to ensure proper installation and that they be regularly cleaned, and if necessary, repaired during septic tank pumping.

Proper design of the outlet tee is critical for the assurance of efficient septic tank treatment. The outlet tee must extend to a sufficient depth below the scum layer without causing interference with the solids blanket. The outlet must be properly sized to ensure that the liquid rising velocity within the tee does not exceed the solids settling velocity resulting in solids out-wash.

Another device that can aid in the prevention of solids discharge is the installation of a gas baffle below the outlet tee. This device can prevent digestion gasses, and accompanying sludge, from rising up into the outlet tee. Tanks constructed with gas baffles consistently perform superior to tanks only equipped with outlet tees (Laak, 1980).

TABLE 12.1.1

**Comparison of Effluent
Biochemical Oxygen Demand and Suspended Solids
For Different Tank Designs**

	Effluent Concentration (mg/l)	
Tank Configuration	BOD	SS
Gas Baffle	80	28
Double-compartment tank	101	40
Single-chamber tank	110	38

(3) - 1,000 gallon tanks loaded at 200 gallons per day

Similar to the inlet tee, the effluent tee must be vented to promote steady laminar flow and to prevent gas bubble entrapment or siphoning (Baumann et al., 1977). A properly vented tee should extend 6 - 12 inches above the water flow surface (Laak and Crates, 1977) with at least a 3 inch clear space provided to the top of the tank.

Hydraulic Considerations

A septic tank acts as a flow equalization and storage device. High velocity, short duration wastewater flows entering the tank do not necessarily correspond to equally excessive outlet flow rates. The large surface area of the tank promotes wastewater storage and effluent discharge at a reduced flow rate. Typically the highest influent flow rate is provided by the toilet which discharges 4 gallons of water at approximately 35 gallons per minute. As this water enters the septic tank it causes a water level rise of approximately 1/5 inch for a standard 4 feet by 8 feet tank. If this were the only flow occurring at that time, a standard four inch diameter outlet pipe set at a reasonable slope, would exhibit a maximum discharge rate of only 0.21 gallons per minute (Baumann et al., 1977).

The available storativity within a septic tank is a function of many parameters including the surface area of the tank, the configuration of the tank inlet and outlet, the available drop between inlet and outlet inverts and the outlet pipe slope and diameter. An effluent pipe constructed at an elevation equal to, or slightly above, the inlet pipe will not provide the tank with sufficient free storage volume. Likewise, a larger tank surface area provides a greater storage volume, leading to a lower effluent flow rate and reduced velocity gradients within the tank. Therefore a large surface area and an adequate elevation drop between inverts is desired.

Sedimentation Theory

Suspended solids heavier than water are removed by gravitational sedimentation within the quiescent liquid settling zone. For each particle size and density there is a unique settling velocity which, along with relevant sedimentation tank parameters, determines the settling rate and capture efficiency. Sedimentation has been described as following four steps: Discrete Particle Settling (Type I), Flocculent Settling (Type II), Hindered or Zone Settling (Type III), and Compression Settling (Type IV).

Type I is the settling of discrete, non-flocculating non-interacting, particles which occurs according to the ideal sedimentation laws developed by Newton and Stokes. These laws equate the gravitational force, the frictional drag force and a shape and flow regime induced drag coefficient to develop an estimation of the terminal settling velocity of each particle. Under ideal conditions, all particles with a terminal settling velocity greater than the design settling velocity (liquid depth ÷ detention time) of the basin, will be captured in the sludge layer. Under actual, non-ideal conditions, turbulence, velocity gradients and short circuiting lowers the actual sedimentation efficiency (Metcalf and Eddy, Inc. 1979).

A portion of the particles with terminal settling velocities less than the design settling velocity will be captured. This removal fraction is directly proportional to the particle settling velocity divided by the basin design settling velocity; $X_r = V_p \div V_c$ (Metcalf and Eddy, Inc. 1979).

Type II, flocculent, or non-discrete, settling occurs when two or more particles coalesce during sedimentation to form a floc. Due to the added mass, the floc generally settles faster than the individual particles. In this manner, many small particles not capable of settling alone can be removed from the effluent (Metcalf and Eddy, Inc. 1979).

The degree to which hindered settling and compression settling occurs helps to determine the sludge thickness, density and percent solids. Concentrated solids within the hindered settling region act as a relatively stationary sludge blanket. As the sludge blanket descends, liquid and gasses provide a buoyant force to partially off-set the settling velocity. At the bottom of the sludge layer, inter-particle attraction results in a compression settling zone (Metcalf and Eddy, Inc. 1979).

Multi-chamber Septic Tanks and Multiple Tanks in Series

Title 5 allows the installation of two tanks in series, but requires that the first tank be sized according to the single tank criteria (150 percent of design flow, 1,000 gallon minimum). While this is not a bad design basis, it does not provide any incentive for the installation of the second tank. Two compartment tanks with transverse baffles are also permitted by Title 5.

Studies have determined that multi-compartment tanks with detention times ranging from 24 to 48 hours have a stable effluent comparable to that achieved by single-chamber tanks with 96 to 192 hour detention times. Multi-compartment tanks have a greater potential of reducing short circuiting and turbulence, producing a less turbid effluent containing up to 50 percent less suspended solids and BOD. An improvement in the suspended solids capture and removal efficiency from 75 percent to 85 percent results in approximately a 20 percent reduction in the suspended solids load imparted on the soil absorption system (Laak, 1980).

All septic tanks appear to work better with extended liquid detention times, with double compartment tanks providing the most consistently favorable results. Additional tests on double compartment tanks sized for 26, 48 and 72 hour detention times indicated that the largest tank size performed the best and that the minimum size of first compartment is more important than the size of second (Laak, 1979).

Two compartment tanks, and two tanks in series, should be designed with a 2:1 compartment size ratio (Baumann et al., 1977) with the first compartment providing a minimum 36 hour liquid detention time. The 2:1 size ratio provides a dampening effect, serving to reduce the adverse incidence of turbulence inducing, volume oscillations between the two compartments (Baumann et al., 1977).

Efficient inlet and outlet baffling and adequate detention time are more important than the number of tank compartments. Multi-compartment tanks without inlet and outlet baffles were determined to be 10 - 20 percent less efficient than similarly sized single-compartment tanks equipped with baffles. Four inch high horizontal slots between compartments were found to be ineffective, with a vented inverted U-fitting preferred (Laak, 1980).

The optimum septic tank design appears to be a two compartment design in which the first compartment provides the majority of the detention time. The compartments should be connected by a vented inverted U shaped pipe or tee, not the transverse baffle design currently prescribed by Title 5. The tees should extend below the scum level while providing a suitable sludge clear depth. Gas baffles should be provided to eliminate unloading of sludge and improve the effluent quality (Laak, 1980).

Septic Tank Siting Criteria

For ease of repair, septic tanks should be sited a minimum of ten feet from buildings and property lines. Adequate cover must be maintained to prevent temperature fluctuations and to protect the tank and distribution system from surface loads. In areas subject to vehicular traffic the tank and pipe system must be designed to handle at least an H-20 loading.

The tank base and backfilled excavation must be suitably compacted and the surface graded so as to direct water away from the tank. The bottom of the tank located above groundwater or the tank should be suitably anchored to prevent buoyancy. Septic tanks should be watertight both to prevent the escape of improperly treated wastewater and to prevent surface or ground water inflow which can drastically increase the hydraulic load directed to the soil absorption system.

12.2 State Regulations

Table 12.2.1 provides a compilation of the septic tank requirements in other states. The required septic tank detention time and the minimum capacity are listed along with the requirements for the use of multi-compartment tanks and tanks in series.

For the states that assign minimum requirements, sizes range from a low of 750 gallons to a high of 1,000 gallons with minimum detention times ranging between 24 and 48 hours.

TABLE 12.2.1

SEPTIC TANK REQUIREMENTS

	MINIMUM HYDRAULIC DETENTION TIME (Hrs)	MINIMUM CAPACITY (Gallons)	2-COMP. TANKS REQUIRED	TANKS IN SERIES ALLOWED	COMMENTS
Alabama	48	750	Y	2 Max.	
Alaska	24	1,000	N		
Arkansas	48	750			
Arizona	38	960	Y		
California	24	750(1)	N		
Colorado	30	750	Y	Y	
Connecticut	24	1,000	Y(2)	2 Max.	
Delaware	24	1,000	Y		
Florida		750			
Georgia					Regulations unavailable
Hawaii					No design criteria given
Idaho	48	900	N	Y	
Illinois		750	N	Y	
Indiana		750	N	Y	
Iowa	24	750	Y		
Kansas					Regulations unavailable
Kentucky		750	N	Y	
Louisiana					Regulations unavailable
Maine		750	N	2 Max.	
Maryland		750(3)	N		
Massachusetts	36	1,000	N	Y	
Michigan	24	1,000	Y(4)		
Minnesota		750	N	4 Max.	
Mississippi					No design criteria given
Missouri		1,000	N	4 Max.	
Montana		900	N		
Nebraska		1,000	Y(5)	4 Max.	
Nevada		1,000	N		
New Hampshire		1,000	N	2 Max.	
New Jersey		900	N		
New Mexico					No design criteria given
New York		750	N		
North Carolina		900	N		
North Dakota		1,000			
Ohio		1,000	N	2 Max.	
Oklahoma		1,000	N		
Oregon	36	1,000			
Pennsylvania					No design criteria given
Rhode Island	48	1,000	N	Y	
South Carolina		890	N		
South Dakota		1,000	Y(5)		
Tennessee		750	Y		
Texas		750	Y	2 Max.	
Utah		1,000(2)	N	3 Max.	
Vermont		1,000	N		
Virginia					Regulations unavailable
Washington		750	Y		
West Virginia		750	N		
Wisconsin		750	N	4 Max.(6)	
Wyoming		1,000	N		

(1) Counties determine minimum septic tank capacity.
(2) Required on septic tanks larger than 2,000 gallons.
(3) Includes use of garbage grinders.
(4) Required on septic tanks larger than 4,000 gallons.
(5) Required on septic tanks larger than 3,000 gallons.
(6) With state approval.

Y = Yes
N = No

12.4 Conclusions and Recommendations

While aerobic pretreatment tanks and cesspools have been utilized with various degrees of success, septic tanks remain the pretreatment option of choice for on-site wastewater disposal systems. For single family domestic systems, without garbage grinders, a single compartment tank with a minimum 48 hour liquid detention time (design daily flow ÷ clear liquid volume; total tank volume below flow line less the scum and sludge storage volume) should be sufficient. The minimum acceptable tank size should remain 1,000 gallons. This tank must be equipped with inlet and outlet tees and the outlet tee must be protected by a suitable gas baffle designed to minimize solids outwash.

For systems with garbage grinders, non-single family domestic systems, or any system with a design flow exceeding 1,000 gallons, two compartment tanks or two tanks in series should be considered the preferred option. While the utilization of an increased size, single compartment septic tank will allow for additional attenuation of the increased hydraulic, organic and solids loads expected from these types of systems, a two compartment tank is preferred. The compartments should be interconnected by a 4 inch minimum diameter vented, inverted U shaped pipe. Gas baffles should adorn both compartment outlets. The first compartment should be sized for a 48 hour hydraulic detention time, with the second providing an additional 24 hours.

The septic tank should be designed to provide the necessary scum and sludge storage volumes, while maintaining the required sludge clear depth and hydraulic detention time. The surface area at the flow line should be maximized and the materials of construction must be compatible with the waste and the anticipated surface loading. Inlet and outlet pipes should be appropriately sized, with a minimum diameter of four inches and a minimum slope of 2 percent. Manholes should be installed above all tees and brought to within 1 foot of grade. An as-built plan should be prepared explicitly detailing the septic tank location and design.

CHAPTER 13

SOIL ABSORPTION SYSTEMS

Proper design, installation and operation of a soil absorption system requires a complete understanding of the mechanisms involved in the transport and treatment of septic system wastes and the associated problems which may lead to system failure. A soil absorption system leaching facility is used to dispense the liquid septic tank effluent into the ground, and therefore must be constructed in soils capable of accepting, treating and dispersing the liquid. Effluent treatment and purification occurs underground as a result of the complex inter-related processes of filtration, adsorption and bio-oxidation. The biomat formed at the soil-gravel interface surrounding the disposal facility serves to filter the effluent and initiate the break-down of organic matter and the immobilization of inorganic compounds.

The rate at which septic tank effluent is applied to a subsurface soil absorption system directly influences the degree of treatment provided by the system and has a great impact on the average life expectancy and the risk of system failure. A properly functioning soil absorption system must convey all of the wastewater to the subsurface while eliminating or significantly reducing the concentration of contaminants released to either the surface or subsurface environment. Failures have been attributed to systems which provide an insufficient hydraulic capacity, (resulting in surface ponding or leachate breakout) and to systems which provide an inadequate degree of contaminant removal. Inadequate contaminant removal usually eludes detection until degradation of the quality of downstream wells or surface water bodies becomes evident.

Soil absorption system design and sizing is predicated upon two very different parameters, hydraulic transport properties and contaminant removal efficiency. A properly operating soil absorption system requires an adequate hydraulic conductivity so as to provide for the downward transport of the liquid waste to the subsurface without risk of surface breakout. The hydraulic conductivity of a soil medium, also referred to as the coefficient of permeability, is defined as the specific discharge per unit hydraulic gradient and expresses the ease with which a fluid is transported through a porous matrix. Hydraulic conductivity is a function of the fluid properties (density and viscosity), and the relevant soil properties (grain size distribution, shape, specific surface area, porosity, moisture content and continuity).

The second design criteria requires that the system provide an adequate detention time so as to allow for proper treatment of the wastes. This is ensured by using soils of sufficiently fine grain size to provide adequate filterability, and by designing a system of adequate size to ensure that unsaturated flow conditions are maintained. Downward effluent transport is required and impermeable boundaries, resulting in preferred pathways and ponding, must be avoided. Unsaturated flow with minimal ponding ensures that the effluent will progress slowly and evenly while maintaining aerobic conditions. This slow movement of the effluent allows for the biological, physical and chemical reactions necessary to provide the required degree of treatment (Anderson et al., 1982).

There are several types of leaching structures currently in use and regulated under Title 5 including: leaching pits, leaching galleries, leaching chambers, leaching trenches, and leaching fields. Each of these leaching facilities is capable of providing a limited volume for the temporary storage of effluent which accumulates due to the slow infiltration rate of the biomat clogging layer. The following sections provide a description and discussion of the leaching facilities regulated under Title 5 and evaluate the effects that various methods of wastewater application have on the treatment and transport processes occurring within the soil absorption system.

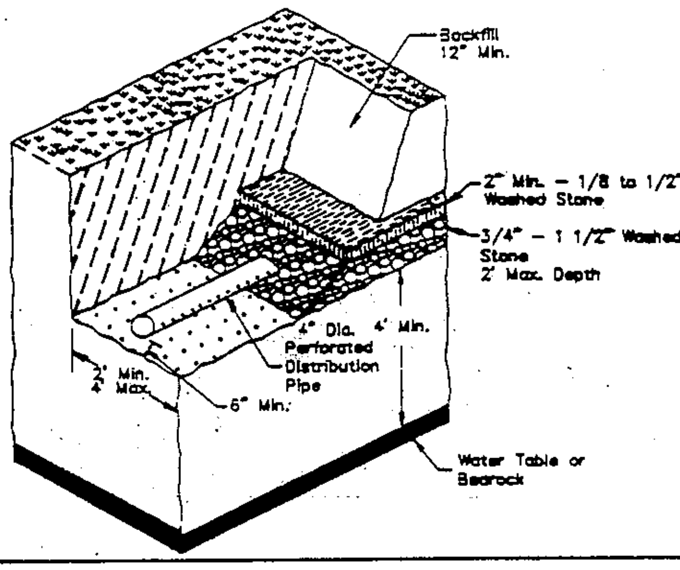
13.1 Literature Review

Leaching Pits

Leaching pits are hollow, cylindrical structures with perforated or open joint walls usually constructed of brick, perforated concrete, or interlocking concrete blocks. They typically require deep excavations, and upon placement are surrounded by 1 - 4 feet of clean, washed stone. Wastewater is stored within the pit chamber until infiltration occurs through the bottom of the pit or the sidewalls of the stone filled excavation. When multiple pits are designed and installed, the separation distance between the sidewalls is required to be no less than twice the effective width or depth of the pit, whichever is greater.

Under Title 5, the total leaching area provided by a leaching pit is calculated as the total pervious bottom and sidewall areas of the stone filled excavation located below the invert level of the inlet. Use of leaching pits is limited to areas with deep ground water tables because of the depth of the structure. They are easy to install, and are not subject to the problems commonly associated with frost or vehicular traffic. They are easily serviceable, provide a large surcharge storage volume capable of assimilating wastewater surcharges and utilize standing head hydraulics during heavy wastewater flows. They require little land area for installation, but demand a greater depth to groundwater than other systems.

FIGURE 13.1.3
TYPICAL TRENCH SYSTEM



<u>Leaching Galleries</u>

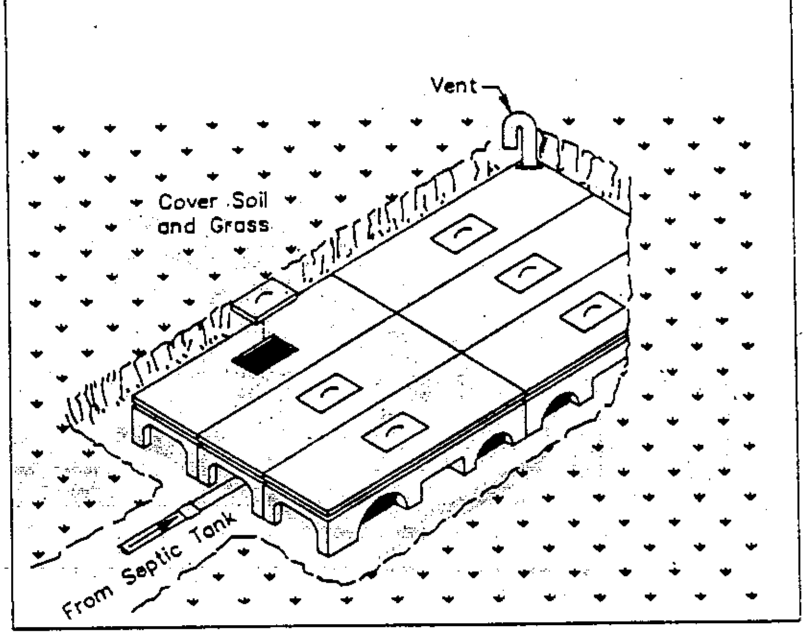
Leaching galleries are hollow structures which are usually rectangular or square in shape. They provide a large interior for visual observation to assess proper functioning. Galleries are open at the bottom with perforated walls or open joints surrounded by washed stone.

Effluent enters the gallery and is dispersed into the interior chamber where it is temporarily stored until dispersal into the soil. Multiple galleries are designed so that the distance between excavation sidewalls is no less than twice the effective width or twice the effective depth of the gallery, whichever is greater. Under Title 5, the leaching area of a gallery is calculated as the pervious bottom and sidewall areas of the excavation below the invert of the inlet.

<u>Leaching Chambers</u>

Leaching chambers are similar in design and construction to leaching galleries. They are open at the bottom with perforated walls or open joints, and are surrounded by washed stone. Effluent enters the chamber and is dispersed into the interior chamber where it is temporarily stored until dispersal into the soil. Leaching chambers can be arranged in either a trench or bed configuration. The minimum distance between leaching chamber trench walls is twice the effective width or twice the effective depth, whichever is greater. When a trench formation is used, the area provided by the chamber is calculated as the bottom area of the chamber and the sidewalls of the excavation below the invert. In bed configuration only the bottom area of the chamber is used in the calculation of leaching areas.

FIGURE 13.1.2
SCHEMATIC OF A LEACHING CHAMBER

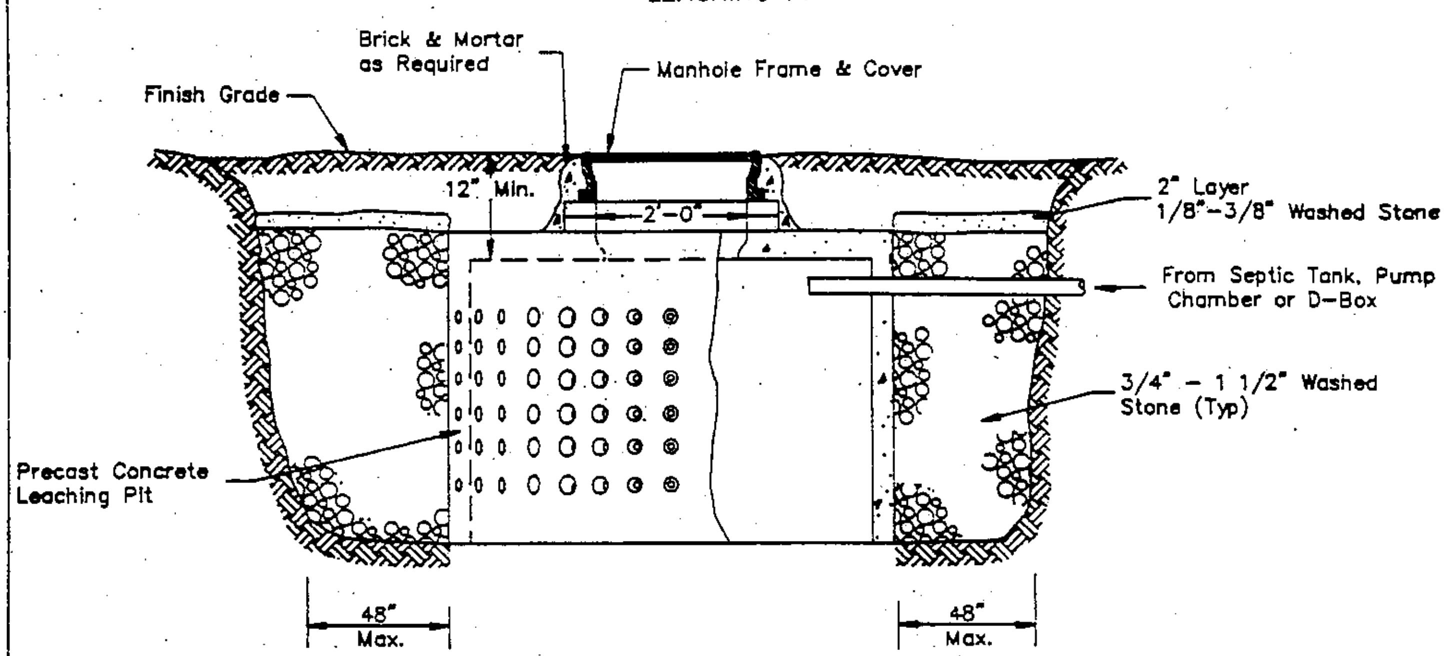


Leaching Trenches

Leaching trenches are shallow, level excavations which are usually not more than 3 - 4 feet deep and 3 feet wide. The bottom of the trench is filled with washed stone supporting a single perforated distribution pipe. Title 5 allows the total leaching area provided by a trench to be calculated as the pervious bottom and sidewall areas of the excavation below the invert of the pipe. Distribution lines must have a minimum diameter of 4 inches, and consist of perforated tile, perforated bituminized fiber, perforated plastic, or vitrified clay pipe laid with an adequate number of open joints. Additional stone is placed over the pipe, and then covered with peastone.

When more than one leaching trench is installed, the distance between excavation sidewalls should be no less than twice the effective width or twice the effective depth of the trench, whichever is greater. Leaching trenches are advantageous in that they can be constructed with the machinery straddling the excavated area, reducing compaction and smearing of the soils underlying the soil absorption system. When designed along contours, trenches are able to function on fairly steep terrain when properly designed. Trenches typically provide more liquid storage capacity than fields and promote standing head hydraulics during heavy flow periods.

FIGURE 13.1.1
LEACHING PIT



Leaching Fields

Leaching fields are shallow facilities consisting of a six to twelve inch layer of 3/4 to 1 1/2 inch washed stone upon which perforated distribution pipes are laid. The distribution pipes consist of a minimum of two 4-inch distribution lines which have been laid to grade. The distribution pipes may consist of perforated tile, perforated bituminized fiber, perforated plastic or open jointed vitrified clay. Leaching fields have negligible sidewall areas and therefore almost exclusively utilize the bottom area for infiltration. Although a distribution box is provided in order to dissipate flow equally to the distribution pipes, effluent loading is almost always greatest near the inlet side of the field as the effluent will tend to exit the distribution pipe through the first openings it encounters.

Leaching fields are capable of providing adequate treatment by spreading the effluent over a greater surface area than used for other systems, thus enabling installations requiring less depth. They may offer advantages for small (< 2,000 gpd) mound systems constructed on sites with high groundwater tables or overly restrictive soil conditions. Leaching fields require a flat terrain and extremely accurate installation. They provide the least amount of volume for surcharge storage and lack the infiltration benefit provided by static head hydraulics.

Alternative Leaching Facilities

Numerous modifications to the conventional trench-type soil absorption system have been proposed to minimize the extent of clogging within the underlying soils. One such system involves a specially designed leaching chamber which can be installed without the addition of washed stone along the bottom and sides of the structure. Individual on-site sewage disposal systems which employ leaching structures without washed stone have been installed and used in the Texas coastal plain since 1978. These systems are referred to as gravel-less systems, a generic classification which includes many design variations (Carlisle and Osborne, 1982). Recent additions to the product line include a gravel-less system utilizing corrugated polyethylene tubing covered with a permeable nylon fabric (Anderson, 1983). Gravel-less trench systems appear to result in variable long term acceptance rates similar to those achieved by conventional gravel filled trenches (Anderson, 1985).

Percolation Testing

In Massachusetts soil absorption systems have traditionally been designed based upon the percolation rate of the underlying soil, which is predicated on the assumption that the slower the percolation rate the more absorption area required. The percolation test, as it is currently conducted, measures the rate at which clear water can be transmitted through the interstices of the soil from a twelve inch diameter hole, under the optimum conditions of soil saturation and the absence of soil clogging. It delivers one permeability value, presumably at saturation, from which the soil absorption system design is based. The percolation test ignores many variables such as the soil type, the grain size distribution, the homogeneity of the soil and the soil moisture tension (Hargett et al., 1982; Jaynes and Tyler, 1984). Inherent problems with basing the design of soil absorption systems solely on the percolation test include ignoring the effects of the elevated suspended solids concentration of the wastewater; the difference between the rate of wetting and drying of soils (hysteresis); the impacts caused by the formation of biomat clogged layers and unsaturated soil conditions; and, the differences between the geometry (surface area, depth and volume) of actual systems and the percolation test hole installed to model them. Numerous attempts at relating percolation rates to the saturated and unsaturated hydraulic conductivity and ultimately to a long term loading rate have yet to produce a uniform, agreed upon numerical correlation.

Soil Type

The percolation test does not take into account the type of soil being tested. Studies conducted in Connecticut by Hill and Frink (1974) on the longevity of soil absorption systems led to some startling conclusions about the use of percolation test results for the design of septic systems. Systems constructed in loose glacial till soils exhibiting initial percolation rates of less than 5 minutes per inch were shown to have a disproportionately high rate of hydraulic failure. The failure rate was attributed to compaction or smearing of the soils during installation and to the particle and pore size distribution and effluent induced mixing of the heterogeneous particles. This mixing of particles resulted in the formation of lower permeability layers due to perched or ponded effluent (Hill and Frink, 1974). These systems, designed solely upon the percolation rate, required the same size soil absorption system as systems installed in sandy soils (Hill and Frink, 1974). This difference in system longevity illustrates the need for septic system design to be based upon soil type and site specific characteristics in addition to the percolative ability of the soil.

The Connecticut study further investigated the effect that increasing the soil absorption system size has on the system longevity. The less than five minutes per inch percolation test results obtained in loose glacial till, sands and gravel soils allowed installation of systems of the smallest allowable size. These small leaching area systems had a lower half-life (age at which half of the systems had failed) than did the larger systems installed in soils which exhibited slower percolation rates. The cause of this was attributed to the development of a biomat clogged layer at the gravel-soil interface which controls the actual long term application rate of effluent (Hill and Frink, 1974).

The percolation test measures some form of the saturated hydraulic conductivity of the soils in the absence of any impermeable, or reduced permeability, layers. The infiltrative capacity of the soil is a measure of the rate at which effluent can enter the soil through the surface on which it is applied. The infiltrative capacity of the liquid-soil interface is always less than the percolation rate due to surface clogging effects, and therefore affects the long term capacity of the drainfield (Canter and Knox, 1985).

* Effective Infiltration Area

The effective infiltration area of a soil absorption system is that portion of the system which productively transmits effluent to the underlying soils for additional treatment and effluent dispersal. The effective infiltration area of a leaching field is based on bottom area exclusively, whereas a leaching trench, gallery, chamber and pit utilize portions of both the sidewall and the bottom areas.

In unclogged soils, both the sidewalls and the bottom areas contribute to the total seepage area, and both have similar equilibrium infiltration rates (Bouma, 1973). Under the influence of biomat clogging, the infiltration rate through the sidewalls is generally believed to be greater than through the bottom. Studies conducted in Perth, Australia using eight columns and three models of soil absorption systems revealed that while both the sidewalls and the bottom areas contribute to septic tank effluent infiltration into the soils, the infiltrative rate through sidewalls of active systems is greater than that through the bottom areas. The measured acceptance rates through bottom and sidewall surfaces of trenches installed in sandy and sandy loam soils indicated that the sidewall infiltration rates were 50 to 110 percent greater than were bottom rates (McGauhey and Winneberger, 1964).

Biomat formation is more pronounced along the bottom surface areas than along the sidewall areas. This is due to the increased percentage of time that bottom areas are inundated, and the additional load from the precipitation and settling of both organic and inorganic matter.

Leaching trenches, leaching pits and leaching galleries utilize a considerable amount of sidewall area, which is less prone to clogging. The sidewall area of these leaching structures is the major infiltrative surface, while the bottom area is of minor significance. Effects of slaking of soil particles and the more rapid clogging of the bottom surface by sedimentation also contribute to this phenomenon.

Biomat clogging of soils significantly reduces the infiltration rate resulting in effluent ponding. If the degree of ponding becomes excessive, anaerobic conditions develop contributing to decreased organic decomposition, increased biomat thickness and a decreased rate of infiltration. The objective of any leaching system design is to balance the rate of biomat formation with the rate of biomat destruction in order to obtain a system which provides the proper degree of treatment without risk of hydraulic failure.

While the sidewall area may provide the highest infiltration rate, the biomat clogged bottom area provides the greatest degree of wastewater purification. A soil absorption system is intended to safely transport septic tank effluent to the subsurface without surface hydraulic failure or subsurface contamination induced by inadequate contaminant removal efficiencies. The different types of leaching facilities address the problem of effluent ponding and infiltration differently and therefore require different basis for their design. A leaching pit is designed to promote effluent infiltration through the sidewall areas. The bottom area of a pit quickly becomes overloaded, promoting anaerobic conditions and effectively minimizing the infiltration rate. As the bottom fails, the liquid rises and more of the sidewall becomes active. The sidewalls along the bottom of the pit exhibit more anaerobic tendencies, driving the system towards a vertical form of creeping failure. With most pit installations, progression towards creeping failure does not result in hydraulic system failure. As the liquid level rises in the pit, static hydraulic pressure increases, which may result in a forcing of effluent through fissures in the clogged bottom surfaces. This phenomena promotes increased flow through the bottom area, lowering the liquid level inside of the pit and allowing the sidewall infiltrative surfaces to be rejuvenated.

Loading Rates

Under most soil conditions the infiltration rate of the clogging mat layer is much lower than the hydraulic conductivity of the surrounding soils, and therefore the clogging mat affects the maximum rate of wastewater application (Hargett et al., 1982). Instances where this is not the case include systems installed in fine grained soils, and systems installed too near the ground water or impermeable soil layers. This may result in reduced hydraulic gradients and lowered hydraulic conductivities (Bouma, 1975e). These conditions can be avoided by placing an upper limit on the acceptable loading rate, and restricting the minimum vertical separation distances between the bottom of the gravel infiltration system and the maximum high groundwater level or depth to impermeable layer.

Long Term Acceptance Rates

The literature presents differing opinions regarding soil absorption system lifetimes. Some of the literature indicates that all systems are doomed to eventual failure due to the continual buildup of the clogging mat and the related reduction in acceptance rate. These researchers believe that the system will never reach an equilibrium state and that it is always proceeding towards its ultimate failure. Reducing the loading rate will not enable a system to last indefinitely, but only prolong its life (Healy and Laak, 1975).

Other studies indicate that an equilibrium between the rate of biomat buildup and destruction will eventually be reached. The infiltrative capacity of the clogging mat formed at this equilibrium and the soil moisture tension in the underlying soil dictate the long term acceptance rate of the soil absorption system. Proper transport and treatment efficiencies can be maintained in these partially clogged systems provided that the rate of biomat formation parallels the rate of biomat destruction (Healy and Laak, 1974); and, the effluent is not applied at such rates as to induce anaerobic saturated flow conditions or hydraulic failure.

An additional theory is that only a small portion of an absorption system is actually being used. Therefore as that small portion becomes subject to clogging, the infiltrative portion of the system moves to another area. This area is then allowed to be used at a reduced loading allowing the biomat destruction forces to act at a rate equal to the biomat formation. If the system is large enough, i.e. the loading rate low enough, the biomat formation and biomat destruction will even out and the system will reach a state of equilibrium. The permeability (in centimeters per day) at this equilibrium state will then be the long term acceptance rate of the system.

The long term acceptance rate of the soil absorption system is established by the degree of clogging mat formed, the soil's unsaturated hydraulic conductivity and the matrix potential. The long term acceptance rate also is affected by the concentration of polysaccharides and polyuronides in the wastewater (Jaynes and Tyler, 1974a). It is this long term acceptance rate, not the initial saturated hydraulic conductivity determined by percolation tests, which governs the operation of the system. Some sources have stated that the long term acceptance rate is independent of the effluent loading or initial unclogged soil conductivity (Otis, 1985).

Most of the literature supports design of a system based on long term acceptance rates (LTAR) of between 1 and 3 cm/day (0.25 - 0.75 gpd/sf) depending on the soil type, system configuration and method of loading. The soil type appears to be an important issue in long term acceptance rate determination. Coarse sandy soils allow for an increased penetration of suspended solids which may result in a thicker, more permeable active biological zone allowing for increased long term acceptance rates (Healy and Laak, 1974). Identical clogging mats will not induce the same effects on all soil types. The type, moisture content and permeability of the soils underlying the clogged layer will determine the moisture tension and resistance to flow caused by the biomat (Bouma, 1975e).

Typical LTAR's for various soil types have been determined through studies conducted by Bouma (1975e). These typical values, which are based only on the bottom areas of the leaching structure, are presented in the table below.

Soil Conductivity Type	Soil Texture	Long Term Acceptance Rate (cm/day)	(gpd/sf)
type I	Sands	5.0	1.23
type II	Sandy loams, loams	3.0	0.74
type III	Silt loams, some silty clay loams	5.0 (1.0)	1.23 (0.24)
type IV	Clays, some silty clay loams	0.6	0.15

The LTAR reported for type III soils may not represent expected values for different, though similar, soils. A value somewhere between that reported for the type II and type IV soils, (probably 1.0 cm/d, 0.24 gpd/sf), may be more indicative of the actual conditions (Anderson et al., 1982).

Most of the soil absorption system loading rate investigations have utilized lysimeter studies in an attempt to determine a clogging/loading rate relationship. Adapting the results of these studies for the determination of a long term acceptance rate for each of the different soils requires a standardization of the experimental methods. Healy and Laak (1974) attempted to standardize the tests and reevaluate the results. By compiling much of the previous work and comparing the experimental procedures and results, they determined that variations in the applied head caused the greatest amount of variability in the results. They then made adjustments to the results, based on a uniform one foot of available head across the top of the system to push the fluid into the soil. Healy and Laak used this adjusted long term acceptance rate data in developing an equation for the determination of long term acceptance rates, $Q = 5K - (1.2 / \log K)$. Q is in gallons per day per square foot, and K is in feet/minutes (Healy and Laak, 1974). For discussion purposes, the loading rates shown have been based upon a hydraulic conductivity, K, equal to the reciprocal of the percolation rate.

Adjusted Long Term Acceptance Rates

Source	Soil	Initial Permeability (feet/min)	Percolation Rate (min/inch)	Adjusted Long-Term Acceptance Rate* GPD/sf	(cm/day)
Thomas et. al	Ottawa Sand	3.0×10^{-1}	0.3	10	(41)
Jones and Taylor	Uniform Medium Sand	14.4×10^{-2}	0.6	2.75	(11.3)
Laak	Ottawa Sand	1.0×10^{-1}	0.8	6	(16.4)
Winneberger et. al.	Oakley Sand	5.2×10^{-2}	1.6	2	(8.2)
Kropf	Silty Sand	5.0×10^{-2}	1.7	1.4	(5.7)
Healy	Medium Sand	4.6×10^{-2}	1.8	2.2	(9.0)
Orlob and Butler	Oakley Sand	2.0×10^{-2}	4.2	0.37	(1.5)
Kropf	Fine Sand	2.0×10^{-2}	4.2	0.7	(2.9)
Jones and Taylor	Fine Sand	1.4×10^{-2}	5.9	0.7	(2.9)
Orlob and Butler	Yolo loam	1.0×10^{-2}	8.3	0.95	(3.9)
Kropf	Silty Sand	3.2×10^{-3}	26	0.5	(2.0)
Bouwer	Fine Sand	2.8×10^{-3}	30	0.37	(1.5)
Orlob and Butler	Hanford loam	2.0×10^{-3}	42	0.75	(3.1)
Orlob and Butler	Hesperia loam	1.6×10^{-3}	52	0.55	(2.2)
Orlob and Butler	Columbia loam	6.0×10^{-4}	139	0.37	(1.5)

* Based on 1 foot of available head (Healy and Laak, 1974, 529).

13.2 State Regulations

Different states use various methods to determine application rates and soil absorption system sizing. Some states calculate the loading rates based upon gpd/sf, others by square feet per bedroom, and still others by a custom designed system for each lot in adherence with the USEPA Design Manual. Leaching facility design in thirty-four states, and Guam, is based almost exclusively on the percolation rate, while fourteen states use soils based methods for evaluation. Due to the inconsistency of nationwide methods used for evaluation, a comparison among the states would encompass a vast array of exceptions to every rule.

Many states do not specifically impose state design standards for the sizing of a system (Ohio, New Mexico, Kentucky, Washington, and Hawaii) but require the use of the guidelines outlined in the USEPA Design Manual for Onsite Wastewater Treatment and Disposal Systems or require that a system be custom designed for each individual lot. The regulations discuss sizing for an effective leaching area, however, the definition of an "effective leaching area" varies from state to state. Some states, like Massachusetts, base design upon the bottom and sidewall area of the proposed leaching system, while others base theirs solely upon the bottom area of the system. Utah is an example of a state which imposes penalties for an absorption bed, requiring twice the minimum area, in square feet per bedroom, required by a trench. A number of states enforce different application rates based on the type of leaching facility proposed, be it a bed, a trench, an absorption field or a seepage pit.

In Massachusetts, the total leaching area requirements of a leaching facility are a function of the percolation rate (minutes per inch) and the design sewage flow of an establishment (gallons per day). The sewage flow for single and multiple dwelling units, motels, hotels, and boarding houses is estimated per bedroom at a rate of 110 gallons per day. Other establishments are based on the number of seats, square feet, persons, stalls, toilets, lockers, showers, etc.

Thirty-one states use design criteria similar to Massachusetts in determining leaching area requirements (Table 13.2.1). Ten states utilize estimated daily flow rates in conjunction with soil based evaluation methods to determine leaching area requirements (Alaska, Delaware, Florida, Idaho, Kentucky, Michigan, Missouri, North Carolina, Oregon, and Wyoming). Both Maine and Ohio rely strictly on soil profiles and disposal area ratings to determine leaching area size.

Massachusetts calculates the total leaching area of a pit, gallery, trench and chamber as the pervious bottom and sidewall areas of the excavation below the inlet of the invert. A leaching field is calculated as the pervious bottom area of the excavation. A review of state regulations indicates that Utah, Wyoming and Rhode Island are the only states to include both bottom and sidewall pervious areas for the total leaching area of leaching pits (Table 13.2.2). Eleven states figure sidewall area only in their calculations.

Only five states include both bottom and sidewall area in their total leaching area calculations for leaching trenches. Thirteen states calculate bottom area only, and Alaska, Arizona and Utah are the only states to exclusively utilize sidewall area.

Eight states calculate bottom area only for total leaching area of leaching fields. Wyoming and New Jersey include both bottom and sidewall area. Connecticut and Illinois figure total absorption area by multiplying the total bottom area by a predetermined factor.

TABLE 13.2.1

TOTAL LEACHING AREA REQUIREMENTS IN OTHER STATES

	Based Upon Estimated Flow Rates and Percolation Rate	Based Upon Estimated Flow Rates and Soils Evaluation Methods	Strictly Based Upon Rates and Soil Information	Based Upon Sewage Flows Only	Approval from Health Authority
Alabama	X				
Alaska		X			
Arkansas	X				
Arizona	X				
California	X				
Colorado	X				
Connecticut	X				
Delaware		X			
Florida		X			
Georgia					
Hawaii				X	
Idaho		X			
Illinois	X				
Indiana	X				
Iowa	X				
Kansas					
Kentucky		X			
Louisiana					
Maine			X		
Maryland	X				
Massachusetts	X				
Michigan		X			
Minnesota	X				
Mississippi					X
Missouri		X			
Montana	X				
Nebraska	X				
Nevada	X				
New Hampshire	X				
New Jersey	X				
New Mexico					
New York	X				
North Carolina		X			
North Dakota	X				
Ohio			X		
Oklahoma	X				
Oregon		X			
Pennsylvania	X				
Rhode Island	X				
South Carolina	X				
South Dakota	X				
Tennessee	X				
Texas	X				
Utah	X				
Vermont	X				
Virginia					
Washington	X				
West Virginia	X				
Wisconsin	X				
Wyoming		X			
Guam	X				

TABLE 13.2.2

BASIS FOR TOTAL LEACHING AREA OF LEACHING FACILITIES IN OTHER STATES

	TRENCH		PIT		BED	
	Pervious Bottom Area	Pervious Sidewall Area	Pervious Bottom Area	Pervious Sidewall Area	Pervious Bottom Area	Pervious Sidewall Area
Alabama						
Alaska		X		X		
Arkansas	X					
Arizona		X		X	X	
California	X	X(1)		X		
Colorado				X		
Connecticut	X			X	X x¼	
Delaware						
Florida	X				X	
Georgia						
Hawaii						
Idaho						
Illinois	X			X	X x1½	
Indiana	X					
Iowa						
Kansas						
Kentucky						
Louisiana						
Maine	X	X			X	
Maryland	X			X		
Massachusetts	X	X	X	X	X	
Michigan						
Minnesota						
Mississippi						
Missouri	X					
Montana						
Nebraska						
Nevada						
New Hampshire	X	X				
New Jersey					X	X
New Mexico						
New York	X	X		X		
North Carolina						
North Dakota	X			X		
Ohio						
Oklahoma						
Oregon						
Pennsylvania						
Rhode Island	X		X	X		
South Carolina	X					
South Dakota						
Tennessee						
Texas	X				X	
Utah		X	X	X		
Vermont	X			X	X	
Virginia						
Washington						
West Virginia						
Wisconsin	X			X	X	
Wyoming	X	X	X	X	X	X
Guam						

(1) Statistical allowance for sidewall area

13.3 Local Regulations

Eighty-one of the towns that have submitted copies of their board of health regulations to the Department of Environmental Protection in accordance with the requirements of M.G.L. c. 111, s. 31, have imposed more stringent requirements for the minimum leaching areas or design loading rates. Similar to the regulations enacted by the other states, the town regulations vary considerably in the means by which they require loading rate reductions. Some towns, like the town of Stow, require a minimum leaching area based upon the number of bedrooms proposed. Others simply increase the Title 5 flows by a set factor. An example of this is the town of Raynham which requires the Title 5 flow estimate to be increased by 50 percent. A third approach used by some towns, including the towns of Agawam and Abington, is to specify the minimum leaching area based upon the type of leaching structure that is used. Agawam requires a larger leaching area when galleries are used instead of trenches. Abington requires just the opposite, the size for a chamber or trench is twice that required for a pit or gallery.

There are approximately 38 towns that have regulations regarding leaching facilities. The towns of Uxbridge, Wayland, Deerfield, Northbridge and Ashland do not allow leaching fields. Merrimac allows leaching fields when the percolation rate is less than 15 minutes per inch and recommends leaching trenches for percolation rates greater than 15 minutes per inch. Dracut and Pembroke prefer leaching pits, while Dunstable prefers leaching trenches. Southborough discourages the use of leaching chambers, galleries and fields.

The majority of the regulations are related to the construction of leaching trenches. Carlisle requires a minimum of three trenches. Both Sherborn and Townsend require a minimum of 150 feet of trench, with a maximum trench length of 100 feet. Petersham requires a minimum of three trenches 50 feet long and three feet wide. Boylston has a minimum width of two feet for a trench, while Rochester, Norfolk, Gloucester and Dover allow a maximum of three foot wide trenches. The distance between trenches also varies considerably. Plympton requires a minimum three foot separation, while Rowley requires a distance of six feet.

13.4 Conclusions and Recommendations

Because the different leaching systems are designed to promote different types of effluent infiltration, they must be designed with different standards. The static hydraulic pressures associated with the deep leaching pit, gallery and chamber systems may result in reduced contaminant removal efficiencies by both the biomat and the underlying soils, which may approach saturated conditions.

Trench systems are the most widely used method of soil absorption. The majority of the authors agree that design of a trench soil absorption system provides hydraulic and rearation properties which are preferred to those provided by either pits or beds. Trenches should be designed to promote aerobic conditions throughout the vertical flow regime. Excessively wide trenches should be discouraged due to non-uniform effluent loading problems.

The effective leaching area offered by a soil absorption system is defined as the soil area over which the septic tank effluent is intended to be applied. The size of the leaching system should be based only on the effective leaching area. Soil areas for which uniform application of the septic tank effluent is not feasible should be excluded from the determination of the effective leaching area. These unaccounted for soil areas, while they may remain viable infiltrative surfaces, are not optimally located and therefore are best used to provide assimilation of shock loads or dissipation of unanticipated system overloading or excessive soil clogging conditions.

Increased static pressure, developed by an excessive liquid storage depth, promotes saturated soil conditions, accelerated flow velocities, and reduced solute transport and sanitation times. In order to restrict the formation of these adverse conditions, the effective leaching area should be determined based upon a specified maximum liquid depth of a leaching facility. Using this criteria, the effective leaching area should include the bottom of the leaching facility and the lowermost portions of the sidewall.

There is little documentation regarding the establishment of maximum allowable side wall depths. Additional research must be completed in the assessment of the impacts associated with increased hydraulic head and in the development of a leaching pit arrangement that facilitates uniform loading. This may require the minimization of internal storage volume.

Systems in bed or field configuration offer additional constraints. These configurations, due to their excessive size, restrict the soil reaeration rate, promoting anoxic conditions and slowing the rate of biological oxidation. In order to counter this reduction in treatment efficiency, the effective infiltration area of a bed or field should be limited to a fixed percentage of the available bottom area of the system and no credit should be given for sidewall area.

To ensure uniform wastewater application throughout the entire infiltrative surface, limitations on the maximum widths and lengths of leaching structure and requirements for the inlet and distribution line spacing, must also be formulated. These restrictions are necessary to ensure that a clarified effluent is delivered uniformly throughout the infiltrative surface.

Our recommendations in this regard are as follows:

Leaching Pit, Gallery or Chamber

Effective Depth	A maximum of 2 feet of sidewall depth should be credited towards calculation of the effective leaching area. This sidewall depth must be provided entirely below the invert of the inlet.
Surrounding Stone	4 feet maximum per side.

The following table provides recommended hydraulic loading rates for small systems (<2,000 gpd) based upon extensive research on long term application rates.

Proposed Loading Rates

Percolation Rate min./inch	Loading Rate[1] GPD/sf (cm/day) Type I*	Type II*	Type III*	Type IV*
5 (and less)	0.74 (3.0)	0.60 (2.5)	-	-
6	0.70 (2.9)	0.60 (2.5)	-	-
7	0.68 (2.8)	0.60 (2.5)	-	-
8	0.66 (2.7)	0.60 (2.5)	-	-
10	-	0.60 (2.5)	-	-
15	-	0.56 (2.3)	0.37 (1.5)	-
20	-	0.53 (2.2)	0.34 (1.4)	-
25	-	0.40 (1.6)	0.33 (1.3)	-
30	-	0.33 (1.3)	0.29 (1.2)	-
40	-	-	0.25 (1.0)	-
60	-	-	0.15 (0.6)	0.15 (0.6)

1) The loading rates suggested in this report are to be used for the effective area of the leaching structure.

* Soil Type:

Type I	Sands
Type II	Sandy loams, loams
Type III	Silt loams, some silty clay loams
Type IV	Clays, some silty clay loams

Separation Distance	3 times the effective width or depth whichever is greater. Two or more chambers connected together in series shall constitute a chamber system. The required separation distance should apply to adjacent chamber systems, not to the individual interconnected chambers.
Inlets	Inlets to chamber systems installed in trench configuration should be provided at intervals not to exceed 20 feet. Chamber systems in bed configuration shall be provided with at least one inlet for every 40 foot square section.

Leaching Trenches

Width	2 feet minimum, 4 feet maximum.
Effective Depth	Equal to the depth of the trench below the distribution line up to a maximum depth of 2 feet.
Maximum Lateral Length	100 feet
Separation Distance	3 times the effective width or depth whichever is greater.
Effective Leaching Area	Trench bottom area and a maximum of two feet (per side) of sidewall area.

Leaching Bed or Field

Distribution Line Separation	A maximum of 6 feet on center and a maximum of four feet to all sides.
Distribution Line Length	A maximum of 100 feet.
Number of Distribution Lines	A minimum of two required
Effective Leaching Area	75 percent of bottom area. No credit for sidewalls.

The soil absorption system sizing prescribed by Title 5 is based solely on the initial permeability of the soils, measured by the percolation test. This design technique neglects the inevitable, and desirable formation of the clogging mat, which greatly restricts the infiltrative capacity of the gravel-soil interface and allows for increased levels of contaminant removal. The reduction in infiltrative capacity is especially great for high permeability soils, sands and sandy loams. Using the infiltrative capacity of the clogging mat to control the loading rate enables the system to perform properly and to decrease the percentage of premature failures. At low permeability values, i.e. percolation rate slower than 20 minutes per inch, the hydraulic conductivity of the soils influences the infiltration rate through the clogging mat, and therefore controls the loading.

CHAPTER 14

PRESSURE DOSING AND DISTRIBUTION

While providing uniform effluent distribution throughout the soil absorption system may be the single most important design consideration, under Title 5 guidelines, it is oftentimes relegated to secondary status. Distribution to the infiltrative surface can be accomplished by either gravity or pressure distribution networks. Gravity fed laterals are the most commonly used application technique for trench and bed design soil absorption systems. These systems commonly utilize 4-inch diameter PVC pipes set at a slope of approximately 0.05 feet per foot. Regardless of the degree of care taken in design and installation, gravity fed systems will undoubtedly result in uneven distribution throughout the network. This is especially true for large systems and systems constructed in fill in which uneven settling, producing localized low areas, may occur.

14.1 Literature Review

Factors affecting the development and intensity of clogging mat formation include the pattern of wastewater application, loading rate, and wastewater quality - particularly with respect to BOD and the concentration of suspended solids (Hargett et al., 1982). Loading patterns can be separated into three categories - continuous ponding, dosing and resting, and uniform application. Continuously ponded, gravity distribution systems are the most common, simplest to design, and least expensive of the wastewater application options. Large diameter pipe (4-inch diameter) gravity systems do not usually provide uniform application. This creates localized overloading conditions leading to groundwater contamination in coarse grained soils and more rapid and severe clogging in finer textured soils (Otis, 1982).

Continuous ponding increases the infiltrative area by submerging the sidewalls of the leaching structure. The elevated liquid depth increases the hydraulic gradient across the infiltrative surface, which in turn may increase the infiltration rate. A drawback to this type of system is that the bottom of the absorption system trench is continuously flooded, thereby inducing anaerobic conditions which may cause increased clogging mat buildup resulting in problems with hydraulic flow and biological decomposition (Anderson et al., 1982).

The uniform application of septic system effluent to a soil absorption system requires knowledge of the long term acceptance rate of the soil and the clogging mat. The effluent is applied uniformly to the entire infiltrative surface at a low rate, thereby ensuring that unsaturated and aerobic conditions are always maintained. This method results in no ponding and minimizes the resistance created by the clogging mat.

Uniform application at a rate below the clogged soil infiltration rate is expensive and difficult to effectively achieve. Uniform application is usually accomplished through the use of a pressure distribution system (USEPA, 1980b). These types of systems should only be used on very rapidly, or very slowly, permeable soils for which gravity or dosed systems are not feasible (Otis, 1982).

Dosing, a practice of intermittent flooding followed by prolonged recovery periods, has been found to be beneficial in the prevention of excessive biomat clogged zone depths (Bouma et al., 1975; Veprakas et al., 1974). An additional benefit of dosing is the ability to control effluent application to ensure even distribution over the entire soil absorption system (Bouma, 1975e). Dosing creates a short term ponding condition which improves the hydraulic head in the system. Prolonged rest periods allow the soil to drain promoting reaeration and degradation of the clogging mat (Hargett et al., 1982). Dosing and resting, especially when prolonged rest periods of up to several months are used, can significantly prolong the lifetime of soil absorption systems (Otis, 1985). Dosing systems, even if they consist only of a low pressure, or gravity fed, dosing mechanism minimize the adverse effects of localized overloading commonly affiliated with the simpler, continuously loaded gravity systems. These dosing systems rely on a siphon or mechanical manifold to control the application frequency.

Dosing and resting a soil absorption system provides the best treatment efficiency while producing the lowest incidence of soil clogging induced failure. Alternately dosing and resting a system allows a wastewater load to be applied quickly, resulting in effluent ponding. With time the liquid is absorbed into the soil and the biomat is allowed to rest and regenerate its infiltrative capacity. Dosing frequencies of between 1 and 4 times per day, depending upon soil conditions, have been recommended (Otis, 1980).

Dosing Frequency

Sand	4 doses per day
Sandy loam	1 dose per day
Silt loam, silty clay loam	1 dose per day

For large systems served by two or more soil absorption systems, alternating the dosing between the two systems is prescribed. Each system should be served by a separate pump or siphon with a manifold designed to enable proper operation in the event of failure of either unit.

Gravity Distribution Systems

The simplest and most commonly used method of effluent distribution is a gravity system where wastewater, discharged from the septic tank is allowed to flow through relatively large diameter pipes into and within the soil absorption area. The most commonly used distribution pipe is a standard 4-inch (10 cm) diameter perforated polyvinyl chloride (PVC) pipe with two rows of holes located 45 degrees off vertical center. The holes are typically 1.3 to 1.6 cm in diameter. The pipe is generally set at a slope of 0.05 feet per foot in order to equalize the effluent distribution to the entire soil absorption system. Studies have shown the inconsistent flow distribution provided by large diameter pipes since most of the effluent will be discharged through the holes at the lowest elevation (R. May, CT DEP, Personnel communication). Consideration should be given to the use of smaller diameter pipes, both for gravity distribution and for dosing systems.

Gravity distribution in bed systems has been extensively studied and has been found to generally result in a non-uniform flow distribution. Water trickles out of the perforations installed at the lowest elevation, regardless of how the holes are oriented. This causes uneven flow distribution and localized system overloading.

Studies on the effluent distribution in leaching trenches have also demonstrated the non-uniform loading provided by gravity distribution systems. As effluent enters the distribution pipe, it exits through a few holes located at the inlet area, middle, or far end of the trench. This causes small areas of the leaching trench to receive a greater proportion of the septic tank effluent resulting in localized overloading. Effluent is then forced to flow along the biomat until it reaches an unclogged area. This event is known as "creeping" or "progressive" clogging. (McGauhey and Winneberger, 1964; Bouma et al., 1972).

Pressure Distribution Networks

Non-uniform effluent distribution is to be avoided as it causes ponding, increased soil clogging and localized system overloading. A locally overloaded area constructed in sand may lead to saturated flow conditions resulting in decreased hydraulic detention times and poor wastewater renovation and purification efficiencies (Converse et al., 1977). One method of achieving uniform application of effluent is through a pressure distribution system. This system consists of a dosing chamber containing a pressurization unit (pump or siphon) capable of collecting and directing equal amounts of effluent to all areas of the soil absorption system. The pressure distribution method allows for more uniform application, thus facilitating equal division of flow between multiple leaching facilities.

The pressure distribution network was originally developed for mound systems at the University of Wisconsin (Converse, 1974). Pressure distribution systems are now used to overcome problems at sites with restrictive soil horizons, steep slopes and large flows (US.EPA, 1980a). However, due to the tedious nature of their design, pressure distribution systems have been primarily limited to larger systems (Otis, 1981c).

In order to obtain uniform wastewater application, the use of pressure distribution systems with small diameter laterals and orifices is advocated. Machmeier (1975) developed the following chart for the maximum allowable lateral length. This chart is a solution to the orifice discharge, friction and head loss equations and is dependent upon perforation spacing and pipe diameter (Converse et al., 1977).

Maximum Allowable Lateral Length (feet)

Perforation Spacing (in)	Perforation Diameter (in)	1 inch	Pipe Diameter 1-1/4 inches	1-1/2 inches
30	3/16	34	52	70
	7/32	30	45	57
	1/4	25	38	50
36	3/16	36	60	75
	7/32	33	51	63
	1/4	27	42	54

Pressure distribution systems provide a more uniform application rate because each perforation is loaded at approximately the same pressure and therefore provides an equivalent discharge rate. Approximately 65 - 85 percent of the total headloss of the network occurs crossing the orifice with an additional 10 - 15 percent lost due to pipe friction. The remaining head loss, which occurs due to friction caused by passage through pipe junctions and fittings, is usually neglected (Otis et al., 1977).

An effective pressure distribution system is usually operated with a minimum of 2 - 3 feet of head at the terminal end of each lateral. Higher pressures are preferred in order to offset orifice discharge rate variations due to elevation differences. The flow rate through each orifice can be calculated by using the sharp-edged orifice discharge equation (Otis et al., 1977).

$$Q = Ca(2gh)^{.5}$$

where:

Q = orifice discharge rate (ft^3/s)
C = orifice discharge coefficient = 0.6
a = cross-sectional area of orifice (ft^2)
g = acceleration due to gravity (32 ft/s^2)
h = head applied to orifice (ft)

Pressure distribution systems are designed to discharge an equal amount of effluent from each perforation. These systems permit irregular field configurations and allow an equal division of flow between multiple trenches in large systems or at sloping sites (Otis, 1982). In order to be considered uniform, the maximum allowable variation in flow rate between any two orifices on the same lateral should be 10 percent, and the maximum allowable flow rate variation between any two orifices in the system should be 15 percent (Converse and Otis, 1982).

Even a properly designed and constructed pressure distribution system will exhibit some degree of flow variation. As the system is being pressurized, discharge (leakage) will occur from the first few perforations in the system. In order to minimize this effect, the manifold supplying effluent to the laterals should have as small a volume as possible and should be situated below the laterals so that it completely fills with liquid before any discharge from the orifices is permitted (Otis, 1982).

Provisions for air venting of the laterals (usually by including a horizontal slot in the lateral end cap) and for gravity draining of the manifold must be included to prevent freezing. The manifold should be either back-drained to the pump chamber or allowed to discharge to the soil absorption system (Otis, 1982). Back-draining of the manifold can not be permitted if siphon systems are used. The back-drain volume must be taken into account in the dosing chamber design (Converse et al., 1977).

Lateral Spacing and Orifice Design

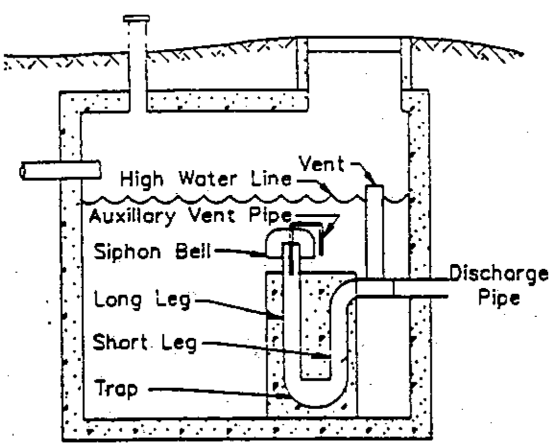
Pressure distribution systems can be designed by a number of different techniques, all intended to deliver a uniform volume of effluent to each orifice. A simplified pressure distribution system design developed by Otis is included as an appendix to this chapter.

Siphon Design and Performance

Siphons have been proposed as a low cost, low pressure dosing system. A siphon is a non-mechanical device which uses gravity, air and water pressure to provide an automatic dosing cycle to deliver a set volume of effluent to a down gradient soil absorption system. Siphons can be purchased or constructed on-site from standard PVC pipe and fittings. While there are many different siphon designs, most consist of the same components: a siphon gas bell equipped with an auxiliary vent, a long leg, a short leg (main trap), a back vent and a discharge outlet (Feiden, 1984). The size of the various components determines the pressure required to activate the system and therefore the discharge pressure.

In order to deliver the requisite dosing volume, a siphon must be installed inside an appropriately sized dosing chamber. As liquid rises within the chamber, air is trapped within the siphon bell. Continued liquid rise compresses the trapped air, forcing the liquid in the long leg of the siphon to move towards the short leg. When the liquid level in the long leg reaches the bottom of the trap, pressure is released and the siphon is activated. This produces a gravity induced, pressurized flow to the soil absorption system. Flow will continue until the water level in the dosing chamber is lowered to the bottom of the bell. The auxiliary vent provides assistance in reaerating the bell and initiating the next dosing cycle (Converse et al., 1984).

FIGURE 14.1.1



Typical siphon tank installation for dosing septic tank effluent into soil absorption systems. Note location of siphon and vent pipe in relation to tank openings, especially vent pipe.

Two similarly sized siphons, installed within the same dosing chamber, can be used for automatic alternating dosing to separate soil absorption systems. As the dosing chamber fills, one of the siphons invariably discharges first, directing a full dose of effluent towards its soil absorption system. After this first dosing cycle is completed, the second siphon, which has already undergone a compression step, will need slightly less pressure to induce discharge than the completely activated first unit. As the water level rises for the second time, the second siphon discharges, and the first is prepared to accept the next cycle (Converse et al., 1984).

Performance studies have revealed that siphon failure rates may approach 50 percent (Converse et al., 1984). When a siphon fails to operate properly, head is not allowed to accumulate and dosing will not occur. In this event the siphon acts as nothing more than a gravity system, discharging effluent as it enters the chamber. This continuous gravity discharge of a siphon is called trickling (Converse et al., 1984).

Siphon malfunction can occur due to a number of correctable causes. Improperly designed or constructed siphons, air leaks or distribution pipe back-flow may all cause a siphon to malfunction. Fixing the cause of the malfunction, and repriming the siphon may suffice. However, all siphons need to be adequately monitored to ensure that dosing is occurring and to signal when repairs and/or repriming is necessary (Converse et al., 1984).

If two siphons were intended to provide alternating dosing, the first siphon to fail will trickle feed all of the effluent, overloading one soil absorption system. The second, properly operating siphon, will never be subjected to the pressures required to activate. It is, therefore, recommended that if multiple siphons are to be relied upon for providing alternating dosing, frequent monitoring, possibly through discharge flow recorders, must be provided.

A properly designed dosing chamber and siphon should discharge the required volume of effluent (average daily flow ÷ dosing frequency) over a relatively short period of time. Each component of the siphon, to some extent, controls the dosing characteristics of the system. The volume of the bell determines the drawing depth of the siphon (the difference between the high water level and the low water level in the dosing chamber), the length of the long leg of the siphon determines the total head of the effluent, and the length of the auxiliary vent determines the amount of air entrapped within the bell and siphon. Varying the discharge flow rate is accomplished by modifying the siphon pipe diameter. The orifice discharge equation and the Hazen-Williams equation for pipe-friction losses are used for determining the effluent discharge rates (Feiden, 1984).

Orifice Discharge Equation:

$$Q = Ca(2gh)^{0.5}$$

where:

Q = orifice discharge rate (ft^3/s)
C = dimensionless coefficient (0.6)
a = area of opening (ft^2)
g = acceleration due to gravity (32 ft/s^2)
h = liquid head applied to opening (ft)

Hazen-Williams Equation for Pipe-friction Losses

$$H = K \cdot V^2/2g$$

where:

H = bell and siphon entrance head loss (ft)
K = dimensionless coefficient, varies with entrance geometry (0.2 - 0.9)
V = liquid flow velocity (ft/s)
g = acceleration due to gravity (32 ft/s^2)

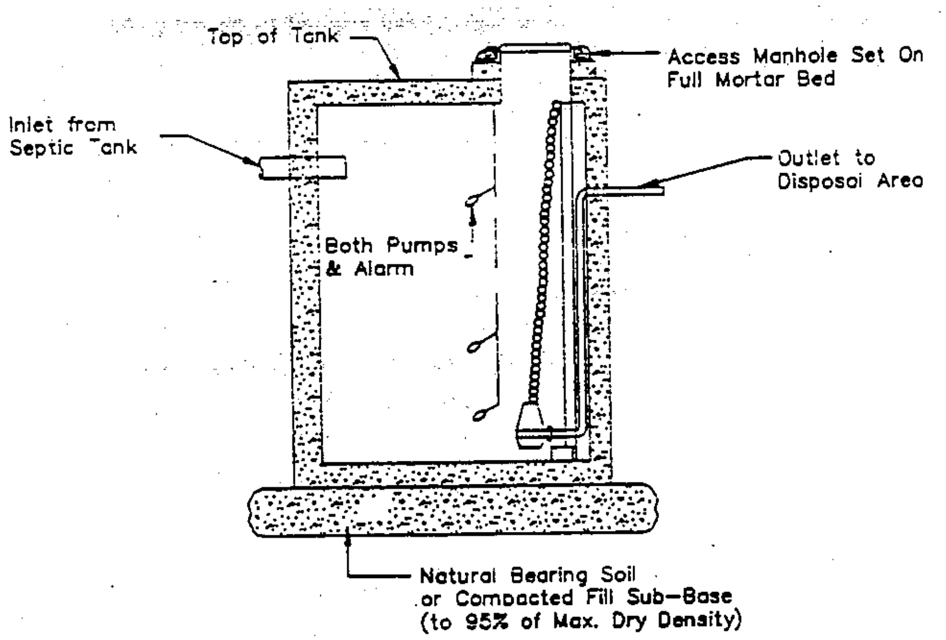
Pump Design

Whenever the soil absorption system is sited at a higher elevation than the septic tank or a pressure distribution system is specified, a properly sized dosing chamber and pump is required. The dosing chamber volume is dependent upon the average daily effluent flow divided by the dosing frequency. Additional volume is required for effluent backdraining from the distribution network (for protection from freezing conditions). A back-up pump must always be provided and the pump chamber sized to contain an additional volume, above the high water alarm, at least equal to the average daily flow of the system. Since the dosing chamber must be equipped with high-low water alarms, this additional volume should enable sufficient time for repairs, routine maintenance or short term power outages.

The pump should be designed to filter any solids which may inadvertently enter the dosing chamber and to deliver the required liquid volume, at the mandated pressure. Pump efficiency curves and manufacturers specifications should be consulted for pump sizing. The two alternating pumps should be provided with pump monitors to ensure that both pumps are operating, and if so equipped, that both soil absorption systems are receiving the required effluent load.

FIGURE 14.1.2

FINAL EFFLUENT DOSING CHAMBER



14.2 Conclusions and Recommendations

Dosing and resting of any system is the preferred method of wastewater application. It provides a limited hydraulic head to aid infiltration, followed by a prolonged aeration period which promotes biomat digestion and respiration. We therefore recommend consideration be given to requiring dosing facilities in conjunction with the various leaching systems. We also suggest that consideration be given to the use of smaller diameter pipe for both pressure and gravity distribution of effluent.

Regardless of soil absorption system configuration, uniformly applying the effluent, through pressurized dosing and resting, provides the optimum chance for successful long-term operation. Small diameter lateral, pressure distribution systems, can be designed to evenly discharge effluent throughout the soil absorption system. A pressure distribution system should be considered properly configured if there is less than 10 percent variation in orifice discharge throughout any one lateral, and less than 15 percent variation between any two orifices in the system.

All soil absorption systems with design flows greater than 2,000 gallons per day, and septic systems served by multiple soil absorption systems, should have the effluent distributed by a dosing system pressurized by alternating pumps. Siphon designs can successfully pressure dose a medium (2,000 to 5,000 gallons per day) or small system (<2,000 gallons per day). Alternating pumps are recommended for systems with design flows greater than 5,000 gallons per day because malfunctioning (trickling) siphons can behave as continuous feed gravity distribution systems, leading to non-uniform loading, localized ponding and creeping failure.

Appendix 1, Pressure Distribution System Design

This simplified design procedure is adopted from the article entitled Pressure Distribution Design for Septic Tank Systems, written by Richard J. Otis, (1982).

Step 1: Layout the network using a manifold and lateral design intended to provide uniform coverage of the infiltrative surface.

Step 2: Select the orifice size and spacing. In bed designs the spacing between orifices and between adjacent laterals should be equivalent. Orifices should be directed downward, and should be placed at the vertices of equilateral triangles.

Step 3: Determine the appropriate lateral pipe diameter, compatible with the chosen orifice size and spacing. (Otis developed graphical figures for each lateral length and orifice spacing and size to aid in this decision. These charts were based upon the total energy (sum of velocity head, pressure and elevation) available at each orifice.)

$$q_j = Ca(2gh_j)^{0.5}$$

where:

- q_j = orifice discharge rate from the orifice in the j^{th} lateral segment.
- a = area of opening
- g = acceleration due to gravity
- h_j = liquid pressure behind orifice
- C = dimensionless coefficient dependent upon the characteristics of the opening

$$\Delta h_j = 4.71 l_j (Q'_j / C_h D^{2.63})^{1.85}$$

where:

- Δh_j = friction loss in lateral segment, j
- l_j = orifice spacing
- Q'_j = sum of orifice discharge rates downstream of j^{th} lateral segment
- D = lateral diameter
- C_h = Hazen-Williams friction factor

$$\Delta h'_j = \frac{V'^2_j - V'^2_{j-i}}{2g} - \frac{v_j^2}{2g}$$

where:

- $\Delta H'_j$ = pressure change across orifice j
- V'_j = velocity in lateral segment upstream of orifice
- V'_{j-1} = velocity downstream of orifice
- v_j = velocity through orifice

$$h'_e = (\phi V'^2_j / v_j^2 + \theta) v_j^2 / 2g$$

where:

ϕ and θ are dimensionless coefficients

$$q_n / q_1 = 1.1$$

$$q_n/q_1 = \left[\frac{h_d + \Sigma\Delta h_j}{h_d}\right]^{1/2} = 1.1$$

h_d = desired in-line pressure at distal end of lateral

$$\Sigma\Delta h_j = 0.21\ h_d$$

$$q_{M,N}/q_{1,1} = 1.15$$

$$q_{M,N}/q_{1,1} = \frac{(h_d + 0.21h_d + \Sigma\Delta H_i)^{1/2}}{h_d^{1/2}} = 1.15$$

$$\Sigma\Delta H_i = 0.1h_d$$

$$\Sigma\Delta H_i = 4.71\ \frac{\Sigma L_i Q_i^{1.85}}{(C_h D_m^{2.63})^{1.85}}$$

where:

L_i = length of manifold segment or lateral spacing
Q_i = flow rate in manifold segment, i
D_m = diameter of manifold

If all manifold segments are of equal length this can be simplified to:

$$\Sigma F_i = 4.71\Sigma Q_i^{1.85} = 0.1h_d\ \frac{(C_h D^{2.63})^{1.85}}{i \times L}$$

Step 4: Calculate the lateral discharge rate, Q_i based upon the total number of orifices in a lateral (n), and the discharge rate of each orifice (q).

$$Q_i = q \times n$$
$$q = 11.79d^2 h_d^{1/2}$$

Step 5: Calculate the appropriate manifold size based upon the number, spacing and discharge rate of the laterals.

$$F_i = 9.8 \times 10^{-4} Q_i$$

$$D_M = \left[\frac{\Sigma L_i F_i}{f h_d}\right]$$

f = fraction of total head loss desired in that manifold segment (for less than a 10% loss, f must be less than 0.1)

Step 6: Determine the dose volume requirement. The minimum dose volume should be 5 - 10 times the network pipe volume to minimize the leakage effects due to filling and draining the network.

Step 7: Set the minimum pump or siphon discharge rate equal to the sum of the lateral discharge rates.

Step 8: Calculate the total friction losses in the dosing chamber and the network.
Dosing chamber friction losses Hazen-Williams equation:

$$\text{Friction Loss} = L_d \left[\frac{3.55Q_m}{C_h D_d^{2.63}}\right]^{1.85}$$

Network friction losses, $F_n = 1.31\ H_d$

Step 9: Select the pressurization unit based upon available head and discharge rates.

Step 10: Size the dosing chamber based upon the dosing volume and any additional storage necessary for system back-flow. A one day storage volume should be available above the high water alarm for repair, power outages or system shut-down.

CHAPTER 15

SYSTEMS CONSTRUCTED IN FILL

Some sites have subsurface conditions unsuitable for the installation of a conventional septic tank/soil absorption system. This includes areas with low-permeability soils, heterogeneous or anisotropic soils containing hydraulically limiting layers, and areas with perched, confined or seasonally high ground water.

The restrictions imposed by these local hydrogeologic conditions may be overcome in certain instances through the installation of the sewage disposal system in a suitable fill material. The specific limiting conditions determine whether the installation of a fill system represents a viable treatment alternative. Additionally, the limitations dictate the type of fill system to be installed and the design criteria necessary to ensure proper treatment with the minimum risk of system malfunction or failure.

This chapter of the report considers the design criteria for leaching facilities constructed in fill. These systems have been segregated into two categories, below grade, excavate and fill systems and mounded systems constructed above the natural grade.

Limiting soil conditions which can be suitably counteracted by an excavation and fill system include shallow confining soil horizons consisting of slowly permeable or overly fine natural soils. Mound type fill systems may offer a solution where there is at least four feet of permeable soils above bedrock

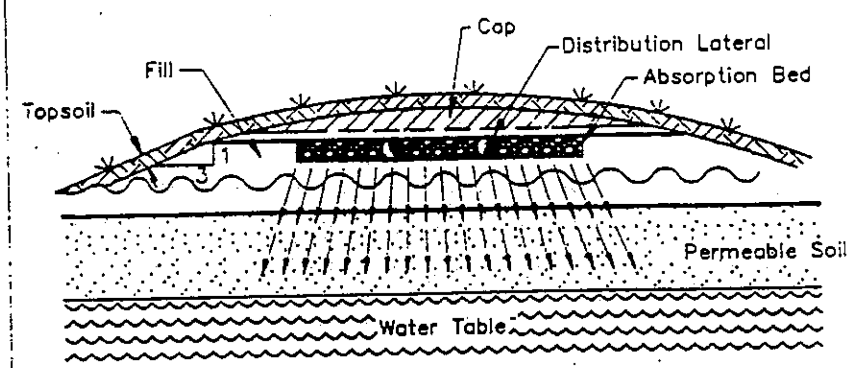
or impermeable formations but the natural site conditions are deemed to be unsuitable due to high ground water.

15.1 Literature Review

Below Grade Excavate and Fill Systems

In areas with locally limiting or confining soil conditions situated above pervious soils of sufficient depth to allow the construction of a soil absorption system, excavation of the undesirable upper layers of natural material and replacement with a suitable fill may represent an appropriate solution permitting safe and effective on-site wastewater treatment and disposal. In constructing a below grade excavate and fill system, all impermeable soils must be removed and replaced by a suitable fill material. The excavation must extend an adequate distance beyond the proposed leaching facilities. In no case should an excavate and fill system be permitted where less than four feet of permeable natural or fill material is provided between the bottom of the infiltrative surface of the soil absorption system and the highest ground water elevation.

FIGURE 15.1.1
TYPICAL MOUND SYSTEM



Cross Section of a Mound System for a Permeable Soil, with High Groundwater

Mounded Systems

Mounded systems may offer an acceptable sewage disposal alternative when hydrologic conditions prohibit the installation of a conventional subsurface soil absorption system or a below grade excavate and fill system. Mounded systems, as the name implies, are constructed by fabricating a mound of suitable fill material over the naturally occurring soils. Trench or bed type leaching facilities are constructed within the mound with the infiltrative surface maintaining the appropriate clearance above mean annual high ground water conditions. A minimum natural remaining soil depth to any impermeable layer is required in order to ensure the provision of an adequate horizontal flow capacity. Some states allow fill to be placed upon a layer of naturally occurring soils as thin as twenty inches. However, a high percentage of breakout problems have been noted where less than four feet of naturally occurring pervious soils are present below the fill material.

The fill material provides the organic and suspended solids waste strength reduction, thereby precluding the development of a biomat at the fill/natural soil interface. Mounded systems offer the additional benefit of increased reaeration rates through the top and sides of the mound. This increases the oxygen concentration in the mound, accelerates the rate of aerobic biodegradation and ensures a fully oxidized effluent. The interface with the remaining natural soil, hereinafter referred to as the base, is delivered a clarified, filtered effluent more amenable to clear water percolation (Bouma et al., 1975).

A successfully designed mound system must be sized such that the long term acceptance rate of the infiltrative surface, the basal loading rate, and the toe loading rate are not exceeded. If the capacity of any of these three flow regimes is exceeded, the system will cease to function in its desired capacity of providing wastewater treatment and safely conveying all of the liquid to the subsurface.

The basal acceptance rate is the rate in which properly treated liquids from the fill material are incorporated into, and transported from, the natural soil base. Although the base materials may have a lower permeability than the fill material, they receive a purified effluent spread out over a greater surface area. The basal materials must be able to provide adequate infiltration for the prevention of excessive ponding within the mound or breakout at the toe of the mound slope. Uniform distribution over an adequately sized basal area is important for maintaining a sufficiently low basal loading rate (Converse and Tyler, 1984). Preparation of the base should include clearing, grubbing and removal of all organic and impervious matter. All work on a mound system should be completed during dry periods to minimize smearing and compaction of the basal material (Bouma et al., 1975).

On flat sites the center of the system generally receives the greatest percentage of flow, whereas in mounded systems with sloping basal areas, the loading at the down slope edge may become more important. The downslope ponding at the interface of slower permeability natural soils on sloped sites can be alleviated by either leveling the natural base or providing additional down gradient area for effluent absorption.

The toe loading rate, or lateral acceptance rate, is the rate at which the natural soils surrounding the system laterally convey the liquid to the subsurface environment. Exceeding the lateral acceptance rate at any location in the downgradient flow path will result in effluent breakout or surface seepage. A layer of low permeability soil can be placed along the toe of the slope as an extra precaution in preventing this surface breakout.

The length to width ratio of the absorption system is the most important parameter to consider when evaluating the toe loading rate. Long, narrow infiltrative surfaces, installed perpendicular to the flow stream, produce the least toe loading by horizontally spreading the load over a greater lateral area (Converse and Tyler, 1984).

The design of a mounded system is generally accomplished in the following five steps (Bouma et al., 1975; Converse et al., 1977).

(1) Sizing the required basal area should be based upon the maximum daily flow and the saturated hydraulic conductivity of the least permeable soil horizon. The basal area assists in wastewater purification and provides for effluent absorption into and lateral conveyance from the underlying subsoil. The basal area must be sufficiently sized for the prevention of any surface breakout or seepage.

TABLE 15.1.1

APPROXIMATE BASAL LOADING RATES

Percolation Rate	Loading Rate
0 - 30 min/inch	1.23 gpd/sf (5 cm/d)
31 - 60 min/inch	0.74 gpd/sf (3 cm/d)

Due to the wastewater treatment occurring within the fill material these clear water loading rates are significantly higher than recommended for a conventional subsurface soil absorption system. For sloping sites, the basal area upgradient of the absorption zone is not considered active, and is therefore excluded from the available basal area calculations.

(2) Sizing the absorption system includes determining the bed or trench length and width, along with the spacing between adjacent trenches.

(3) Design of the effluent distribution system including distribution rate and pressure, lateral spacing and orientation and orifice spacing and diameter. The purpose of this step is to evenly distribute the effluent throughout the absorption system.

(4) Final dimensioning of the mound to ensure that the mound is adequately sized to fully incorporate all of the applied load. Special attention must be directed to the distance between the edge of the absorption system and the downslope toe or edge of the mound. Downslope toe breakout or seepage must be prevented and the mound sides must be appropriately sloped to direct surface water away from the mound while not initiating surface scouring. A maximum sideslope of 3:1 is recommended, although a slope of 5:1 is preferred.

A sufficient vertical separation distance must be provided to ensure at least four feet of unsaturated separation between the infiltrative surface and the top of any effluent ponding within the fill material or the natural less-permeable material.

Adequate sizing of the absorption system is essential in avoiding excessive loading rate induced liquid storage within the fill material. A trench system, with adequate separation distances between adjacent trenches, is generally considered to be the preferred option. Long narrow bed systems are also recommended (Converse and Tyler, 1984). Mound formation calculations, using the Dupuit-Forcheimer assumption for horizontal flow applied to the topsoil, can be conducted for calculating the trench widths (Bouma et al., 1975).

$$(h_0^2 - h_1^2) = (I \times W^2)/2K$$

where:

h_0 = Liquid mound height at middle of trench (cm)
h_1 = Liquid mound height at edge of trench, width/2 (cm)
I = Applied loading rate (cm/day)
W = Trench width (cm)
K = Permeability of fill material (cm/d)

Wisconsin Mound

The "Wisconsin Mound" is a particular type of fill system designed to elevate the infiltration surface above wet, slowly permeable natural soils. Wisconsin mound systems retain the natural topsoil which is plowed or furrowed to facilitate infiltration. The permeable fill materials distribute effluent over a greater area and filter the wastewater slimes thereby preventing excessive clogging of, and reducing the effective loading rate imparted upon, the natural soils.

As the wastewater percolates through the fill material in a "Wisconsin Mound", it collects and ponds along the top of the natural soils. This promotes the onset of anaerobic conditions at the base which may appreciably augment the nitrogen removal efficiency of the system by allowing for denitrification of the fully oxidized wastewater. In order to properly function, the remaining natural soils under a "Wisconsin Mound" must, like any other mounded system, retain an adequate hydraulic capacity to safely convey the liquid effluent away from the system.

Selection of Fill Material

The emplaced permeability of the soil is generally the parameter most widely used in the selection of a suitable fill material. The emplaced permeability is a function of many variables including the soil structure, texture and relative compaction. Too rapid an emplaced permeability increases the hydraulic capacity of the system but also reduces the detention time necessary for organic waste strength reduction (Kilduff, 1989) and increases the loading rate imparted upon the natural underlying soils.

Increasing the relative compaction raises the bulk density of an emplaced soil. This volume reduction diminishes the size, continuity and frequency of pore spaces leading to a decline in the rate of soil reaeration and a reduced saturated permeability. The degree of soil compaction and settling which occurs within a fill material is dependent upon the soil moisture content, organic matter content, soil structure and particle size distribution (Engle and Hermanson, 1982).

Numerous research projects, including those conducted by the Wisconsin Small Scale Waste Management Project, and the University of Connecticut, have been undertaken in order to develop criteria for the use of fill material in the design of septic systems. Conclusions from these investigations led to categorizing a suitable fill material, based on textural analysis, as one which contains a high percentage of medium sized (.5 - .25 mm) sands while containing a low percentage of clay, silt fines, very fine sands and coarse fragments (greater than 2mm) (Engle and Hermanson, 1982). Coarse textured, non-cohesive sand, sandy-loam and loamy-sand soil classes, containing a minimal amount of organic matter were found to be the most desirable (Engle and Hermanson, 1982). Of these three soil classes, the soils containing loam provided the better contaminant removal properties, but also exhibited a greater propensity towards clogging (Bouma et al., 1975).

Hydraulic Considerations

For the design of a fill system the capacity of the three flow regimes; flow through the infiltrative surface, unsaturated vertical flow, and saturated lateral flow, must be determined and must not be exceeded (Kilduff, 1989). The continuity equation dictates that under steady flow conditions the effluent flow rate through these three regimes must be equivalent. The regime with the minimum flow potential determines the maximum hydraulic capacity of the system (Kilduff, 1989).

Continuity Equation:

$$Q = K_L i_L A_L = K_V i_V A_V$$

where:

Q = Flow rate (volume/time)

K = Permeability or hydraulic conductivity (length/time), $K_L \neq K_V$

L = lateral flow from the system

V = vertical flow through the most restrictive layer

i = Hydraulic gradient, dH/dx

A = Cross-sectional area perpendicular to flow ($length^2$)

The absorption capacity of the infiltrative surface is determined by the long term permeability and the area available for infiltration. The long term permeability, more commonly referred to as the long term acceptance rate, is dictated by the soil structure and the degree of biomat formation. An estimate of the long term acceptance rate (LTAR), based upon initial soil permeability has led to the following equation developed by Laak (1980).

$$LTAR\ (gal/day/ft^2) = 5K - (1.2/\log K)$$

where:

K = Initial soil permeability ($gal/day/ft^2$)

The permeability of a soil can be estimated by using a falling head permeability test or by the Moulton Equation, which estimates permeability based upon the grain size analysis and porosity of the fill material (Kilduff, 1989). Values for emplaced soils can be calculated from laboratory testing by including correction factors for differences in the relative density of the emplaced soil and laboratory samples.

Moulton Equation for Permeability (based upon grain size analysis)

$$K\ (\text{ft/day}) = \frac{6.214 \times 10^5 \times D_{10}^{1.478} \times N^{6.654}}{P_{200}^{0.597}}$$

where:
K = Permeability (ft/day)
D_{10} = Sieve size passing 10% of sample
N = Porosity, $1 - [D_s/(D_w \times G)]$
D_s = dry density of soil (mass/volume)
D_w = density of water (mass/volume)
G = specific gravity of soil grains (Assume 2.65 - 2.70)
P_{200} = Percent passing #200 sieve

Falling Head Permeability Test

$$K = \frac{a \times L}{A(T_2 - T_1)} \log_e (H_1/H_2)$$

where:
K = Permeability (length/time)
a = Cross sectional area of standpipe (length^2)
A = Cross-sectional area of soil (length^2)
L = Length of soil sample (5 - 10 cm, typ.)
T_1 = Time corresponding to liquid height, H_1

Relative Density

$$\text{Relative Density (\%)} = \frac{D_{max} (D_i - D_{min})}{D_i (D_{max} - D_{min})}$$

where:
D_{max} = Maximum Density
D_i = Initial Density
D_{min} = Minimum Density

15.2 State Regulations

Research of other states regulations reveals that the majority of the states allow the construction of soil absorption systems within fill material. Approximately half of the states allow this type of construction with prior approval from the state agency; whereas, the remainder of the states allow the local health department to provide approvals.

Most of the states that provided a minimum depth to the limiting layer require only two feet of naturally occurring material beneath the system.

The characteristics of an acceptable fill material vary among the states. North Carolina requires the placement of a 4 - 6 inch layer of coarse sand beneath the gravel aggregate to act as a coarse filter. The remaining fill material is comprised of a mixture of coarse sand (88 - 93 percent) and sandy loam (7 - 12 percent). Pennsylvania requires that the fill material meet certain specifications for clay content (5 - 15 percent); whereas, Wisconsin advocates use of a medium textured sand. The sand in a Wisconsin mound system does not have to be washed, as some fines are desirable, but should not contain significant amounts of silt or clay (Converse et al., 1977).

TABLE 15.2.1

CONSTRUCTION IN FILL REQUIREMENTS

	ALLOWED	STATE APPROVAL REQUIRED	MINIMUM DEPTH TO LIMITING LAYER	COMMENTS
Alabama	Y	Y		
Alaska	Y	Y	2 ft	
Arkansas				(1)
Arizona	Y	Y	2 ft	
California	Y	Y		
Colorado	Y	Y		
Connecticut				(1)
Delaware	Y	Y		
Florida				(1)
Georgia				Regulations unavailable
Hawaii				(1)
Idaho				(1)
Illinois	Y	Y		
Indiana				(1)
Iowa	Y		3 ft	
Kansas				Regulations unavailable
Kentucky	Y			
Louisiana				Regulations unavailable
Maine	Y	Y		
Maryland	Y		2 ft	
Massachusetts	Y		4 ft	
Michigan	Y		2 ft	
Minnesota	Y		2 ft	
Mississippi				(1)
Missouri				(1)
Montana	Y	Y	4 ft	
Nebraska				(1)
Nevada				(1)
New Hampshire				(1)
New Jersey				(1)
New Mexico				(1)
New York	Y		2 ft	
North Carolina	Y	Y	2 ft	
North Dakota	Y			
Ohio				(1)
Oklahoma	N			
Oregon				(1)
Pennsylvania	Y		6 ft	
Rhode Island	Y	Y		
South Carolina				(1)
South Dakota	Y	Y	4 ft	
Tennessee	Y	Y		
Texas	Y			
Utah	Y	Y		
Vermont	Y	Y		
Virginia				Regulations unavailable
Washington	Y			
West Virginia	Y	Y		
Wisconsin	Y	Y	2 ft	
Wyoming	Y			

(1) Construction in fill not discussed within regulations.

15.3 Local Regulations

Fifty-seven boards of health have adopted regulations that govern the use of fill in the construction of septic systems. Of these, nine forbid septic systems to be constructed in fill, including Blandford and Wales. Other towns, such as Blackstone, Chatham and Hingham, allow construction in fill after it has settled a minimum of twelve months or has been mechanically or hydraulically compacted.

Several towns including Holden and Foxborough, require that the fill meet the percolation rate of the underlying soils. Duxbury and Rochester do not allow fill to be mounded above the existing grade.

Other local regulations concerning fill requirements include: (1) specifying the minimum inspections; (2) mandating that both primary and reserve be filled at the same time; and, (3) specifying the amount of area around the system to be excavated and replaced with the fill.

15.4 Conclusions and Recommendations

Certain limiting site conditions, including shallow horizons of constricting material and high natural ground water, can be overcome by excavating undesirable soils and replacing them with select fill. The fill material and its placement must, however, be carefully controlled in order to minimize risk of system malfunction or failure.

A subsurface sewage disposal system may be constructed in fill material provided there is a sufficient depth of naturally occurring pervious soils beneath the entire fill area. Preparation of the fill area should be completed during dry periods to minimize smearing and compaction of the native soils and should include proper clearing and grubbing.

Before placement of fill material, all top soil, peat, and other impervious materials should be removed from all areas beneath the proposed leaching facility and for a distance of at least ten feet in all directions therefrom when the leaching facility is below natural grade. For mounded systems, the entire basal area should be cleared of top soil, peat, and other impervious materials before any fill placement is initiated. The size of the basal area should be based on the maximum daily flow and the saturated hydraulic conductivity of the least permeable soil horizon, but in no case should the basal hydraulic loading rate exceed 3 cm/d (0.74 gpd/sf). The basal area should be level wherever possible. A slope of no greater than ten (horizontal) to one (vertical) may be allowed, provided the naturally occurring soil beneath the base of mound exhibit a percolation rate no slower than 20 minutes per inch.

The side slopes of the mound should be no greater than three to one. The following separation distances should be provided between the leaching facility and adjacent sideslope.

Mounded System Side Slopes (horizontal:vertical)	Horizontal Separation (feet)
less than 7:1	15
between 5:1 and 7:1	25
greater than 5:1	35

The separation distance for mounded systems should be measured from a point representing the furthest most extremity of the leaching facility, along a line drawn as a horizontal extension of the top surface of the peastone layer to the nearest point of intersection with the adjacent side slope. The slope should be maintained until the point of intersection with the natural grade.

An eight-inch layer of low permeability soil with a coefficient of permeability of 1.0×10^{-5} centimeters per second should be placed over the side slope of mounded systems. This layer of low permeability soil shall begin two feet above the toe of the fill area and extend two feet into the natural occurring soils. That portion of the low permeability soil which extends above the natural grade should be covered with a six-inch drainage blanket comprised of soils with a coefficient of permeability of 1×10^{-2} centimeters per second. The drainage blanket, in turn shall be covered by at least three inches of top soil. A geotextile fabric shall be installed between the drainage and top soil layers.

No portion of the mound should extend beyond the property boundary unless a valid slope easement has been granted and recorded on the deed of the affected property.

Fill should consist of select on-site or imported soil material, free from organic matter and other deleterious substances, classified as SC, SP, or SW, in accordance with ASTM D2487 and the Unified Soil Classification System. Mixtures and layers of different classes of soil is not be acceptable. The fill material should be comprised of clean granular sand meeting ASTM specification C-33, Specification for Fine Aggregate, having a percolation rate before and after placement of less than five minutes per inch but not less than one minute per inch, and graded such that the total sample sieve analysis meets the following specification.

TABLE 15.4.1

FILL MATERIAL SPECIFICATIONS

SIEVE SIZE #	EFFECTIVE PARTICLE SIZE	% PASSING
3/8-inch	9.50 mm	100
4	4.75 mm	95 - 100
8	2.36 mm	80 - 100
16	1.18 mm	50 - 85
30	0.60 mm	25 - 60
50	0.30 mm	10 - 30
100	0.15 mm	2 - 10

Imported soil shall be approved by the designer and an official representative of the Approval Authority prior to placement. The excavated soil may be used as backfill above the fill material if approved by the Approval Authority. A representative of the Approval Authority shall be present for all fill placement and may require soil sampling and laboratory testing as needed to determine compliance with the standards for fill material.

Specified fill material shall be carefully compacted in layers of loose thickness not exceeding one-half foot. Approved mechanical equipment and the appropriate water additions shall be used to obtain the required 95 percent relative compaction. Fill material shall be conditioned with a uniformly distributed moisture content within 2 percent of the optimum moisture content as determined in accordance with ASTM D 1557. In areas where the fill material is to extend below the existing ground water table, appropriate dewatering techniques should be employed to allow proper placement and compaction of the material.

The following procedures shall be used in laboratory testing of soils and fill materials to determine whether the fill has been adequately compacted:

A. ASTM D 1556 - Standard Test Method for Density of Soil in Place by the Sand Cone Method.
B. ASTM D 1557 - Standard Test Methods for Moisture Density of Relations of Soils and Soil-Aggregate Mixtures using 10 pound Rammer and 18 -inch Drop.
C. ASTM D 2216- Standard Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures.
D. ASTM D 2487 - Standard Test Method for Classification of Soils for Engineering Purposes.
E. ASTM D 2922 - Standard Test Method for Density of Soil and Soil-Aggregate in Place by Nuclear Method (shallow depths).
F. ASTM D 3017 - Standard Test Method for Moisture Content of Soil and Soil-Aggregate in Place by Nuclear Method (shallow depths).

CHAPTER 16

SIDE SLOPE REQUIREMENTS

The current Title 5 regulations contain minimum design criteria for setback distances to side slopes which are calculated using a standard formula - Distance = 150 x Slope (expressed as a fraction). The setback distance is measured from the top of the leaching facility horizontally to a point which intercepts the slope adjacent to the system. There is no maximum slope specified within the Code provided that the calculated setback distance is maintained.

Title 5 does not include provisions regulating the use or design of retaining walls. Retaining walls are often proposed for use with subsurface sewage disposal systems on lots where the slope setback distance established by Title 5 can not be achieved. The walls are used as a break in the proposed slope around a soil absorption area, enabling a return to the existing grade. Because Title 5 does not specifically address the use of retaining walls, approvals for installation have been required to comply with the variance procedure specified in 310 CMR 15.20.

16.1 Literature Review

A thorough review of the literature indicates that a minimal amount of research has been completed on the evaluation of side slope requirements for conventional subsurface sewage disposal systems. This is evidenced by the lack of specific design criteria within most septic system regulations. Obvious concerns relative to side slope setback distances include: slope stability, side slope breakout of effluent due to system failure, and construction limitations.

Slope Stability

Erosive forces assailing upon exposed construction areas include water, wind, ice and gravity. The rate of erosion from construction sites is considered to be 10 - 20 times faster than that of cropland (U.S. Dept. of Agric., 1983). Water is one of the most severe climatic factors which expedites erosion and siltation. This is particularly evident in Massachusetts which receives an average of 44 inches of annual precipitation.

The main objective in erosion control is to limit the amount of exposed area during construction based on the principle that the greater the travel distance of unattenuated water, the greater the erosional damage. Soil characteristics are an important factor affecting erosion. The ease of detachment of soil particles is controlled by soil texture, structure, organic matter content, and drainage characteristics (U.S. Dept. of Agric., 1983). Soils comprised of silts and fine sands are highly erodible. Clays are not very susceptible to separation, but once detached are transported very easily.

Vegetative Stabilization Techniques

Soil characteristics, topography, climate, and vegetative cover all play a role in erosion losses. Vegetation protects the surface of the soil from the impact of falling rain, holds soil particles in place, maintains the soil's capacity to absorb water, and slows the velocity of runoff. Proper stabilization of a sloped area entails uniform grading and placement of topsoil over exposed areas, followed by seeding.

It is recommended that 4 - 6 inches of topsoil be placed over the entire exposed area overlaying the subsurface sewage disposal system to establish the growth of grasses and prevent erosion (Bouma et al., 1975). Topsoil and grass cover is encouraged to maximize limited benefits of evapotranspiration. The seeded areas preferably should be covered by straw, cheesecloth of other material to provide optimal growing conditions. There are many types of slope stabilizers available today, both natural or artificial, temporary or permanent. The most practical and economical means of stabilization of large exposed areas includes the planting of grasses. Species selection and establishment method are the two important factors when considering grasses.

It is crucial to choose an appropriate seed mixture which is suitable for the area to be vegetated. There are a number of seed mixtures available which are prescribed for problem areas, such as slopes. These mixtures usually are comprised of one dominant species.

Seeding and sodding are the most common methods of planting grass. Grass seed can be broadcast by hand, spread by a mechanical seeder, or spread by a tractor operated seeder. Hydroseeding is beneficial in sloped areas because it allows the applier to stand back from the area to be seeded and cause as little disturbance as possible. Stabilization of sloped areas takes longer by seeding because mature formation of grass roots takes up to a year compared to the immediate results supplied by the more expensive sod.

Sod provides instant protection to critical areas. Rolls of sod are placed over topsoil which has been limed and fertilized. Proper irrigation is required after sodding. Sod should not be planted on side slopes greater than a 3:1 slope (U.S. Dept. of Agric., 1983).

Side slope stabilization can be supplemented by the planting of shrubs along the slope. Shrubs should not be planted on top of the system but may be placed around the slopes for stabilization. Those shrubs planted at the toe of the slope should be moisture tolerant in order to withstand wet periods (Converse et al., 1977). The EPA Design Manual recommends that grass be planted over the entire system using grasses adapted to the area. Shrubs can be planted around the base and up the sideslopes (USEPA, 1980b).

Artificial Stabilization Techniques

Matting and mulching are both methods which stabilize areas subject to erosion until the development of a vegetative cover. Matting can be comprised of either man-made or natural fibers which should be anchored carefully to prevent slippage and allow moisture to penetrate. Natural fibers in the matting include jute or wood excelsior; manmade fibers consist of glass fibers or polypropylene.

Mulch is a temporary covering spread over areas exposed for less than 6 months when seeding does not have a suitable growing season. Mulch materials can consist of hay/straw, peat moss, wood chips, compost material, cornstalks, pine needles, and sawdust.

Side Slope Stability

Virtually no research has been performed to specifically address the degree of contouring required to provide a stable side slope to a conventional subsurface sewage disposal system. Although there is minimal supporting literature on this topic, similar design principles can be examined by reviewing the side slope requirements of mounded systems. Extensive developmental research has been performed in Wisconsin on mound systems which were developed in the 1970's in response to limiting site conditions. Approximately fifty percent of the land area in Wisconsin was unsuitable for on-site effluent disposal by conventional systems due to high ground water table, bedrock or impervious soil layers (Bouma, 1975f). The mound system was developed to overcome the site limitations that inhibited the use of a conventional subsurface sewage disposal system.

The main constituents of a mound system are a septic tank, pumping chamber and a raised soil absorption system. The mound itself consists of fill material (usually medium textured sand), a gravel distribution system, a cap and topsoil (Canter and Knox, 1985). Effluent is treated as it passes through the fill material and into the unsaturated zone of the underlying soils via a furrowed natural topsoil. The mound system maintains the existing hydraulic characteristics of the underlying soils while providing additional treatment by the sandy fill of the mound. The treatment provided by a Wisconsin mound system has been shown to equal or exceed that of a conventional soil absorption system (Otis, 1982). A 1979 survey of over 640 Wisconsin mound systems indicated only three failures by surface seepage (Otis), 1982). These failures were not due to design but were attributed to poor maintenance, construction or siting.

Some seepage was found at the toe of the mound in a few cases because there was insufficient basal area to accept the effluent (Tyler, 1980). The problem with the first generation mound systems was rectified by extending the fill on the downslope side of the system which increased the absorption area. Extending the basal area downslope for most failing systems reduces the breakout problem because it allows for more vertical flow and less horizontal flow, resulting in lower toe loading (Converse, 1984).

A review of the literature on mound systems indicates a consensus among authors that a maximum three (horizontal) to one (vertical) slope should be maintained around the system. Converse and Tyler recommend a slope of three to one to maintain good stability and ease of maintenance of vegetative cover (Converse, 1977; Converse, 1980). The USEPA Design Manual requires a maximum three to one slope as the design criteria for typical mound systems (USEPA, 1980b). The three to one slope is sufficiently steep to direct surface water flow off the soil absorption system, while remaining stable and supporting vegetation.

Side Slope Setback Distance

O. Benjamin Kaplan (1987) recommends a fifteen foot horizontal setback distance between any part of a conventional soil absorption system and ground surface when the disposal field is installed in sloping ground. The USEPA Design Manual (1980b) defines a side slope setback as being equal to the mound height at bed center times a three to one slope.

A study on four seepage trench disposal fields installed on slopes up to 45 percent in Oregon indicated that slope steepness is not a limiting factor in proper effluent disposal (Oregon Experimental, 1982). The study illustrated that there was no ponding or side slope breakout in any of the systems. Limitations in equipment operation mandated the use of hand labor in soil absorption area installation.

Construction Limitations

Proper site selection is important in the placement of a soil absorption system. Existing site topography can dictate what surface drainage problems can be expected in the post development condition. Ground slope can affect the stability of hillside trenches and the distance effluent will travel through the soil (Canter and Knox, 1985). Steeper slopes shed water faster and may be more suitable as soil absorption systems, as long as they do not exceed 25 percent (Parker). Concave slopes will cause surface water to collect in a central location, while convex slopes will diffuse runoff.

Construction costs are an obvious concern to the property owner when constructing in steep areas. Soil absorption areas are easiest to install at level grades. Excessive slopes can present construction limitations in that additional time and care must be taken to avoid surface smearing and compaction of the soil absorption area.

Construction practices play a primary role in the success or failure of a system (Anderson, 1982). Compaction of the natural soils through the use of heavy equipment increases the bulk density of the soil and lowers the soil's hydraulic conductivity (Hantzsche). Sites consisting of slopes in excess of 25 percent can be utilized for disposal of effluent provided that the use of construction machinery is limited (USEPA, 1980b).

All heavy equipment should be kept off the area of the soil absorption system and lightweight tracked vehicles should be used in sites with severe slope constraints. Trench systems can be constructed fairly easily with little damage to the underlying soils because construction equipment can straddle the trenches. On sloped sites, trenches should be installed parallel to the contours so that the infiltrative surface is maintained and excavation is kept to a minimum (Canter and Knox, 1985).

Retaining Walls

Although a significant amount of literature is available on the design of retaining wall, the majority of the literature deals with the structural design of the walls rather than their effectiveness as a mechanism used to interrupt existing or proposed slopes. It is clear that, based upon the available literature, retaining walls should be designed by a competent structural engineer based on the specific site conditions encountered.

16.2 State Regulations

A review of state regulations indicates that a majority of the states have specific language stating that exposed areas covering the subsurface sewage disposal system shall be loamed and seeded. Whereas the majority of the states did not have specific language regulating side slope requirements, it is not surprising that there is little reference to the stabilization of these slopes.

Colorado, Idaho, Oregon, Washington, and Maine have regulations which contain language similar to Title 5 specifically addressing side slope setbacks. Oregon and Washington both require a minimum 25 foot setback distance. Colorado calculates the minimum horizontal setback distance by multiplying four times the height of the bank, measured from the top edge of the bank. Idaho's setbacks are based on soil types and impermeable layers above and below the base of the soil absorption system. Maine requires a three foot separation from the soil absorption system to the top of slope which has a maximum four to one slope back to original grade.

The majority of the states indirectly address side slope setbacks by defining maximum site slopes allowed to support subsurface sewage disposal systems. As illustrated in Tables 16.2.1 and 16.2.2, nineteen states have site suitability assessment criteria requiring maximum site slope limitations ranging from 12 percent (Indiana) to an unlimited maximum slope. The average allowable maximum site slope of these fifteen states is 25 percent. Kentucky, Montana and Oregon have determined some intermediate site slopes provisionally suitable provided additional special conditions are met.

There is very little in the state regulations regarding retaining walls. Not one state includes provisions regulating the design and installation of retaining walls in their subsurface sewage disposal regulations.

TABLE 16.2.1

SIDE SLOPE REQUIREMENTS

	MAXIMUM SITE SLOPE ALLOWED	SITE SLOPE/SIDE SLOPE REQUIREMENTS
Alabama	25%	
Alaska	25%	50 feet uphill from any man-made or natural slope where the slope changes by 25%
Arkansas		No criteria given
Arizona		>20%, 20 foot setback from ground surface required
California		No criteria given
Colorado		Min. hor. distance from cut banks and fill areas to SSDS = 4 x height of bank
Connecticut		15 foot minimum setback from toe of fill areas
Delaware	15%	
Florida		No criteria given
Georgia		Regulations unavailable
Hawaii		No criteria given
Idaho	20%	Setback based on soil types, impermeable layers above and below base
Illinois	None	
Indiana	12%	
Iowa		No criteria given
Kansas		Regulations unavailable
Kentucky	15-30%	Study of soil characteristics, installation of curtain drains
Louisiana		Regulations unavailable
Maine	Max. 25% to original soil	25 foot setback from downhill slope greater than 33%
Maryland	25%	25 foot horizontal separation distance from 25% slope
Massachusetts		Minimum setback of 150 feet x Slope
Michigan		Minimum 10 foot setback from top edge of slopes >25%
Minnesota	None	
Mississippi	15%	
Missouri	30%	>30%, approval from administrative authority required
Montana	25%	>15%, more information required on soil and groundwater
Nebraska	None	
Nevada		>20%, 20 foot setback from ground surface required
New Hampshire	None	5 foot setback from maximum 3:1 slope down to existing grade
New Jersey		No criteria given
New Mexico		No criteria given
New York	None	
North Carolina		15 foot setback from slopes 2 feet or more in vertical height
North Dakota	None	
Ohio		No criteria given
Oklahoma	None	
Oregon	45%(1)	25 foot minimum setback, 50 feet with impermeable layer
Pennsylvania	25%	10 foot separation from natural/man-made slope >25%
Rhode Island		No criteria given
South Carolina		15 feet from top of slope
South Dakota		(2)
Tennessee	25%	>25% slope requires special investigations
Texas	15%	
Utah	25%	10 foot setback distance, 50 foot requirement from downhill slope >35%
Vermont	None	
Virginia		Regulations unavailable
Washington	30%	Maximum 3:1 slope, 25 foot setback distance, 6 feet natural material
West Virginia	25%	Serial distribution system for sloped sites
Wisconsin		20 foot setback from top of 3:1 slope
Wyoming	25%	Maximum slope based on perc rate
Guam		No criteria given

(1) >30% designated as "Steep Slope System"

(2) Serial distribution system to be used where elevation difference of ground surface exceeds 8" within absorption field

Table 16.2.2

STATE	MAXIMUM SITE SLOPE ALLOWED TO SUPPORT SSDS	SITE SLOPE/SIDE SLOPE REQUIREMENTS
Alabama	25%	
Alaska	25%	50 Feet uphill from any man-made or natural slope where the slope changes by 25%.
Colorado		Minimum horizontal distance required from cut banks and fill areas to individual sewage disposal system components four times the height of bank.
Idaho	20%	Setback based on soil types, impermeable layers above and below base. 300 200 100 Imp. Layer Above Base: 75 50 50 Imp. Layer Below Base: 50 25 25
Kentucky	>30% Unsuitable 15 - 30% Provisionally Suitable	Thorough study of soil characteristics. Installation of curtain or vertical drains upslope from lat. field system.
Maine	Maximum 25% to original soil	25' Setback from downhill slope greater than 33%, adequate distance maintained to assure that the toe of all fill does not extend to 33% slope.
Maryland	25%	Horizontal separation distance from steep slope (25%) 25'.
Minnesota		
Mississippi	15%	

<table>
<tr><td>Montana</td><td>>15% Special Condition - More Info. on Soil & GW
25%</td><td></td></tr>
<tr><td>Nebraska</td><td>No Maximum</td><td></td></tr>
<tr><td>New Hampshire</td><td></td><td></td></tr>
<tr><td>Oklahoma</td><td>No Maximum</td><td></td></tr>
<tr><td>Oregon</td><td>45%
>30% Steep Slope Systems</td><td>25' Minimum setback requirement.
50' With impermeable layer.</td></tr>
<tr><td>Pennsylvania</td><td>25%</td><td>10' Separation from natural/man made slope >25%.</td></tr>
<tr><td>South Carolina</td><td></td><td>15' From top of slope.</td></tr>
<tr><td>South Dakota</td><td></td><td>Serial distribution system to be used where elevation difference of ground surface exceeds 8" within absorption field.</td></tr>
<tr><td>Tennessee</td><td>25%</td><td>>25% Slope requires special invest.</td></tr>
<tr><td>Utah</td><td>25%</td><td>10' Setback distance.
50' Requirement from downhill slope >35%.</td></tr>
<tr><td>Washington</td><td>30%</td><td>Maximum 3:1 slope.
25' Setback distance, 6' natural material.</td></tr>
<tr><td>West Virginia</td><td>25%</td><td>Serial distribution system for sloped sites.</td></tr>
<tr><td>Wyoming</td><td>25%</td><td>Maximum slope based on perc rate.
<table>
<tr><td>(min/inch)</td><td>max. slope</td></tr>
<tr><td><5</td><td>25%</td></tr>
<tr><td>6 - 45</td><td>20%</td></tr>
<tr><td>46 - 60</td><td>15%</td></tr>
</table></td></tr>
</table>

16.3 Local Regulations

Eleven towns have instituted side slope requirements in local health regulations. Examples include the towns of Hardwick and Sturbridge which have set limits on the grade of the slope, varying from 5:1 to 3:1 and the town of Holden which has a setback distance of 50 feet from any slope greater than 3:1.

West Newbury and Topsfield appear to be the only towns with regulations restricting retaining walls used to meet side slope requirements. West Newbury does not allow impervious walls, while Topsfield prohibits any type of wall.

16.4 Conclusions and Recommendations

A review of the literature indicates that side slope requirements have not been extensively studied to date. This is probably due to the belief that an adequate degree of protection is afforded by the current regulations. Additional research is necessary to study the relationship between loading rates, slope steepness and hydraulic properties of the soil before definite conclusions based on supporting documentation can be made.

A three horizontal to one vertical design slope appears to be sufficient in most cases from an erosion control and slope stability standpoint. Grassing exposed areas over a subsurface sewage disposal system can be accomplished by seeding or sodding. Either method has shown to be a sufficient stabilizer of sloped areas. Slopes greater than three horizontal to one vertical should not be sodded.

Sideslopes can be stabilized through the use of artificial stabilization techniques including mesh or blanket matting or mulching. Sideslopes can be additionally stabilized by the placement of shrubs along the bank. These shrubs should be moisture tolerant in order to withstand wet conditions.

It is the recommendation of this report that a minimum side slope requirement of three horizontal to one vertical be required. Proper loaming and seeding/sodding should then result in a stable side slope. Proper site design should include the diversion of stormwater runoff away from the soil absorption system. Good surface drainage is critical in maintaining stable soil conditions necessary in any earthen structure susceptible to saturation due to water buildup.

Use of the existing Title 5 setback formula results in overly restrictive setback distances particularly in situations involving the placement of fill materials. This, coupled with the fact that the formula has been a chronic source of confusion, suggests that modification to the current side slope setback requirements are justified.

The setback formula in use today has proven to be one of the least understood provisions within Title 5. The Department of Environmental Protection receives more questions regarding side slope requirements than any other regulation within Title 5. There is conflict even within the Department regarding proper interpretation and implementation of the regulation. Discussions with Department representatives revealed a need for clarification of these requirements, as well as implementation of simpler design standard.

A maximum design slope of three to one is recommended as the basis for the following proposed regulation revision:

DESIGN/NATURAL ABSORPTION SYSTEM SIDE SLOPE		SIDE SLOPE SETBACK (FT)
less than	7:1	15
between	5:1 - 7:1	25
greater than	5:1	35

The separation distance for systems constructed in naturally occurring soils should be measured from a point representing the furthest most extremity of the leaching facility, along a line drawn as a horizontal extension of the top surface of the effective leaching area to the nearest point of intersection with the adjacent side slope ("Point A"). The slope should be measured from "Point A" to "Point B" as illustrated in Figure 1.5.5.1. "Point B" is located at the intersection of a horizontal line drawn four feet below the bottom of the leaching facility and the land surface of the adjacent side slope after finished grading.

Retaining Walls

Retaining walls appear to be an adequate method of providing a mechanism to intercept a slope on parcels where steep natural slopes would require excessive amounts of fill to meet Title 5 slope requirements. Retaining walls should meet the same horizontal setbacks from leaching facilities as are required for cellars under housing units. Retaining walls should also be waterproofed to protect against leakage and contain no weepholes at the base of the wall. Requirements should be included in any revisions to Title 5 allowing the use of retaining walls with the provision that they are designed and inspected by a structural engineer. Retaining walls if properly designed and constructed should serve to provide the same protection against sewage effluent breakout as would a strict compliance with the Title 5 slope requirements.

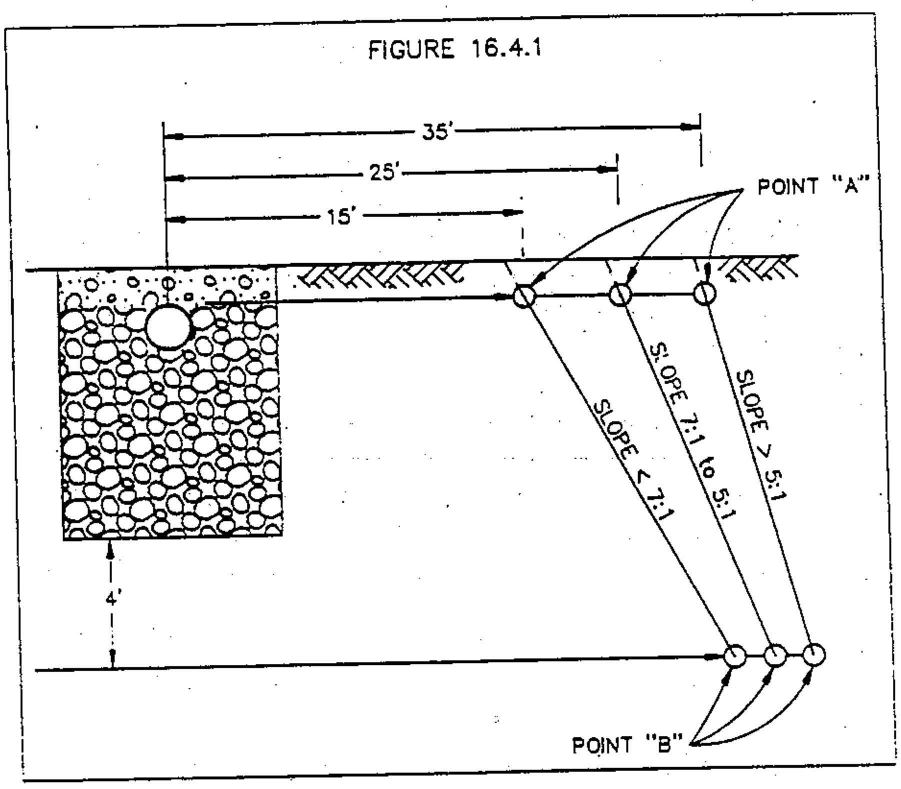


FIGURE 16.4.1
35'
25'
15'
POINT "A"
SLOPE < 7:1
SLOPE 7:1 to 5:1
SLOPE > 5:1
4'
POINT "B"

CHAPTER 17

LARGE SYSTEMS

The Massachusetts Ground Water Discharge Permit Program (314 CMR 5.00) and the Massachusetts Ground Water Quality Standards (314 CMR 6.00) establish the minimum acceptable degree of wastewater treatment and dictate the effluent limitations required for all regulated discharges to the ground and ground waters of the Commonwealth. These limitations effectively preclude the use of septic systems as a option for sanitary waste disposal where the design flow exceeds 15,000 gallons per day.

Massachusetts General Laws c.21A s.13 stipulates: "A duly registered sanitarian or a professional engineer registered in the Commonwealth may prepare plans for subsurface systems for disposal of domestic sewage of not more than two thousand gallons per day (gpd). Any other plans for a sewage disposal system shall be prepared by a professional engineer registered in the Commonwealth." This requirement recognizes that larger systems are more complex and therefore need a higher degree of design expertise.

For purposes of this report, a large septic system is defined as any septic system designed to discharge between 2,000 and 15,000 gallons per day. This section of the report will summarize the prior information and expand upon it to include the more extensive design standards and site investigation expertise necessary to ensure that these large systems function properly.

17.1 Literature Review

Sewage disposal regulations have traditionally been based upon the research and design experience gained from small individual on-site septic systems. The information and conclusions drawn from these small scale studies has been expanded well beyond the extent originally intended and, for the most part, is not sufficiently detailed for adoption to the siting and design of large systems. In general, large systems impart an increased hydraulic load upon the environment and create an increased potential for localized ground and/or surface water contamination (Magner, 1984).

Analysis of a wide range of septic system sizes has revealed a significant trend towards poor performance with higher design and operating flows (Plews and DeWalle, 1985). A primary cause of the elevated failure rate of large systems appears to be inadequacy of the current site investigation procedures originally developed for single user on-site domestic systems (Tyler and Converse, 1984).

An additional problem with the operation of large systems is that, even though unsaturated flow conditions may prevail throughout the underlying soil regime, the extreme size of these systems precludes adequate lateral reaeration rates (Siegrist et al., 1984). Surface aeration alone is usually insufficient to satisfy the oxygen demand initiating the development of anoxic conditions in the underlying soils.

Anoxic conditions, which may prevail along the interior of the leaching facilities of large systems, and in the saturated flows of improperly functioning small systems, results in increased biomat formation and incomplete nitrification of the effluent leading to the discharge of ammonia (Plews and DeWalle, 1985). Positively charged ammonium ions are quickly adsorbed onto negatively charged soil grains competing with metal attenuation and removal mechanisms. When the limited attenuation capacity of the soil has expired, ammonia is discharged to the groundwater resulting in acidification and depletion of the dissolved oxygen concentration.

On the other hand, use of large community systems may permit more effective isolation of the soil absorption system from domestic wells and environmentally sensitive areas (Nettles and Ward, 1987). A single large system is relatively inexpensive to construct, easily operated and maintained, and, if controlled by a homeowners group with operation overseen by a responsible party, may provide a degree of monitoring and protection not afforded by the relatively unregulated, and often neglected, individual single-user on-site systems (Steinbeck, 1984).

A survey of 369 existing large systems located in 10 counties in Washington determined that these systems were exhibiting a 22 percent overall failure rate (Deese and John, 1986). For this study, poor performance and failure was only defined as the onset of surface break-out. An appraisal of the incidence of groundwater contamination was not included in the quantification of poor system performance (Plews and DeWalle, 1985).

For the Washington study, large systems were segregated into three categories based upon flow, low (<5,900 gpd), medium (5900 - 11,500 gpd), and high (>11,500 gpd). For the low flow systems, increasing the loading rate did not result in a corresponding acceleration in the onset of poor performance, whereas increasing the loading rates to high flow systems did. This was attributed to inadequate liquid distribution and localized hydraulic overloading which becomes more prominent with increased system size (Plews and DeWalle, 1985). Conclusions of these studies included the observations that:

- (a) lower actual and design flows correspond to a lower incidence of system failure;
- (b) non-residential systems fail at a lower rate than similarly size residential units;
- (c) a lower failure rate is attributed to non-mechanical system designs; and,
- (d) system failure rates rise with increasing design flows, increased total loading, and increased bottom loading.

The study further concluded that increased care should be given to the investigatory process, system design and system installation for all systems intended to dispose of greater than 6,000 gallons per day or to utilize loading rates in excess of 2 - 3 gpd/sf (Plews and DeWalle, 1985).

In order for a large system to operate effectively, the location and extent of all limiting site conditions need to be adequately assessed. Variable conditions across the disposal site, which now encompasses a much larger infiltrative area, require the performance of an intensified investigation process (Magner, 1984). This site suitability study should include, at a minimum, a complete analysis of the soils, the hydrogeology, and the topography, along with an assessment of the potential impacts to sensitive receptors and surrounding uses (Magner, 1984).

A complete analysis of the soils, to a depth at least six feet below the bottom of the proposed infiltrative surface, should be completed (Siegrist et al., 1984). This investigation should include a determination of the soil texture, soil morphology, clay content and pollutant attenuation capabilities, along with an assessment of the location, depth and extent of all limiting layers, discontinuities and anomalies underlying the site.

Larger systems require additional study of the available unsaturated treatment zone. A significant groundwater mound may develop beneath a large soil absorption system, reducing the availability of unsaturated soils and radically altering the natural groundwater flow patterns and velocity (Magner et al., 1988). Altered flow fields may impact domestic wells, change the natural hydraulic gradient, alter the transport potential of pollutants, and create localized regions of decreased groundwater flow resulting in the development of a ground water stagnation point upgradient of an effluent mound (Magner et al., 1988).

Groundwater mounds can extend considerable distances and rise to great heights. Because the extent of mound development is greatly influenced by local features, a hydrogeologic investigation is required to determine the existing soil conditions and to assess the hydraulic characteristics of the site. In addition to judging the soil and surface drainage properties and characteristics, this study should include a determination of the ground water flow patterns, the hydraulic gradient and conductivity, the saturated aquifer thickness, the location of all hydraulic boundaries and the extent of seasonal ground water fluctuations (Magner, 1984). Approved ground water flow and solute transport models can then incorporate this information to estimate the height and extent of the resultant ground water mound and to assess the potential impacts to sensitive receptors such as drinking water supply wells.

Otis and Hargett (1983) suggested that large systems be designed with conservative loading rates. In citing studies conducted by Bouma (1975), who recommends variable acceptability at a loading rate of 5 centimeters per day (cm/d) in sands and by Simons and Magdoff (1979) who recommend 2 cm/d loading rates for coarse sandy soils, with lower loading advised for non-coarse sands, Otis and Hargett concluded that even a 2 cm/d (0.5 gpd/sf) loading rate may be too high for large systems installed in fine sands (Siegrist et al., 1984).

Wastewater application studies have determined that low frequency dosing, with extended rest periods, is the preferred method of wastewater application. Dosing the effluent periodically and uniformly throughout the leaching facility improves the absorption field performance and increases field longevity (Berkowitz, 1984). For gravity fed systems, conventional distribution is preferred to serial distribution (Plews and DeWalle, 1985).

Mound type systems have been proposed for the disposal of large quantities of waste generated by cluster housing developments. These large mound systems have been shown to bridge the gap between small and large system performance. Performance is enhanced by the improved aeration potential, both lateral and surficial, provided by mound design. An interconnected pressure distribution system, ensures uniform distribution, allows resting, and provides for back-up protection in the event of mechanical failure (Hantzsche and Fishman, 1982).

Variability of effluent flow rates and composition, combined with unequal effluent distribution, commonly results in localized system overloading and ponding. These problems are intensified by expanded system size. Larger systems may exhibit greater flow variability and increased surface loading rates (Dewalle, 1981), resulting in an applied hydraulic load per unit area which is elevated by several orders of magnitude (Magner, 1984).

Many of the adverse impacts of large systems can be minimized through the use of shallow trench designs supplied by pressure distribution networks. A drawback of these designs is that they typically require large land areas and result in increased design, material and installation costs. Galley and pit systems have also been employed for large soil absorption systems. These systems can prove to be suitable, provided that an adequate vertical separation distance is available for proper contaminant removal and allowances are made for the development of a groundwater mound. Groundwater mound development may be intensified by these types of systems due to the higher hydraulic loading per unit area provided by their extensive use of sidewall infiltration areas.

A computer model is a tool that, given the correct input parameters, can provide a theoretical simulation which demonstrates how a ground water system works. The goal of ground water modelling is the prediction of unknown variables, such as the hydraulic head or the concentration of a particular solute, at various points in the aquifer.

It is incorrect to assume that computer generated solutions always provide an accurate and precise prediction of the ground water mounding and solute transport process. Accuracy, the measure of how well the model predicts the behavior of the modeled environment, is dependent upon the correct use of input parameters and assumptions. A complete, accurate understanding of the ground water flow regime is essential. An inaccurate model, while being a correct mathematical solution to the input parameters, will not correctly assess the actual behavior of the system. This model may give a false sense of security and inappropriately direct system design.

It is beyond the scope of this report to discuss and derive the flow and transport equations involved in ground water modelling. Further information is contained in the Division of Water Supply, Policy 87-12, "Quality Assurance for Groundwater Modelling". Discussed here is a brief overview of model capabilities and limitations.

Types of Models

There are two basic types of models, analytical and numerical, with the major difference being the degree of simplification assumed for the ground water or mathematical system boundary conditions. Analytical models usually contain a substantial simplification of the ground water system (Walton, 1985). Simplifying assumptions commonly used include:

(1) the aquifer is completely homogeneous and isotropic;
(2) the aquifer is of infinite areal extent;
(3) the aquifer is of uniform thickness; and
(4) ground water temperature, density, and viscosity are constants.

There are a number of commercially available analytically based computer programs which allow computation of ground water mounding effects from various artificial recharge systems. Most analytical models are based on an equation derived by Hantush (1967). This equation predicts the height of a ground water mound beneath a recharge area. A modified version of this equation appears in Walton (1985) as follows:

$$h_{x,y,t} - H = {}^{Vt}/_{4f} \left(F_{(\alpha,\beta)} \right)$$

where:

$h_{x,y,t}$	= the height of the water table above an impermeable layer at point x,y at time, t;
H	= the original height of the water table;
V	= the arrival rate of water from the basin;
t	= time since the start of recharge;
f	= fillable porosity (1 > f > 0);
L	= length of the recharge basin (y);
W	= width of recharge basin (x);
$F_{(\alpha,\beta)}$	= $\int \text{erf}(\alpha^{-1/2}) \cdot \text{erf}(\beta^{-1/2})$

$F_{(\alpha,\beta)}$ is a function that allows calculation of the height of the water mound at any coordinate point (x,y) within the defined rectangular area. The mound will be the highest at the center of the recharge area, (where x = 0, y = 0), diminishing with increased distance. In contrast, numerical models, instead of simplifying the geologic environment, simplify the analytical mathematical equations. These models approximate the governing partial differential equations by algebraic difference expressions relating the unknown variables (Javandel et al., 1984). For this reason they are referred to as finite-element or finite-difference models. Numerical models are useful for modeling hydrogeologic regimes exhibiting three-dimensional flow or containing variable flow rates or transmissivity.

Solutions generated by the Hantush equation, by various other analytical models, and by the finite-difference model developed by Rao and Sarma (1980), were evaluated by measuring the mound formation beneath a large soil adsorption system in Norwood, Ontario (Chan and Sykes, 1984). This model comparison was accomplished by varying the actual and computer loading rates, and comparing the computer generated solutions to the measured ground water fluctuations. This study concluded that both the Hantush and the Rao-Sarma models gave reasonable, but conservative, predictions of ground water mounds. It further concluded that the Hantush model was simpler to calibrate.

Solute-transport models are used to simulate the distribution and movement of a solute within a system. These models use many different methods to simultaneously solve both the flow equation and the transport equation (Cantor and Knox, 1985). The Konikow and Bredehoeft (1978) model uses a method of characteristics solution (MOC). Because solute transport involves many different physical, chemical and biological actions, an assessment requires a multi-disciplinary approach integrating geologic, hydrologic, chemical, and biologic attributes in an approximation of the transport, fate and attenuation mechanisms (Keely, 1987).

According to studies completed by Sudicky (1986), advection may be the most important aspect of solute transport and a detailed hydraulic conductivity analysis may be the most important factor in simulating solute transport. This would tend to make determining the values of the various input parameters, such as dispersion coefficients and biotransformation rates (which are difficult to measure and are subject to much debate) unnecessary. Additionally the influence of biological processes are frequently overlooked parameters affecting the fate of contaminants.

Adequately describing the complex nature of all these interactions mathematically, requires the use of simplifying assumptions or the omission of certain minor parameters (Keely, 1987). Therefore, the accuracy and predictability of solute-transport model simulations must be carefully analyzed.

The most commonly used solute transport models are: PLASM and MOC. MOC was evaluated by Cantor and Knox (1985) through application to a site in Edmond, Oklahoma. Their conclusion was that sophisticated models are only as good as the field data available and that for large systems expanded field studies are justified.

In order to apply these models, or even to simply decide on the proper type of model to use, a qualified professional must first develop a conceptual model describing how the real hydrogeological system works. This conceptual model must include all of the controlling factors in the system, such as aquifer extent and thickness, sources, sinks, and hydrogeologic boundaries.

The final selection of the type of model, either analytical or numerical, should be based on the complexity of the system, the availability of data to adequately construct and calibrate the model and a complete understanding of system boundary conditions. No model is correct for every situation and requiring the use of a particular type of model or predetermining the model input parameters, is not advised.

Modeling methodology should follow a systematic, clear and effective scheme. The following format, adapted from the Department's "Standard References for Monitoring Wells", details the information that should be included in the final report:

(1) Describe and validate the conceptual model based on the geology and hydrogeology of the site.

(2) Explain how, when, and by whom the data on the subject hydrogeologic system was collected, analyzed, and interpreted.

(3) Document the ground water flow and contaminant transport model (code) utilized. Explain why the model being utilized was chosen. All simplifying assumptions inherent to the application of the model should be stated and justified, as well as the impact these assumptions may have on model results.

(4) All initial conditions, boundary conditions, hydraulic and transport parameter values should be defined and justified.

(5) The report should describe, present and discuss the calibration and model validation procedures. Focus should be placed on the overall model water and/or chemical balance.

(6) The sensitivity of the model should be tested and the parameters of the model that have the greatest influence on the results should be determined.

(7) Quality Assurance/Quality Control for all pre- and post-processing of model input data should be maintained.

(8) The model output from all predictive scenarios should be presented and interpreted in an easily understood form.

(9) The physical/chemical accuracy of the model (how well does the model represent the actual physical and chemical processes of the environment?) should be determined and discussed.

17.2 State Regulations

Table 17.2.1 summarizes the results of a survey of on-site septic system regulations currently in effect across the country. For the most part, this table is limited to the additional large system requirements specifically mentioned in the "small flows" septic system regulations. Additional design and review requirements may be contained in related environmental protection and public health regulations.

Table 17.2.1 demonstrates the increased awareness that many states have for the problems commonly attributed to large septic systems. Minimization of these adverse effects is controlled by mandating a state review and approval process, requiring a ground water discharge permit, specifying more stringent standards, and/or completing a hydrogeologic investigation in order to estimate the groundwater mounding effects and/or nitrate induced groundwater degradation.

17.3 Local Regulations

Currently several towns, including Marshfield and Yarmouth, have made an attempt to evaluate regional water quality impacts by requiring a hydrogeologic assessment for septic systems intended to discharge more than 2,000 gpd. These regulations stipulate which models are permitted and specify the parameters to be used. Unfortunately, these regulations, as they are currently written, are too specific. They do not allow any flexibility for site-specific conditions and current research developments. For example, the mandated dispersivity values appear to be based on the Otis studies (LeBlanc, 1984). More recent studies performed by (Robertson, et al, 1984) indicate that more conservative values may be appropriate. These regulations also do not account for the ground water mound and its impact on the ground water flow regime. In general, the local assessment requirements include:

1. Completion of geologic boring logs;
2. Compilation of a water table map detailing ground-water flow direction(s) and hydraulic gradient(s).
3. Calculation of the projected downgradient concentrations of nitrogen, using predetermined parameters in a two-dimensional solute transport model.

Currently only PLASM with Random Walk written by Prickett and Lonnquist (1981) and the USGS Konikow and Bredehoeft (1978) model (MOC) are accepted by these towns. The required predetermined modeling parameters include:

(1) transmissivity to be determined by on-site slug or pump test;
(2) aquifer thickness to be determined by on-site boring (This step also requires input for the location of confining layers and estimated plume thickness);
(3) dispersivity equal to 40 feet longitudinal and 30 feet transverse;
(4) hydraulic gradient as determined from hydraulic potential measured from the installed monitoring wells;
(5) no retardation factor; and,
(6) sewage flow estimates as defined by Title 5 design flows.

TABLE 17.2.1

LARGE SYSTEMS

	STATE APPROVAL REQUIRED	GROUNDWATER DISCHARGE PERMIT	INCREASED REGULATIONS REQUIRED	HYDROGEOLOGIC STUDY REQUIRED	MAXIMUM SIZE
Alabama	1,200		5,000		
Alaska	>Duplex		2,500	2,500	
Arkansas					
Arizona		20,000	10,000	2,000	
California		County Rules Prevail			
Colorado	2,000		1,000		
Connecticut			2,000/5,000		
Delaware		2,500	2,500	2,500	
Florida	5,000		5,000		
Georgia					
Hawaii	800				
Idaho					
Illinois					
Indiana					
Iowa					
Kansas					
Kentucky			2,000		
Louisiana					
Maine					
Maryland			5,000		
Massachusetts	15,000	15,000			15,000
Michigan	1,000	10,000	2,000	10,000	10,000
Minnesota	5,000/15,000				
Mississippi	400				
Missouri					
Montana					
Nebraska					
Nevada					
New Hampshire		20,000	2,500		
New Jersey					
New Mexico					
New York	1,000	10,000	1,000		
North Carolina	3,000		480	3,000	
North Dakota					
Ohio					
Oklahoma					
Oregon	2,500	5,000	300/2,500		
Pennsylvania				10,000	
Rhode Island	5,000	5,000	2,000		
South Carolina			1,500		
South Dakota			7,500		
Tennessee			3,000		
Texas		5,000			
Utah			5,000		15,000
Vermont		6,500	5,000	10,000	40,000
Virginia					
Washington			3,500		14,500
West Virginia			3,000/5,000		
Wisconsin			1,500/5,000		
Wyoming			2,000	2,000/10,000	

In addition to completing this modeling exercise, approval of large system designs must include provisions for long term ground water quality monitoring. This usually requires the installation of a minimum of three (3) downgradient and one (1) upgradient multi-level wells. Ground water samples must be collected on a quarterly basis and tested for the parameters controlled under the Ground Water Discharge Permit Program 314 CMR 5.00.

17.4 Conclusions and Recommendations

Research indicates that, to ensure proper installation of large septic systems, designers need to posses an increased measure of skill and knowledge not currently demanded by the cook-book designs of smaller systems. In addition to increased engineering expertise, proper design demands that an added emphasis be extended to the siting process. The site investigation and assessment process must extend beyond the immediate vicinity of the disposal system to include the regional impacts induced by larger septic systems.

Site investigations must be directed by competent personnel intent on achieving the best system possible. Site specific assessments of potential impacts should be conducted as a design aid, not just as a means of satisfying the minimum investigatory standards mandated by State or local rules and regulations.

The following subsections outline design considerations necessary for large system installations. Also included are more advanced siting techniques, as well as legal and financial requirements. All of these large system design requirements can also be applied to individual sites as deemed necessary by a qualified professional.

Design Considerations

As system size increases, maintaining conservative loading rates and utilizing suitable soils become increasingly important factors. The following tables should be used for sizing the leaching facilities intended for systems with design flows in excess of 2,000 gallons per day. These charts are based upon both the soil type and the percolation rate.

Table 17.4.1 details the maximum loading rates deemed acceptable for the protection of large (greater than 5,000 gallon per day) systems. These reduced loading rates are intended to account for the reduced reaeration rates associated with extreme system size. Additionally, a maximum acceptable percolation rate of thirty minutes per inch is suggested for large systems.

TABLE 17.4.1

PROPOSED LOADING RATES FOR LARGE SEPTIC TANK/SOIL ABSORPTION SYSTEMS

(greater Than 5,000 gallons per day)

Percolation Rate min./inch	Loading Rate gpd/sf (cm/day) Soil Type Type I	Type II	Type III	Type IV
0 - 5	0.50 (2.0)	0.50 (2.0)	-	-
6 - 10	0.50 (2.0)	0.50 (2.0)	-	-
10 - 15	-	0.34 (1.4)	-	-
16 - 20	-	0.29 (1.2)	-	-
21 - 25	-	0.25 (1.0)	-	-
26 - 30	-	0.15 (0.6)	-	-
31 - 40	-	-	-	-
41 - 60	-	-	-	-

For medium sized systems (2,000 - 5,000 gallons per day), reducing the loading rate is not as critical. These systems do not undergo the great reduction in lateral reaeration rates demonstrated by larger systems. For these medium sized systems, the loading rates proposed for domestic systems with some restrictions, should suffice. A maximum acceptable percolation rate of 30 minutes per inch is also suggested for these systems.

Additionally, because larger systems require an increased need for uniform effluent distribution, pressure dosing should be required for all systems designed in excess of 2,000 gallons per day. Effluent disposal for systems with design flows greater than 5,000 gallons per day should be divided into two equally sized areas each served by a separate pumped pressure distribution network. Pump discharge piping should be manifolded and valved to allow the use of either of the effluent disposal areas in the event of a pump failure.

TABLE 17.4.2

PROPOSED LOADING RATES FOR MEDIUM SIZED SEPTIC TANK/SOIL ABSORPTION SYSTEMS

(2,000 - 5,000 gallons per day)

Percolation Rate min./inch	Loading Rate GPD/sf (cm/day) Soil Type Type I	Type II	Type III	Type IV
0 - 5	0.74 (3.0)	0.60 (2.5)	-	-
6 - 10	0.66 (2.7)	0.60 (2.5)	-	-
11 - 15	-	0.56 (2.3)	0.37 (1.5)	-
16 - 20	-	0.53 (2.2)	0.34 (1.4)	-
21 - 25	-	0.40 (1.6)	0.33 (1.3)	-
26 - 30	-	0.33 (1.3)	0.29 (1.2)	-
31 - 40	-	-	-	-
41 - 60	-	-	-	-

Soil absorption system configuration should take into account the effects of increased ground water mound formation from wide beds or closely spaced trenches. Long narrow beds or widely spaced trenches oriented perpendicular to the direction of ground water flow cause the least hydraulic impacts minimizing ground water mound height and alteration of the natural ground water flow regime.

Advanced Siting Techniques

Small septic system designs are based upon a limited amount of information, with investigations primarily confined to the immediate vicinity of the soil absorption system. For larger systems (>2,000 gpd) a more complete assessment must be conducted and an understanding of the regional hydrogeology must be acquired.

Completion of a thorough hydrogeologic assessment and development of a conceptual model should be intended to satisfy two main design objectives: demonstration of the ability of the geologic environment to accept and disperse the design wastewater volumes, and assurance that the proposed discharge will not present a health hazard or impose adverse environmental impacts. A properly thought-out assessment should consist, at a minimum, of the following:

A. The advancement of at least three borings each completed with appropriately configured monitoring wells. This task is intended to supply the following information:

   (1) The nature and extent of the soils and the subsurface geology that defines the stratigraphy. Bedrock should be defined whenever the overburden thickness is forty feet or less.
   (2) The depth to ground water, hydraulic gradient, and ground water flow direction(s).
   (3) All monitoring wells should be constructed according to the Department's guidelines entitled, "Standard References for Monitoring Wells".

B. The determination of the mounding potential and an evaluation of the environmental impacts. These conclusions should be based upon the results of the following required information:

   (1) An evaluation of the hydraulic conductivity, porosity, thickness of the aquifer and the thickness, extent, and interconnection of any confining layers.
   (2) A determination of the ground water velocity.
   (3) A determination of the seasonal and/or tidal fluctuations in ground water elevation.

(4) A determination of the type and competency of the bedrock through coring and the Rock Quality Designation (RQD), if bedrock is less than 40 feet below grade.

(5) An assessment of the aquifer characteristics in accordance with the methods described in the Departments guidelines: "Standard References for Monitoring Wells"

(6) When the hydrogeology of the site is extremely complex, making accurate modelling cost prohibitive, completion of a field loading test at the proposed design flows may be desirable.

C. An evaluation of the potential impacts on current and/or potential municipal and private drinking water sources and other sensitive environmental receptors. This evaluation should include:

(1) A location of all municipal or public water supplies within a one mile radius, and private wells within a one-half mile radius, of the site. Private well screen locations (in the bedrock or the overburden) should also be determined.

(2) A determination as to whether any area within a one-half mile radius of the site being investigated as a possible water supply.

(3) An analysis of the following ambient water quality parameters: nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, total phosphorus, chloride, specific conductance and volatile organic compounds (EPA Method 524).

(4) A determination of the ground water mounding potential through the use of an appropriate ground water model.

(5) If required by threshold exceedance, an appropriate solute transport model should also be used to assess the downgradient impacts of the discharge.

D. The preparation of a hydrogeologic assessment report containing the following:

(1) An interpretation of background geologic data for the area compiled from the following sources:
U.S.G.S. topographic map;
U.S.G.S. surficial geologic map;
U.S.G.S. bedrock map;
Hydrogeologic Atlas;
other available water resource studies.

(2) A base map of appropriate scale incorporating geologic, hydrogeologic, subsurface and cultural features present at the site.

(3) Well driller's and geologist's logs for all subsurface exploratory work.

(4) Monitoring well construction details (including all benchmarks utilized).

(5) A water table contour map.

(6) A bedrock contour map (if appropriate)

(7) Geologic cross-sections in the direction of ground water flow.

E. Depending on the environmental sensitivity of the site, development of a ground water monitoring plan may be advisable. This plan should include the following:

(1) Quarterly sampling to determine ground water surface elevation and to assess water quality. Test parameters should include nitrate-nitrogen, total Kjeldahl nitrogen, total phosphorus, chloride and specific conductance.
(2) Annual water quality analysis for volatile organics (EPA Method 524).

Legal Issues

Because large systems usually involve more than one user, contingency plans should be formulated with provisions included in a users agreement, or purchase and sales agreement. In the event that the large common system fails to perform properly, this agreement would define the repair alternatives, (such as construction of a wastewater treatment facility or connection to a municipal sewage treatment system) and outline the method of procuring the necessary remediatory funds. In addition, a comprehensive management program, including the formation of a private maintenance authority responsible for performing monitoring and evaluations and the establishment of a capital reserve fund may ensure that routine maintenance and repairs are expeditiously performed (Hantzsche and Fishman, 1982).

The first and most important legal issue facing large systems is documenting ownership and financial capabilities. As detailed in the Departments "Guidelines for the Design, Construction, Operation and Maintenance of Small Sewage Treatment Plants with Land Disposal", the following items should be required:

(1) a single entity should be responsible for facility operation, maintenance, repair and replacement;
(2) the entity that owns the large septic system should also own the land it is located on or should be allowed access through valid easements;
(3) the entity should have an indefinite life span and should continue to be responsible for the facilities for as long as their use is necessary;
(4) the entity should have the requisite financial resources and rights to ensure that all responsibilities are met;
(5) the entity should have the authority to impose restrictions on the use of the sewage facilities including, if necessary, the ability to promulgate and enforce regulations or bylaws concerning their use; and
(6) the entity should have the ability to enter into contracts and make purchases of equipment, supplies and land as necessary.

Documentation of the above should be submitted, along with an application for a disposal works construction permit. Ownership documentation should include submitting a copy of the property deed(s) for the land on which the sewage facilities are to be located. If the owner is other than an individual, organizational documents which specify the owners legal authority should be included in the submittal. This documentation should include, at a minimum, the following items:

(1) for a private corporation or authority, the articles of incorporation;
(2) for a partnership or a limited partnership, the partnership agreement;
(3) for a condominium association, the master deed;
(4) for a trust, the declaration of trust; and
(5) for a residential homeowners association or cooperative, the cooperative agreement.

Financial documentation describing the arrangements for service charge assessments to the users of the system for expenses related to the operation, maintenance, repair, or replacement of the septic system should be required. The system of assessments should be adequate to generate revenues sufficient to fund a capital reserve account to provide for the complete replacement of the system (or other options, such as construction of a wastewater treatment plant).

Prior to the commencement of operation of the large septic system, the owner should be required to provide adequate security to serve as a source of funding for the immediate repair of the septic system. The security amount should be based upon such factors as the design flow and construction costs. Such security should be in a form of:

(1) an interest bearing bank escrow account;
(2) bank loan agreement; or
(3) a letter of credit.

In addition, it is suggested that the owner(s) maintain an interest bearing capital reserve account(s) dedicated to all expenditures for operation, maintenance and repairs of the large septic system.

Operation and Maintenance

An operation and maintenance plan should be prepared and kept current for all systems designed to discharge greater than 2,000 gpd. For medium sized systems (2,000 to 5,000 gallons per day) an abbreviated operation and maintenance plan may suffice. For all systems larger than 5,000 gallons per day this operation and maintenance plan should contain all of the information necessary to properly operate and maintain the sewage system. A copy of the operation and maintenance manual should be submitted to the local Board of Health at the completion of the construction of the facilities. The operation and maintenance manual should be kept current and reviewed by the owner(s) at least every two years.

The operation and maintenance manual should include copies of all plans, permits and approvals. Also included should be a detailed description of responsibilities of the owner(s), a copy of the agreement between a qualified individual or firm responsible for the removal and transport of septage to an appropriate, approved off-site treatment and disposal facility, a description of the septage handling and disposal requirements including the name and telephone number of the septage hauler, name and telephone number of the septage disposal facility and record keeping requirements. Additionally, information showing that the individual or firm engaged in handling the septage is properly licensed by the Board of Health of the municipality in which the system is located and by the Massachusetts Department of Public Utilities.

The operation and maintenance manual should also include a listing of all sampling and compliance monitoring required, together with appropriate protocols for proper sampling, storage, transportation and analysis. The owners should maintain all testing results, along with septage pumping history (date and volume) and certification of disposal for inspection, and should submit copies of the results to the Department and the local Board of Health as required.

An emergency operating and response plan should be included detailing the procedures to be followed in the event of flooding or system failure.

If a compliance monitoring plan is required, submittal of a written report should include an assessment of the condition of the facilities, results of sampling (including a statement regarding whether or not established protocol was followed during sample collection, storage and transport to the approved laboratory) as well as, any recommendations for improving operation.

Included in the Operation and Maintenance plan should be rules and regulations regarding the use of common sanitary sewers. These rules should be contained within the owners organization documents and, in the case of tenancy use, in the lease or rental agreements. The recommended rules are as follows:

(1) There shall be no discharge of any storm water, surface water ground water, roof runoff or subsurface drainage to any sanitary sewer;

(2) No person shall discharge or cause to be discharged any of the following described waters or wastes to any sewers:

- (a) any gasoline, kerosene, benzene, naphtha, fuel oil, or other flammable or explosive liquid, solid, or gas;
- (b) any non-latex paints, paint thinners, paint removers, or strippers;
- (c) any organic solvent or any liquid containing any organic solvent;
- (d) any photographic fluids including waste developer, fixer and rinse water;
- (e) any pesticide including insecticides, fungicides, rodenticide and herbicides of any sort;
- (f) any waters or wastes containing toxic or poisonous solids, liquids, or gases in sufficient quantity, to interfere with the sewage treatment process, constitute a hazard to humans or animals, create a public nuisance, or create any hazard in the ground water;
- (g) any waters or wastes having a pH higher than 9.5 or lower than 5.5;

(h) solid or viscous substances in quantities capable of causing obstruction to the flow in sewers, or other interference with the proper operation of the sewage works such as, but not limited to ash, ashes, cinders, sand, mud, straw, shavings, metal, glass, rags, feathers, tar, plastics, wood, unground garbage, whole blood, paunch manure, hair and fleshings, entrails and paper dishes, cups, milk containers, etc., either whole or in parts.

(i) any water or waste containing fats, wax, grease, or oils, whether emulsified or not, in excess of 100 mg/l or containing substances which may solidify or become viscous at temperatures between 32 and 150°F (0 and 65°C);

(j) any garbage that has not been properly shredded. The installation and operation of any garbage grinder equipped with a motor of three-fourths (3/4) horsepower or greater should be subject to the review and approval of the system owners or their designated agent.

Fees

These additional design, siting and legal requirements place additional technical and financial stress on both the local Board of Health and the Department. These increased burdens will require either additional time of the Board Members, or the hiring of a consultant to evaluate the large system design, the hydrogeologic modeling and/or the legal documents. An increased fee schedule for large systems similar to that imposed by the town of Yarmouth, which imposes a hydrogeologic review fee would seem warranted.

CHAPTER 18

GARBAGE GRINDERS

The wastewater generated in a domestic household is commonly separated into three general waste streams according to the type of waste. These include toilet wastes ("black water"), garbage grinding wastes, and the remaining "grey water" collected from all other sources which may include the kitchen sink, bathtub and shower, bathroom lavatory, dishwasher, and clothes washing machine (Brandes, 1978).

Domestic wastewaters can also be grouped according to their source within a household. For the most part, wastewater is produced in three areas: the bathroom, the kitchen, and the lavatory. These sources can be further broken down into several specific wastewater producing events. For example, bathroom wastes are comprised of toilet wastes, baths, showers, hand and face washings, tooth brushings, and shaving waters. Kitchen wastewaters contain dish rinsings and washings, food preparation wastes, and garbage grinder wastes; while laundry wastes normally contain wastes from an automatic clothes washing machine with some hand laundering included (Ligman et al., 1974).

The characteristics of the individual waste flows each have an effect on the overall composition of the wastewater influent entering the septic tank. The degree to which they affect the overall characteristics is determined by a combination of their pollutant concentration and their contribution to the total flow. In particular, garbage grinder wastes exhibit a high Biochemical Oxygen Demand (BOD), and high Suspended Solids (SS) content. These wastes increase the rate of sludge and scum accumulation within the septic tank and may contribute to an increased rate of failure of soil absorption systems (Siegrist, 1977).

The garbage grinder is used to grind vegetable remains, meat trimmings, and table scraps produced in the daily preparation of foods and their consumption. The addition of these organic materials to domestic wastewater flows can have a significant effect on the characteristics of the wastewater entering the septic tank. No data was available on the percentage of today's homes using garbage grinders but it was assumed that enough homes presently use them and more new homes will be built with them to warrant a discussion of their effects on septic tank/soil absorption systems.

This chapter presents the principles which should be employed in establishing the design criteria for septic tank/soil absorption systems receiving garbage grinder wastes, and evaluates changes to the existing regulations that should be considered.

> "Garbage Disposal - Garbage grinders are not recommended where they discharge to subsurface disposal facilities. When they are installed, the liquid capacity of the septic tanks shall be at least 200 percent of the estimated design flow, but in no case less than 1,500 gallons."

18.1 Literature Review

Garbage Grinder Waste Characterization

Numerous studies have been conducted in an attempt to characterize the individual waste streams according to their pollutant contribution to the overall wastewater discharged into the septic tank. However, very few of these studies have specifically included the characterization of garbage disposal wastes. Table 18.1.1 illustrates one such study which separated domestic wastewater into the three basic categories of black water, grey water, and garbage disposal wastes.

This study revealed that garbage disposal wastewater can be a significant contributor to the overall wastewater pollutant strength. It should be noted that the values presented are averages, and that considerable day to day variations may occur at any given home. From Table 18.1.1, it can be seen that, in this particular study, the garbage disposal wastes contributed 28 percent of the total BOD_5 and 37 percent of the total suspended solids loads while only contributing 4 percent of the total flow. Other studies have determined that the wastewater from a garbage grinder may contribute as much as 39 percent of the BOD_5 concentration and as much as 48 percent of the suspended solids content, while only contributing a small percentage of the total flow (Ligman et al., 1974).

A comparison between the expected garbage disposal waste characteristics, determined in three separate studies, is shown in Table 18.1.2. This comparison illustrates that considerable variation in concentrations can be expected to occur.

TABLE 18.1.1

AVG. POLLUTANT CONTRIBUTIONS OF MAJOR DOMESTIC WASTEWATER FRACTIONS[1] (Siegrist, 1977)

Parameter	Garbage Disposal[2]	Black Water[2]	Grey Water[2]	Total[2]
BOD_5	18,000	16,700	28,500	63,200
Suspended Solids	26,500	27,000	17,200	70,700
Nitrogen	600	8,700	1,900	11,200
Phosphorous	100	1,200	2,800	4,000
Approximate Flow (gal/c/d)	2	16	29	47

1. Measured prior to entering septic tank
2. All values in mg/capita/day except as noted

TABLE 18.1.2

COMPARISON OF GARBAGE GRINDER WASTE CONCENTRATIONS[1]

Parameter	(Ligman et al., 1974)	(Siegrist et al., 1976)	(Siegrist, 1977)
BOD_5	30,844	10,900	18,000
Total Solids	61,235	25,800	ND
Suspended Solids	43,545	15,800	26,500
Fats	7,711	ND	ND
Nitrogen	ND	630	600
Phosphorous	ND	130	100

ND = No data given
1. All values in mg/capita/day except as noted

Effects on Septic Tank/Soil Absorption System Performance

The septic tank is designed to protect the soil absorption system primarily by removing the settleable solids and retaining the grease and scum contained in the wastewater. As the septic tank fills with sludge and scum, solids may begin to flow into the soil absorption system. If the septic tank is under-designed, this increased solids outflow may accelerate the rate of soil absorption system clogging. Excessive soil clogging causes a premature hydraulic failure of the absorption system (Mancl, 1983). This problem can be avoided through proper sizing of the septic tank and periodic pumping of the solids which accumulate within the tank. While some degree of soil clogging improves treatment of the wastewater through physical/chemical and biochemical processes in the biomat and in the underlying unsaturated soil, severe clogging can lead to hydraulic failure, anoxic soil conditions, and greatly reduced wastewater treatment (Siegrist, 1988).

Soil clogging development is closely related to the cumulative mass density loadings of BOD_5 and TSS on the soil absorption system. Prior studies have shown that soil clogging is generally accelerated under increased concentrations of organic matter at a given hydraulic loading rate. One such study found that sands receiving septic tank effluent with elevated concentrations of BOD_5 and TSS exhibited a faster rate of soil clogging than those receiving septic tank effluent containing typical concentrations of BOD_5 and TSS (Siegrist, 1988). As illustrated in Table 18.1.3, wastewater containing garbage grinder wastes exhibits higher concentrations of BOD_5 and TSS than those without garbage grinder wastes. Consequently, if two domestic wastewaters, one with garbage grinder wastes and one without, were pre-treated through septic tanks of equal capacity, the septic tank effluent with the garbage grinder waste would contain higher concentrations of BOD_5 and TSS than the one without and its soil absorption system would be expected to fail sooner.

The additional suspended solids contributed by garbage grinder wastes increases the normal rate of sludge and scum accumulation within the septic tank. This increased amount of sludge decreases the clear space that is provided for the wastewater to pass through. A decrease in the clear space volume results in a decreased efficiency of solids removal. In order to provide the same degree of treatment as wastewater without garbage grinder wastes, additional capacity must be provided to accommodate this increased accumulation of sludge and scum. This increase should provide the available volume increase for the storage of sludge and an increased clear space volume necessary to provide the additional wastewater treatment (Baumann et al., 1977).

An appreciable amount of BOD_5 removal does not occur within the septic tank. What removal does occur is accomplished through the removal of the organic suspended solids. The design of the septic tank is, therefore, based on efficient suspended solids removal and adequate storage of the anticipated accumulation of solids.

TABLE 18.1.3

TYPICAL DOMESTIC WASTEWATER CHARACTERISTICS WITH AND WITHOUT GARBAGE GRINDER WASTES[1]

Parameter	Wastewater without garbage grinder wastes	Wastewater with garbage grinder wastes
BOD_5	260	355
TSS	260	390
Fats	20-40	45-65

1. All values in mg/l

References: (1) Siegrist, 1977
(2) Ligman et al., 1974
(3) Baumann et al., 1977

Sludge Accumulation

In a typical medium strength domestic wastewater without garbage grinder wastes, the suspended solids average approximately 260 mg/l, of which about 70 percent (182 mg/l) are settleable (Siegrist, 1977). Assuming a 4 bedroom house, the expected amount of solids retained in the septic tank over the course of one year, assuming 100 percent retention, is calculated as:

(4 bedrooms x 110 gal/br/day x 365 d/yr x 8.34 lb/gal x 182 lb/10^6 lb) = 244 lb dry solids/yr

Since the suspended solids are typically 75 percent volatile and 25 percent non-volatile (Metcalf & Eddy, Inc. 1979), 183 lb/yr of volatile and 61 lb/yr of non-volatile solids would enter the tank. Over a time period of one year, the sludge in the tank could be expected to convert to a condition of 40 percent volatile and 60 percent non-volatile solids (Baumann et al., 1977). The non-volatile solids content would not change by digestion. Therefore a total of 61 percent or 110 lbs of solids would remain in the tank, consisting of 65 lbs of non-volatile material and 45 lbs of biologically resistant organic material.

The solids settled in concentrated form at the bottom of the tank would be expected to reach a maximum concentration of 10 percent (Baumann et al., 1977). Assuming a specific gravity of 1.0, the total volume of digested solids collected based on a 110 gallon per day per bedroom design flow in a year would be calculated as:

$$\frac{102 \text{ lb dry solids/yr}}{\dfrac{0.1 \text{ lb dry solids}}{\text{lb wet solids}} \times 8.34 \text{ lb/gal}} = 122.3 \text{ gal sludge/yr}$$

The standard septic tank criterion currently used by Title 5, includes sizing the liquid capacity at 150 percent of the design flow (660 gallons) but not less than 1,000 gallons. Therefore, the septic tank would have a volume of 1,000 gallons and approximately 12 percent of the volume would be occupied by the sludge accumulation anticipated in one year.

Performing similar calculations for a wastewater containing garbage grinder wastes having an initial suspended solids concentration of 390 mg/l, yields a total accumulation of 182.9 gallons of sludge per year. The percent increase in sludge production is calculated as follows:

$$\frac{182.9 \text{ gal} - 122.3 \text{ gal}}{122.3 \text{ gal}} \times 100\% = 50\ \% \text{ increase}$$

As the design flow increases, the sludge production for both types of wastewater increase accordingly. However, the percent increase in sludge production remains approximately 50 percent.

Scum Accumulation

Along with the accumulation of sludge, there is also a build-up of floating debris, or scum. The concentration of fats and grease in wastewater without garbage grinder wastes ranges from 20 to 40 mg/l. One year's accumulation of scum would be calculated as:

$$(4 \text{ bedrooms} \times 110 \text{ gal/br/day} \times 365 \text{ d/yr} \times 8.34 \text{ lb/gal} \times 30 \text{ lb}/10^6 \text{ lb}) = 40 \text{ lb grease/yr}$$

Since the scum is lighter than water it accumulates on the surface of the wastewater within the septic tank where it tends to dry out and harden. The dryness of the scum causes it to digest at a slower rate than the sludge on the bottom of the tank. The volume of scum expected, assuming a specific gravity of 0.9 and a solids concentration of 5 percent (Metcalf & Eddy, 1979), is calculated as:

$$\frac{(0.9) \times 40 \text{ lb grease/yr}}{\dfrac{0.05 \text{ lb dry solids}}{\text{lb wet solids}} \times 8.34 \text{ lb/gal}} = 86.3 \text{ gal scum/yr}$$

Performing similar calculations for a wastewater containing garbage grinder wastes and having an initial grease concentration of 55 mg/l, yields a total accumulation of 159.0 gallons of scum in one year.

Since the increased scum production does not displace a significant amount of liquid volume, it minimally increases the required tank volume necessary to provide an equal degree of treatment to the wastewater with garbage grinder wastes. The increase in tank volume necessary to account for the increased amount of sludge is generally sufficient to provide the required scum storage increase as well.

The sludge production increase is shown to be a 50 percent in volume. Therefore, a 50 percent increase in the tank volume would provide the capacity necessary to accommodate the increased solids loading associated with the use of garbage grinders.

18.2 State Regulations

Very few states have considered the effects of garbage grinder on septic tank/soil absorption systems. Table 18.2.1 provides a summary of those states which discuss the use of garbage grinders in their septic system regulations. It is interesting to note that three other states, Arizona, Colorado, and New Jersey, require increases in the capacity of the soil absorption system of 25, 20, and 25 percent respectively.

TABLE 18.2.1

GARBAGE GRINDER USE REQUIREMENTS

	REQUIRED INCREASE IN TANK CAPACITY	REQUIRED INCREASE IN LEACHING FIELD CAPACITY	COMMENTS
Alabama			(1)
Alaska			(1)
Arkansas			Use not recommended
Arizona	25%	25%	
California	250 Gal.		Use not recommended
Colorado		20%	
Connecticut			(1)
Delaware			(1)
Florida			More frequent inspections required
Georgia			Regulations unavailable
Hawaii			(1)
Idaho			(1)
Illinois	60-70%		
Indiana			(1)
Iowa			(1)
Kansas			Regulations unavailable
Kentucky	250 Gal.		
Louisiana			Regulations unavailable
Maine			(1)
Maryland	(2)		
Massachusetts	33%(3)	50%	
Michigan			(1)
Minnesota			(1)
Mississippi			(1)
Missouri			(1)
Montana			(1)
Nebraska			(1)
Nevada			(1)
New Hampshire	50%		
New Jersey	50%	25%	
New Mexico			(1)
New York			(1)
North Carolina			(1)
North Dakota			
Ohio			(1)
Oklahoma			(1)
Oregon			(1)
Pennsylvania			(1)
Rhode Island			(1)
South Carolina			(1)
South Dakota	20%		
Tennessee			(1)
Texas	(4)		
Utah	(2)		
Vermont	25%		
Virginia			Regulations unavailable
Washington			(1)
West Virginia	20%		Use not recommended
Wisconsin			(1)
Wyoming			(1)

(1) The use of garbage grinders not discussed within regulations.
(2) Septic tank requirements already incorporate the use of garbage grinders.
(3) 50% increase below flow of 667 GPD.
(4) Consideration shall be given to increase in required size if garbage grinder use anticipated.

18.3 Local Regulations

Sixty-one towns have adopted regulations that deal in some way with garbage grinders. Fifteen of these towns, including Northbridge and Rutland, prohibit garbage grinders altogether. Eight towns including Ashland, Wendell and Natick recommend that they not be installed. Princeton and Tyngsborough require an increase in the minimum septic tank size to 2,000 gallons when garbage grinders are being used.

When garbage grinders are used in Bolton and Burlington the minimum septic tank size is 2,000 gallons and the design flow is multiplied by 200 percent. Pembroke also multiplies the design flow by 200 percent, but requires a septic tank with 3,000 gallons of capacity. Ashland and Dover require that 50 percent additional leach area be added to all systems for garbage grinders even when not proposed.

Hardwick requires dosing for all systems that are designed with garbage grinders. Other towns, such as Boylston do not allow the use of garbage grinders when the percolation rate is less than 10 minutes per inch.

18.4 Conclusions and Recommendations

As past studies have shown, the use of garbage grinders can have an extreme adverse affect on the performance of a septic tank/soil absorption system if the increased solids loadings associated with the use of garbage grinders are not taken into account during the design process. Garbage grinders increase the BOD_5 and suspended solids concentrations of the wastewater. This requires the tank size to be increased to accommodate the increased organic loading.

A minimum volume increase of 50 percent is required to effectively treat wastewaters containing garbage grinder wastes. A look at the existing Title 5 regulations regarding the sizing of septic tanks receiving garbage grinder wastes, reveals that up to a design flow of 667 gallons per day the conclusions made here are satisfied. However, past this design flow there is only a 33 percent increase in septic tank volume for wastewaters containing garbage grinder wastes. It is recommended that the regulations be changed to require a minimum 50 percent increase in septic tank volume for all design flows when garbage grinder are used.

The use of garbage grinders in conjunction with septic tank/soil absorption systems should continue to be strongly discouraged. Since it is virtually impossible to enforce a regulation prohibiting the installation of garbage grinders after the septic system has been approved and installed, the Department should consider requiring all new systems to be designed based upon their use. This would entail provisions for a 50 percent increase in tank size and enforcement of a rigorous maintenance program.

The majority of the wastes handled by garbage grinders could be effectively handled as solid wastes. Considering their possible effects on septic tank/soil absorption systems, it is advisable to handle them as such. A strong public education program should also be considered. Local boards of health should alert homeowners to the possible dangers of their continued use.

CHAPTER 19

GREASE TRAPS

Along with residential households, a wide variety of commercial establishments and service oriented facilities utilize septic tank/soil absorption systems. The wastewater sources for many of these establishments are sufficiently similar to those in dwelling unit that the residential wastewater characteristics are applicable. However, the wastewater characteristics at other establishments can be vastly different from those of a typical residence, thus presenting a unique set of concerns in the use of conventional sewage disposal systems.

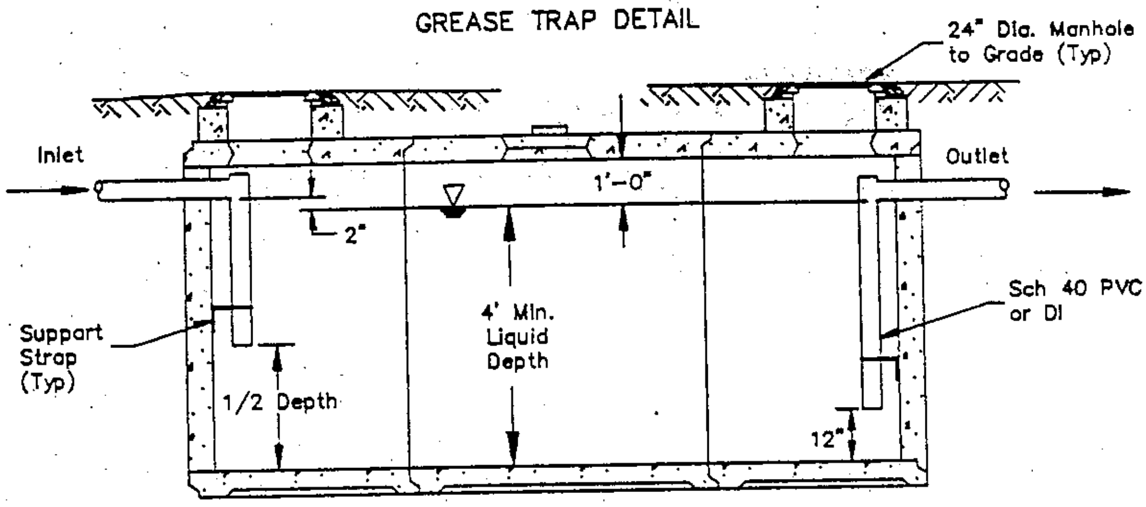
One such group of establishments include restaurants, schools, hospitals, nursing homes, hotels, drive-in theaters, or any other installation at which large quantities of grease can be expected to be produced (USEPA, 1980b). The term "grease" as commonly used, "includes the fats, oils, waxes, and other related constituents found in wastewater" (Metcalf & Eddy, Inc. 1979). If not properly addressed, the accumulation of grease can be a problem as it may result in clogged sewer lines, and clogged inlet and outlet structures in septic tanks. Worse yet, the introduction of grease into the soil absorption system may result in the clogging of the infiltrative surface of the soil. All of these effects result in restricted flows and generally poor septic tank/soil absorption system performance.

The purpose of a grease trap is to remove excessive amounts of grease from the wastewater prior to the septic tank. This is accomplished by flotation of the grease within a separate chamber that traps the grease while the clearer liquid beneath it is discharged to a septic tank. Grease trap design is very much like the design of a septic tank. The traps should be situated such that they receive only the wastewater flow from the kitchen, where the majority of the grease is produced.

Grease traps should be designed to accomplish a number of objectives. First, the trap should be located as close as possible to the source of the wastewater flow, while still maintaining the required setback distances. This allows the wastewater to enter the grease trap while it is still hot. Although the increased warmth of the wastewater hinders the separation of the grease from the liquid portion of the wastewater, cooling prior to the tank promotes clogging of the influent pipes. Secondly, the grease trap should have a sufficient detention time to allow the grease to separate and cool properly. As the grease cools, it congeals and floats on the surface of the wastewater. High loadings and short detention times may not allow sufficient time for grease separation and cooling to occur, resulting in short circuiting of the flow and a poor removal efficiency. The inlet and outlet should also be properly baffled to prevent short circuiting, and the clogging of those components (USEPA, 1980b).

A grease trap is designed to remove the only floatable grease contained within a waste stream. Therefore, the concentrated solids containing wastewaters from garbage grinders should not be discharged to grease traps. A high solids loading can reduce the grease trap performance and greatly increase both the solids accumulation and the cleaning frequency. Garbage grinder wastes, if allowed, should be discharged directly to the septic tank which should be designed with sufficient capacity to accomodate the increased solids loading. Septic tanks receiving grease trap effluent should be designed based on the total design flow for the particular establishment (kitchen wastes and toilet wastes).

FIGURE 19.1.1
GREASE TRAP DETAIL



19.1 Literature Review

Grease Trap Design Requirements

An improperly designed grease trap can impose a significant threat to the operation of a septic tank/soil absorption system servicing a restaurant or other food processing establishment. Influents to grease traps are typically very hot and contain extremely high organic loads including grease, oils, fats, and dissolved food particles, as well as detergents and suspended solids. It is important that a grease trap be properly designed so as to minimize the impact of these materials on the treatment capacity of the system.

One method of determining the required size of a grease trap utilizes the wastewater flow calculated from the number and kind of sinks and fixtures discharging to the trap. For each type of fixture, there is a recommended maximum capacity required for the grease trap ~~and a grease retention~~ capacity rating. These numbers are a function of the design flow of each fixture in gallons per minute. The grease retention capacity rating is the amount of grease (in pounds) that the trap can retain before its average efficiency drops below 90 percent (USEPA, 1980b). The grease retention capacity in pounds should be equal to at least twice the flow capacity in gallons per minute. For example, a grease trap rated for 30 gallons per minute should retain at least 90 percent of the grease discharged to it until it holds approximately 60 pounds of grease. The majority of commercially produced grease traps are rated in accordance with this procedure. For the most part, this procedure is used for the sizing of smaller in-house grease traps or "grease interceptors" which are normally placed within the building and receive wastewater from individual sinks and fixtures within the kitchen.

A design method for exterior grease traps is presented in the USEPA Design Manual "Onsite Wastewater Treatment and Disposal Systems" (1980b). This method has been developed through previous experience at a large number of installations. For restaurants, the required volume of the grease trap is calculated from the following equation:

$$\text{Grease Trap Volume (gal)} = D \times GL \times ST \times HR/2 \times LF$$

where:

- D = Number of seats in dining area
- GL = Gallons of wastewater per meal
- ST = Storage capacity factor - 2.5 recommended for on-site disposal
- HR = Number of hours open
- LF = Loading factor - 1.25 interstate highways
  - 1.0 other freeways
  - 1.0 recreational areas
  - 0.8 main highways
  - 0.5 other highways

Grease trap capacities for other types of commercial establishments with varied seating capacities, such as hospitals and nursing homes, are calculated using the following equation:

$$\text{Grease Trap Volume (gal)} = M \times GL \times ST \times LF$$

where:

- M = Meals served per day
- GL = Gallons of wastewater per meal
- ST = Storage capacity factor - 2.5 recommended for on-site disposal
- LF = Loading factor -
  - 1.25 garbage disposal and dishwashing
  - 1.0 without garbage disposal
  - 0.75 without dishwashing
  - 0.5 without dishwashing and garbage disposal

The required grease trap capacity for either type of establishment should be determined from the applicable equation, but should be no less than 750 gallons.

The proper design of the inlet and outlet tees in the grease trap are important factors in the performance. The tees should be situated such that the grease accumulated within the trap is not allowed to enter the outlet tee or to clog the inlet tee. The inlet tee is designed to introduce the liquid below the accumulated grease layer and should extend from approximately 3 inches below the inside top of the trap to approximately the midpoint of the liquid depth. Similar to a septic tank, the minimum liquid depth in a grease trap should be four feet. The outlet tee should be longer than the inlet tee to reduce the chance of grease entering the outlet of the tank. The outlet tee should extend from approximately 3 inches below the inside top of the trap to a point approximately 12 inches from the bottom of the tank. Since the outlet tee is placed very near the bottom of the tank, careful inspections are necessary to ensure that the tee does not become clogged with any solids that may accumulate. If routine maintenance is provided, the solids accumulation should not affect the operation of the grease trap.

Interior Grease Interceptors

Certain establishments are required by the Uniform State Plumbing Code (248 CMR 2.09) to have a grease interceptor "installed in the waste line leading from sinks, drains or other fixtures" to remove grease which could cause a line blockage or interfere with sewage disposal. These units are normally smaller than the exterior grease traps required by Title 5 and should have a grease retention capacity of not less than two (2) pounds for each gallon per minute of flow, as required by section 2.03 (c) of the Plumbing Code.

The use of these interior grease interceptors does not eliminate the need for an exterior grease trap, nor does the use of an exterior grease trap negate the need for the interior units. The interior units do remove certain quantities of grease which will help maintain the flow in the interior plumbing, however, their effectiveness in protecting the operation of the septic system is suspect. One study of restaurant wastewater has shown that the septic tank effluent of systems using in-house grease interceptors has a concentration of grease as much as two times higher than a similar system equipped with an exterior grease trap (Siegrist et al., 1984). One reason for this may be the fact that the wastewater is very warm when it enters the interior grease interceptor. These units usually provide a relatively short detention time compared to exterior traps. These short detention times may not be sufficient to allow the grease to separate and cool properly.

Another drawback to the use of interior grease interceptors is the frequent cleaning that is required to maintain efficient removal of the grease. Due to the relatively small size of these units, frequent cleaning is necessary to remove grease accumulations. Since these units are generally located under sinks or other fixtures within the kitchen, the employees working within the kitchen are often responsible for the maintenance of the unit. Consequently, it is entirely possible that these units are not cleaned as often as necessary due to the foul nature of the work entailed. This results in a decreased efficiency in the removal of grease.

On the other hand, an exterior grease trap can be cleaned merely by calling a licensed septage hauler to come and pump out the tank. The probability that the scheduled cleaning of the exterior grease trap is neglected is much less than that of the interior unit.

Double-compartment Grease Traps

It is generally agreed that multi-compartment septic tanks perform better than single compartment tanks under a given set of circumstances. The same applies to grease traps. The addition of another chamber within a grease trap improves the efficiency of grease removal by reducing the possibility that short circuiting will occur.

The first chamber within a multi-compartment grease trap serves as the grease separation and cooling zone allowing the grease to congeal and float on the surface. This first chamber also serves to collect the solids normally accumulated within a grease trap. The connection to the second chamber should be a tee configuration or an inverted U-fitting, set below the grease layer. This type of connection minimizes the discharge of grease to the second chamber.

The second chamber traps the remaining grease prior to discharge to the septic tank. The outlet in this chamber should be the same design as that of a single compartment tank. There is less of a chance that the tank outlet will get clogged in a double-compartment tank due to the majority of the settleable solids being removed in the first chamber.

Operation & Maintenance

As with any component of a septic system the grease trap's continued effectiveness is heavily dependent upon the establishment of a proper maintenance program. Failure to properly clean the grease trap and remove the accumulated grease and solids can result in excessive grease build-up which can lead to the discharge of grease in the effluent.

In order to facilitate inspections and maintenance of the grease trap a minimum of two (2) access manholes should be provided at grade, one over the inlet and one over the outlet. The grease trap should be located such that it is accessible for cleaning at all times. Title 5 states in 310 CMR 15.06(13):

> "Cleaning - Grease traps shall be inspected monthly and shall be cleaned when the level of grease is 25 percent of the effective depth of the trap or at least every 3 months."

This frequency of cleaning is more stringent than any of the recommended cleaning frequencies found in the literature or the other states' regulations. The USEPA recommends cleaning be performed whenever 75 percent of the grease-retention capacity has been exhausted. With this frequency of cleaning, the pumping occurrence at a restaurant may range from once a week to once every 2 or 3 months (USEPA, 1980b).

The cleaning frequency prescribed in Title 5 is more desirable. If the accumulated grease is allowed to stand for too long a time, it will continue to congeal and solidify, making removal increasingly difficult. Excessive accumulations also may block the inlet and outlet.

The use of degreasers, emulsifiers or other additives will not keep the system free of grease. By creating an emulsion, grease may be passed through the trap and septic tank possibly clogging the soil absorption system. The use of additives should, therefore, be prohibited.

19.2 State Regulations

Table 19.2.1 lists the grease trap requirements of each state. Many of the state regulations did not have any grease trap regulations within the material researched. Many of the regulations of those states which had no mention of grease traps pertained only to individual on-site septic tank/soil absorption systems for residential homes. Since grease traps are generally not needed or recommended for individual dwellings, it is not surprising that there is no mention of grease traps in these regulations. These states may have grease trap requirements under separate regulations for commercial establishments, however, this information was not available.

A total of 20 states discuss the installation of grease traps to one degree or another in their on-site sewage disposal regulations. Some states give minimum size requirements, while others require traps for certain facilities but do not include design criteria. Four states do include design methods for calculating the required grease trap size. These states are Arizona, Florida, South Carolina, and Wyoming. A discussion of each of their methods follows.

Arizona and Wyoming

Arizona and Wyoming require that all commercial users of private septic tank/soil absorption systems with liquid wastes containing grease install and maintain an appropriate grease interceptor. All grease interceptors in Arizona and Wyoming are required to have two compartments. These tanks are sized according to the following formula:

Grease Interceptor Volume = NM × R × T × 4 × F

where:

NM = # meals/peak hour

R = waste flow rate (gallons/meal)
- 6 g/m commercial kitchen w/ dishwashing
5 g/m commercial kitchen w/o dishwashing
2 g/m single serve kitchen

T = required detention time (hrs)
- 2.5 hrs for commercial kitchens with dishwasher and or disposal
1.5 hrs for single service kitchen waste with disposal

F = storage factor
- 1 for 8 hr operation
2 for 16 hr operation
3 for 24 hr operation
1.5 for single serve kitchen

There are three problems with this method of calculating the required volume. First, it provides a relatively small detention time which may allow the grease to pass through the interceptor. Secondly, the use of the number of meals during the peak hour may present problems in the design. It would seem to be difficult to determine an actual number of meals served during the peak hour. The third problem with this method is that it allows the use of garbage disposal in conjunction with the grease trap.

Florida

A minimum volume of 750 gallons is required for all grease traps in Florida. Florida also imposes a maximum volume of 1,250 gallons. When a volume in excess of 1,250 gallons is required, the grease interceptors must be installed in series. The volume required for restaurants is determined by the following formula:

Grease Interceptor Volume = S × GS × HR/12 × LF

where:

S = number of seats in dining area

GS = gallons wastewater per seat
- 25 gal for ordinary restaurant
10 gal for single serve restaurant

HR = number of hours open

LF = loading factor - 1.25 interstate highways
1.0 other freeways
1.0 recreational areas
0.8 main highways
0.5 other highways

For other types of establishments with kitchens the following formula is used:

Grease Interceptor Volume = M × GM × LF

where:

M = meals prepared per day

GM = gallons of wastewater per meal - use 5 gal/meal

LF = loading factor - 1.00 with dishwashing
0.50 without dishwashing

A possible problem with this method is the determination of the loading factor. This requires a classification of the road on which the establishment is located. This approach may be open to a certain amount of interpretation.

South Carolina

South Carolina requires that a grease trap, which shall be no less than 1,000 gallons in size, be sized by the following formula. The state also requires that for sewage flows in excess of 1,500 gallons per day either a two-chambered tank or individual tanks in series be provided.

Grease Trap Volume = GPD × LF × RF

where:

GPD = total maximum estimated daily sewage flow (gpd)

LF = loading factor (proportion of total flow from food preparation areas)
- 0.3 Schools and other installations
- 0.4 Restaurants
- 0.5 Retail food stores

RF = minimum retention and storage factor
- 2.5 for on-site disposal

TABLE 20.2.1

GREASE TRAP REQUIREMENTS

	MINIMUM HYDRAULIC DETENTION TIME (Hrs)	DESIGN FLOW CRITERIA	MINIMUM LIQUID CAPACITY (Gallons)	RECOMMENDED CLEANING FREQUENCY (% grease accumulation)	COMMENTS
Alabama	48	3 gal/meal	1,000	75%	
Alaska					(3)
Arkansas		4 × peak flow (lbs)	125	25%	
Arizona	1.5	6 gal/meal	(1)	50%	
California					(3)
Colorado					(3)
Connecticut	8	10 gal/meal	333		
Delaware		2 × peak flow (lbs)	(1)	75%	
Florida			750(2)	50%	
Georgia					Regulations unavailable
Hawaii					(3)
Idaho					(3)
Illinois					(3)
Indiana					(3)
Iowa					(3)
Kansas					Regulations unavailable
Kentucky					No design criteria given
Louisiana					Regulations unavailable
Maine		3 gal/person/day			
Maryland					No design criteria given
Massachusetts	24	15-35 gal/seat/day	1,000	25%(6)	
Michigan			750	75%	
Minnesota					(3)
Mississippi					(3)
Missouri					(3)
Montana					(3)
Nebraska					No design criteria given
Nevada					(3)
New Hampshire	36		1,000		
New Jersey					No design criteria given
New Mexico					(3)
New York					(3)
North Carolina					(3)
North Dakota		5 gal/seat	30		
Ohio					(3)
Oklahoma					(3)
Oregon					(3)
Pennsylvania					(3)
Rhode Island	24	70 gal/seat	1,000		
South Carolina			1,000(5)	(4)	
South Dakota					(3)
Tennessee			750	75%	
Texas			100		
Utah					(3)
Vermont					(3)
Virginia					Regulations unavailable
Washington					(3)
West Virginia			150		
Wisconsin					No design criteria given
Wyoming	1.5		(1)		

(1) Double-compartment traps required.
(2) Maximum of 1,250 gallons. Above this traps in series must be provided.
(3) Grease traps not discussed within available regulations.
(4) Clean as required.
(5) Flows in excess of 1,500 gpd require a double-compartment tank.
(6) At least every 3 months.

A clear distinction between a "restaurant" and a "retail food store" was not provided within the regulations. South Carolina also allows the use of the formulas contained in the USEPA Design Manual "Onsite Sewage Treatment and Disposal Systems" (1980b).

19.3 Local Regulations

Of the regulations adopted by municipalities and filed with the Department of Environmental Protection, there are none that address grease or grease traps.

19.4 Conclusions and Recommendations

Title 5 currently requires grease traps to be sized to provide a minimum of 24 hours detention time for the kitchen flow, with a minimum acceptable capacity of 1,000 gallons. The kitchen flow is calculated in accordance with 310 CMR 15.02(13) which requires a flow estimate of 15 gallons per seat per day be used.

There are various methods used to determine the required size of a grease trap. However, there is no documentation which indicates that any one method is better than the others. For the most part, the design flow estimates in Title 5 have proven to provide an adequate means of determining the design basis for grease traps.

There are, however, some changes to the Title 5 regulations that should be considered in order to increase the degree of grease removal. It has been shown that two-compartment tanks are more efficient than a single compartment tank, particularly in the prevention of short circuiting of the flow through the tank. Treatment efficiency improves when detention times are increased from 24 to 48 hours. One of the main concerns in the design and operation of a grease trap is providing a sufficient detention time during which the grease can cool and properly congeal. If the wastewater is not allowed enough time to cool, the grease will tend to flow through the grease trap into the septic tank. The use of a two-compartment tank, with a combined minimum 48 hour detention time could insure that an acceptable degree of grease removal is being achieved. These changes would allow the temperature of the liquid within the tank to cool sufficiently to allow the maximum removal of grease.

A minimum size grease trap of 1,500 gallons or 200 percent of the design kitchen flow, whichever is larger, should be provided to allow the complete removal of grease. Similar to the discussion of multi-compartment septic tanks, the first chamber within the grease trap should encompass two-thirds of the tank volume providing a detention time of 32 hours. The second chamber would subsequently provide a detention time of 16 hours.

CHAPTER 20

INNOVATIVE AND ALTERNATIVE SYSTEMS

This chapter evaluates alternative and emerging on-site sewage treatment and disposal technologies, in addition to reviewing the higher levels of treatment afforded by small wastewater treatment facilities. Many of the alternative systems included in this review involve simple modifications to the components and processes which comprise the conventional septic tank/soil absorption system. These modifications will be discussed and compared to conventional systems in terms of improved treatment efficiencies, reliability and ease of operation and maintenance.

Title 5 states in section 15.02 (14) "Type of System", that "Except as provided in 310 CMR 15.18, an individual sewage disposal system shall consist of a septic tank discharging its effluent to a suitable subsurface sewage disposal area as hereinafter described. Where buildings are served by more than one system, each system shall consist of a septic tank discharging its effluent to a suitable subsurface sewage disposal area. Separate systems for laundry waste disposal are not recommended."

Any wastewater treatment system not containing components specifically conforming to the requirements of Title 5 is considered to be an alternative treatment system requiring Department of Environment Protection approval. Examples of non-Title 5 systems which fall into this category and which will be considered in this section include: wastewater reduction alternatives (composting and waterless toilets and segregated grey/black water systems), alternative pretreatment systems (aerobic treatment systems and multi compartment septic tanks) and alternative disposal systems (rapid sand filtration or recirculating sand filtration followed by surface disposal, evapotranspiration systems and lagoons). Advanced treatment processes (disinfection, chemical addition and nitrogen reduction techniques) will also be explored. Additionally, wastewater treatment plants will be covered as an alternative providing an increased level of treatment and environmental protection.

20.1 Literature Review

Conventional Septic Tank/Soil Absorption Systems

The conventional septic system consists of a septic tank, a distribution network and a soil absorption system. The system, through a complex combination of chemical, physical and biological processes, provides a certain degree of waste transformation and waste reduction depending on a number of site specific parameters.

Septic tanks are buried watertight receptacles designed and constructed to separate suspended solids from discarded wastewater. Quiescent conditions within the tank allow particulate matter carried in the sewage to settle to the bottom of the tank where it undergoes limited anaerobic digestion. A scum of lightweight material including fats and grease rise to the top of the tank. Partially clarified liquid is allowed to flow through a specially designed outlet structure with an opening located below the floating scum layer.

Under optimum conditions, the septic tank provides waste strength equalization, and reductions in suspended solids, and oil and grease by sedimentation and flotation. A small amount of organic waste strength reduction, most of which is attributable to the removal of settleable solids and the resultant anaerobic biological activity which digests a portion of the accumulated sludge, also occurs in the tank.

The partially clarified effluent flows from the septic tank, either by gravity or pressure distribution, to the subsurface soil absorption system. The soil absorption system consists of a piping network, a leaching facility providing storage and natural aeration properties, and a soil infiltration area which hydraulically removes and physically, chemically and biologically transforms and various constituents of the liquid waste.

Grey Water and Black Water

Numerous studies have been conducted regarding the treatment advantages gained through the segregation and separate treatment of toilet and washwater wastes. Wastewater streams commonly incorporated into the general classification of septic system waste include toilet wastes ("black water"), garbage wastes, and the remaining "grey water" collected from all other sources which may include the kitchen sink, bathtub and shower, bathroom lavatory, dishwasher, and cloths washing machine (Brandes, 1978). Some investigators simply group the waste streams into two groups, black water (toilet waste) and grey water (all other wastewater streams including garbage grinder wastes).

Black waters are the most highly contaminated of the two wastewater streams and produce the majority of the sewage sludge (65.7 liters/person/year for black water compared to only 8.3 liters/person/year for grey water) (Brandes, 1978). Black water comprises approximately 35 percent of the sewage flow and contains 37 percent of the BOD, 61 percent of the SS, 82 percent of the nitrogen, and 30 percent of the phosphorus (Siegrist, 1977).

Not only are the relative concentrations of the various components in the black and grey waste streams variable, but the chemical forms of many of these pollutants are also vastly different. The dominant form of nitrogen in black water (90 percent) is chemically reduced ammonia, whereas grey water is much more highly oxidized containing only 15 percent of the nitrogen as ammonia. Therefore, nitrification of black waters is required prior to denitrification processes occurring. Eighty-eight percent of the phosphorus found in grey water is in an insoluble easily precipitated form, whereas only 18 percent of that contained in black water is insoluble. Toilet wastewater has undergone partial digestion and treatment in the human intestines and therefore the remaining waste may be less easily degradable than the waste forms comprising the grey water.

Separation of the black water and grey water waste streams may serve many purposes including the enhancement of conventional wastewater disposal methods or facilitating the development of innovative alternative treatment systems (Siegrist, 1977) including the use of composting and incinerating toilets and many denitrification techniques.

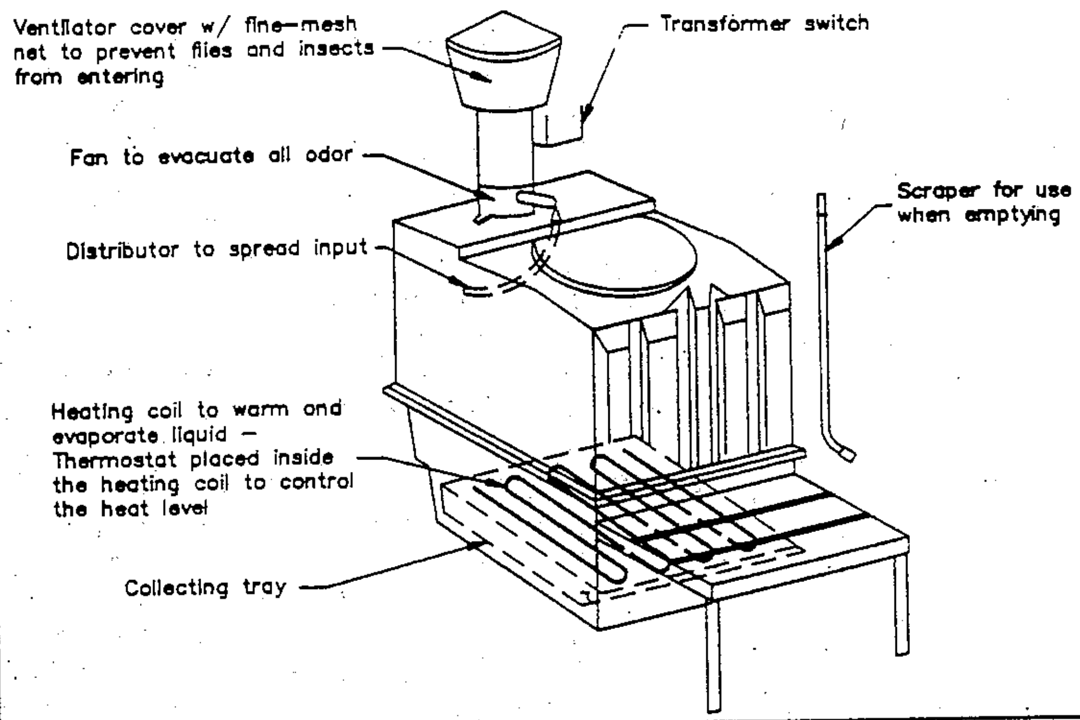
Wastewater Reduction

The toughest problem in the installation of a septic system is finding an acceptable area of suitable soils for the installation of the soil absorption system. One theoretical method for maximizing development on a lot where the suitable soils are limited is through the use of water saving devices intended to reduce liquid flows, thereby decreasing the required absorption system size.

Waterless or low-water volume toilet systems come in many forms including composting toilets, digesting toilets, incinerating toilets, recycling toilets (oil flush, chemical, and water) and sliding valve toilet systems. These systems are intended to collect black water, or a low water content form of black water, for either on-site treatment or off-site disposal. Title 5 includes provisions for the use of privies and chemical toilets, 310 CMR 15.16; and for humus toilets, 310 CMR 15.17. The code specifies that these types of systems "shall not be constructed or continued in use unless the Board of Health has approved, in writing, its construction or continued use based upon a determination by the Board of Health that the system will not endanger the health of any person or cause a nuisance.". Humus toilets are further restricted by the requirement "that the end product will be disposed of in a sanitary manner". These systems may provide an advantage in some instances in that "a reduction not to exceed 40 percent of the design flow for subsurface sewage disposal may be allowed for the reduced water usage."

Composting toilets, also called dry or humus toilets, were developed in Sweden in the late 1930's with use in this country starting in the mid 1960's. These systems use microorganisms to decompose toilet waste (black water) and garbage within a sealed, vented bin to produce an inert humus material (Mass DWPC). Digesting toilets are similar to, although smaller than, composting toilets. Digesting toilets collect toilet waste and garbage in a heated, vented chamber for conversion to a humus acceptable for use as a soil additive.

FIGURE 20.1.1
COMPOSTING TOILET



Both of these systems have some merit in isolated cases. They collect the toilet waste and convert it to a less offensive, small volume humus waste which may be easily disposed of in remote areas. While these types of systems do not eliminate the need for a septic system or sewer connection for the elimination of the grey water, they may effectively handle 35 - 40 percent of the liquid flow, while significantly reducing the volume of sludge produced and removing a large portion of the nitrogen from the wastewater stream by incorporating it in the humus.

Significant amounts of water conservation can be accomplished through the use of low volume toilets, forms of which include recirculating toilets (utilizing either chemically stabilized water or oil as the transport fluid) and sliding valve toilets, similar to those currently used on boats and campers, which use a flow of approximately 1 pint of water per flush (as opposed to a standard toilet which uses 5 - 6 gallons per flush). While these systems do indeed present a significant water savings, they do not offer long term treatment benefits. Neither system results in a reduction of the organic or suspended solids load. Since the total organic waste load remains the same, no reduction in the size of the septic tank or soil absorption system should be allowed with the use of these devices.

Pretreatment Systems

Septic tanks act as anaerobic separation chambers in which a limited degree of waste strength reduction occurs. Aerobic pretreatment tanks have been studied to provide increased treatment prior to the wastewater filtration step. An aerobic pretreatment tank uses oxygen to increase the rate of biological activity in the pretreatment tank. The oxygen is supplied by compressed air delivered through diffusers or spargers or by mechanical agitation using surface mixers or subsurface mixers equipped with draft tubes (Hutzler et al., 1977).

Single family on-site aerobic treatment units were first promoted in the 1950's to replace the conventional septic tank/subsurface soil absorption system. These early systems utilized a simple aerobic chamber followed by a separate settling chamber discharging effluent to a surface water body. Based upon knowledge gained from these early attempts, more than 60 manufacturers now market various forms of aerobic treatment processes for single family on-site use (Hutzler et al., 1977).

The majority of aerobic pretreatment units have been proposed for use in instances where limiting conditions make the option of subsurface disposal either impossible or impractical. These units have been used in association with a clarifier or recirculating sand filter, and oftentimes a disinfection unit, to provide an effluent which manufacturers claim is suitable for a surface discharge, utilizing either surface waters or land spraying techniques. Regulatory acceptance of these aerobic treatment systems has been slow, due primarily to the lack of data regarding unit maintenance and treatment efficiencies and the concern over possible homeowner misuse of the system (Hutzler et al., 1977).

When correctly operated, aerobic treatment units may indeed produce a high quality effluent suitable for surface discharge. Unfortunately, the average homeowner does not possess the training necessary to ensure proper operation and cannot be relied upon or entrusted with its care, maintenance or operation. Experience with surface discharging aerobic treatment units is limited primarily to Kentucky, Maine and Wisconsin, where they are used to abate existing discharges of untreated sewage into the surface waters of coastal areas. A two year study of 151 units, completed by Veoll and Vance (1974), indicated the alarming rate of failures of these types of systems. Ten percent of the studied units exhibited control problems, 6 percent exhibited problems with blown fuses, 10 percent showed problems with odors, 75 percent revealed empty dry-feed chlorinators, and 57 percent had lost solids into the effluent. Additionally, they reported that the air blowers on the units were only reliable for approximately a two year period (Hutzler et al., 1977).

It is because of the uncertainty involved in operation and maintenance that the use of aerobic treatment units with surface discharges cannot be recommended for single family on-site use. These systems may be proven to be suitable for small community or cluster development use provided that a competently trained treatment plant operator is employed to oversee the operation, maintenance, and testing of the system. However this involves a rather substantial financial commitment on the part of the users of the system.

Studies regarding the use of aerobic units as a pretreatment device followed by subsurface discharge in a soil absorption system, indicates that these units may be beneficial, although data are limited and the conclusions of many researchers differ. A soil column comparison on identically prepared soils was performed to test the hypothesis that aerobically pretreated wastewater may be applied to leaching fields at higher rates than septic tank effluent without causing failure of the leaching field. A literature survey conducted as a precursor to that study revealed the limited quantity of work performed specifically comparing the two methods of pretreatment. This study (Mitchell et al., 1982) concluded that:

1. Aeration pretreatment will prolong the life of a soil leach field.

2. Even soil leach fields receiving pretreated wastewater will eventually fail if hydraulically overloaded.

3. Recovery by resting is unlikely in soil leach fields receiving (aerobic) pretreated wastewater.

A conflicting study concluded that the method of pretreatment had little effect on the final effluent quality but will have significant impacts on the construction, operation and maintenance costs (Effert et al., 1984).

A study on the performance of household treatment units investigated the average effluent quality, variability in effluent quality and total annual cost of various treatment options. This study concluded that aerobic units (in this case an aerobic tank and clarifier system) do provide a higher degree of treatment, with respect to BOD and fecal coliform, than septic tanks. No advantage was found for these systems with respect to the suspended solids content of the effluent and even the more highly treated aerobic unit effluent would not meet national secondary effluent discharge criteria for either BOD or SS. The individual aerobic units exhibited substantial variability resulting in periodic biological solids carryover and sludge bulking, especially in winter when the temperature within the unit dropped below 15 degrees Centigrade. The individual aerobic unit was more costly than a conventional septic system, both for capital equipment and for the energy and personnel required for proper system operation and maintenance. Proper operating procedures included providing an external source of heat to the unit in the winter, monitoring of the mixed liquor suspended solids content in the reactor, frequent (every 8 - 12 months) solids removal, the installation of a surge control tank to prevent hydraulic upsets, the removal of garbage grindings prior to wastewater introduction into the aerobic unit, and careful control of household chemical usage including toilet bowl deodorizers which were found to have detrimental impacts on aerobic bacteria (Otis and Boyle, 1976).

The use of recirculating sand filters following a pretreatment system (either a septic tank or an aerobic unit) and preceding a conventional soil absorption unit may present some advantages. Studies conducted by Bernhardt (1973) determined that effluent absorption in slowly permeable soils is greater for highly oxidized effluent than for septic tank effluent. This study utilized septic tanks followed by recirculating sand filters as the preferred method of pretreatment. Therefore, the soil absorption systems in the test were receiving oxidized wastewaters which were more highly treated and contained less solids, than the wastewater discharged to conventional septic tank soil absorption systems. This study further concluded that recirculating sand filters can also be used to protect the soil absorption system against solids discharge from overloaded septic tanks and those in need of cleaning and solids removal (Loudon, 1984).

20.1.1 Alternative Disposal Systems

In areas in which an adequate area of suitable soils is not present, or where limiting conditions occur, alternative disposal systems, including surface discharge, evapotranspiration beds and sewage lagoons, have been proposed.

Surface Discharge

Surface discharge of pretreated sewage can be accomplished by many disposal methods including land spreading with sprinklers or surface water discharges. Most of the proposals promoting surface discharge techniques involve the use of pretreated effluent flowing from an aerobic chamber (although sometimes an anaerobic septic tank is proposed) to a sand filtration unit. The sand filtration unit of choice was originally a rapid sand filter but more recently recirculating sand filtration units, RSF's, or other alternative innovative design have gained acceptance. The effluent from the sand filter is then usually subjected to disinfection through the use of dry feed chlorinators or ultraviolet light disinfection units, prior to final disposal via surface sprinkling or surface water discharge.

Single family on-site, surface water discharging, treatment systems are not a preferred method of wastewater disposal. The operation, maintenance and control problems reviewed in the discussion of aerobic treatment units should relegate acceptance of these units to emergency situations where no alternative (including the installation of a tight tank) is available. These systems, when operated by the homeowner, cannot be relied upon to consistently provide the secondary treatment and disinfection levels necessary to be suitable for direct discharge into the surface water environment.

Land spraying techniques, including the spraying of residential lawns with sand filter effluent may have limited suitability in northern regions subject to freezing temperatures and significant amounts of precipitation (Hathaway and Mitchell, 1984).

Filtration

Although the use of filtration followed by disinfection and surface discharge is not a recommended alternative for single family homeowner operated on-site wastewater systems, it may present an alternative for small community and cluster type developments which propose a single wastewater treatment system to be maintained and controlled by a competent operator. Sand filtration has been used for the purification of wastewater prior to surface discharge since the late 1890's (Hathaway and Mitchell, 1984). Early filters were essentially rapid or intermittent gravity sand filters which provided aerobic filtration of the effluent discharged from a settling or septic tank. More recent filter designs utilize intermittent single pass surface sand filters, buried sand filters, recirculating sand filters, upflow gravel filters and locally discharging gravel beds (Hines et al., 1977; Effert et al., 1984).

Single pass surface sand filters are relatively simple mechanical filtration systems which use approximately 24 inches of sand to provide polishing to septic tank effluent intermittently loaded to 2 or more filtration units. These systems may present some odor and freezing problems and require periodic raking of the surface to break-up the hard crust which develops. Buried sand filters were developed as an alternative in order to minimize the offensive odor and troublesome freezing problems oftentimes associated with surface filters. These units are typically designed with 1 - 3 gallon per day per square foot loading rates intended to provide adequate detention times necessary to achieve maximum suspended solids removal. Low influent suspended solids content and diversion of drainage waters is required (Hines et al., 1977).

Recirculating sand filters, RSF's, were developed in the 1960's to prevent clogging of filter surfaces and to promote denitrification of the wastewater (Hines et al., 1977).

Upflow gravel beds are not really a filtration unit but rather an anaerobic contact chamber designed to provide a denitrifying environment following aerobic pretreatment units (Effert et al., 1984).

Aerobic Lagoons

Aerobic lagoons have been proposed for rural areas where for some reason, usually the occurrence of impermeable soils, conventional septic systems are not possible. The design of aerobic lagoons is similar to that used for the stabilization ponds, oxidation ponds and aerobic lagoons utilized in many large wastewater treatment plants. A municipal oxidation pond will typically use a detention time of approximately 30 days. Household aerobic lagoons, due to their much smaller size and increased chance of short circuiting, are typically sized with a detention time of 100 days corresponding to a surface area of approximately 220 square feet per person and a liquid depth of 3 feet. The minimum recommended size of an aerobic lagoon is 900 square feet, with improved operation noted when a minimum size of 1,050 square feet is used. Anaerobic conditions may result in the bottom sediments (facultative lagoons) with aerobic treatment layers only present on the surface. This may lead to increased odor problems, and therefore should be avoided or closely monitored.

The effluent quality of an aerobic lagoon is generally very good, especially in warm months where greater than 90 percent BOD reductions may be accomplished. The unit should be preceded by a septic tank and should be located 150 - 200 feet downwind of the nearest residence, open to direct sunlight and wind. Berms and fences should be constructed surrounding the lagoon utilizing proper construction techniques including 3:1 sideslopes, a 4-foot wide top and 2 feet of available freeboard.

Sewer lines to the lagoon should be water tight laid at a minimum 2 percent slope with cleanouts positioned at 100 foot intervals.

Maintenance of aerobic lagoons is limited to mowing of the grasses along the berms and leaf removal to prevent vegetation from entering, thereby increasing the organic load and providing a mosquito breeding ground. Additional maintenance should include herbicide additions to control shallow water growth, the removal of algae from the surface to prevent odors and facilitate aeration, the addition of sodium nitrate or ammonium nitrate in the spring to increase the oxygen content, and periodic additions of water in warm, dry summer months.

Disadvantages to the use of aerobic lagoons include the ultimate need for effluent disposal, as direct discharge to surface water bodies may not be allowed; unacceptability for urban sites or for sites smaller than 1 or 2 acres in size; and, the possible problems in selling a home utilizing this form of wastewater treatment which many home buyers may find unattractive (Hines et al., 1977).

Evapotranspiration

There are approximately 5,000 evapotranspiration units currently in use in the United States (Hines et al., 1977). Evapotranspiration and evapotranspiration/seepage systems have been proposed as a simple solution to the widespread wastewater disposal and ground water contamination problems. Evapotranspiration systems utilize capillary action in shallow sand beds or trenches to draw liquid up towards the surface and the plant root zone where it is removed by evaporation or utilized by vegetative transpiration (Gunn, 1988). An evapotranspiration/seepage system uses the limited infiltrative capacity of the soils surrounding an unlined evapotranspiration bed to provide soil absorption to aid in the elimination of the applied liquid load (Hines et al., 1977).

Many factors affect the rate of evapotranspiration at a particular site including the available solar radiation, temperature, elevation, relative humidity, wind speed, soil moisture availability, plant density and species distribution, and bed surface area (Hasfurther et al., 1977). Additional factors which need to be considered in the design and siting of an evapotranspiration bed include the annual and seasonal temperature patterns and rainfall intensity and duration (Salvato, 1983).

Evapotranspiration beds are best suited for hot, semi-arid regions (Hines et al., 1977). The combination of restrictions imposed by the New England climate makes evapotranspiration of limited use in the reduction of wastewater volumes. While a conventional soil absorption system may actually involve some degree of evapotranspiration in the removal of nutrients and liquid wastes in the summer months, this impact is usually neglected in the design of actual systems (Gunn, 1988).

Peat Bed filtration

Estimates are that 32 percent of the land area of the United States is unsuitable for conventional soil absorption systems. Because of this, alternative wastewater disposal techniques are always being investigated. Peat moss has proven to be effective in the removal of trace metals (copper, nickel, cobalt and zinc) and has been successfully used in the treatment of industrial wastes. Nineteen cities in Finland use peat bogs for municipal wastewater treatment and studies have been conducted in Wisconsin regarding the use of peat bogs for the polishing of effluent from sewage lagoons and secondary treatment plants (Rock et al., 1982). Peatlands, peat trenches, and swamplands have been used as a main form of wastewater treatment, following pretreatment in a septic tank and aerated receiving pond, in the northern region of NW Quebec (Pause, 1987).

Studies conducted in Maine on the construction and use of Sphagnum peat beds for wastewater treatment reveals that these systems may indeed offer some benefits but will need increased study to prove their worth, and if found to be acceptable will require competent designers and installers. Peat beds display a range of hydraulic conductivities, depending upon the degree of humidification, water content, dry density, type of peat and depth of sample. The reported study utilized a 75 cm (30 inch) deep peat bed and a loading rate of 1.5 cm/d (0.35 gpd/sf). The results of the study indicate that the peat bed worked satisfactorily with no problems or odors and no visible ponding of effluent. Phosphorus removals were initially 70 percent but dropped to approximately 32 percent by the third year of operation indicating that the limited availability of phosphorus removal sites was being depleted. The discharged effluent exhibited a yellowish color and a rather acidic pH of around 5.0. The system exhibited good COD, TSS, and coliform removal efficiencies and may demonstrate increased nutrient removals if the installation is completed with a grass cover (Rock et al., 1982).

20.1.2 Advanced On-Site Treatment Systems

Additives and Chemical Additions

Through the years, numerous inventive minds have been busy pursuing low cost methods of providing an increase to the degree of treatment supplied by conventional septic systems. One form of these low cost alternatives includes the more than 1,200 brand name products and countless "homemade remedies" intended for use as septic system additives and soil absorption regenerators and conditioners (CT. DEP, 1980). This section of the report will rely heavily on the "Report on Available Subsurface Disposal System Additives", prepared by the Connecticut DEP with additional literature citings made as indicated.

Septic tank additives have been grouped into two major categories: cleaners (organic and inorganic) and flocculants. Cleaners are intended to dissolve the sludge and scum build-up which occurs inside of a septic tank. They accomplish that objective by acting either in a corrosive manner (inorganic cleaners) or as a surfactant or solvent, capable of liquefying the accumulated scum and grease deposits (organic cleaners).

The benefit of reduced sludge, scum and grease accumulations is observed by a reduced frequency of septic tank pumping. Initial impressions would hint that this benefit could also extend to the soil absorption system where a reduction in the frequency of solids unloading due to excessive accumulations would be observed. Unfortunately the solids removal processes provided by septic tank cleaners are usually detrimental to the subsequent treatment processes. Septic tanks are intended to reduce the solids load directed to the soil absorption system. Liquefying the solids acts in exactly the opposite manner, converting essentially stable solid accumulations into additional liquid organic loads which oftentimes overload or clog the soil absorption system.

In addition to the increased organic load to the soil absorption system, septic tank cleaners may exhibit additional detrimental effects including the formation of bulking, rising or poorly settling sludge, destruction or inactivation of the bacteria needed to provide efficient wastewater treatment, increased soil clogging due to recongealed grease and scum or decreased permeability attributed to altered soil structure, and an increased incidence of ground water contamination due to the introduction of organic solvents many of which exhibit toxic, carcinogenic or mutagenic properties (Noss et al., 1987).

Organic enzymes and bacterial, fungal and yeast cultures, offer little benefits to a septic system while increasing the organic load and oftentimes hindering the settling of solids. A septic tank and soil absorption system contain far more (a couple orders of magnitude) microorganisms than could possibly be added through the use of septic system enrichments.

Flocculants added to septic tanks may indeed promote the settling of suspended solids and thereby aid in extending the life of the soil absorption system. Of the two most often prescribed flocculants, baking soda (sodium bicarbonate) and copper sulfate, only copper sulfate received the limited recommendation of the Connecticut DEP. The use of baking soda was not recommended due to the public health implications regarding elevated levels of sodium in drinking waters.

The final two types of septic system additives are synthetic soil conditioners and absorption system regenerators (hydrogen peroxide). Soil conditioners have been promoted as providing increased infiltration rates in certain types of soils. Studies have shown that in order for soil conditioners to provide any significant improvements in the percolation rate, they need to be applied to artificially dried soils (0 percent moisture, five fold increase in percolation rate; 4 percent moisture slight increase; 8 percent moisture detrimental effects) (CT. DEP, 1980).

The use of hydrogen peroxide to aid in the regeneration of failed soil absorption systems has been the most extensively studied of the chemical additive options. Hydrogen peroxide is a strong oxidizing agent, which when applied, is reduced to oxygen and water. The Connecticut DEP study revealed that hydrogen peroxide additions remove the biological crust and may be good for undersized systems (CT. DEP, 1980). Studies by Harkin et al. (1976) theorize that hydrogen peroxide oxidizes the black, insoluble sulfides to sulfate and thiosulfate while also oxidizing some of the organic matter. This oxidation and the resultant effervescence serves to break up the crust and rejuvenate fields which failed due to organic overload (Bishop and Logsdon, 1981).

Further research reveals the mixed results obtained from the use of hydrogen peroxide to regenerate failed soil absorption systems. Studies have shown the treatment effects to range from highly variable, partial absorption system regeneration in sands; to ineffective, unpredictable and often deleterious effects in other soil conditions (Hargett et al., 1985). While hydrogen peroxide doses may in fact oxidize the biomat crust, they may also destroy soil aggregation and structure leading to reduced porosity along with disrupting the accumulated organic and ammonia nitrogen concentrations in the crust and underlying soils, leading to increased nitrate loading of the ground water (Bicki, 1988).

The conclusions of the Connecticut study revealed that most septic system additives at best provide severely limited benefits, and may conversely cause significant harm to the septic system or the surrounding soil and ground water environment. The U.S. Public Health Service (1967) reported that out of over 1,000 commercial products available for septic systems, none had proven to be effective (Hargett et al., 1985).

Recirculating Sand Filters

Recirculating sand filters were developed in the 1960's as a simple cost effective alternative to the use of subsurface soil absorption systems and as an improvement on the frequently clogging intermittent sand filter system. RSF's are similar to intermittent sand filters in their design and operation but incorporate a recycle loop which allows a dilution of the applied wastewater load, thereby reducing the organic waste strength and lowering the incidence of surface clogging induced failure (Hines et al., 1977).

RSF's were originally developed in Illinois as a means of providing secondary treatment following a septic tank, prior to surface discharge. In Michigan, where filters discharging to the surface are not allowed, RSF's have been developed for use following septic tanks, prior to subsurface effluent disposal. Studies conducted by Bernhardt (1973), found that effluent absorption in slowly permeable soils is greater for highly oxidized effluent, such as those achieved with an RSF, than for effluent pretreated with a septic tank alone. The RSF was found to also protect the soil absorption system against solids discharge from a septic tank that is in need cleaning or is otherwise overloaded (Loudon et al., 1984).

Recirculating sand filters may provide a notable function for small community or cluster development systems if used following septic tanks, prior to subsurface soil absorption system discharge. These systems may also be used as a cost effective replacement for the unregulated rapid sand filtration units in use at many schools and hospitals (Swanson and Dix, 1988). RSF's require minimal maintenance, usually limited to raking of the surface to remove weed growth and periodic flushing and checking of the pipes and the pumps. RSF's may provide substantial benefits including increased effluent quality, increased soil absorption system life, and possibly some degree of denitrification (Loudon et al., 1984). Nitrification occurs during the sand filtration phase, while denitrification (40 percent - 80 percent) occurs in the recirculation tank (Loudon et al., 1984).

Recirculating sand filters are usually constructed above ground to promote aerobic conditions at the sand surface. Winter operation is possible through the use of surface sprinklers which can be designed to be immune to ice build-up and with coarse sand which promotes free draining of the warm filtrate before the onset of freezing (Loudon et al., 1984). RSF's incorporate a recirculation tank, approximately the same size as a standard septic tank, which is used for mixing the raw septic tank effluent with the RSF filtrate. A recirculation ratio of between 3 and 5 parts filtrate to one part septic tank effluent is usually maintained, with 5:1 found as the optimum for the prevention of odors (Swanson and Dix, 1988).

Anaerobic Filters

Anaerobic filters were first used in England in 1876 to purify sewage (Kennedy, 1982). Anaerobic filters have since been developed as a pretreatment device for domestic discharges and for high strength or acidic industrial wastes (Rittman et al., 1982; and Khan et al., 1982) and are currently receiving increased attention as an alternative treatment process designed to anaerobically treat and denitrify aerobic treatment unit effluent (Effert et al., 1984).

The first use of an anaerobic filter system is as a pretreatment device following a standard septic tank. Anaerobic plug flow filters are chambers filled with a solid media which promotes fixed film and interstitial microbial growth. These chambers are usually operated in an upflow mode and can be as simple as a concrete septic tank or water-tight chamber filled with rock. Anaerobic plug flow filter systems provide many advantages to the use of aerobic filters, including the removal of organics as gases like methane, carbon dioxide and nitrogen rather than fixed as new cell material. This results in a decreased sludge volume which is 6 - 10 times as dense as an aerobic sludge. Additional advantages include the ability of the system to handle shock loads, the ability of the system to survive for extended periods on no load at all, an improved effluent quality transported to the soil absorption system, and low cost of operation and maintenance (Kennedy, 1982).

A more recent utilization of anaerobic filters is for the promotion of denitrification of wastewaters. Anaerobic filters following aeration, either through the use of aerobic pretreatment tanks or rapid sand filtration, provides an environment in which denitrification can be initiated. A carbon source must be provided either through the addition of methanol which has been shown to result in a 90 percent nitrogen reduction or through the addition of previously segregated grey waters in order to effect appreciable denitrification. A grey water segregation system developed by Dr. Rene Laak at the University of Connecticut, claims to provide a 90 percent nitrogen reduction. Recent testing of the system has resulted in nitrogen reductions in the 70 percent range. However a number of operational problems were noted (Kennedy, 1982).

Disinfection

Disinfection of wastewaters can be accomplished by a variety of chemical, physical, mechanical, and radiation techniques designed to physically trap the bacterial cell or to inactivate the cell by mechanisms causing damage to the cell wall, alteration of the cell permeability, alteration of the colloidal nature of the protoplasm or inhibition of the enzyme activity. Disinfection of household wastewaters has been advocated in many states prior to surface discharge to water bodies. Simple disinfection devices which have demonstrated some reliability in domestic use include ultraviolet radiation using mercury vapor lamps and dry feed chlorination systems (Sauer and Boyle, 1977). Proper disinfection requires a clarified effluent as suspended solids, metals, and refractory organics interfere with the process. Because of this need for a highly purified effluent, sand filters may be necessary prior to disinfection.

An additional use of disinfection that requires further study is the disinfection of pretreatment unit effluent prior to subsurface discharge. This use will substantially reduce the risk of pathogenic viral and bacterial contamination of the subsurface, while relying on the indigenous bacterial populations in the soil absorption system for additional treatment. Chlorine disinfection would probably prove to be unsuitable for this application due to the formation of toxic chlorine residuals which may inhibit the indigenous bacterial populations.

Sewage Treatment Facilities

The preceding sections evaluated non-conventional and modified treatment processes intended either to provide an alternative to the conventional septic system or to expand the extent of treatment provided by it. Many of the treatment options discussed in the preceding sections have processes which go beyond the scope of the simple subsurface septic system and would approach being classified as sewage treatment facilities. This section will detail the use, benefits, permitting, and operation and maintenance of sewage treatment facilities.

Sewage treatment facilities have been used in Massachusetts for many years to treat wastewater flows from condominium developments, industrial parks, shopping malls and other projects under single ownership that generate sewage flows in excess of fifteen thousand gallons per day (15,000 gpd). There are over two hundred small, sewage treatment facilities permitted for use in the Commonwealth of Massachusetts. Of these, approximately sixty involve the Rotating Biological Contactor treatment process.

Regulation of sewage treatment facilities is vested in the Department of Environmental Protection under its Bureau of Resource Protection's Division of Water Pollution Control. The Massachusetts Ground Water Permit Program (314 CMR 15.00) requires any person who discharges or proposes to discharge pollutants to the ground waters of the Commonwealth to obtain a discharge permit from the Director of the Division of Water Pollution Control pursuant to G.L. c.21 s.43. Further, it prohibits the construction, installation, modification, operation, or maintenance of an outlet for such a discharge or any treatment works required to treat such discharge without a currently valid permit from the Director.

The permitted sewage treatment facility must be operated by a Certified Wastewater Treatment Plant Operator in accordance with the "Rules and Regulations for Certification of Operators of Wastewater Treatment Facilities" (257 CMR 2.00). The permittee bears the ultimate responsibility of providing for the proper operation and maintenance of the facilities in accordance with "Operation and Maintenance and Pretreatment Standards for Wastewater Treatment Works and Indirect Discharges" (314 CMR 12.00).

Sewage treatment facilities approved under this program utilize a combination of treatment units generally including primary settling followed by aerobic treatment, secondary settling, filtration and disinfection. Effluent disposal is usually accomplished through either open sand beds or some form of subsurface disposal. Separate units are often added to the treatment process to accomplish nitrogen removal in environmentally sensitive areas.

Primary settling is typically accomplished through the use of a septic tank for pretreatment of the wastewaters. The pretreatment tanks are designed to provide twenty four-hours detention time, thereby allowing sufficient storage of influent in the event that the discharge needs to be ceased entirely to repair the system. All waste sludges produced by the various treatment processes are directed to the primary settling tank. This tank is designed with the capacity to hold waste solids for a twelve month period. Every six months the tank is pumped by a licensed septage hauler and the contents are transported to an approved sludge treatment and disposal facility.

An equalization tank is then provided to insure a constant flow through the treatment system. Sewage flows at small treatment plant installations typically peak twice each day; once in the morning, and again in the early evening hours. A peaking factor which varies depending on the population served, is used for design purposes to establish the daily flow pattern. The average daily, peak hourly and maximum daily flow rates are essential elements in the design of the flow equalization tank. The Department of Environmental Protection generally requires a flow equalization tank sized to retain fifty percent of the calculated average daily flow to provide sufficient storage to attenuate surges so that they do not adversely affect the facility's performance. The flow equalization tank also allows all subsequent units to be designed based on the average daily flow rate.

Sewage is generally pumped to the biological treatment units from the equalization tank. A constant feed device controls the rate of flow through the biological units and all subsequent treatment processes. Excess sewage is returned to the equalization tank through an overflow device. The facility's operator is able to adjust the feed rate to the units to maximize the treatment efficiency. Aerobic treatment is normally provided to convert dissolved organic constituents within the wastewater to biological solids.

Clarifiers are used for biological solids removal. These tanks provide a quiescent zone for the settling of solids generated during the biological treatment process. Solids which settle to the bottom of the clarifier in the form of a sludge are directed to a hopper by rotating sludge rakes. Sludge is then removed from the clarifiers and returned to the pre-treatment tanks at regular intervals. The clarifiers also capture floating matter which is also pumped to the pre-treatment tanks for temporary storage prior to removal from the system.

The tertiary filter is usually comprised of two individual dual media filter cells. Removal of suspended solids, in the effluent from the clarifiers, occurs as the wastewater passes through the filtering medium (anthracite and sand). Each filter cell is set to backwash automatically when the wastewater reaches a pre-determined level above the surface of the media.

Disinfection is often provided prior to discharge, particularly where open infiltration basins are utilized. Disinfection of treatment facility effluent allows for the destruction of pathogenic bacteria and viruses to further protect ground water or surface water. Disinfection can consist of either chlorination, or in sensitive areas, ultraviolet radiation. A number of factors combine to make the ultraviolet method a desirable disinfection technique. The ultraviolet process is capable of destroying all types of pathogens in clear liquids. The fact that small treatment plants are equipped with effluent filters, which will remove virtually all particulate matter from the wastewater, allows for an effective use of ultraviolet rays. The ultraviolet light, produced by special lamps in an enclosed chamber, is capable of providing a rapid pathogen reduction without the addition of chemicals or heat.

Leaching facilities to dispose of the effluent from the plant may consist of open sand beds, leaching chambers leaching trenches or leaching pits. Since the effluent entering the leaching facilities is superior in quality to that of a septic system significantly higher hydraulic loads are typically used in the design of these structures. Monitoring wells are required to be installed both upgradient and downgradient of the leaching facilities to allow analysis of the ground water on a routine basis.

Rotating Biological Contactors have recently become the biological treatment process of choice, due to their ability to handle wastewaters of variable flows and strength without adversely effecting effluent quality. The rotating disc process of biological wastewater treatment evolved from research work begun in 1955 at the Technical University of Stuttgart, West Germany. Commercial use of the process began in Europe in 1959 and in the United States in 1965. The process is currently used at thousands of installations worldwide for the treatment of sanitary sewage, industrial wastewater, and septage.

There are many firms manufacturing and marketing Rotating Biological Contactors (RBC) treatment devices both within the United States and abroad. Although there are physical differences in the various manufactured units, the basic concept is universal. A series of polyethylene discs, mounted on a steel shaft are rotated with approximately 40 percent submergence in wastewater. Microorganisms (primarily bacteria but also other simple life forms such as algae, protozoa, and rotifers), naturally present in the environment, adhere to the discs forming a biological slime layer. This biological layer utilizes the soluble organic compounds in the wastewater as a source of energy and as a supply of the basic elements necessary to produce new cell material. Rotation of the media alternately exposes the organisms to their food, the soluble organic matter, and the atmosphere which provides the oxygen needed for respiration. Shearing forces exerted on the organisms during rotation through the wastewater causes excess growth to slough from the media into the wastewater solution (referred to as mixed liquor). The mixing action of the rotating media keeps the sloughed solids in suspension, and the mixed liquor flow carries them out of the unit for separation through subsequent processes of clarification and filtration. The treatment process produces a sludge which needs to be processed and ultimately disposed.

If the organic strength of the wastewaters entering the Rotating Biological Contactors is not as high as that assumed in the design process, micro-organisms will adhere to only enough disks to handle the pollutant load. The remainder of the disks will be available as excess capacity. If the wastewater is at design standards the entire surface area will develop a micro-organism growth. Thus the system quickly adjusts to the strength and volume of the influent wastewater stream.

During the biological treatment of sewage, nitrogenous compounds present within the wastewater are oxidized to nitrate-nitrogen (NO_3-N) through a series of biochemical reactions known collectively as nitrification. In recent years, a variation in the RBC process utilizing submerged media in air tight vessels, designed to starve the organisms of free oxygen, has proven extremely successful in providing additional treatment known as denitrification. This process removes the NO_3-N from the wastewater by bacteria functioning in anoxic (devoid of dissolved oxygen) environments, to produce nitrogen gas.

The necessary anoxic environment is provided by completely submerging the fixed biological growth in the waste stream. Reduction of total nitrogen values have been demonstrated to be in excess of ninety percent. Effluent concentrations of total nitrogen of less than the primary drinking water standard of 10 mg/1 have been consistently achieved at plants so equipped. The efficiency of this particular unit operation is, however, directly dependent on the ability of the facility's operator to monitor and make the appropriate process adjustments. As an added safeguard, a recycle option is often incorporated in the design. The recycle line can be used to divert plant effluent back to the pretreatment tanks at the headworks of the facility. The anoxic environment within the pretreatment tanks contains the same denitrifying bacteria necessary to reduce the nitrate-nitrogen to nitrogen gas.

A review of available data on the operation of Rotating Biological Contactor Treatment Systems demonstrates that they are extremely effective and reliable in providing a consistent high quality effluent. Standard process monitoring parameters such as 5-day Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS) demonstrate removal rates generally in excess of eighty-five percent. Operational records on file at the DEP indicate that permitted Rotating Biological Contactor Systems have historically met the requirements of their ground water discharge permit for BOD and TSS ninety-nine percent of the time. Recent Ground Water Discharge Permits have also included limitations on the amount of Total Nitrogen allowed in the discharge. Several plants have experienced problems in consistently achieving the standards for nitrogen because they were not specifically designed to remove this constituent. Those plants equipped with submerged Rotating Biological Contactors have little problem meeting a 10 mg/l Total Nitrogen limit. This record strongly suggests small treatment facilities employing Rotating Biological Contactors represent a viable technology, and that consideration should be given to expanding their application to areas that require special precautions to protect important sensitive resources.

Sewage treatment facilities have the potential to produce an effluent far superior to that produced by conventional septic tank systems. Septic tanks can be expected to remove nearly all settleable solids and floatable grease and scum so that a reasonably clarified liquid is discharged. BOD removal in the range of thirty percent can be expected within the septic tank; additional treatment is provided within the soil matrix. But, the lack of aerobic conditions prevents any significant removal of nitrogen within the septic tank. The nitrogen concentration (predominately in the form of ammonia-nitrogen as the wastewater exits the septic tank, with conversion to nitrate-nitrogen occurring within the soils) can be significant and is generally a concern in areas where ground water is used as a source of drinking water.

Aerobic biological treatment processes are capable of removing substantial amounts of BOD and TSS over and above that removed in the conventional septic tank. More importantly, the process is capable of nitrifying the ammonia in the wastewater to nitrate-nitrogen, which then can be removed through a denitrification process. Disinfection is also typically employed at such facilities providing significant reductions in the number of pathogenic organisms in the wastewater prior to its release into the environment.

A comparison of typical septic tank effluent quality (prior to the soil absorption) to the expected effluent quality of the proposed sewage treatment plant (also prior to soil absorption) is presented in the table below. This data illustrates the potential for a superior effluent quality from the proposed sewage treatment facility.

Sewage treatment facilities employ an aerobic process to accomplish waste treatment. This process provides the additional benefit that volatile compounds which may enter the system can be volatilized as they pass through the system. It should be noted that sewage treatment facilities are not designed to remove volatile organic compounds but generally provide significant removals just the same. In contrast, the anaerobic septic tank system will provide no opportunity for removal of volatile organic compounds. A study conducted for the United States Environmental Protection Agency determined that toxic chemicals were routinely found in household septic tank effluent and that the septic tank provides no appreciable treatment of the identified toxic compounds (NTIS, 1985). A similar study conducted by the Department of Environmental Protection on a number of small biological treatment facilities also identified low levels of toxic chemicals in the sewage treatment plant influent. The DEP study, however, illustrated substantial decreases in the concentration of the toxic chemicals in the treatment plant effluent (Unpublished data on file with the DEP).

Table 20.2.1

SEPTIC TANK EFFLUENT VS. ADVANCED WASTEWATER TREATMENT FACILITY EFFLUENT CHARACTERISTICS[1]

Parameter	Influent Quality[2]	Effluent Quality[2] Septic Tank	WWTF[3]
BOD_5	300	170	15
Suspended Solids	300	60	<10
Total Nitrogen (as N)	45	42	<10
Ammonia-Nitrogen (as N)	12	40	<2
Nitrate-Nitrogen (as N)	0.6	0.04	<10
Total Phosphorus (as P)	25	14	10
Fecal Coliform (coliform/100ml)	3×10^4	5×10^6	<100

1. Measured prior to land application
2. All values in mg/1 except as noted
3. Secondary treatment followed by denitrification and disinfection

References:

(1) Canter, L.W., and Robert C. Knox, Septic Tank Systems Effects on Ground Water Quality Lewis Publishers, Inc., Chelsea, Michigan 1985

(2) Massachusetts Division of Water Pollution Control File Data

(3) USEPA, Alternative for Small Wastewater Treatment Systems, EPA - 625/4-77-011, 1977

The Department of Environmental Protection requires that a licensed operator be present at the treatment facility at least two hours per day to perform operational supervision and routine maintenance. The State also requires that a Registered Professional Engineer inspect the treatment facility at least once per month to monitor the operation and collect samples to determine if the facility is meeting its ground water discharge permit. A report must be submitted by the engineer to the Department of Environmental Protection and the local Board of Health. Annually, the Department conducts its own independent compliance inspection of the facility.

There are many safety factors incorporated in the design of the small sewage treatment plants. First, design calculations for the size of each unit operation include design safety factors. In addition, the Division's sewage flow estimates which are contained in Title 5 and serve as the design flow criteria have been conservatively calculated to include a margin of safety.

High water level switches which activate both audible and visual alarms to alert the operator of a potential problem are provided. Additionally, an auto-dial telephone paging system provides the operator with notice of an unanswered alarm.

All pumps in the system have a duplicate unit plumbed and wired to automatically start should the primary pump malfunction. Any pump malfunction also activates the alarm system. A spare parts inventory is required to be maintained to minimize the down-time of any unit due to a malfunction.

Treatment facilities are required to be equipped with a permanently mounted emergency generator of sufficient size to generate enough electricity to operate the entire facility including all pumps, treatment processes and lighting. The treatment plants are generally equipped with an automatic transfer switch which would activate the emergency generator in the event of a prolonged power outage. The facility's main control panel is equipped with a sequential starter to prevent an overload on the circuitry upon transfer to the alternate electric source.

Under existing Massachusetts Ground Water Protection Regulations sewage treatment facilities are required for projects under single ownership where more than fifteen thousand (15,000) gallons per day is generated. A Generic Environmental Impact Report (GEIR) on Privately Owned Sewage Treatment Facilities prepared for the Commonwealth of Massachusetts by ICF, Inc (1990) suggests that treatment facilities be considered for systems with multiple owner and for systems with flows less than fifteen thousand (15,000) gallons per day. In particular the GEIR suggests that treatment facilities be considered in environmentally sensitive areas.

One of the major advantages of the septic system is that it has no moving parts and, therefore, needs very little routine maintenance. A properly designed and maintained concrete septic tank should last for fifty years or more. However, one cause of septic tank problems involves a failure to pump out the sludge (septage) when required. As the septage depth increases, the effective liquid depth of the tank and the detention time of the liquid within the tank decreases. As this occurs, septage scouring increases and treatment efficiency falls off. Left unattended the system will eventually fail due to the solids carry over into the soil absorption unit.

Despite their advantageous treatment capabilities, aerobic biological treatment processes are much more susceptible to mechanical failures. In order to consistently produce a high quality effluent, the treatment plant operations must receive regular supervision and maintenance. This supervision requires trained and skilled personnel. Based on field experience, five to ten person hours per week plus analytical services are required to insure reasonable performance. The cost of this additional attention represents a significant increase over that involved for conventional septic systems.

Essential to the successful operation of a wastewater treatment facility, regardless of whether it is privately of publicly owned, is the establishment of a financial system designed to guarantee that adequate funds will be available for the plant's operation, maintenance, repair and ultimate replacement. This requires careful planning to assure that sufficient revenues are generated to cover not only routine operational expenses, but also to provide systematic savings to allow for the replacement of treatment plant components after they have served their useful lives. The financial system must include assessments which fairly and equitably distributes the facility's costs among the individual members of the user group. It also requires cash flow management to ensure that adequate funds are available to offset expenses as they come due.

The Department of Environmental Protection requires a financial plan tailored to fit the specific application be prepared as a condition of the discharge permit for wastewater treatment facilities. The key elements of this financial plan include: (1) the establishment of a system for the assessment of user fees; (2) the posting by the project proponent of security to serve as a source of funding for the immediate repair or replacement of any sewage treatment component which fails prior to its design life; (3) the establishment of a capital reserve account to provide for treatment plant replacement; and, (4) the preparation of an annual financial report which provides a complete description of revenue collected, disbursements made, current account balances and projected assessments for the coming year.

The project proponent generally provides security to the Department of Environmental Protection and the local board of health as a temporary source of funding to cover any unexpected malfunctions of treatment plant equipment. In effect, by posting this security, the proponent is providing insurance against catastrophic failure of the treatment plant equipment until such time as sufficient funds have been set aside in the capital reserve account. The amount of the security is determined by the Department based upon such factors as the average operating and maintenance costs associated with the design flow of the facility. The security must be in a form acceptable to the Department and may include an interest bearing bank escrow account, a bank loan agreement, a letter of credit or a bond.

20.2 State Regulations

Most states allow for alternative systems capable of providing increased treatment of wastewater (Table 20.2.1). New Hampshire and Massachusetts are the only New England states which do not allow innovative systems on a routine basis. The majority of the states that allow alternative systems include a stipulation in their regulation that alternative systems are allowed, but will be considered on a case by case basis. Six states only allow alternative systems when a standard septic system cannot be installed or is not suitable.

Twenty-three states allow aerobic pre-treatment of wastewater, which is the most popular alternative treatment system listed. Although a majority of the states provide for alternative systems, design criteria for specific treatment systems is not included the regulations. Seventeen states address mound systems; seventeen states address a form of non-discharging toilets; and fifteen states allow the use of sand filters. Only Maine and Texas allow for peat filters in their regulations.

20.3 Local Regulations

Title 5 does not allow innovative systems except as approved by Department of Environmental Protection under the variance provisions. Because of this, there are no local regulations regarding these types of systems. Title 5 does require treatment for discharges over 15,000 gallons per day. This has prompted several towns, including Hingham and Wayland, to generate regulations controlling the design and use of small wastewater treatment plants.

TABLE 20.2.1

ALTERNATIVE SYSTEMS

	INNOVATIVE SYSTEMS	NON-DISCHARGING TOILETS	AEROBIC PRE-TREATMENT	SAND FILTERS	MOUND SYSTEMS	EVOPTRANS-PIRATION	PRESSURE DIST.	GREYWATER/ BLACKWATER SEGREGATION	PEAT FILTERS	HOLDING TANKS
Alabama	X	X	X					X		
Alaska	X				X					
Arkansas	X		X							
Arizona	X		X	X	X	X	X			
California	X				X			X		
Colorado	X	X	X	X	X	X				
Connecticut	X	X								
Delaware	X			X	X		X			X
Florida	X	X	X				X	X		
Georgia(1)										
Hawaii(2)										
Idaho										
Illinois	X	X	X	X	X					
Indiana	X	X		X	X		X			
Iowa	X	X	X	X	X		X			
Kansas(1)										
Kentucky			X		X	X		X		X
Louisiana(1)										
Maine	X		X	X					X	X
Maryland	X		X		X					X
Massachusetts										
Michigan	X						X			
Minnesota	X		X				X	X		X
Mississippi(2)										
Missouri	X		X	X			X			X
Montana	X		X	X		X	X			
Nebraska							X			
Nevada(2)										
New Hampshire		X	X				X			
New Jersey	X									
New Mexico	X	X								X
New York	X		X	X	X	X				
North Carolina	X	X	X							
North Dakota	X	X		X						X
Ohio		X	X	X						
Oklahoma			X			X				
Oregon	X		X	X		X	X	X		X
Pennsylvania	X	X		X	X	X				
Rhode Island	X	X								
South Carolina	X						X			
South Dakota	X				X	X		X		
Tennessee	X				X		X			
Texas	X	X	X		X		X		X	
Utah										X
Vermont	X				X		X			
Virginia(1)										
Washington	X	X	X	X						
West Virginia	X		X							
Wisconsin					X		X			X
Wyoming	X	X	X			X				X
Guam(2)										

(1) Regulations unavailable.
(2) No alternative systems discussed within regulations.

20.6 Conclusions and Recommendations

The major benefit of a conventional system is its simplicity and ease of operation. Modified or alternative systems may provide increased treatment of wastewater, but they also usually require additional operation and maintenance and expertise that the average homeowner does not possess.

Title 5 needs to provide some incentive promoting the development of alternative systems capable of providing higher levels of treatment. However, any modifications to the regulations should include provisions that ensure that should any one, or all, of the components of an alternative system fail, the system will continue to function in a manner no worse than a conventional septic system. Because alternative systems involve careful consideration and detailed technical reviews, we recommend that the Department of Environmental Protection assist the local boards of health in the review process. The current practice of requiring that variances be granted for such systems provides an excellent opportunity for the Department to become involved in the approval process.

In environmentally sensitive areas, where increased treatment is desirable, community sewage treatment plants should be considered. Of course, adequate financial and legal assurances must be in place before any privately owned multiple-lot system is approved.

We recommend that a small scale pilot program be undertaken by the Department where members of the Department's Title 5 staff assist several communities in the review and aproval of alternative systems. This pilot program will help the Department identify the resources that will be necessary to implement a full scale program as well as provide a better understanding of the capabilities of local boards of health.

CHAPTER 21

DRAINS

Surface drains have been proposed in areas where ground water, either perched or naturally high, has limited the effectiveness of the septic system. Properly installed, drains can artificially lower the water table and thus provide unsaturated soil conditions beneath the leaching structure necessary for proper treatment. Vertical drains, curtain drains and underdrains are the most commonly employed methods. Soil characteristics, hydrogeologic conditions and the general topography of the site determine which method is preferred.

Some designs have successfully used drains to control perched ground water. Drains used to lower the actual ground water table, however, have been problematic. The failures associated with these systems are often caused by designs which do not consider the origin of the water or the overall geology of the site. Since Title 5 does not include provisions regulating the use of drains, any system proposed to lower the ground water must also be approved through the variance procedure.

In some cases, lowering the water table is not possible and the only available option short of condemnation is the use of a tight tank. A tight tank is basically an enclosed septic tank, with only an inlet tee, used to collect wastes for removal from the site. Tight tanks are approved by the Department of Environmental Protection only for existing establishments for which it has been proven that no other feasible alternative exists. The Department's reluctance to approve tight tanks is based in part on the limited number of approved facilities which are capable of accepting the wastes for treatment. Furthermore, disposal costs are very high and can place severe financial restraints on the owners of the systems.

21.1 Literature Review

Surface Drains

Proper design of artificial drainage systems depends upon a correct diagnosis of the drainage problem (EPA, 1980b). In order to effect a successful design, consideration must be given to the origin of the water. The design engineer must have a complete understanding of the hydrogeologic conditions, particularly with respect to the soil characteristics.

Problem water conditions usually fall into one of four general categories: (1) free water tables; (2) water tables over artesian aquifers, (3) perched water tables; and, (4) lateral ground water flow conditions. Artificially lowering a free water table for an extended period of time is not only difficult, but very costly. It is not practical to drain aquifers that are saturated for prolonged periods, particularly on level sites. Ground water which is fed by artesian aquifers, moves in the direction of decreasing hydraulic gradient and is impractical to drain. Water removed from this type of aquifer, or any free phreatic aquifer, is constantly being recharged in large quantities.

The only practical use of surface drains is for the draining of finite quantities of water, such as that associated with a perched water table moving laterally across the site. This problem is often encountered in stratified soils and occurs when recharge water (rain water infiltration), encounters a layer of reduced permeability material which impedes its downward movement to the actual water table.

Table 21.1.1 illustrates various types of drainage problems, soil characteristics and the preferred type of drain commonly employed to solve the problem.

TABLE 21.1.1

DRAINAGE METHODS FOR VARIOUS SITE CHARACTERISTICS
(Adapted from USEPA, 1980b)

Site Characteristics	Problem	Method
Saturated or mottled soils above a restrictive layer with water source located at a higher elevation; site usually sloping	Lateral flow	Curtain drain Vertical drain
Saturated or mottled soils above a restrictive layer; soil below restrictive layer is unsaturated; site is level or only gently sloping	Perched water	Underdrain[b] Vertical drain[a]
Deep uniform soils mottled or saturated	Free water table	Underdrain[b]
Saturated soils above and below restrictive layer with hydraulic gradients increasing with depth	Artesian-fed water table	Avoid

a. Use only where restrictive layer is thin and underlying soil is reasonably permeable.
b. Soils with more than 70% clay are difficult to drain and should be avoided.

Before designing and installing any drainage system the site characteristics must be thoroughly investigated. This includes a careful topographic survey, soil profile descriptions, estimation of the seasonal high ground water elevations and determination of the direction of ground water flow.

Topographic maps of the site with 1 to 2 foot contour intervals should be used as base maps (USEPA, 1980b). Water table elevations, seep areas and areas with wetland vegetation should be located, along with the elevations of ridges, knolls, rock outcrops and natural drainage ways. This information can be used in establishing the source of the ground water, its flow direction, and determining the proper placement of the drainage system.

Soil texture, density, color, zones of saturation and root penetration aid in identifying soil stratification. Thick units of uniform soils indicate a free water table. Soils, underlain by glacial till often have a perched or lateral flow ground water problem.

Soil mottling helps identify soils that are periodically saturated, whereas grey soil indicates continuous saturation. The highest elevation of the mottling provides an estimate of the seasonally high water table, while the top of the grey zone indicates the seasonally low water table elevation (USEPA, 1980b).

Curtain drains should be located on the upslope or upgradient side of the soil absorption area to intercept the water. These drains consist of perforated pipe placed in a trench. If possible, the drains are piped to the surface downslope to allow free drainage. When this is not possible pumps must be used to evacuate the water.

Vertical drains may be used if the layer creating a perched water table is thin and overlies permeable soil. Vertical drains consist of trench excavations backfilled with coarse material, to be located on the upslope-upgradient side of the soil adsorption system, installed through the restrictive layer into the more permeable soil below. Perched water moving toward the excavation is able to drain downward into the underlying permeable soil.

FIGURE 21.1.1

CURTAIN DRAIN TO INTERCEPT LATERALLY MOVING PERCHED WATER TABLE CAUSED BY A SHALLOW, IMPERMEABLE LAYER

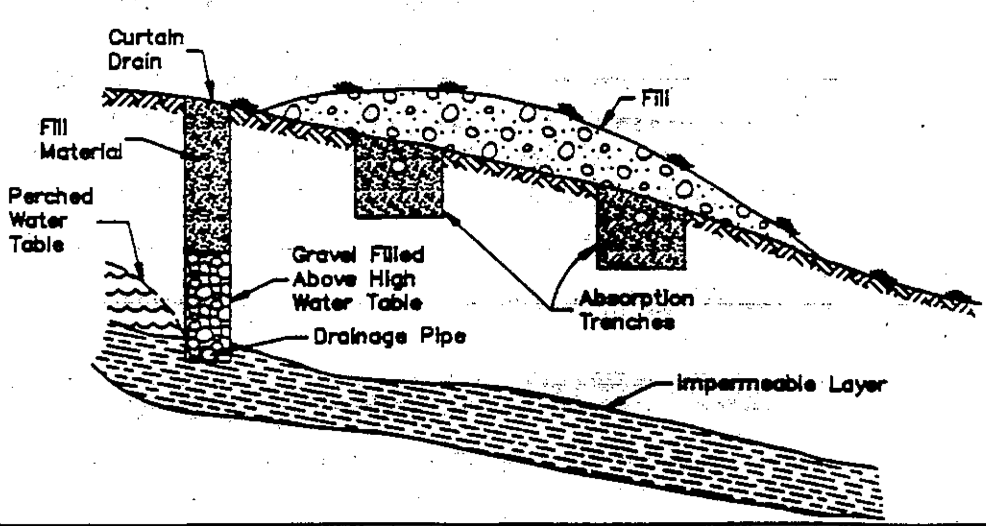
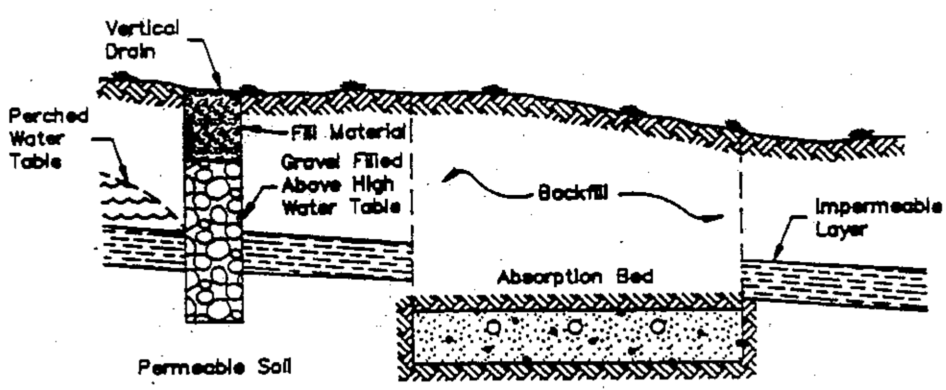


FIGURE 21.1.2

VERTICAL DRAIN TO INTERCEPT LATERALLY MOVING PERCHED WATER TABLE CAUSED BY A SHALLOW, THIN, IMPERMEABLE LAYER



21.2 State Regulations

Arkansas, Connecticut, Delaware, Kentucky, New Hampshire, Ohio, Oregon, Texas and Vermont all have specific design criteria for the use of drains to lower ground water. Arkansas only allows drains in sloping terrain. Oregon requires that the effectiveness of the dewatering system be demonstrated prior to the issuance of a construction permit.

21.3 Local Regulations

There are approximately 20 towns that have regulations regarding subsurface drains. The towns of Wendell, Pelham, Natick and Stow prohibit their use. The town of Sherborn allows them with frequent inspection and monitoring, while the town of Boxborough allows them only if they are gravity drained. Ashland only permits subsurface drains for repairs and Boylston requires that they be installed and tested during deep hole season, before a disposal works construction permit is issued. Carlisle and Weston allow drains, while Uxbridge requires them in some cases.

21.4 Conclusions and Recommendations

Surface drains have been used with some success to lower perched ground water on lots with steep slopes and on lots where permeable soils exist under a layer of impervious material. Only limited success has been achieved, however, when attempting to lower the true ground water table.

It would appear that the lowering of perched ground water is possible under the proper conditions. However, it must be remembered that the most important factor in the treatment of septic tank effluent is the vertical separation between the leaching facility and ground water. Therefore if an attempt to lower the ground water is not successful, contamination of the ground water could result.

It is recommended that, due to the serious consequences of a failure to adequately lower ground water elevations, surface drains only be allowed under the variance provisions of Title 5. Surface drain systems should only be designed after extensive review of site conditions including soil layer, ground water elevations and site topography. Qualified engineers or hydrogeologists should submit surface water designs to the Department of Environmental Protection for review and approval.

If approved, curtain drains should be placed some distance upslope from the proposed soil absorption system to intercept the ground water, and around either end of the system to prevent intrusion. On sites with sufficient slope, the drain should be extended downslope until it surfaces, to provide free drainage. The drain should be placed slightly into the restrictive layer to ensure that all of the ground water is intercepted. A separation distance of twenty-five feet from the soil absorption system is recommended to prevent insufficiently treated wastewater from entering the drain. This distance may have to be increased depending on the soil permeability, the topography, and the depth of the drain below the bottom of the absorption system.

The size of the drain should be determined based on the soil permeability, the size of the area to be drained, and the gradient of the pipe. Silt traps should be provided in the drain to improve the quality of the discharged drainage.

A clean coarse, porous material such as gravel or crushed rock, etc., should be placed under and above the pipe to maximize infiltration of the ground water into the pipe. The porous material should extend above the high water table elevation. To prevent silt from entering the pipe while the disturbed area is stabilizing, the tops of the joints or perforations should be covered with waterproof building paper or the pipe jacketed with mesh. Natural soil material can be used for the remainder of the backfill. Drain outlets should be protected from small animals by a covering of porous material such as crushed rock or gravel.

Vertical drains may be used to intercept a laterally flowing perched water table. Separation distances between the drain and the bottom of the soil absorption system should be the same as for curtain drains to maintain an unsaturated zone under the absorption system.

The size and placement of the drain should be determined based upon the relative permeabilities of the saturated soil above and less permeable soil below, in addition to the size of the area to be drained. The infiltrative surface of the vertical drain (sidewalls and bottom area) should be sized to absorb all the water it receives. The width and depth of the drain below the restrictive layer should be calculated by assigning an infiltration rate to the underlying soil.

Interceptor drains should be dug to the desired depth and width, and backfilled with a clean coarse, porous media such as coarse sand, 1/4- to 1/2-inch (0.6 to 1.3 cm) gravel, or similar material, to a level above the high perched water table elevation. Natural soil materials can be used for the remainder of the backfill.

PART V

MANAGEMENT PRACTICES

CHAPTER 22

COMPATIBILITY

In developing an effective and efficient regulatory framework, it is important to ascertain the compatibility of the various related policies and regulations. In addition, it is important to explore how effective the administrative system is in implementing the regulations and creating the desired outcomes. Title 5 co-exists with laws, policies, programs, and individual decisions that determine the extent to which development occurs in a particular location.

Part of the technical evaluation of Title 5 is, necessarily, an analysis of the compatibility of existing, applicable policies and regulations. Inconsistency and incompatibility in this area impedes effective and efficient regulation. Thus any such incompatibility should be corrected to ensure the intended outcome of the regulations.

This chapter of the report examines the compatibility and consistency of Title 5 with other regulations governing general building construction and environmental protection. Inconsistencies are examined for their impact on Title 5's effectiveness in protecting public health and environmental resources. Recommendations are offered to reconcile inconsistencies between Title 5 and other laws and regulations. These recommendations are designed to engender flexibility in Title 5 that will enable it to adapt to the ever-changing regulatory framework while continuing to meet its mission of public health and environmental protection.

22.1 Literature Review

22.1.1 Title 5 in an Evolving Regulatory Context

When Article XI of the State Sanitary Code, the precursor to Title 5, was promulgated, policy makers and regulators had an innate understanding of the environmental issues facing the Commonwealth and the potentially adverse impacts affiliated with sanitary waste disposal by the use of septic systems. Similar to the Building and Plumbing Codes, Title 5 established standard design, review, and construction requirements and procedures for the installation of septic systems servicing individual homes, institutions and businesses in locations inaccessible to public sewer systems. Title 5 is intended to protect the total environment rather than focus on a single building as the Building and Plumbing Codes do.

Since that time, our understanding of the relationship between residential and industrial development patterns and waste disposal practices and their resulting environmental impacts has greatly advanced. During the past two decades, a number of important federal and state environmental protection laws and regulations have been written. These include: the Massachusetts Environmental Policy Act (MEPA), the Wetlands Protection Act, the Clean Water Act, numerous acts authorizing construction of wastewater treatment works, and hazardous and solid waste legislation. Policies, such as those articulated in the Generic Environmental Impact Reports on Privately Owned Sewage Treatment Facilities (IEC, 1990), have also fueled the environmental debate.

The principal orientation of these new policies, laws and regulations is protection of the environment. Typically this is established through strict standards governing the use or alteration of resources such as surface and ground waters, wetlands and coastal areas and in some cases by designation of areas inappropriate for development based on environmental considerations. Additionally, many of these laws institute controls over the handling, use, storage, transportation and disposal of materials considered to pose a potential environmental risk.

22.1.2 Framework for the Compatibility Analysis

Regulations typically contain sections describing the intended purpose, asserting jurisdiction, specifying the review and evaluation process, and establishing approval and permitting standards or criteria. To often, however, insufficient attention is given to the interrelationship with other regulatory entities.

Before undertaking a compatibility analysis between Title 5 and other laws and regulations, it is essential to define terms such as compatibility and consistency. For purposes of this discussion, compatibility shall denote similarity in scope, outcome and aims. Consistency shall denote absence of contradiction.

<u>Regulations and Policies Examined for Compatibility</u>

The evaluation of the compatibility of Title 5 with other laws and regulations entailed the review of:

State Building Code	780 CMR 100
State Plumbing Code	248 CMR 2.00
Wetlands Protection Regulations	310 CMR 10.00
Coastal Zone Management Policies	301 CMR 20 and 21
Chapter 91 Regulations	310 CMR 9.00
Drinking Water Quality Regulations	310 CMR 22.00
Protection of MDC Waters Regulations	350 CMR 8.00
Disposal into MWRA Sewers Regulations	360 CMR 10.00
Ground Water Discharge Permit Regulations	314 CMR 5.00
Ground Water Quality Regulations	314 CMR 6.00
Surface Water Discharge Permit Regulations	314 CMR 3.00

Surface Water Quality Standards Regulations	314 CMR 4.00
Sewer System Extension and Connection Regulations	314 CMR 7.00
Hazardous Waste Regulations	310 CMR 30.00
Solid Waste Management Regulations	310 CMR 19.00
Water Management Act Regulations	310 CMR 36.00
Massachusetts Environmental Policy Act Regulations	301 CMR 11.00

In addition to these regulations, the draft policies contained in the Generic Environmental Impact Report on Privately Owned Sewage Treatment Facilities (GEIR) and the permitting guidelines for privately owned treatment plants were also reviewed.

22.1.3 Compatibility of Purpose

As the first step in the compatibility analysis, it is important to understand the primary purpose of the various regulations, and the relationships that exist between them. The regulations considered in this analysis were promulgated for the following reasons:

1. Building design and construction standards;

   Title 5, the State Building and Plumbing Codes, the Sewer Extension Regulations and portions of the Chapter 91 Regulations, have been promulgated to institute standards for design and construction, and in some cases, for use and operation. A primary purpose of these regulations is to ensure that structures and/or facilities are safely designed and constructed and that the public's health and safety is protected.

2. Protection of environmental resources and environmentally sensitive areas;

   The Wetlands Protection Regulations, Coastal Zone Management Act Regulations, Drinking Water Regulations, Surface Water Quality Standards, Ground Water Quality Standards, and MDC Water Supply Protection Regulations and the Draft PSTF policy have the protection of environmental resources and environmentally sensitive areas as their primary objective. These regulations typically identify areas which are presumed to be inappropriate for development and set standards for the use of particular environmental resources.

3. Promulgation of standards for the handling and disposal of waste materials;

   The Solid Waste Regulations, Hazardous Waste Regulations, MWRA Sewers Regulations, Ground Water Discharge Permit and Surface Water Discharge Permit Regulations have the safe transportation, storage, use and disposal of potentially dangerous materials as their primary focus.

4. Review of projects for environmental impact.

MEPA requires analysis of environmental impacts for projects exceeding certain thresholds.

Title 5 is very closely related to the construction codes which specify minimum design standards. There is some overlap of jurisdiction and requirements between Title 5, the Building Code and the Plumbing Code, and the public interest is best served when the level of compatibility and consistency among these regulations is optimized.

Title 5 also maintains an affiliation with the environmental protection regulations which determine the siting constraints within which wastewater handling systems may be installed. Even though a performance standard approach is used in most environmental protection regulations rather than the design standard that is inherent in Title 5, the latter must be compatible with the State's environmental protection regulations. The Title 5 design standards must also maintain a degree of flexibility in order to ensure that septic tank/soil absorption systems maintain the level of environmental protection envisioned in the state's environmental policies.

Septic tank/soil absorption systems are only remotely influenced by provisions contained in the Solid and Hazardous Waste Regulations, the regulations protecting MDC Waters Regulations and the MWRA Sewer Regulations. The only area of common concern is the handling and disposal of septage.

The only similarity between Title 5 and the Water Management Act Regulations is that the use of septic systems may, in certain instances, allow the Water Management Act goal of minimizing interbasin transfers of water to be achieved. The Chapter 91 Regulations are remotely related to Title 5 in that the Standards for Marinas, Boatyards and Boat Ramps require that adequate restrooms and boat pumpout facilities be provided (310 CMR 9.39(1)(a)(3)).

Uniform State Plumbing Code, 248 CMR 2.00

The Plumbing Code states that it regulates the ability to "alter, amend, and repeal rules and regulations relative to the construction, alteration, repair, and inspection of plumbing", and it defines plumbing as:

> "the work and/or practice, materials and fixtures used in the installation, removal, maintenance, extension and alteration of the plumbing system of all the piping, fixtures, fixed appliances and appurtenances in connection with any of the following: sanitary drainage or storm drainage facilities, special wastes, the venting system and the public or private water-supply systems, within or adjacent to any building, structure or conveyance to their connection with any point of public disposal or other acceptable termination within the property line. (248 CMR 2.03)"

The plumbing Code defines a "sanitary sewer" as "a pipe which carries sewage and excludes storm, surface and groundwater" (248 CMR 2.03). The Plumbing Code regulates all of the plumbing within a building as well as the "building sanitary drain" which conveys the discharge of plumbing fixtures "to a terminating point ten feet outside the inner surface of the foundation wall". The "building sewer" begins at the terminal point of the "building sanitary drain" concluding at the connection to a public sewer or a point of acceptable termination such as a sanitary waste system (248 CMR 2.03). Likewise, Title 5 defines the "building sewer" as "the pipe which begins 10 feet outside the inner face of the building wall and extends to a public sewer, septic tank, or other place of sewage disposal." The Plumbing Code has jurisdiction over waste collection within all buildings and conveyance to a point located 10 feet from the structure, whereas Title 5 jurisdiction is limited to facilities utilizing subsurface disposal of sanitary sewage and begins at this terminal point and extends to the subsurface discharge structure.

The Plumbing Code requires interceptors to prevent the discharge of oil, gas, grease, sand and other substances into the building drainage system, the public sewer, or sewage treatment system. Oil and gas separators are to be installed on commercial garages, gas stations, and factories where oil is being used (248 CMR 2.09(2)). Sand filters and special filters may be used for laundries and bottling plants (248 CMR 2.09(3)).

Both the Plumbing Code and Title 5 call for the installation of grease traps at facilities that are expected to produce large volumes of grease such as restaurants. The regulations are similar in intent, but differ in the following:

Title 5 regulations specify that "Grease traps shall have a minimum depth of 4 feet and a minimum capacity of 1,000 gallons, and shall have sufficient capacity to provide at least a 24 hour detention period for the kitchen flow (310 CMR 15.05(3)). The Plumbing Code requires a minimum "grease retention capacity not less than 2 pounds for each gallon per minute of flow" (248 CMR 2.09(2)(c)).

Title 5 sets out a number of construction requirements, such as the materials that can be used and the elements that may be included in the design of a trap (310 CMR 15.05 (4)-(9)). The Plumbing Code does not address these issues.

The Plumbing Code requires that grease traps include flow control devices (248 CMR 2.09(2)(d)) that are not addressed in Title 5.

The Plumbing Code sets forth a number of prohibitions with regard to grease traps (i.e. no food grinder waste can be disposed of in this system, 248 CMR 2.09(2)(e)). In addition, the Plumbing Code forbids the use of water cooled interceptors (248 CMR 2.09(2)(f)). Title 5 does not address these issues.

The Plumbing Code allows sumps and pumping equipment to be used where the building drains cannot be discharged by gravity (248 CMR 2.15(10)). Title 5 prohibits pumping of sewage prior to a septic tank unless approved in writing by the Department of Environmental Protection (310 CMR 15.06(18)).

Two options exist to strengthen the compatibility and interrelationship between Title 5 and the Plumbing Code. First, the Department of Environmental Protection and the Board of State Examiners of Plumbers could amend their respective codes by adopting complementary text. Alternately, Department of Environmental Protection could unilaterally incorporate by reference relevant sections of the Plumbing Code.

It should be noted that at the time of this writing several proposed changes to the Plumbing Code are under consideration by the Board of State Examiners of Plumbers and Gas Fitters. These proposed modifications include additional requirements for the following: Separators and Holding Tanks (248 CMR 2.09(1)(c)); Hazardous Waste Floor Drains (248 CMR 10(11)(a)(4)); and, Hazardous Waste Treatment and Disposal Facilities (248 CMR 2.13(1)(h)). Although these changes will improve compatibility between the Plumbing Code and Department of Environmental Protection Regulations, they do not completely address the discrepancies outlined above.

Uniform State Building Code, 780 CMR

Title 5 states that "no building permit, foundation permit, special building permit or plumbing permit shall be issued until a Sewer Entrance Permit or Disposal Works Construction Permit has been obtained, unless the board of health determines that the existing sewage disposal system is adequate for the proposed alteration or addition to an existing dwelling" (310 CMR 15.02(7)).

The Building Code provides that building inspectors shall issue a permit if they are satisfied that the proposed work conforms to all of the Building Code requirements and all pertinent laws thereto (780 CMR 114.1), but does not specifically name Title 5. The project applicant is, however, required to include in the application a plan showing the "method and amount of ventilation and sanitation" (780 CMR 113.5). There are a number of specialized codes which are adopted by reference in the Building Code (780 CMR 100.5), but Title 5 is conspicuously absent from this listing. It can be reasonably argued that Title 5 is an essential regulation which governs the construction of certain buildings and therefore is deserving of the additional recognition given by the specialized code designation.

Ground Water Discharge Permit Program, 314 CMR 5.00

Under the Massachusetts Ground Water Discharge Permit Regulations, no person is allowed to discharge pollutants to the ground waters of the Commonwealth without a valid permit issued by the Department. In addition, no person is allowed to engage in any other activity that may reasonably be expected to result, directly or indirectly, in the discharge of pollutants into ground waters of the Commonwealth without a valid permit. Activities which constitute discharges of pollutants requiring a permit are numerous but can generally be considered to include any facility which discharges a liquid effluent onto or below the land surface. Certain activities are exempt from this regulation. One such exemption is the discharge of sanitary sewage up to 15,000 gallons per day through an on-site subsurface sewage disposal system in accordance with the requirements of Title 5.

The applicability of various provisions of Title 5 to sewage treatment facilities that are approved by the Department pursuant to the Ground Water Discharge Permit Program (314 CMR 5.00), and Massachusetts General Laws (M.G.L.) Chapter 111, Section 17, has been raised as an issue in a number of specific cases. There appears to be a disparity in opinions concerning the appropriate interpretation of Title 5 of the State Environmental Code even among Department employees. Specifically, the following questions need to be resolved:

(1) Must recipients of Ground Water Discharge Permits and M.G.L. c.111 s.17 plan approvals return to the Board of Health to obtain a disposal works construction permit, pursuant to 310 CMR 15.02(1)?

(2) If so, is a variance from the provisions of 310 CMR 15.02(18), required in issuing such permits where the system is to serve more than one lot?

One of the questions about jurisdiction of Title 5 over sewage treatment plants approved under M.G.L. c. 111, arises from the statement in the preamble to Title 5 that asserts that "Title 5 has been promulgated to provide minimum standards for the protection of the public health and the environment when circumstances require the use of individual systems for the disposal of sanitary sewage in areas where municipal sewage systems are not accessible." One could argue, therefore, that Title 5 was intended to set standards for individual (on-lot) subsurface sewage disposal systems in areas not served by municipal sewage systems, and that sewage treatment plants approved by the Department under M.G.L. c.111 s.17, with a Ground Water Discharge Permit issued by the Department pursuant to 314 CMR 5.00 are not meant to be subject to Title 5.

Under the preamble language of Title 5 cited above, sewage treatment facilities are neither "individual sewage disposal systems", as defined in the Code, nor are they municipal sewage systems. On the other hand, the Ground Water Discharge Permit Program (314 CMR 5.00) appears to be compatible in that it states in pertinent part in 314 CMR 5.03 -

> "No person shall discharge pollutants to ground waters of the Commonwealth without a currently valid permit from the Director pursuant to M.G.L. c.21 s.43 and this chapter, unless exempt in 314 CMR 5.05. No person shall construct, install, modify, operate or maintain an outlet for such a discharge or any treatment works required to treat such discharge without having first obtained a discharge permit in accordance with this subsection and written approval from the Department."

Under this program, protection of the public health and environment is satisfied by the Department's review and approval in accordance with M.G.L. c.111 s. 17 and the issuance of a Ground Water Discharge Permit.

Sewage treatment facilities that involve discharge of treated effluent to surface waters as opposed to the subsurface are clearly not subject to the provisions of Title 5. These discharges are instead regulated under the Department's Surface Water Discharge Program (314 CMR 3.00). Some feel the Department likewise did not intend, in adopting Title 5, to impose a second level of technical review by boards of health for projects involving sewage treatment facilities with ground discharges, particularly since many of the sewage treatment facilities include effluent discharge to surface infiltration beds rather than subsurface structures.

It has been argued that since Ground Water Discharge Permit Program includes input by boards of health and a formal public comment period, during which time a board of health may have its comments and concerns addressed, there is no need for a second technical review by the local board of health. Title 5 has also been interpreted to explicitly require both that the board of health permit be obtained, and that chronologically the approval of the Department must precede the board of health permit. 310 CMR 15.02 provides -

> "No individual sewage disposal system or other means of sewage disposal shall be located, constructed, altered, repaired, or installed ... until a permit for its location, construction, alteration, repair or installation shall have been issued by the board of health. A permit shall not be issued for any system of individual sewage disposal when the total volume of sewage to be disposed of on any lot is in excess of 15,000 gallons per day, or where sewage treatment facilities are proposed on the lot to be served, until the plans for such system have been approved by the Massachusetts Department of Environmental [Protection] in accordance with G.L. c.111 s.17."

The expressed reference to sewage treatment facilities approved by the Department, and the inclusion of "other means of sewage disposal" in the first sentence, undermines the argument that treatment plants approved by the Department are not also subject to regulation under Title 5. Moreover, the definition of "individual sewage disposal system" may be construed to at least include a subsurface leaching structure used to discharge the effluent from a sewage treatment facility into the ground. An "individual sewage disposal system" is defined as a subsurface sewage disposal system owned and operated by a person; a "person" includes every individual, partnership, corporation, firm, association, or group, including the Commonwealth and its subdivisions. Further confusing the matter, 310 CMR 15.02(14) provides that, in general, individual sewage disposal systems shall consist of a septic tank discharging its effluent to a suitable disposal area.

If one accepts the argument that 310 CMR 15.02(18) requires a disposal works construction permit be obtained from the local board of health for a sewage treatment plant when the effluent is discharge to the subsurface, there is no tenable basis to suggest that the standards set forth in 310 CMR 15.02(18), which state: "the use of a subsurface sewage disposal system by more than one lot is prohibited", do not apply where a sewage treatment facility is designed to service multiple lots.

Title 5 provides two subject matter exclusions; neither discharges to surface water nor systems for the treatment and disposal of industrial wastes are regulated under Title 5. Since surface discharges and industrial waste treatment are at least as important as subsurface discharges of treated sewage, one must question whether Title 5 was in fact intended to regulate sewage treatment facilities as well as conventional septic systems from a resource utilization standpoint alone. It certainly does not make sense to have the Department commit its resources to a more detailed legal and technical review to ensure that the project provides proper protection of public health and the environment only to have the project denied by a local agency. A preferable approach would be for the local agency to work together with the Department of Environmental Protection in a review process, such as that under the Ground Water Discharge Permit Program. This would avoid a duplication of effort and would assure that neither agency wastes its time on a project that ultimately may be denied by the other.

There is no statutory requirement that compels the Department to require applicants seeking to construct sewage treatment plants which discharge into the ground to secure a disposal works construction permit from the board of health following the Department's approval of the plant pursuant to M.G.L. c. 111 s. 17. Title 5 could be amended to specifically include wastewater treatment facilities used to treat sewage and/or industrial waste, whether the effluent is discharged to the ground or to surface waters. However, it would seem more appropriate to remove the requirement for a Disposal Works Construction Permit and use the Ground Water Discharge Permit Regulations as the exclusive procedure for the review and approval of projects involving sewage treatment facilities.

Ground Water Quality Standards, 314 CMR 6.00

The Ground Water Quality Standards are to be a guide for the regulation of discharges of pollutants to ground water. The Massachusetts Ground Water Quality Standards consist of ground water classifications which designate and assign the uses for which the various ground waters of the Commonwealth shall be maintained and protected, water quality criteria necessary to sustain the designated uses, and regulations necessary to achieve the designated uses or maintain the existing ground water quality.

These regulations establish three classes of ground water based upon the most sensitive designated use. Class I waters are fresh ground waters which serve or could potentially serve as a drinking water source. Class II waters are saline ground waters which could be converted to fresh water for use as a drinking water or could be used for their mineral content. Class III waters are ground waters which are designated for uses other than drinking water purposes on a case-by-case basis.

The regulations include both numerical and narrative requirements. Numerical standards are quantitative parameters (maximum contaminant levels) assigned to specific substances, while narrative standards are descriptive parameters that are applied to the particular class of ground water. The vast majority of ground waters in the Commonwealth have been designated as Class I. The minimum quality criteria for Class I ground waters include the National Interim Primary and Secondary

Drinking Water Standards promulgated under the Federal Safe Drinking Water Act, federal Maximum Contaminant Levels and Health Advisories adopted by either the U.S. Environmental Protection Agency or the Department of Environmental Protection.

While the standards should be used to regulate discharges of pollutants to ground water, this has not necessarily been the case for individual systems for the subsurface discharges of sanitary sewage. 314 CMR 6.07(2) states in part -

> "Establishment of Discharge Limits. In regulating discharges of pollutants to ground waters of the Commonwealth, the Division shall limit or prohibit such discharges to insure that the quality standards of the receiving waters will be maintained or attained."

There is no mechanism whereby the impact on water quality is considered in the siting of individual systems used for the subsurface disposal of sanitary sewage.

It is now recognized that conventional septic tank/soil absorption systems are not effective in their treatment of certain sewage constituents (most notedly nitrogen containing compounds). Class I ground water standards may be exceeded in areas where septic tank/soil absorption systems are used for sanitary sewage disposal. In areas where septic system use is high, it is not unusual to find exceedances of the Class I ground water standard for nitrate-nitrogen of 10 mg/L.

This inconsistency needs to be addressed if the Department is to successfully control and abate discharges of pollutants so as to maintain and protect the most sensitive use of ground waters and hydraulically connected surface waters. To be effective, the program needs to address all discharges including those from individual subsurface sewage disposal systems. Given that the treatment capabilities of the conventional septic system are limited, controls on the density of these contaminant sources may be necessary to protect and maintain the desired quality of ground and surface waters.

Drinking Water Regulations, 310 CMR 22.00

The Drinking Water Regulations establish procedures and criteria for the Department of Environmental Protection's approval of public water supply wells and wellfields. These regulations require that certain wellhead protection mechanisms be implemented prior to bringing a new well or wellfield on line in a public water system and prior to expanding or replacing an existing well or well field.

Under these regulations, public water suppliers are required to implement certain zoning and non-zoning controls designed to protect the ground water from contamination before the Department will approve a new water supply source or the expansion of an existing source. Wellhead protection zoning and non-zoning controls are mandated in 310 CMR 22.21(2) which states in part -

"Wellhead protection zoning and nonzoning controls submitted to the Department in accordance with 310 CMR 22.21(1), shall collectively prohibit the siting of the following land uses within the Zone II or Zone III of the proposed well or wellfield, whichever is applicable.

5. individual sewage disposal systems that are designed in accordance with 310 CMR 15.00 to receive more than 110 gallons of sewage per quarter acre under one ownership per day, or 440 gallons of sewage on any one acre under one ownership per day, which ever is greater, except the replacement or repair of an existing system that will not result in an increase in design capacity above the original design;

6. treatment works that are subject to 314 CMR 5.00, except the following:

   a. the replacement or repair of an existing system(s) that will not result in a design capacity greater than the design capacity of the existing systems(s);

   b. the replacement of an existing subsurface sewage disposal system(s) with wastewater treatment works that will not result in a design capacity greater than the design capacity of the existing system(s);

   c. treatment works approved by the Department designed for the treatment of contaminated ground or surface waters; and

   d. if the Department amends 314 CMR 5.00 on the basis of the Final Generic Environmental Impact Report (FGEIR) on Privately Owned Sewage Treatment Facilities (PSTFs), privately owned sewage treatment facilities permitted in accordance with 314 CMR 5.00, as amended."

These regulations represent the Department's first attempt to control the number of individual sewage disposal systems within a sensitive environmental resource area. Although this is a commendable first effort at reducing the incidence of contamination from on-site systems of sewage disposal, it represents a piecemeal approach to a much larger problem.

Further, the Department appears to be taking a step backward by denying the use of sewage treatment facilities in Zone II and Zone III areas in favor of continuing to use septic systems. Sewage treatment facilities offer a higher degree of protection to public health, and environmentally sensitive areas such as water supplies. These facilities provide advanced levels of treatment and can be more closely monitored. Thus the Department of Environmental Protection should be encouraging sewage treatment facilities.

These regulations also fail to recognize the significance of existing sewage disposal systems within zones II and III. No attempt is made to require areawide management plans aimed at controlling unacceptable levels of contaminant releases from pre-existing sources. The Department must not only limit new sources of potential contamination, but must insist that existing sources be evaluated and remedial actions taken where it is deemed necessary.

These particular Drinking Water Regulations only apply to community public water suppliers seeking the Department's approval of a new source or an expansion of an existing source. There is no requirement for the imposition of similar controls on existing public water supplies, nor do these restrictions apply to any other resource areas such as areas dependent on private wells. Additionally, these new public water supply restrictions have not been coordinated with the Department of Environmental Protection's programs such as Title 5.

For example, the only explicit protection afforded public and private water supplies by Title 5 is the minimum setback distances. Title 5 stipulates distances of 50 feet and 100 feet for septic tanks and leaching facilities from water supplies be they wells or surface water. These minimum setback distances are the only protection afforded public and private water supplies by the code. Additional restrictions, including a limit on the density of sewage disposal systems within areas of critical environmental concern such as public water supplies, need to be given serious consideration.

An integrated program designed to limit the quantity of sewage discharged in sensitive resource areas has yet to be developed. Such a program is a prerequisite to an effective resource protection program. The Department must review all of its environmental regulations, including Title 5, to assure that they are appropriately focused on protecting sensitive resource areas such as public ground water supplies.

<u>Wetland Protection Regulations, 310 CMR 11.00</u>

The Wetland Protection Regulations apply to projects involving the filling, dredging, removal or altering of any bank, freshwater wetland, coastal wetland, beach, dune, flat, marsh, meadow, swamp, land under water bodies, land subject to tidal action, land subject to coastal storms flowage and land subject to flooding. The program protects public interest by regulating projects to prevent damage to public and private water supplies, ground water supplies, fisheries, land containing shellfish and wildlife habitat areas and to prevent increases in flooding, storm damage and pollution (M.G.L. c. 131, s. 40).

A subsurface sewage disposal system that is to be constructed in compliance with the requirements of Title 5 is presumed to protect the interests identified in the Massachusetts Wetland Protection Act, but only if none of the components of the sewage disposal system is located within the following resource areas:

(a) Coastal

1. coastal bank
2. coastal beach
3. coastal dune
4. coastal marsh

(b) Inland

1.	wet meadow		creek
2.	marsh	bordering	river
3.	swamp	on any	stream
4.	bog		pond
			lake

and only if the leaching facility of the system is set back at least 50 feet horizontally from the boundary of said area, as required by Title 5 (310 CMR 15.03(7)).

This presumption concerning Title 5 provides an excellent cross reference allowing uniform application of the two regulations. However, there are still discrepancies between the Wetland Protection Regulations and Title 5. Probably the most significant area of concern involves the measuring point for determining setback distances of Title 5 leaching facilities from the resource area. The problem arise from the stipulation in Title 5 that all distances shall be measured from the average of the mean annual flood elevation in inland areas and from the mean high water in coastal areas. Confusion also results from differences in terminology in the Wetland Regulations and Title 5. The Wetland Regulations define the boundary of bordering vegetative wetlands, one of the resource areas, not merely on the high water elevation, also in terms of vegetation.

These inconsistencies can be remedied in one of two ways. First, the definition of "watercourse" in Title 5 could be amended to be the same as the definition found in the wetlands regulations (which is also the same as the Chapter 91 regulations, drinking water regulations, etc.). Secondly, the natural resource specific setbacks could be deleted from Title 5 and replaced by language which requires the project proponent to identify whether the Title 5 system is in a wetland resource area. If it is, the appropriate setbacks could be determined within the wetland regulations governing the protection of that resource with references to the appropriate regulations included in Title 5. Ideally, to be effective, the Title 5 and Wetland reviews should be concurrent.

MEPA Regulations, 301 CMR 11.00

The Massachusetts Environmental Policy Act (M.G.L. c.30, ss.61-62H) requires that all Commonwealth agencies take all feasible means to minimize damage to the environment when they take action. The mechanism by which information is gathered to allow the agencies to meet this charge is through a review process set forth in regulations administered by the MEPA Unit of the Executive Office of Environmental Affairs. The MEPA regulations are codified as 301 CMR 11.00.

Although boards of health in issuing disposal works construction permits are acting on behalf of a state agency, the Department of Environmental Protection, individual sewage disposal systems are not typically reviewed under the MEPA process. The Title 5 permit is considered a local permit, and not a state action triggering a MEPA review. Additionally, the MEPA regulations do not include specific thresholds for Title 5 systems. If a Title 5 system were to be reviewed by MEPA, it would likely be considered through the review of another more significant aspect of a project triggering a MEPA review threshold, or by invocation of the "Fail-Safe" Provision (310 CMR 11.03(6)).

The absence of MEPA review over individual subsurface sewage disposal systems is understandable given the administrative burden such a review would impose. However, since the State is now experiencing some threats to water quality and public health, more attention must be directed to the cumulative impacts of subsurface sewage disposal systems. On-site subsurface sewage disposal systems represent discrete contaminant sources. The potential risk of ground water or surface water contamination from an individual system that is properly designed, constructed and maintained is not very significant. However, in areas where there is a high density of on-site sewage disposal system usage, these discrete sources may collectively have an adverse impact on the public health and the environment.

The MEPA process has the potential to provide an appropriate forum for a complete environmental review of projects that include the use of septic systems in areas that have been identified as containing critical environment resources. The potential for adverse impacts on the area's ground water and surface water quality could be reviewed and evaluated to determine the overall impacts on the natural environment posed by the individual sewage discharges within the area.

22.1.4 Overall Compatibility with Other Regulations and Policies

The Title 5 regulations, with the exception of the sections in the regulations that address septage disposal, do not address the issue of chemical wastes which may be illegally disposed of in septic systems. The Hazardous Waste Regulations encourage households to dispose of household hazardous waste safely, rather than disposing of these wastes by flushing them down the toilet. The Title 5 regulations could be strengthened by references to these regulations, and by adding a requirement for household hazardous waste education (at a minimum) and alternative disposal options to be included in the Title 5 permit. Also, the regulations should include a prohibition on the use of septic tank cleaners and additives. These products have been demonstrated to be primarily ineffective and, in most cases, harmful to the septic system or the environment.

The Private Sewage Treatment Facility policies and permitting requirements recommend that any facility proposed to service more than one owner be accompanied by an agreement identifying responsible parties and also providing adequate financial security for long term maintenance and repair. Instituting similar requirements for Title 5 systems, particularly the larger systems, may enable improved long term maintenance and timely replacement.

22.2 Conclusions and Recommendations

There is a lack of integration between Title 5 and the building construction, natural resource protection and waste handling regulations. In general, Title 5 does not reference other regulations which may affect the design, siting and construction of Title 5 systems, nor do these other regulations address the handling of the wastes that go into and are pumped out of septic systems.

The public interest would be better served by a carefully constructed and implemented integration of the Building Code, Plumbing Code and Title 5. Such integration could begin with a statement of clarification in each set of regulations detailing the interactions between the three codes and providing appropriate cross-references.

Consistency with the natural resource protection regulations could occur with a statement in Title 5 regarding how Title 5 works in concert with the natural resource protection regulations. In turn, the natural resource protection regulations should identify areas which are inappropriate for siting Title 5 systems and should also provide minimum setback standards designed to protect natural resource areas.

Additional remedies for current inconsistencies include:

- Changes to both Title 5 and to the Building and Plumbing Codes should be made to ensure that design standards are consistent. A single section in Title 5 can be created to provide detailed design standards affecting the other construction codes. The Department of Environmental Protection should seek to have that section either adopted in whole or incorporated through reference in the Plumbing and Building Codes. Title 5 appears to be the appropriate location for these revised requirements, as it is the set of regulations most directly responsible for the design and use of septic facilities.

- To rectify the sequencing problem, the Building and Plumbing Codes should be amended to include a provision that prohibits the granting of a building or occupancy permit until the issuance of the Title 5 permit. In addition, the Department of Environmental Protection, the State Board of Building Regulations and Standards and the State Board of Examiners of Plumbers and Gas Fitters should try mediation as a way of resolving the fundamental issues of jurisdiction which currently exist between these organizations. The Governor has statutory authority to require agencies to reconcile differences. This authority should be invoked to resolve any outstanding jurisdictional issues between the Department of Environmental Protection, the State Board of Building Regulations and Standards, and the State Board of Examiners of Plumbers and Gas Fitters.

- The Secretary of the Executive Office of Environmental Affairs should order agencies within the secretariat to reconcile differences in setback distances. Further, the proponent should be required to demonstrate whether the project is in an environmentally sensitive area. Specific criteria for this demonstration should be adopted by the Department of Environmental Protection. The Title 5 regulations should refer the project proponent of projects within sensitive areas to the sections in the environmental protection regulations that deal with setbacks in specific environmental resource areas. If the project is not in such an area, then a standard setback described in the Title 5 regulations should be used. This proposal allows Title 5 to remain consistent over time with other regulations. Consideration should be given toward amending the MEPA regulations to allow an overall environmental review of the cumulative impacts of projects involving subsurface sewage disposal systems in areas of critical environmental concern.

- The Department of Environmental Protection should remedy the lack of Title 5 integration with other regulations by referencing the existence and the requirements of the other regulations in the Title 5 regulations and disposal works construction permit. For example, it would be very useful to add a section in Title 5 which clearly states that Title 5 systems are subject to the hazardous waste regulations. In addition, one of the conditions on the Title 5 permit should be compliance with hazardous waste laws. Boards of health should be encouraged to enforce these laws. This enforcement would necessitate aggressive household hazardous waste collection programs in areas with Title 5 systems.

- The Department of Environmental Protection should work with other state environmental agencies, possibly through the Water Resources Commission, to assure that Title 5 is consistent with the Commonwealth's overall environmental protection strategies. In addition to specifying design standards for individual systems, Title 5 needs to address the Commonwealth's Water Resource Protection Goals. The State's Ground Water Quality Standards and Surface Water Quality Standards should be used to guide the decision making process for the areawide use of individual sewage disposal systems just as these regulations are used for determining the appropriateness of treatment and disposal systems for commercial or industrial wastewaters and large systems for the discharge of sanitary sewage.

- The Department of Environmental Protection should review the appropriateness of prohibiting sewage treatment facilities within the Zone II and Zone III of public water supplies as required by 310 CMR 22.21(2) It would appear that this requirement is in direct opposition to the interest of the Department's Ground Water Discharge Permit Program Regulations, 314 CMR 5.00. These regulations establish discharge limits for the protection of ground water which dictate the use of sewage treatment facilities. Perhaps clarification of the Department's intention in 310 CMR 22.21(2) will resolve the apparent contradiction.

- The Department of Environmental Protection should separate the issue of approval of sewage treatment facilities from Title 5. A single regulatory system should apply to such decisions. Sewage treatment facilities should be regulated under the Ground Water Discharge Permit Program Regulations, 314 CMR 5.00 and not Title 5. Appropriate references should be added to Title 5 to exempt projects involving sewage treatment facilities which are permitted under 314 CMR 5.00.

Inter-agency disputes are a threat to public health. The above recommendations will help reduce the regulatory conflicts between Title 5 and other regulations, but they will not prevent all disputes. When regulatory disagreements arise concerning Title 5, it is recommended that the Department of Environmental Protection and the other agencies attempt to resolve the dispute and if they cannot, that they seek alternative dispute resolution such as mediation or that the issues be resolved through appropriate legislation.

CHAPTER 23

REVIEW THRESHOLDS

Regulations must establish a means by which jurisdiction and the level of regulatory authority can be clearly established, particularly in instances where the program is administrated by more than one agency. In Massachusetts, the responsibility for regulating the use of individual systems for the disposal of sanitary sewage has been delegated to local boards of health, with the Department of Environmental Protection reserving the right to review and participate in the approval process for larger more complicated projects. The Department has established certain thresholds for the purpose of determining which projects require these more detailed technical reviews.

Boards of health have sole responsibility for the review and evaluation of the sewage disposal system when the total volume of sewage to be disposed of on the lot is 15,000 gallons per day or less. Additional review by the Department of Environmental Protection is required when the design flow exceeds this threshold, when a variance to the minimum requirements specified in Title 5 is required, or when an innovative or alternative system is proposed.

The Department's review of projects involving on-site discharge of more than 15,000 gallons per day was intended to promote the use of sewage treatment plants to ensure that the highest practical level of treatment was provided for projects with larger wastewater flows. At the time Title 5 was enacted, 15,000 gallon per day was believed to represent the minimum flow at which on-site treatment plants were both operationally and economically viable. As science and technology have progressed, these advanced treatment systems have proven to be effective at installations with much smaller flow rates.

The 15,000 gallon per day review threshold has in many instances been inappropriate. It encourages project proponents to subdivide large lots into smaller parcels in an effort to avoid regulatory review by the Department. It also has failed to address the need for a more detailed assessments of larger systems in the 2,000 to 15,000 gallons per day range. Use of a single large system may have distinct advantages over use of a number of smaller individual units. There are, however, a number of inherent concerns associated with larger systems which are not now addressed.

Large septic systems have been regulated under Title 5 by a simple extrapolation of the criteria used for smaller, single family septic systems. This has resulted in a significant number of large system failures and other related problems. There are at least four specific areas of concern relative to the use of large septic systems. These are:

(1) the ability of soils to treat and disperse large volumes of waste over a long time period;

(2) the possibility that the soils will not be able to handle the increased hydraulic load because of the creation of a ground water mound under the soil absorption area;

(3) the ability to maintain aerobic conditions in the unsaturated zone beneath the absorption system given the aerial extent of the biomat clogging layer; and,

(4) non-uniform application.

These issues must be addressed through the development of new site evaluation requirements and special design criteria for larger systems. Along with these technical changes, new regulatory strategies need to be considered. The need for a thorough technical review of these larger systems must be accompanied by stricter regulation and monitoring throughout the permitting process.

Since the inception of Title 5, there have been numerous jurisdictional disputes related to the threshold language. This, in combination with the fact that sewage treatment facilities may be capable of effective treatment of smaller flows, and the fact that more detailed technical review should be undertaken on the larger septic systems, would suggest that an alternative review threshold or thresholds may be warranted. This chapter of the report will evaluate the need for revised thresholds to determine the different technical standards needed to govern the siting, design, operation and maintenance of large systems and to establish the level of state and local involvement in the review process.

23.1 Literature Review

Sewage Treatment and Large Systems

The current threshold beyond which subsurface disposal systems are subject to review by the Department of Environmental Protection is an average flow of 15,000 gallons per day (gpd) on any lot. Discharge in excess of this amount "may require additional treatment of the waste prior to its disposal to the ground" (310 CMR 15.02(1)).

When development occurs in rural areas, or is scattered on very large lots, a sufficiently low risk of significant contaminant of ground water resources may justify an even higher threshold standard. In areas of intense land use, however, the public health and environmental risks associated with subsurface sewage disposal increase significantly. For example, there is a much greater potential for contaminants emanating from a subsurface sewage disposal system to impact a water supply. Also, the cumulative impacts of individual sewage discharges may raise the concentration of contaminants in the ground water to dangerously high levels.

In order to protect environmental resources from excessive concentrations of persistent pollutants, additional treatment requirements must be imposed or land use controls adopted. Sewage treatment facilities sited, designed, constructed, operated, and maintained in accordance with the Department of Environmental Protection's Ground Water Discharge Permit Program have been demonstrated to provide a higher level of treatment and greater degree of environmental protection than do sewage disposal systems permitted in accordance with Title 5 (ICF, 1990). In fact, the Generic Environmental Impact Report on Privately Owned Sewage Treatment Facilities indicates septic tank/soil absorption system discharges with volumes less than 15,000 gallons per day can degrade water quality and impair environmental resources. Sewage treatment technology has improved significantly since the 15,000 gpd standard was set so that smaller sewage treatment facilities are now not only operationally and economically feasible, but under certain circumstances may be desirable for sewage flows as low as 2,000 gallons per day (ICF, 1990).

An alternative to the construction of on-site sewage treatment facilities is the installation of a large sewage disposal system serving multiple lots within a single development. Large community septic tank/soil absorption systems can provide significantly lower design, construction, and operation and maintenance costs (Magner, J.A., 1984), with minimum expenditures conceivably approaching a quarter of those associated with centralized collection and treatment alternatives (Deese, P.L. and John, S.F., 1986). Of course, any relative cost comparison will need to be site specific, based upon the various features of a project including the specific soil and ground water conditions, the design flow, operating conditions and the location and availability of municipal treatment alternatives.

Technical Issues Concerning the Use of Large Systems

Historically, the U.S. Environmental Protection Agency and individual states have promulgated sewage disposal regulations based upon reports, tests and studies performed on small, individual on-site septic systems. Information and conclusions drawn from these small scale studies have been extrapolated far beyond the extent intended by the original investigations to design systems capable of incorporating the flows generated by larger cluster, community or commercial developments (Tyler, E. and Converse, J., 1984). Promulgation of the regulations included little, or no, consideration of the additional problems associated with the disposal of the large quantities of septic tank effluent generated by large or multi-user soil absorption systems.

Reports have recommended that any system which is designed to discharge greater than 1,200 gallons per day, and/or serve three or more dwellings, be classified as a large system. These classification criteria were based on the additional induced hydraulic load and the increased potential for contaminant transport to domestic water wells (Magner, J.A., 1984). For this chapter of the report a large system will signify any system, not to exceed 15,000 gpd, which is designed for flows exceeding 2,000 gpd[1] and/or intended to serve any site other than a single family domestic dwelling.

As rural areas undergo increased development, it is becoming more difficult to find soils suitable for the repair of individual on-site septic tank/soil absorption systems. For existing developments, the use of community sewage disposal systems with separate septic tanks discharging to a common soil absorption area may prove to be an advantageous alternative to the continued reliance upon individual subsurface disposal systems. Use of this type of disposal practice may enable the soil absorption system to be effectively isolated from domestic wells and environmentally sensitive areas[2], while promoting system installation in soils capable of providing the optimum prospect for success (Nettles, D.L. and Ward, R.C., 1884).

It has been proven that large systems are relatively inexpensive, easily operated and maintained, and, if controlled by a homeowners' group with operation overseen by a responsible party, may provide a degree of monitoring and protection not afforded by the relatively unregulated, and often neglected, single-user on-site systems (Steinbeck, S.J., 1984). Such a disposal alternative results in one easily monitored soil absorption system instead of many individual systems. Failures are more readily recognized, allowing corrections to be completed on a more timely basis. Septic tanks could be more closely monitored, ensuring that pumping occurs on a regular basis, thereby reducing the percentage of failures attributed to system neglect and solids overloading (Nettles, D.L. and Ward, R.C., 1984; Steinbeck, S.J., 1984).

A failing system sometimes results in the installation of a sub-standard repair system or in extreme cases the installation of a tight tank. This need not happen with a large system. Contingency plans can be formulated for the large system with provisions included in a homeowners agreement, or a purchase and sales agreement, stating that in the event that the large common system fails to perform properly, the repair alternatives are limited to the construction of a wastewater treatment facility, connection to a municipal sewage treatment system, or construction of individual septic systems for

1 The 2,000 gpd threshold was selected because of the long history of its use in Massachusetts. Article XI required state review of projects in excess of this flow rate. Additionally, 2,000 gpd is the established limit for systems designed by Registered Sanitarians.

2 The term "environmentally sensitive areas" is used throughout this document to indicate valuable resource areas deserving an added degree of environmental protection. The term is purposely used in a broad sense and is intended to include resource areas such as zones of contribution to water supplies, Areas of Critical Environmental Concern, certain marine embayments and fresh water bodies. The exact definition is expected to be determined by the Department of Environmental Protection depending on the types of controls it intends to adopt.

each of the buildings. A comprehensive management program, including the formation of a private maintenance authority, responsible for performance monitoring and evaluation, along with the establishment of a capital reserve fund may ensure that routine maintenance and repairs are expeditiously performed (Hantzsche, N.N. and Fishman, N.J., 1982).

It is important to note that if this method of sewage disposal is allowed for new construction it may promote development of areas previously regarded as undevelopable, or moderately profitable, due to restrictive soil conditions encompassing a portion of the site. While this will be advantageous for the developers, it may also short-circuit the local growth control processes which have often utilized limiting soil conditions as a substitute for adequate zoning control.

Large subsurface disposal systems, if properly designed, sited, operated and maintained, may provide contaminant segregation and abatement properties exceeding individual on-site disposal expectations. Large systems release effluent into one localized plume. This enables more effective isolation of sensitive receptors from the potential for adverse impacts. Management and control of operation is facilitated by the use of a single large system. This encourages the utilization of increased monitoring activities not typically performed on individual systems, thereby enabling more effective evaluation of system performance and contaminant removal efficiencies.

On the other hand, analysis of septic systems has revealed a trend towards poor performance with higher design and operating flows (Plews, G.D. and DeWalle, F.B., 1985). This increase in poor performance, while requiring additional study in order to be adequately quantified, may be caused by a variety of reasons (Deese, P.L. and John, S.F., 1986; Plews, G.D. and DeWalle, F.B., 1985). A primary cause of the elevated failure rate of large systems appears to be inadequacy of the current site investigation procedures originally developed for single user on-site domestic systems (Tyler, E. and Converse, J., 1984).

A typical subsurface investigation involves the excavation of two deep hole observation test pits in the vicinity of the proposed soil absorption system. One or two percolation tests are then conducted in the "most restrictive layer". The results of this limited investigation are then utilized for the design of the system. While this level of investigation may be adequate for small individual systems located in suitable homogenous soils, it does not provide an adequate assessment of the conditions required for large system designs. Variable site conditions, less than optimum soil characteristics and detrimental ground water and hydrogeologic properties may substantially impact larger systems. These systems may extend over many vastly different geologic soil formations and include anisotropic conditions, limiting layers and hydraulic boundaries significantly impacting the vertical and horizontal acceptance rates of the site (Tyler, E. and Converse, J., 1984).

The location and extent of all limiting site conditions need to be adequately assessed in order to design a large system that operates effectively. Variable conditions across the disposal site, which now encompasses a much larger infiltrative area, requires the performance of an intensified investigation process (Magner, J.A., 1984). This site suitability study should be conducted by an investigatory team of professionals, and should include, at a minimum, a complete analysis of the soils, the hydrogeology, and the topography along with an assessment of the potential impacts to sensitive receptors and surrounding uses (Magner, J.A., 1984).

A complete analysis of the soils to a depth at least six feet (1.8 meters) below the bottom of the proposed infiltrative surface should be completed (Siegrist, R.L. et al., 1984). This investigation should include a determination of the clay content, soil texture, soil morphology, and pollutant attenuation capabilities, along with an assessment of the location, depth and extent of all limiting layers, discontinuities and anomalies underlying the site.

The hydrogeologic investigation would be required to determine the existing conditions and to assess the hydraulic and contaminant dispersal properties of the site. In addition to the soil properties, surface drainage characteristics and flow patterns, this study should include a determination of the hydraulic flow patterns and gradient; the location of all boundary conditions; the chemical composition of the effluent and natural ground water; the saturated and unsaturated horizontal and vertical hydraulic conductivities; the extent of seasonal ground water fluctuations; and the location, depth and thickness of phreatic, perched and confined ground waters (Magner, J.A., 1984). This information can then be incorporated into a tested, approved and verified ground water model to estimate the orientation and extent of the resultant ground water mound and point source contaminant discharge plume and/or to assess the potential impacts to sensitive receptors, particularly drinking water supply wells.

Conventional systems have typically been required to have four feet of permeable soil situated between the bottom of the leaching system and the maximum ground water elevation. For small single family on-site soil absorption systems, the provision of four feet of unsaturated soils above the maximum ground water level, (determined by historical data, sound scientific principles and observed soil conditions) should provide adequate treatment of the effluent. Larger systems, however, require additional study of the available unsaturated treatment zone. A significant ground water mound may develop beneath a large soil absorption system, reducing the availability of unsaturated soils and radically altering the natural ground water flow patterns and velocity (Magner, J.A. et al., 1988). Altered flow fields may impact domestic wells, change the natural hydraulic gradient, alter the transport potential of pollutants, and create localized regions of decreased ground water flow resulting in the development of a ground water stagnation point upgradient of an effluent mound (Magner, J.A., et al., 1988).

Ground water mounding is greatly influenced by aquifer characteristics and hydrogeologic conditions. Mounds can extend considerable distances and significantly rise above the surrounding water table. A large, deep, rapidly flowing aquifer possessing a high hydraulic conductivity and overlain by porous unsaturated soils will show the least impacts of ground water mound formation (Magner, J.A. et al., 1988). A competent modeler, using an approved ground water modelling program and acceptable input parameters, can accurately predict (with less than 6% error) the resultant mounding provided that the ground water rise is limited to less than 50% of the initial depth of saturation (Griffin, D.M. and Warrington, R.O., 1988). Thicker aquifers posses a greater buffering capacity, thereby resulting in diminished impacts from mounding. A large subsurface soil absorption system installed above a relatively thin aquifer, will overwhelm the aquifer resulting in extreme mound build-up and an increased chance of back-up into the leaching system (Magner, J.A. et al., 1988). Lower soil hydraulic conductivities result in higher mounds to adequately disperse a given amount of daily recharge (Allen, D.H.).

Hydraulic failure occurs if the mound is too big, whereas infiltrative surface failure is attributed to an undersized leaching system (Allen, D.H.). Short term hydraulic failure is possible after rain storm events when the thin aquifer does not have the storage capacity, hydraulic conductivity or porosity to maintain adequate flow (Magner, J.A. et al., 1988).

Large systems require that additional care and expertise be exhibited by designers, installers and regulatory officials. Variability of effluent flow rates and composition, combined with unequal effluent distribution, commonly results in localized system overloading and ponding. These problems are intensified by expanded system size. Larger systems may exhibit greater flow variability and increased surface loading rates (DeWalle, F.B., 1981), resulting in an applied hydraulic load per unit area which is often elevated by several orders of magnitude (Magner, J.A., 1984).

Improper/illegal disposal of non-domestic wastes, including household and commercially used chemical disinfectants, cleaners and solvents, via septic systems, poses a significant risk of chemical, both organic and inorganic, contamination of the subsurface soils and ground water. This risk level rises as the size of the system, and the number of users, increases.

Large septic systems are typically proposed for strip mall, commercial and office developments. While regulations exist prohibiting the disposal of non-domestic wastes, these types of uses are likely to utilize on-site drains and septic systems as an inexpensive means of disposing of "non-controlled" hazardous chemicals. Likewise, a large community system also presents an elevated risk of disposal of hazardous chemicals and organic solvents. This increased risk may be due to the increase in the number of users resulting in a decrease of contaminant awareness and system accountability. This risk is further exaggerated by increased flow volumes, possibly resulting in decreased treatment efficiencies and altered ground water flow patterns and velocity (Greer, B.A. and Boyle, W.C., 1988).

23.2 State Regulations

Table 23.2.1 summarizes the results of a survey of on-site septic system regulations currently in effect across the country. For the most part, this table is limited to thresholds specifically mentioned in the "small flows" septic system regulations. Additional design and review thresholds may be contained in related environmental protection and public health regulations.

Table 23.2.1 demonstrates the increased awareness that many states have for the problems commonly attributed to large septic systems. Minimization of these adverse effects is controlled by mandating a state review and approval process, requiring a ground water discharge permit, specifying more stringent standards, and/or completing a hydrogeologic investigation in order to estimate the groundwater mounding effects and/or nitrate induced groundwater degradation.

23.3 Local Regulations

Several towns, including Yarmouth and Marshfield, have adopted thresholds that require hydrogeologic assessments when sewage design flow rates exceed 2,000 gpd. These regulations require the applicant to determine the general hydrogeologic conditions at the site and analyze water quality impacts at downgradient receptors using appropriate solute transport models. Unfortunately, neither town requires hydraulic analysis to interpret ground water mounding or possible changes in ground water flow direction.

23.4 Conclusions and Recommendations

Thresholds are used to determine jurisdiction over the regulatory review process. Permit issuance under Title 5 is delegated to the boards of health, while the Department of Environmental Protection provides an additional level of review for larger and more complicated projects requiring detailed multidisciplinary technical evaluations.

The previous 15,000 gallon per day threshold was based almost entirely on the Department's preference toward sewage treatment facilities. The threshold was selected because it represented that quantity of flow which was deemed necessary for a sewage treatment plant to be feasible. Sewage treatment technology has changed significantly since the adoption of Title 5 in 1978. Sewage treatment facilities now represent a potentially viable alternative to conventional septic tank/soil absorption systems at installations with much smaller flows.

The level of understanding concerning the ground water quality impacts associated with the conventional septic tank/soil absorption system has also improved. It is now recognized that septic tank/soil absorption systems have a limited treatment capacity and that some constituents are assimilated only through dilution in the ground waters. Individual subsurface sewage disposal systems may represent a relatively small point source but, unless there is a limit on the number of systems within a given area, they may collectively result in high concentrations of contaminants in the underlying ground water.

TABLE 23.2.1

THRESHOLDS
(Gallons per Day)

	STATE APPROVAL REQUIRED	GROUNDWATER DISCHARGE PERMIT	INCREASED REGULATIONS REQUIRED	HYDROGEOLOGIC STUDY REQUIRED	MAXIMUM SIZE
Alabama	1,200		5,000		
Alaska	>Duplex		2,500	2,500	
Arkansas					
Arizona		20,000	10,000	2,000	
California		County Rules Prevail			
Colorado	2,000		1,000		
Connecticut			2,000/5,000		
Delaware		2,500	2,500	2,500	
Florida	5,000		5,000		
Georgia					
Hawaii	800				
Idaho					
Illinois					
Indiana					
Iowa					
Kansas					
Kentucky			2,000		
Louisiana					
Maine					
Maryland			5,000		
Massachusetts	15,000	15,000			15,000
Michigan	1,000	10,000	2,000	10,000	10,000
Minnesota	5,000/15,000				
Mississippi	400				
Missouri					
Montana					
Nebraska					
Nevada					
New Hampshire		20,000	2,500		
New Jersey					
New Mexico					
New York	1,000	10,000	1,000		
North Carolina	3,000		480	3,000	
North Dakota					
Ohio					
Oklahoma					
Oregon	2,500	5,000	300/2,500		
Pennsylvania				10,000	
Rhode Island	5,000	5,000	2,000		
South Carolina			1,500		
South Dakota			7,500		
Tennessee			3,000		
Texas		5,000			
Utah			5,000		15,000
Vermont		6,500	5,000	10,000	40,000
Virginia					
Washington			3,500		14,500
West Virginia			3,000/5,000		
Wisconsin			1,500/5,000		
Wyoming			2,000	2,000/10,000	

Recent research also suggests that a single large subsurface sewage disposal system may offer advantages over the use of a number of small individual systems. However, more stringent siting requirements and design standards must be imposed whenever large systems are proposed.

Evaluation of projects involving density issues, sewage treatment facilities and large septic tank/soil absorption systems involve detailed engineering, scientific and legal issues. These projects should be handled differently than small conventional septic systems. We, therefore, propose a review matrix using system size and density factors to separate projects into different categories instead of the previous single threshold method. Each category of project would be subject to different standards and levels of reviews depending upon the degree of risk and complexity of the issues.

Proposed Thresholds

A. Projects on lots where the septic system density is less than 110 gallons per day per quarter acre.

1. Individual systems with design flows less than 2,000 gpd: Local review in accordance with proposed small system standards.

2. Individual systems with design flows between 2,000 and 15,000 gpd.

    a. Lot is not located in an environmentally sensitive area:

        i. Individual systems with design flows between 2,000 and 5,000 gpd - Limited hydrogeologic study (mounding evaluation) required, local review and permit.

        ii. Individual systems with design flows between 5,000 and 15,000 gpd - Expanded hydrogeologic study (mounding evaluation and nitrate loading analysis) required, state review and evaluation in addition to local permit.

    b. Lot is located in an environmentally sensitive area:

        i. Individual systems with design flow between 2,000 and 15,000 gpd - Expanded hydrogeologic study (mound formation and nitrate loading analysis) required, state review and permit required.

3. Individual systems with design flow greater than 15,000 gpd - state review and permit, advanced treatment (treatment plant) required.

B. Projects on lots where the septic system density is greater than 110 gallons per day per quarter acre.

1. Lot is not located in an environmentally sensitive area: Expanded hydrogeologic study (mound formation and nitrate loading analysis) required. State review and evaluation required in addition to local permit.

2. Lot is located in an environmentally sensitive area: State review and permit required, advanced treatment (treatment plant) required.

Staffing Requirements

There is no readily available data regarding the number of Title 5 systems annually proposed statewide. The Department currently employees a minimal number of full-time staff people to process the approximately 1,000 variance requests received each year. A reduction in the threshold would require more staffing resources for the Department or a reallocation of existing resources. To quantify the anticipated impacts caused by changing the threshold requirements, an estimate of the number of Title 5 systems, categorized by size, that are permitted each year would need to be completed. From this information, and an estimate of the staff resources needed to review each project of a certain size or complexity, an estimate of the required staff augmentation can be completed.

In addition, to make the program as efficient as possible, the Department should consider adopting a systematic review and approval process, whereby the Department of Environmental Protection has a fixed time period of 30 to 60 days within which to review the subject case and issue a decision. The review procedures should be integrated into the fee program recently formulated by the Department of Environmental Protection (310 CMR 4.00).

Before the threshold for state review and/or permitting is revised, it is recommended that further analysis be conducted to fully evaluate system performance and assess the regulatory implications. A six month pilot program, using a suitable study area incorporating a wide range of problems is recommended.

At a minimum, this pilot program should be fashioned so as to properly quantify and qualify the problems encountered by high density developments and the utilization of systems with flows between 2,000 and 15,000 gallons per day. After the results of this pilot project are analyzed, an effective statewide program addressing the needs of large system design and review can be crafted. A complete mapping of the study area detailing the location and extent of all sensitive environmental receptors, water supply wells, septic systems, and known sources of pollution should be undertaken as part of the pilot program. Particular goals of the program should include accumulation of data leading to a complete understanding of the following:

1. What is the average number of systems with design flows between 2,000 - 15,000 gallons per day existing in a particular area? How many are proposed and permitted each year?

2. What are the design parameters, hydrogeologic site conditions, and intended use of these systems?

3. What are the problems or limitations encountered with design and use of these systems?

4. What is their failure rate?

5. What was the cause(s) of system failure?

6. What is an appropriate response to system failures?

7. What constitutes an adequate level of investigation?

8. What is the septic system density throughout the test area, (gpd/acre)?

9. What are the regional and local environmental and health related impacts? How do they correlate to density?

If it is determined that the state cannot support the resources necessary to implement this program, the Department of Environmental Protection should evaluate the possibility of requiring boards of health to employ qualified professionals to conduct these reviews. Chapter 593 of the Acts of 1989 provide a mechanism for the funding necessary for these more detailed local reviews. The local reviews offer the advantage of integrating the board of health's knowledge and understanding of the local conditions and area history.

CHAPTER 24

POLICIES

An administrative agency promulgates regulations to implement the laws enacted by the legislative branch of government. Once promulgated, these regulations serve to guide the agency in the administration of its regulatory program. Regulations have the force of law, and a violation incurs penalties, just as a violation of the law would.

The agency has an obligation to make sure that regulations are clearly expressed. Those subject to the requirements should not have to guess at meanings or expectations. Therefore, it is important that the intent of the regulations be concisely stated using plain language which is readily understood by the regulator, as well as the regulated community. Even carefully crafted regulations, however, may be found to contain certain ambiguities needing clarification or interpretation. Ideally, whenever a provision of the regulations is determined to be confusing or its meaning unclear, the issuing agency would immediately implement an amendment to the regulations providing full disclosure of its intent.

Administrative agencies are subject to rules which specify the proper procedures for adopting regulations. These rules generally stipulate a formal process including public notification and hearing requirements. Since these procedures are time consuming and require a substantial commitment of resources, agencies often take a shortcut and issue policy statements or opinions in place of regulatory amendments. These policy statements and opinions can be issued at any time and, since they do not actually alter the regulations, they do not require public participation .

Unlike regulations, an agency's policies are considered to be guidelines, not binding requirements. Nonetheless, the law commands that great deference be given to the policies and opinions of administrative agencies. The restrictions enforced by an agency through policy statements and opinions are generally upheld by the courts unless the agency is found to be acting in an arbitrary or capricious fashion.

The Department of Environmental Protection has issued thirteen such policy statements concerning various aspects of Title 5 of the State Environmental Code. This section of the report provides a review these policy statements to determine whether there is still a need for separate and distinct guidelines.

24.1 Policy Review and Recommendations

As boards of health have attempted to administer Title 5, a number of questions concerning the original intent of the regulations have been raised. In addressing these queries, the Department has chosen to issue periodic policy statements rather than formally amending the regulations. These policy statements cover diverse topics including: side slope requirements, setback requirements for slab construction, grease trap sizing, use of fiberglass and polyethylene septic tanks, leaching facility setback standards, the use of pumps prior to septic tanks, the use of sewage tight tanks, requirements for foundation drains, the use of separate grey water disposal systems, requirements for boat pump-out facilities, standards for septage lagoon closures, procedures for the approval of innovative and alternative systems, and standards for the disposal of wastes generated at funeral homes.

Many of these topics have been discussed in other chapters of this report. In an effort to minimize redundancy, our review of these policy statements will simply involve a brief summation of the issues.

24.1.1 Side Slope Requirements

Title 5 allows a soil absorption system is be constructed wholly or partially in fill, provided that after the removal of all impermeable materials there remains at least four feet of naturally occurring pervious soil beneath the proposed fill layer (310 CMR 15.02(17)). The fill must consist of coarse sand or other granular material having a percolation rate before and after placement of less than two minutes per inch. The finished system may be constructed above the natural grade, as long as all impermeable materials are removed beneath the proposed leaching facility for a distance of twenty-five feet in all directions therefrom.

Unlike soil absorption systems construction completely in naturally occurring soils, which have specified slope setback requirements (310 CMR 15.12 and 15.14), the code contains no restrictions on the steepness of the slope used on a mounded system. In an attempt to provide guidance in this regard, the Department issued Title 5 Policy Memorandum #87-1 which states:

> "Illustrations A and B (Figure 1, 310 CMR 15.12 and 15.14) show "natural soil" around leaching pits, galleries, chambers and trenches. Section 15.02(17), however allows leaching facilities to be constructed in fill material provided certain minimum criteria are satisfied. Questions have been raised about the method used to calculate the breakout prevention distance for facilities constructed in fill, and, in those cases where the fill material extends above natural grade, whether the slope as determined at the point of measurement must extend continuously until it meets natural grade.
>
> When reviewing a proposed leaching facility which is to be constructed in fill, Figure 1 of Title 5 (illustrations A, B, and C) shall apply. The location of disposal facilities in relation to adjacent downhill slopes is therefore determined by using the formula - distance = 150 x slope (y/x) - as shown on the illustrations.

A strict interpretation of this requirement would mandate that the slope, as measured at a point located along a line drawn as a horizontal extension of the top surface of the washed stone at the calculated distance, should extend continuously to meet the natural grade. This is best demonstrated by using, as an example, a case where a near vertical slope is encountered. The required separation distance, using the above equation, would approach infinity as the slope approaches the vertical.

In some cases this strict interpretation may cause undue hardship as maintaining the required slope may be impractical or even impossible for a particular site. In these cases one must not lose sight of the intent of this requirement. That is: to provide a simple and concise method for determining the required separation distance necessary to protect against surface breakout of the effluent. In the cases where the enforcement of the slope requirement would do manifest injustice, the applicant should demonstrate that the same degree of environmental protection against breakout can be achieved without strict application of this particular provision by performing a more detailed geohydrologic investigation of the site. A variance to the slope requirement could then be granted pursuant to 310 CMR 15.20. A retaining wall or other flow restrictive barrier may be considered in these instances."

The existing Title 5 setback formula results in overly restrictive setback distances particularly in situations involving the placement of fill materials. This, coupled with the fact that the existing formula has been a chronic source of confusion, prompted the suggestion that the Department implement modifications to the current side slope setback requirements.

Additionally, it is recommended that Policy Memorandum #87-1 be incorporated into the Code through the addition of slope requirements for mounded systems. These requirements should be consistent with the standards for absorption systems installed in naturally occurring soils.

24.1.2 Set Back Requirements for Slab Construction

Septic system components should be sited an appropriate distance from buildings or other above ground obstructions to facilitate repairs and system replacement. Furthermore, since the septic tank effluent flows both vertically and laterally as it is dispersed by the soil absorption system, there should be no subsurface protrusions in close proximity to the leaching facility.

Title 5 presently requires that septic tanks and leaching facilities be located at least ten feet and twenty feet respectively from a cellar wall or inground swimming pool (310 CMR 15.01(7)). Cellar Wall is defined in 310 CMR 15.01 as "the inside of the cellar wall above the footings and below the ground surface".

Buildings, portions of buildings such as porches or decks, and other structures such as garages constructed with concrete slab or pile foundations do not have cellar walls as defined within Title 5. This has resulted in a number of questions relative to the application of the setback criteria for above ground structures without cellar walls. The Department of Environmental Protection issued Title 5 Policy Memorandum #87-2 in response to these questions. This policy states:

> "310 CMR 15.03(7) provides that no septic system shall be closer than 10 feet and no leaching facility closer than 20 feet from a cellar wall. Buildings constructed on concrete slab foundations do not have cellar walls within the meaning provided in section 15.01. Slab foundations typically do not extend more than two feet into the ground and thus do not pose the problem of restricting horizontal ground water flow.
>
> This office has, therefore, developed a policy that septic tanks and leaching facilities shall be separated a minimum distance of 10 feet from the outside edge of a slab foundation. This distance will provide for an adequate area for excavation of the subsurface disposal system components and will provide for the protection of public health should a failure occur."

Ten feet of separation between septic system components and permanent above ground structures is desirable for providing needed access for routine operation and maintenance of the sewage disposal system.

It is recommended that the requirements specified in Policy Memorandum #87-2 be added to the Code. Additionally, we would recommend that a minimum separation of ten feet be required between any component of the septic tank/soil absorption system (except the building sewer) and any permanent above ground structure.

The distance should be measured from the point representing the furthest extremity of any spread or combined footing, foundation mat, pile, pier or caisson providing support for any building, component of a building or accessory structure.

24.1.3 Sizing of Grease Traps

310 CMR 15.02(13) provides a table for estimating the daily quantities of sewage which are expected to be generated at different establishments. This table provides three separate listings for Restaurants based upon the number of seats or chairs in the establishment. The sewage estimate for a food service establishment, lounge or tavern is given as 35 gallons per seat per day; the sewage flow from thruway service areas is given as 150 gallons per seat per day; while, kitchen flow is estimated based upon 15 gallons per seat per day. Since food service establishments, lounges, taverns and thruway service areas may all include kitchens, there was some confusion as to whether the kitchen flow was intended to be included in, or added to, the sewage flow estimated by the other two categories. Title 5 Policy Memorandum #87-3 addresses this matter by providing:

> "Grease traps shall be designed and constructed as noted in 310 CMR 15.05. When determining the capacity of a grease trap, kitchen flow is calculated in accordance with 310 CMR 15.02(13), typically 15 gallons per seat or chair per day. This flow estimate is not to be added to the Title 5 flow estimate of 35 gallons per seat or chair per day used to size the septic tank and leaching facilities."

It is suggested that modifications be made to the Code to eliminate the need for Policy Memorandum #87-3. This could be as simple as adding a footnote to the table of flow estimates that indicates that a kitchen flow of 15 gallons per seat or chair should be used only to calculate the design flow for grease traps.

24.1.4 Use of Fiberglass and Polyethylene Septic Tanks

Title 5 requires that septic tanks be water tight and constructed of sound and durable material not subject to excessive corrosion, decay, or frost damage, or to cracking or buckling due to settlement or backfilling (310 CMR 15.06(7)). Traditionally, septic tanks have been constructed of either steel or pre-cast reinforced concrete, with concrete being the most popular.

With the advent of space age materials that are both light-weight and durable came a number of questions concerning the use of septic tanks fabricated with plastics. This is the subject of Title 5 Policy Memorandum #87-4 which reads:

> "In response to the numerous inquiries received by the Department of Environmental Quality Engineering relative to the use of fiberglass and polyethylene septic tanks, this office has developed the following policy regarding the approvability of septic tanks constructed by these materials.
>
> This office considers fiberglass and polyethylene to be sound and durable materials which can satisfy the provisions of 310 CMR 15.06(7) of Title 5 of the State Environmental Code. Therefore, fiberglass and Polyethylene may be approved for use provided all other applicable provisions of Section 15.06 are satisfied.
>
> It is important to note that our review of the design features of septic tanks by various manufacturers who utilize these materials has failed to reveal any apparent public health advantage over the more commonly used precast reinforced concrete tanks.
>
> The following list of deficiencies noted by this office during its review of several different designs of fiberglass and polyethylene septic tanks may be used as a guide in reviewing a particular design for approval. These include:
>
> 1. Light-weight tanks could be subject to flotation in areas of high ground water. In installations of this-type, buoyancy forces on the tank when empty should be calculated and ballast should be provided as appropriate. (This also applies to precast concrete tanks installed under similar conditions);
>
> 2. Cylindrical and oval tank designs reduce the volume available for sludge and scum storage;

3. Rounded septic tank bottoms make it difficult to adequately compact backfill below the mid-depth of the tank;

4. Access manholes are difficult to adapt to cast iron frames and covers and to raise to, or to within 12 inches of, finished grade. Fiberglass and polyethylene covers are unsuitable in instances where covers are required to be at finished grade;

5. The structural data in some cases does not appear to preclude structural damage when a point load is imposed directly on an access cover at finished grade. All system components must be capable of withstanding H-10 wheel loads except in areas subject to vehicular traffic where an H-20 wheel load applies;

6. Accessibility of inlet and outlet tees from the access manhole extension may be difficult, impractical and/or impossible;

7. The distance between the outlet and inlet of the tank measured at the bottom of the tees must be at least equal to the liquid depth of the tank (4 feet minimum, preferably more on oval or circular tanks)."

We do not feel that it is necessary to specifically list the benefits and deficiencies of various construction materials in the Code itself. General standards should be sufficient. When septic tanks constructed of materials other than steel or pre-cast reinforced concreted are proposed, they should be evaluated on a case by case basis. Policy Memorandum #87-4 should be updated and reissued to provide guidance to boards of health in their review of tanks fabricated with non-traditional materials.

24.1.5 Leaching Facility Set Back

One hundred feet is the minimum acceptable distance between a leaching facility and a well and no variance shall be granted for a lesser distance except with prior written approval of the Department of Environmental Protection (310 CMR 15.03(7)). In some instances, particularly where repairs are required to existing sewage disposal systems on lots with on-site water supply, it is not feasible to maintain this minimum separation.

The Department views a variance to the required well setback to be a serious matter warranting careful deliberation. Where new construction is involved, the answer is a relatively simple one. The risks are far too great to chance endangering the health and welfare of those using the water supply. Therefore, a variance of this sort is not allowed for new construction.

Existing facilities are another matter entirely. Many of the early subsurface sewage disposal systems do not meet the 100 foot setback requirement. Prior to 1962 septic system setbacks were not subject to state regulations.

When an owner of a pre-existing septic system wants to undertake modifications to the system but can not provide the required separation, the Department and the board of health are faced with a serious dilemma. They must chose the least undesirable alternative from a list of options which includes, condemning the building, granting a variance to the setback requirement, or approving a sewage holding tank. Each choice presents its own unique set of problems depending on the specific circumstances of the case.

A condemnation strips the property of its value as a developable parcel. This generally results in an undue hardship on the owner of the property. Because of the problems associated with condemnation, the Department and boards of health are reluctant to condemn a building based on Title 5 violations alone, selecting instead to agree to alternatives which otherwise would not be allowed.

Granting a variance sometimes offers the best solution for an existing malfunction where a replacement system can not be installed in compliance with the requirements dictated for new systems. This is particularly true in instances where the existing sewage disposal system has not caused a problem with the on-site well. If the well is on the same lot and at least the same separation distance can be maintained between the well and the replacement system as was provided between the well and the old system, the Department will generally grant a variance. Variances of this type are usually approved with a requirement that the well be routinely monitored for signs of contamination and that the variance be recorded with the property deed to provide notice to potential purchasers.

Policy Memorandum #87-5 was written to provide guidance in this regard. It reads as follows:

> "Prior written approval of the Department of Environmental Quality Engineering will not be granted on new construction where less than the 100 feet minimum acceptable separation distance between the leaching facility and a well is provided.
>
> Approvals for a lesser distance may still be considered for repairs to existing systems on a case by case basis. In these instances the Department's approval will be dependent upon a recording in the appropriate registry of deeds of a notice that discloses the existence of a variance for the sewage disposal system and routine monitoring of the water quality at the well will be required."

Title 5 provides criterion for new construction with little regard to the correction of existing malfunctioning systems. Regulating the design and installation of septic tank/soil absorption systems for new installation is much simpler than correcting an existing malfunction where it may be necessary to select the least undesirable alternative from a number possible solutions.

Title 5 requires that a variance be granted when replacement systems cannot be installed in full compliance with the Code requirements. Since the specific criteria and procedure necessary for obtaining a replacement system variance are not clearly stated in the regulations, the Department's position on these matters has had to be elaborated through policy statements. The existing policy concerning leaching facility setbacks from wells is not explicit and therefore does not necessarily assure equal consideration in every situation of this type.

We encourage the Department to consider instituting specific standards for projects involving modifications to existing sewage disposal systems. This will provide much needed guidance to boards of heath and will assure consistent handling of situations involving repairs and upgrading of existing sewage disposal systems.

24.1.6 Sewage Pumping to Septic Tank

The primary function of the septic tank is to provide quiescent conditions for gravitational removal of the suspended solids contained in the wastewater. Excessive turbulence within the tank may cause the resuspension and carryover of settled solids to the leaching facility. This results in increased clogging of the soil matrix and a reduction in the ability of the soil absorption system to disperse the septic tank effluent. Depending on the extent of soil clogging, the disposal system may fail to function.

Pumps discharging sewage into septic tanks at high rates could cause particulate matter to be scoured into the leaching facility. Therefore, the pumping of sewage into a septic tank is not allowed without the written approval of the Department of Environmental Protection (310 CMR 15.06(18)). Since it is not always possible to avoid pumps altogether, the Department is frequently petitioned for a variance to this provision of the Code. As a result the Department issued Title 5 Policy Memorandum #87-6 to provide additional guidance in instances where the use of pumps prior to septic tanks can not be avoided. This policy is as follows:

> "The Department may consider a proposal for the use of a pump to discharge sanitary sewage to a septic tank provided that only a small portion of the total sewage flow to the septic tank is pumped and that the pump use for such pumping is of a low volume capacity.
>
> Written approval of the Department is required (310 CMR 15.06(18))."

Since the use of pumps prior to septic tanks are a common occurrence, the Department would be well advised to consider incorporating specific standards within the Code to reduce the number of individual reviews it must perform. it is recommended that the use of pumps prior to a septic tank be avoided wherever possible. Where pumps are determined to be necessary, the volume of sewage pumped to the tank should not exceed twenty percent of the total daily flow, and the capacity of the pump should not exceed thirty gallons per minute. Stilling basins or other means of attenuating the flow, such as doubling the septic tank size, should be incorporated in the design of septic tank/soil absorption systems when the pump discharge is greater than twenty percent of the total daily flow or the pump capacity exceeds thirty gallons per minute.

24.1.7 Sanitary Sewage Tight Tank Policy

Site limitations are sometimes so severe that the methods of on-site wastewater disposal described in Title 5 cannot be utilized even with reasonable variances. In these situations, the possibility of temporarily storing the dwelling's wastewater in water-tight tanks with periodic pumping and off site disposal of the tank's contents may be the only remedy to a failing sewage system short of condemning the building.

The Department of Environmental Protection recognizes the use of water-tight holding tanks as an interim solution only. These systems require continuous maintenance and frequent pumping. Limited resources at the state and local levels make it difficult to monitor their use and assure that they are being properly operated and maintained.

Facilities for off-site disposal of the tank's contents are extremely limited and pumping can become prohibitively expensive. Therefore, the use of tight tanks must be restricted to instances where municipal sewers or other long-term solutions for sewage disposal will become available within a reasonable timeframe or where temporary malfunctions of an on-site disposal system occurs and occupancy of the home must continue while the system is being renovated.

The use of pump and haul procedures is not considered to be a viable long-term alternative for a number of reasons including: (1) the continuing costs to operate and maintain the system; (2) the lack of management mechanisms to assure the continuation of pumping contracts; (3) the difficulty in finding approved disposal areas for the sewage; and, (4) the potential for illicit connections to drains, ditches, or surface waters. The Department's Policy Memorandum #87-7 addresses issues relating to the use of sanitary sewage tight tanks. This policy is as follows:

"1. Existing Situation - A tight tank may be approved under Regulation 18.1 of Title 5 of the State Environmental Code to eliminate an existing malfunctioning subsurface sanitary sewage disposal system when, in the opinion of the Regional Engineer having jurisdiction over subsurface sewage disposal, there is no other feasible alternative. Evidence must accompany application for approval showing proof of "no feasible alternative". Reasonable variances from the Code must be carefully considered prior to approval of any tight tank. The following design criteria will be used.

2. Design Criteria -

   a. Size - 500% of the average daily flow, but in no case less than 2,000 gallons.

   b. Plans - Plans must be submitted by a Massachusetts Registered Professional Engineer for approval.

   c. Alarms - Bell and light at three-fifths capacity in suitable convenient location. Transmission of the alarm signal to a locus manned 24 hours per day may be required.

d. Pumping - The application for approval must indicate the method and frequency of removal of the contents.

e. Disposal of Contents - The specific location and method of disposal of the contents must be indicated and be in a proper manner at a location approved by agencies having jurisdiction.

f. Accessibility - All tight tanks must have at least one 24-inch diameter cast iron frame and cover at finished grade constructed so as to eliminate entrance of surface waters. Permanent suction piping may also be required.

g. Location - The tank shall be located so as to provide year-round access for pumping.

h. Permit - A permit to install the tank must be obtained from the local Board of Health under Title 5 of the State Environmental Code (or in accordance with the provisions of any successor code, law or regulation).

i. Monitoring - The local Board of Health must certify that the system will be monitored by them to see that it is being properly operated and maintained. Additional monitoring will be by Department of Environmental Quality Engineering personnel having jurisdiction over subsurface sewage disposal on a spot check basis or on complaint.

j. Ground Water - Tanks must be water proof and watertight and should not be located below the water table without extensive testing to prove the integrity of the tank and be designed against uplift.

k. Odor Control - Aeration or some other method of odor control may be required.

l. Reports - Monthly reports may be required to be submitted to the local Board of Health and/or the Department of Environmental Quality Engineering.

m. Certification - The tight tank shall not be utilized until written certification that it has been constructed in accordance with the approved plan has been submitted to the Department of Environmental Quality Engineering and the Board of Health. Said certification shall be submitted by a Professional Engineer who is registered in the Commonwealth of Massachusetts. Nothing in this provision is intended to interfere with the right of the Board of Health to inspect the holding tank at any time during construction in order to assess compliance with the approved plan.

3. Approvals - The Regional Engineer may approve (subject to the restrictions in paragraphs 6 and 7 below) all tight tank applications, an escrow account may be required to ensure availability of funds for continuity of maintenance. Escrow accounts will be in the name of the owner or person having control of the tight tank to be used when required by Department of Environmental Quality Engineering or the local Board of Health.

   All replies approving tight tanks shall state that failure of the owner or person having control of the tank to keep it from overflowing and properly maintained will constitute grounds for revocation of approval for the use of such a unit. Approval will be limited to the existing use and any change of use or ownership will require a new approval but may not require new plans.

4. New Building - Tight tanks will not be approved for new construction except in connection with the marina license program of the Department of Environmental Quality Engineering when no feasible alternative exists.

5. Upon availability of a sewerage system, connection shall be made within 30 days and the tight tank system shall be abandoned.

6. Commercial Wastes - No approval for a tight tank at a commercial establishment shall be granted by the Regional Engineer without the prior consent of the Boston Office of the Division of Water Pollution Control.

7. Industrial Wastes - holding tanks for non-hazardous, non-domestic industrial wastes may be approved by the Regional Engineer pursuant to the Industrial Waste Holding Tank Policy Memorandum dated October 7, 1985. No approval for a tight tank for sanitary waste at industrial facilities shall be granted without the prior consent of the Boston Office of the Division of Water Pollution Control."

The Department should consider the possibility of establishing a management or service program under the control of a governmental entity or property association. Formalizing the management program will allow for improved operation and maintenance of these facilities, thus reducing both the costs of servicing and adverse environmental impacts.

Despite their problems, tight tanks are frequently used to remediate failing sewage disposal systems. Their wide spread use would suggest that standards like those contained in Policy Memorandum #87-7 should be included in the Code itself.

24.1.8 Foundation Drains

The State Building Code requires that "subsoil drains shall be provided around foundations enclosing habitable spaces located below grade and which are subjected to ground water conditions" (780 CMR 872.4.1). The Department of Environmental Protection released Title 5 Policy Memorandum #87-8 as a reminder of the separational requirements for subsurface drains. This policy, which emphasizes certain setback requirements listed in 310 CMR 15.03(7), states:

> "This office considers foundation drains to be subsurface drains within the meaning provided in 310 CMR 15.01. Therefore, in those instances where foundation drains are utilized, the separation distances specified in section 5.03(7) for subsurface drains (25 feet for both septic tank and leaching facility where the drain does not lead to a surface water supply, 50 feet for a septic tank and 100 feet for a leaching facility where the drain does lead to a surface water supply) shall apply. Since these separation distances are greater than those specified for a cellar wall, they would be the controlling factor on the location of subsurface disposal system components."

This policy statement primarily reinforces the separation distance requirements stated in 310 CMR 15.03(7). The need for Policy Memorandum #87-8 can be eliminated entirely by simply adding foundation drains to the definition of subsurface drains.

24.1.9 **Separate Grey Water Disposal Areas**

Hydraulic overload is one of the most common reasons for failure of the septic tank/soil absorption system. This condition occurs when too much septic tank effluent is delivered to the soil absorption system. The sewage then backs-up onto the ground surface or into the building. In addition, soil saturated with wastewater will not allow the passage of oxygen into the soil. Under anaerobic soil conditions, clogging of the soil absorption system is accelerated.

Many individuals promote separate disposal facilities for the discharge from washing machines as a means of preventing hydraulic overloads. These people feel that malfunctions are frequently attributed to the excessive water usage of the washing machines and the high rate of flow generated by its discharge pump. While this may be true in cases involving laundromats where the washing machine discharge represents a substantial portion of the total discharge, a properly designed household system should be able to accommodate washing machines intended for domestic use.

The lint particles contained in the washing machine discharge are not readily removed through settling unless combined with other wastewater streams. Therefore, separate disposal facilities are not as effective as the conventional septic tank/soil absorption system.

Policy Memorandum #87-9 reiterates the Title 5 standards as they relate to separate "grey water" disposal facilities.

> "A separate disposal system for grey water is not recommended, however, if separate systems are proposed, both systems must contain all elements of a sanitary sewage disposal system required by Title 5 (septic tank, adequate leaching facility)."

We recommend that the Department include provisions within the amended Code which discourage the use of separate grey water systems. Where separate systems are utilized they should be required to comply with all aspects of the Code including an appropriately sized septic tank and leaching area (primary and reserve).

24.1.10 Boat Pumpouts

In response to an ever increasing demand for boat pump-out facilities, the Department in 1989 issued its policy (#89-1) regarding the use of septic tank/soil absorption systems for discarding sanitary waste collected on recreational and commercial watercraft. This policy encourages the use of pump and haul facilities where sewer connection is not feasible in accordance with the following:

> "In areas where a sewer connection is not available, boat pumpouts should be directed to a tight tank, designed and installed in compliance with Title 5 Policy Memorandum #87-7. Removal of the contents of the tight tank should be done by a licensed hauler, and disposal should be to an approved wastewater treatment facility. Disposal to a septic system is not recommended, because in part of the addition of chemical odor preventatives and disinfectants to boat waste holding systems."

This policy represents an excellent opportunity to reconcile the differences in related regulations. The Chapter 91 regulations should clearly articulate the standards for boat pump-out facilities. Title 5 would then only have to include a reference to the Chapter 91 regulations reinforcing the Department's policy on the use of septic tank/soil absorption systems at these facilities.

24.1.11 Interim Policy Division Review and Approval Process For Individual On-site Sewage Disposal Systems

Conventional septic tank/soil absorption systems are not appropriate for sewage disposal in some soil types and under certain environmental conditions. With recent attention focussing on poor septic system performance and ground water contamination, various innovative and alternative technologies for on-site sewage treatment and disposal are beginning to be proposed as means of overcoming specific restrictions in the use of conventional systems. Title 5 is not suited for addressing these proposals because the Code is rigidly tied to conventional septic system designs and allows only minor variations.

Since communities and individual property owners may benefit from the introduction of alternative technologies, The Department has issued the following Interim Policy (#89-2) which specifies approval requirements for innovative and alternative systems:

"The Division of Water Pollution Control has received numerous, requests for review and approval of new or modified technologies for application in individual on-site sewage disposal systems. The following discussion is intended to present the Division's interim policy on granting approvals for new technology not described in Title 5, concerns regarding small wastewater treatment plants sized for individual homes and expected revisions to Title 5 specific to new technologies.

Title 5 - The State Environmental Code: Minimum Standards for the Subsurface Disposal of Sanitary Sewage (310 CMR 15.00) was last updated in 1978. During the last decade many advances in technology have been made. Many of the new proposals are modifications/improvements to traditional approaches to subsurface disposal. For example, the use of new materials being substituted for ductile iron pipe or concrete structures and improved filter media. It has been the Division's experience that not all of the equipment which falls into this category performs "as advertised". Poorly designed equipment and "black box" technology have forced the Division to proceed very cautiously in its evaluation before granting approval of any new proposal. However, non-mechanical equipment should continue to be evaluated and approved when found to perform to Division satisfaction through performance data supplied by the manufacturer and a Division approved in-situ experimental demonstration project. Specific approval protocol will be addressed later in this discussion.

Individual home sewage disposal systems which include one or more mechanical components, such as pumps, aerators or motors present additional concerns over the non-mechanical category. Despite the significant advance in electronics and mechanical components, inherent limitations in the systems will persist. The greatest concern, however, is with ensuring the continuous operation, preventive maintenance, repair, and replacement of such facilities. The Department is forced to devote major enforcement efforts toward correcting deficient operation and maintenance of municipal wastewater treatment facilities, in spite of the substantial financial and technical resources available to municipalities in comparison to those of the typical homeowner.

Even those municipalities which contract for professional operation of their treatment facilities are sometimes found deficient in operation and maintenance. The Department can, however, concentrate its efforts on the relatively limited number of publicly owned treatment facilities in existence. Poor performance by any significant fraction of a multitude of individual home treatment units, on the other hand, could come to pose intractable environmental problems. Historically, the individual homeowner has been neither aware of his responsibility to properly maintain a conventional septic system nor capable of proper operation and maintenance of a more sophisticated system. Systems requiring periodic maintenance and operational oversight must be routinely inspected by a qualified person knowledgeable with the system. In addition, capital must be readily available both for routine maintenance and emergency repairs. In instances where the homeowner can provide adequate assurance that these concerns will be addressed, no guarantee is possible that this situation will continue if the property is sold.

If the Department were to consider allowing the use of small sewage treatment plants sized for individual home use, the Department's permitting, surveillance, and enforcement capabilities would be overwhelmed by the large number of facilities potentially involved. While each facility would be very small, their cumulative impact would represent a significant threat to public health and the environment. The number of individual entities subject to the Department's oversight would likely be at least an order of magnitude greater than the number currently regulated within the Division's discharge permit programs. Nor is it likely that local Boards of Health would be equipped to perform the necessary plan review, compliance monitoring, and enforcement activities in place of the Department.

As noted above, the Department must be cautious in its approach to on-lot wastewater treatment systems. Before any field testing program, the Department would review the experience of other jurisdictions where such units are in use, including the extent of regulatory resources needed and actually employed by such jurisdictions, as well as environmental impacts where use of individual treatment plants is widespread. In undertaking research on such units, the Department would require that any field tests be conducted only where parallel, environmentally acceptable disposal alternatives are already in place.

Currently, the Department is initiating revisions to Title 5. One of the areas to be addressed is provisions for integrating proven technology in the code and providing a formal procedure for evaluating and approving new technology as they become available. It is not anticipated that a revised code will be promulgated in the next year. As an interim measure, the Department will adhere to the following procedure in evaluating proposed equipment requiring Department approval for use in accordance with Title 5 (310 CMR 15.00):

1) Proposals must be formally submitted to the Division's Boston Office, One Winter Street, Boston, MA 02108.

2) Only non-mechanical equipment will be considered for approval during the interim period. No mechanical devices except those which would be currently allowed under Title 5 will be allowed.

3) All proposals must include:

   A) All available testing and performance data;

   B) A comparison of the proposed equipment with the Title 5 counterpart and evidence that the proposed equipment will provide at least as much protection to the environment; and

   C) A list of other states where equipment is in use or approved for use, the State agency granting approval, and the name of a contact person familiar with the performance of the equipment.

4) For those proposals which meet the above criteria and receive a favorable review, the Division may authorize an in situ experimental testing of the equipment. An approvable testing program must include:

A) The selected testing site must have a parallel system which meets Title 5 or be connected to a municipal sewer;

B) Plans and specifications must be stamped by a Massachusetts Registered Professional Engineer, experienced in subsurface disposal of sanitary sewage, which must include, at a minimum, relative location and dimension of all components, minimum quality of construction materials, detailed design and siting considerations, and specifications for the routine operation and maintenance of the system;

C) Monitoring and sampling must be conducted by an independent testing laboratory or independent university;

D) A testing/monitoring/evaluation plan must be submitted to and approved by the Division prior to initiation of the test;

E) The test shall be for a period of not less than one (1) year of continuous operation and must be open for Division inspection upon request; and

F) A final report shall be submitted to the Division for review and approval at the completion of the test.

5) Equipment granted approval for use by the Division following successful completion of the required testing procedure does not relieve the proponent of the need to request and be granted a variance to the relevant section(s) of Title 5 from the board of health having jurisdiction over the subject system in accordance with 310 CMR 15.20."

Because many alternative systems have not been fully tested under a wide range of environmental conditions, their use must be carefully assessed and closely monitored by the Department. Careful review before approval, complemented by a program of regular maintenance, routine inspections, and performance monitoring such as that detailed in the Department's interim policy is necessary to protect against possible failures. The costs involved in conducting such reviews may be high, but a well-designed and well-implemented program that allows for controlled use of innovative and alternative technologies under carefully monitored circumstances can result in the prevention of ground water degradation and the preservation of public health.

The Department should be committed to ongoing research in the area of on-site sewage disposal systems. Experimental and alternative sewage disposal system permits should be required to allow the use and testing of new and adapted technology which is not included in the current regulations. Experimental and alternative technology permits should be different from the disposal works construction permit, but all three permits should be considered related elements of an overall program.

Experimental permits should be used to test and evaluate new technology or new applications of existing technology for on-site sewage disposal. The experimental system should be required to have a replacement facility which can be used in case of failure of the experiment. Alternative technology permits would be required to allow the use of technologies for which there are no design standards within the Code but have been proven successful, to the Department's satisfaction, for the proposed use. Because alternative systems employ proven technology, a replacement system other than the traditional reserve area would not be required.

The Department should act as the central clearinghouse and classification authority in the case of experimental and alternative technology permits. The Department should keep ongoing records of all the performance of all proposals and should judge when an experimental system has reached a level of reliability necessary to be classified as alternative.

Under this procedure, the Department and local boards of health each retain the responsibility for issuing a permit for on-site sewage disposal systems in accordance with appropriate review thresholds. However, unlike a disposal works construction permit application, the board of health cannot issue either an experimental or alternative technology permit without first addressing the comments of the Department. The Department's comments would include classification of the system as experimental or alternative, recommendations pertaining to design, providing suggested monitoring and reporting requirements, specifying financial securities and warranties, and notifying the board of health as to past experiences with similar proposals. The Department may also comment regarding the acceptability of the proposed replacement system.

24.1.12 Interim Policy Regarding Requirements for Septage Lagoon Closures

The disposal of residual scum and sludge (septage) pumped from septic systems is, for the most part, addressed separately from the septic system management program of Title 5. During the 1970's, due to the emergency nature of the status of septage disposal in many areas of the Commonwealth, the Department encouraged communities to construct temporary disposal facilities consisting of anaerobic lagoons and effluent percolation.

When the Massachusetts Ground Water Discharge Permit Program (314 CMR 5.00) was instituted in 1983, new septage lagoons were no longer allowed and owners of existing facilities were issued enforcement schedules under which they were required to bring their facilities into compliance with the new standards. In 1989, the Department issued Policy Memorandum #89-3, to provide guidelines for lagoon closures. These guidelines are as follows:

"1. Remove all liquids from lagoons for disposal at an approved facility (analysis-dependent).

2. A. Remove all septage solids and dispose of solids at an approved landfill (analysis dependent).

or

B. Obtain a site assignment from local board of health and plan approval from DEQE/DSW and cover on site per approval (on going monitoring required).

3. If solids are removed (2.A.) backfill lagoons with clean fill to natural contours.

4. Regional office must be notified prior to backfilling to verify septage solids removal.

5. If lagoons existed within a Zone II, or in the absence of such 1/2 mile of a public water supply, require the installation of ground water monitoring wells (DWPC guidelines) upgradient and downgradient of the lagoon area and require the following monitoring for at least three years:

Parameter	Frequency
Drinking Water Metals	Quarterly
Volatile Organic Comp. Method 524	Yearly
Nitrate Nitrogen	Quarterly
Total Nitrogen	Quarterly
Sodium	Quarterly
Oil & Grease	Quarterly
pH	Quarterly

6. If lagoons existed within 1/2 mile of private wells require installation of groundwater monitoring wells and at least two rounds of analysis (Spring/Fall) for Item 5 constituents.

7. In order to determine if all solids have been removed soil samples may be required.

8. All closure plans required to be submitted to DWPC must bear Massachusetts P.E. stamp and signature.

9. The local Board of Health and DEQE DWS should be notified (copied) on all closure activities (correspondence)."

The lagoon closure guidelines have limited utility as no new septage lagoons are allowed by the Department and all existing lagoons will have to be closed within the next two years. This policy is expected to remain in force until all lagoons have been closed, therefore there is no need to adopt lagoon closure provisions within Title 5.

24.1.13 Funeral Home/Embalming Wastewater Discharges

Many hazardous chemicals, because they are resistant to biodegradation, pass through septic systems essentially unchanged to contaminate ground water. Such chemicals originate from many sources. They may be added directly to septic tanks as cleaners; they may be contained in household products used for cleaning, painting or maintaining automobiles and appliances which may be discarded down the drain; or they may be discharged by commercial and industrial businesses that use septic tanks.

Title 5 restricts the use of septic systems for the discharge of industrial wastes through a footnote to 310 CMR 15.02(2) which states:

> "all systems for the purification or disposal of industrial waste must be approved by the Department of Environmental Quality Engineering for any flow, as required by G.L. c.11, s.17".

However, there is no similar exclusion for commercial establishments that generate non-domestic wastewater. Policy Memorandum #90-1 was issued to specifically address the use of septic systems at one type commercial establishment where septic systems are frequently utilized to discard non-domestic wastewater, funeral homes. This policy reads:

> "We have had many inquiries regarding the disposal of wastewater from Funeral Homes, particularly where a sewer connection is not available. Therefore, please be advised of the following longstanding Division policy. This Division requires the disposal of blood, formaldehyde, and other body or embalming fluids to a holding tank; not a sanitary subsurface Title 5 system. The holding tank must be pumped on a regular basis and the contents disposed at an approved wastewater treatment facility. The wastes from these establishments are considered as special industrial wastes and as such may not be disposed in-ground without appropriate treatment. Untreated disposal in a septic tank without a groundwater discharge permit is a violation of G.L. c.21, s.43 and 314 CMR 5.00 and subject to the penalties and other appropriate enforcement action under the Massachusetts Clean Waters Act, G.L. c.21, s.26 through 53, and the Commonwealth's Administrative Penalty Act. G.L. c.21A, s.16 contained therein, as well as in G.L. c.21.
>
> The following DWPC requirements for the installation and use of holding tanks for industrial wastes are presented for your information.
>
> 1) The proposed use of a holding tank by an "industry" must be approved by the Division of Water Pollution Control. (See MGL Ch.21 Sec. 27(13) and Ch. 111 Sec.17.) Plans must be prepared and stamped by a Massachusetts Registered Professional Engineer.

Existing facilities found to be using holding tanks can be required to submit plans and make modifications, as appropriate.

2) Holding tanks will only be approved if no reasonable alternative (such as a sewer system) exists.

3) Submission of a contract with a Licensed septage hauler must be submitted. Submission of a new contract is required 30 days in advance of the expiration of the previous contract.

4) A letter of acceptance at an approvable disposal facility is required. A letter from a second facility may be required if the first seems marginally acceptable. Acceptance at a facility must be based on a specified monitoring program.

5) Hauling records and waste analyses must be maintained by the generator. Requiring submission of the records is done on a case-by-case basis.

6) In-ground tanks should be inspected prior to backfilling. Periodic tank testing may be required, as appropriate.

7) All local requirements and approvals of the Board of Health shall be complied with."

This problem is not limited to funeral homes. Many other commercial and industrial establishments readily use and discard potentially hazardous constituents. Printers dispose of organic solvents and metal degreasers. The photo-processing industry discards many organic and inorganic chemicals. Laundries and laundromats dispose of soil and stain removers. Dry cleaners discard used solvents such as trichloroethylene and perchloroethylene. Paint dealers and hardware stores discard many harmful solvents and cleaning products. Gasoline and service stations discard waste oils, degreasers, and other automotive fluids. Laboratory wastes include biological and chemical wastes. Dental offices, doctors offices, health clinics and hospitals discard x-ray wastes, medication and various testing fluids. These, and other similar discharges, must be identified and controlled.

Title 5 does not make a clear distinction between domestic and commercial/industrial wastewaters nor does it provide examples of inappropriate septic system use. As incidents of ground water contamination caused by the disposal of toxic wastes became more common, the Department began to regulate industrial and commercial discharges with an ever increasing intensity. The Hazardous Waste Regulations (310 CMR 30.00), the Ground Water Discharge Permit Regulations (314 CMR 5.00), and the Underground Injection Control Program (310 CMR 27.00) were all introduced after Title 5 was promulgated.

Title 5 should be amended to provide an appropriate cross reference to each of these regulations and to more aggressively regulate the types of wastes that may be introduced into septic systems. The Code needs to specifically identify and limit the constituents that can be disposed in septic systems based on the hazardous characteristics of those constituents. Adopting such measures will reinforce the point that septic systems can only treat certain types of wastes, and that many inorganic and organic pollutants are not removed by the soil absorption system, thereby providing a readily available mode of introduction into the ground water.

CHAPTER 25

DEFINITIONS

Clear and concise definitions are a key to the successful implementation of any regulation. Although great deference is given to regulatory agencies in the interpretation of their own rules and standards, a regulatory program can not be considered effective unless the regulated community is equally capable of understanding each and every aspect of the regulations on the same basis as the regulator.

Title 5 is a comprehensive set of regulations that has survived the test of time. First promulgated in the mid 1970's, the regulations have remained in full force with virtually no changes over the last 13 years. This is not to say that the regulations cannot be improved. Certainly, everyone that has had an opportunity to work with the current code has faced some questions concerning applicability. Some of these questions are trivial in nature, while others have wide reaching implications.

While a fair number of the nuances in Title 5 have been rectified by the Department of Environmental Protection through the release of periodic policy statements and legal opinions, these are not generally publicized and thus are not adequate, much less a legal substitute, for amendments to the regulations. Despite these clarifications on the intent of the regulations, the Department is still faced with several areas of the code that have been particularly problematic.

This section of the report reviews the definitions included in the current Code. Specific emphasis is given to those words or phrases which have associated with them a long history of difficulty. Other environmental and public health regulations, both from within Massachusetts and from other states, were examined in an effort to improve upon the regulations by making them more understandable, and therefore easier to use. The goal in preparing this chapter was to bring clarity and precision to the meaning of essential words thereby providing a new dimension of guidance, particularly to the technical and scientific terms that are used freely within the text of the regulations.

Certain changes in the regulatory approach have dictated that additional words, not currently included in the Code, be defined. Also, in an effort to provide practical solutions to the most troubling words, suggestions have been made for alternate approaches which have the effect of diminishing the importance of certain words that have proven to be extremely difficult to define in a conventional sense.

25.1 Literature Review

Definitions are needed to provide the regulated community with an understanding, comprehension and appreciation of an agency's requirements. Words have a number of different meanings depending on context. Therefore, whenever a word or phase plays a key role in the regulatory process a definition must be given to furnish guidance on the word's intended use. There are several terms used in Title 5 that have been the cause of major disputes over the years due to differing opinions on their meaning. These include: "lot", "bedroom", "watercourse", "emergency repair", "maximum ground water elevations", and "failure". The following section provides a brief explanation as to why these words have been particularly troublesome.

25.1.1 "LOT"

One of the more confusing aspects of the current Title 5 regulations is related to the use of the word "lot". The word is used to determine jurisdiction between and among the board of health and the Department of Environmental Protection, and in the decision process for determining when higher levels of treatment, above and beyond that provided by the conventional septic tank/soil absorption system, are required.

The definition of "lot" can vary considerably depending on its use. The word is defined in the zoning by-laws of virtually every city and town in the Commonwealth. Interestingly enough, even among zoning regulations, where the regulatory intent is the same, the word can be found to have numerous meanings. It is not surprising then, that the word takes on a different connotation in the other state and local regulatory programs designed to enhance public safety, public health or the environment.

Quite clearly the mission of the Department of Environmental Protection and the board of health in controlling on-site discharges of sanitary sewage is different from that of a planning board acting under the state's subdivision control law. The Department's interpretation of the word "lot" under its regulations is therefore often dissimilar to that of a planning board operating under local zoning by-laws. Yet another variation in the use of the word is offered by the building trades as exemplified in the context of State Building Code.

While it may not be necessary to develop a uniform definition of the word "lot" for use by all local and state agencies that implement regulatory programs, it is important that a consistent definition be developed for use in the various environmental programs, particularly those under the jurisdiction of the Department of Environmental Protection.

Currently, Title 5 defines "lot" as -

"An area of land in one ownership, with definite boundaries."

This definition places a great deal of emphasis on the word "ownership", which, coincidentally, is not defined within the text of the code. The regulations do, however, include a definition of "owner". "Owner" is defined as -

> "Every person who alone, or jointly, or severally with others (a) has legal title to any dwelling or dwelling unit, or (b) has care, charge, or control of any dwelling or dwelling unit as agent, executor, executrix, administrator, administratrix, trustee, lessee, or guardian of the estate of the holder of legal title. Each such person thus representing the holder of legal title is bound to comply with the provisions of these minimum standards as if he were the owner. Owner also means every person who operates a rooming house."

Many have argued that the Title 5 definitions for "lot" and "owner" are intentionally vague in order to allow the Department discretionary powers in selecting projects in which the Department will actively participate in the decision making process. Actually, the vagueness is embodied in the general requirements section of the regulations (310 CMR 15.01), which state -

> "(1) Disposal Works Construction Permit No individual sewage disposal system or other means of sewage disposal shall be located, constructed, altered, repaired, or installed .... until a permit for its location, construction, alteration, repair, or installation shall have been issued by the board of health. A permit shall not be issued for any system of individual sewage disposal when the total volume of the sewage to be disposed on any lot [emphasis added] is in excess of 15,000 gallons per day, or where sewage treatment facilities are proposed on the lot to be served, until the plans for such system have been approved by the Massachusetts Department of Environmental [Protection] in accordance with G.L. c. 111, s. 17. Where sewage flows on a lot exceed 15,000 gallons per day, the Department of Environmental [Protection] may require additional treatment of the waste prior to its disposal to the ground."

Beginning in October 1983, when the Department promulgated the Ground Water Discharge Permit Regulations under 314 CMR 5.00, the definition of "lot" became an even more crucial element in determining a project's fate. Under these regulations, discharges in excess of 15,000 gallons per day on a single lot can only be approved by the Department in instances where the applicant makes a clear demonstration that the proposed treatment and disposal system is capable of complying with very stringent ground water quality standards.

Applicants have often been accused of trying to avoid the more stringent effluent standards by dividing large projects into small segments thereby assuring that the sewage discharge does not exceed 15,000 gallons per day on any one parcel of land. Sometimes, as in the case of condominiums, the smaller projects are combined for marketing or other logistical purposes after the conventional septic tank/soil absorption systems for the various phases are separately approved and constructed. This has led to a number of cases in which litigation has been pursued by the Department in order to invoke higher treatment standards on particular projects.

The Department has argued successfully that in the case of a condominium, a "lot" means the total land area that is subject to the master deed; not the individual parcels on which the various phases of the project are completed. A great deal of time and effort has been expended by the Commonwealth in upholding this interpretation. Yet, to this day, there are instances where the regulations are skirted, sometimes intentionally other times innocently by developers who legally subdivide larger parcels into smaller lots.

There are two underlying principles associated with the current 15,000 gallon per day threshold. These are: (1) larger systems have inherent problems and therefore must be held to a higher standard than smaller systems; and, (2) the Department has generally preferred sewage treatment facilities be installed in place of conventional septic tank/soil absorption systems for large installations because sufficient operational and maintenance safeguards can be employed without causing an undue economic burden on the user group. This bias toward higher level treatment systems is deeply implanted in the Ground Water Discharge Permit Program but only flaccidly mentioned in Title 5.

The idea of a fixed limitation of 15,000 gallons per day on any one "lot" does not account for varying lot sizes and soil conditions. Perhaps it would be better to institute a density formula and require additional treatment whenever the discharge exceeds the prescribed limit. A second threshold could then be established for any individual system that is larger than a specified size. This will allow the Department to focus attention on specific projects where sewage disposal is a real concern and to avoid projects involving relatively low density development on large parcels of land. If in fact the Department favors sewage treatment systems over the conventional septic tank/soil absorption system, a clear statement to that effect should be included in Title 5.

The Department has several opportunities to effect a change in the review thresholds section of the regulations. Attention could be focused on "projects" rather than "lots" so that it is clearly understood that the review threshold is triggered by any proposed development involving contiguous land under the ownership and/or control of the project proponent. A system similar to the segmentation rule under the MEPA Regulations could be utilized (301 CMR 11.16) as a model for a regulatory amendment.

In determining review threshold status and conducting project reviews, the proposed project in its entirety, including future expansions, should be considered. Separate phases or segments should be reviewed collectively. In determining whether two or more development schemes are in fact one project, they should be scrutinized for related legal, financial or environmental circumstances suggesting the individual elements should be viewed as one. Consideration should be given to the time interval between construction phases, whether the individual elements taken together constitute a common plan or scheme, and whether environmental impacts can be minimized by considering the project as a whole rather than its individual elements. Ownership by different entities does not necessarily indicate that two developments are separate.

The term "lot" itself could be redefined to clearly include all land under the control of the project proponent whether it is described in a single deed or multiple deeds. Contiguous land in common ownership could be considered one "lot" for purposes of the regulations. Multiple developments controlled by a single master deed, or other legal instrument, which allows for common ownership or use of certain common facilities by the developments could be considered one lot.

Perhaps the best way to address the Department of Environmental Protection's concerns regarding the establishment of review thresholds is a multi-faceted approach which includes a combination of the words "lot" and "project". Modifications to the current regulatory scheme could be made such that practical consideration is given to the two major factors of concern, the density of the project and the size of individual systems.

25.1.2 "BEDROOM"

Another word that has been the cause of great confusion is "bedroom". The term plays a critical role in the sizing of sewage disposal systems serving residential establishments. Since the term is not currently defined in Title 5, the Department of Environmental Protection constantly receives requests for clarification in connection with what constitutes a "bedroom" for sewage flow determinations.

Various unofficial interpretations of the word have been offered by Department employees over the years. Unfortunately, this has not resulted in a uniform standard for use in every instance. The most frequently quoted definition of bedroom is as follows -

> "Any portion of a dwelling which is so designed as to furnish the minimum isolation necessary for use as a sleeping area and includes, but is not limited to, bedroom, den, study, sewing room, living room, unfinished attic meeting Article II of the State Sanitary Code, sleeping loft, or enclosed porch, but does not include kitchen, bathroom, dining room, hall, or unfinished cellar."

As one might expect, even this definition has its problems. Individuals proposing to construct homes in the higher price category, which include multiple rooms such as studies and dens clearly not intended for use as bedrooms, are often forced to construct septic systems that are much larger than what is needed to effectively dispose of the sewage generated at the residence. On the other hand, individuals proposing to construct lower price housing units often underestimate the number of rooms that will actually be used as bedrooms. Many two and three bedroom units have a higher number of occupants than do four and five bedroom units.

Since the basis of design for septic systems serving housing units is dependent on the number of rooms identified as bedrooms, the Department needs to adopt a uniform definition for the word "bedroom" to assure that appropriately sized systems are constructed. In developing a definition the Department needs to give consideration to all types of housing so that the definition accurately portrays the occupancy level of the dwelling. Additionally, consideration should be given to adopting minimum design flows for residential housing.

25.1.3 "WATERCOURSE"

Watercourse is defined in Title 5 as -

> "Any natural or man-made stream, pond, lake, wetland, coastal wetland, swamp, or other body of water and shall include wet meadows, marshes, swamps, bogs, and areas where ground water, flowing or standing surface water or ice provide a significant part of the supporting substrate for a plant community for at least five months of the year.
>
> Swamp, shall mean areas where ground water is at or near the surface of the ground for a significant part of the growing season or where runoff water from surface drainage frequently collects above the soil surface.
>
> Coastal Wetland shall mean any bank, marsh, swamp, flat, or other lowland subject to tidal action."

While the definition appears to be straightforward and relatively consistent with definitions in other programs, a problem develops in the use of the term in combination with applying the setback distance requirements contained in 310 CMR 15.03(7). Footnote 2 indicates that separational distances shall be measured from the average of the mean annual flood elevation in inland areas and from mean high water in coastal areas. This approach is a cause of confusion as it differs in many respects from the other established environmental protection programs, most notably the Wetland Protection Act Regulations.

The Wetland Protection Act Regulations include a presumption concerning Title 5 which provides a excellent cross reference. However, these regulations are still inconsistent in a few areas.

The presumption contained in 310 CMR 10.03 states in part -

> "The setback distance specified above shall be determined by measuring from the boundary of the area in question, from the contour at the mean annual flood elevation in inland areas in inland areas, or from the top of a coastal bank or the contour at the highest spring tide elevation in coastal areas, whichever is further from the water body." [emphasis added]

Although this presumption includes an attempt to clarify some of the ambiguities in the specified separation distances from watercourses contained in Title 5, it has for the most part only added to the confusion. The presumption, which applies only to impacts of the discharge from a sewage disposal system, and not to the impacts from constructing that system, includes some of the language in section 15.03 (7) of Title 5 but then expands on this by including a measurement from the top of a coastal bank. This of course is different than Title 5, which specifies that the measurements should be taken from the water line.

An additional area of confusion results in the differences in terminology of the Wetland Protection Act Regulations (310 CMR 10.00) and Title 5. The Wetland Protection Act Regulations (310 CMR 10.00) defines the boundary of resource areas in a number of ways including the use of vegetation, while Title 5 uses only the water line. The Department should seriously consider adopting the definitions contained in the Wetland Protection Act Regulations (310 CMR 10.00) as the basis of measurement for the various setback distance from watercourse. This small change will go a long way in assuring consistent application of both sets of regulations.

25.1.4 "EMERGENCY REPAIR"

In general, Title 5 prohibits work to be performed under a variance until either the Department has approved the variance or thirty days have elapsed since the Department's receipt of notice of the board of health's grant of the variance. If, however, the board of health or the Department certifies in writing that an emergency exists, then work may be performed under the emergency variance provision contained in 310 CMR 15.20. Further, a variance may be issued for the repair of an existing sewage disposal system without the requirement of notification of all abutters by the applicant. The Department is often asked to render an opinion as to whether certain projects should be considered under the emergency repair provisions.

To reduce confusion, and to avoid situations where a board of health takes an action which the Department feels is inappropriate, the Code should be expanded to include a definition of "emergency" and "repair". The definition of repair will become a greater concern should alternative design standards be adopted for upgrading existing sewage disposal systems as opposed to standards for constructing new systems.

25.1.5 "MAXIMUM GROUND WATER ELEVATION"

Probably the single most important aspect in the design of a subsurface sewage disposal system is the ability to accurately delineate the level at which ground water is expected to rise under severe conditions. High ground water is one of the major causes of septic system failure. Unexpectedly high ground water levels may flood septic systems, causing sewage to back-up in the system, break-out at the land surface, produce obnoxious odors, and devalue property. Despite the importance that the ground water elevation plays, Title 5 includes a rather imprecise definition of Maximum Ground Water Elevation. Title 5 states -

> "Maximum ground water elevation means the height of the ground water table when it is at its maximum level of elevation. This level is usually reached during the months of December through April, and allowances should be made therefore at other times of the year." (310 CMR 15.01)

Ground water elevations can fluctuate several feet in response to the changing seasons and periods of unusual weather conditions. A single water elevation reading, will rarely represent the extreme ground water level even when such testing occurs during the early spring.

The present definition of maximum ground water elevation would have to be modified to reflect the recommended use of various soil science and hydrogeologic principles.

25.1.6 "FAILURE"

It is well documented that the average septic system exhibits a finite useful life during which, if properly designed, constructed and maintained, it adequately performs contaminant removal and waste minimization functions. As septic systems fail, they introduce new contaminant pathways promoting the onset of aesthetic and health problems; increasing risk of the transmission of disease and degradation of the environment. The purpose of sanitary regulations is to ensure that a minimum acceptable degree of wastewater treatment is provided throughout the useful life of the system. Recognizing and promptly correcting system failures, or the risk of failure, minimizes the chance for exposure, thereby protecting the population and the environment from contamination by improperly treated septic system wastes. A definition of system failure and a procedure to discover, or to predict an elevated risk of system failure, must be developed and implemented.

Causes of System Failure

Failure of a septic system occurs whenever the system, or any component of the system, ceases to perform the intended function of adequately treating and conveying to the subsurface "treated" septic system wastes in accordance with the minimum sanitary standards imposed by Title 5. A seemingly simple system malfunction can result in significant undetected degradation, or accelerated deterioration, of additional system components. Therefore, it is extremely important that septic systems receive routine maintenance and inspection.

Septic system failure is generally considered to have occurred when the soil absorption system either fails to accept wastewater or fails to adequately treat the wastewater prior to discharge to the ground water. However, a failure of any portion of the septic system can lead to accelerated failure of the soil absorption system. Therefore, inspection of the entire system is necessary for early detection of problems which can be easily corrected to prolong the life of the soil absorption system.

One method of insuring that routine inspections of septic systems are completed on a regular timetable would be to include in Title 5 a requirement that inspections be conducted on a specified timeframe by a qualified or licensed inspector. A report of each inspection would be filed with the board of health. Ideally the inspection would be conducted by a licensed septage hauler who would pump the septic tank, if necessary during the inspection. An inspection could be as simple as insuring that the septic tank is not surcharged, that the inlet and outlet tees are in place, and that there is no ponding or surface breakout in the area of the soil absorption system.

Examples of System Component Problems

The following are examples of system component problems which, if not addressed could lead to system failure and public health or environmental concerns:

a. Building Sewer Break or Blockage - A break or block in a building sewer line could lead to a sewage back-up into the building being served. Generally this type of problem is easy to correct and because of the nuisance created in the building, usually receives immediate attention.

b. Septic Tank Failures - Septic tank failures may result from a number of causes including inadequate sludge, scum and "clarified" effluent storage volumes (too small a tank or too large a load), improper installation or breakage of sanitary tees, and improper maintenance leading to solids washout (inadequate pumping frequency). Proper function of the septic tank is necessary to promote solids separation, containment and organic degradation and to ensure that the soil absorption system receives a "clarified" liquid effluent, devoid of excess solids, scum and non-degradable wastes.

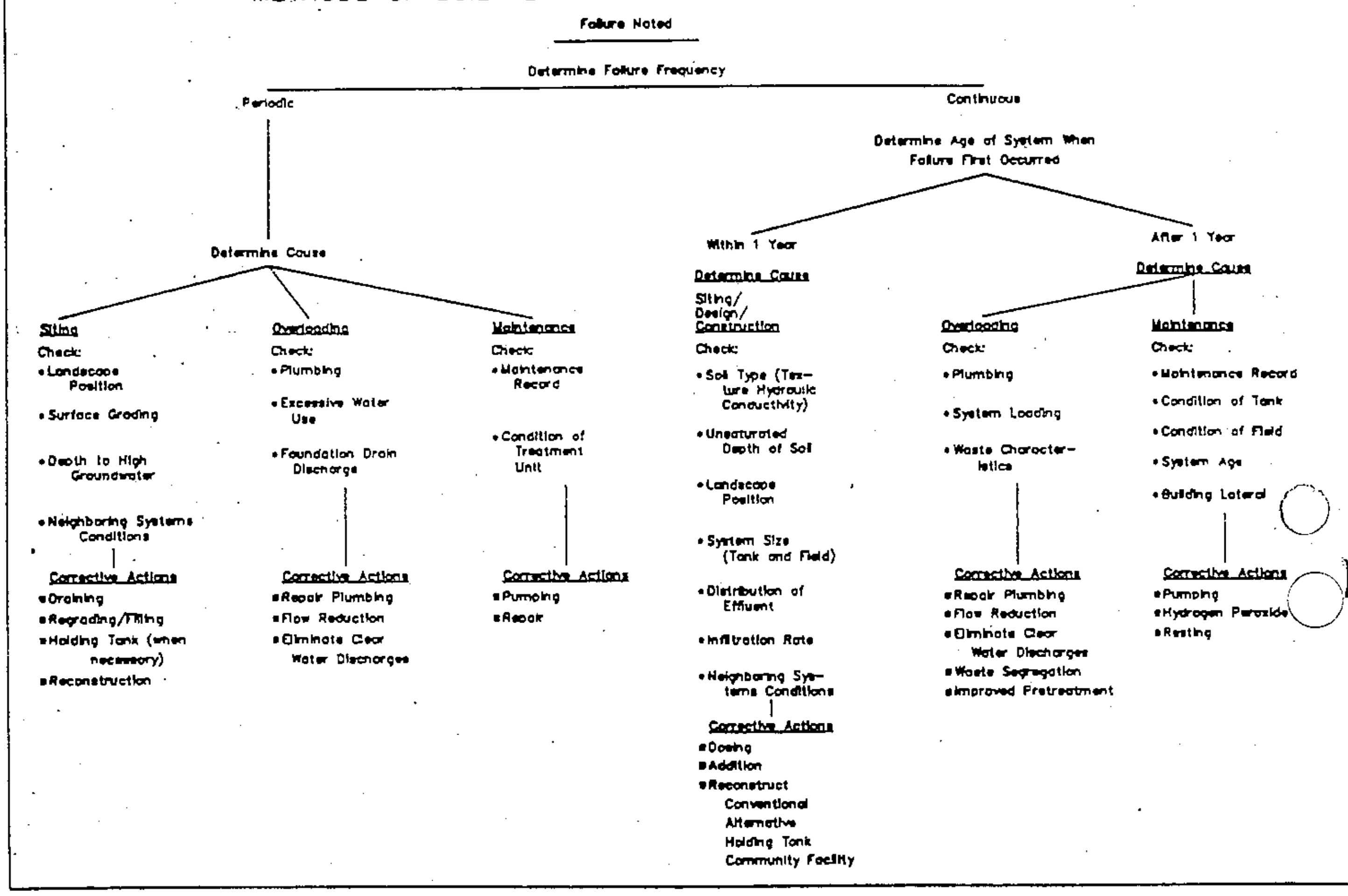
   Many soil absorption system failures can be attributed to failure of the septic tank. Solids washout increases the organic load to the soil absorption system and may result in increased biomat depth and density. The increased biomat may result in premature absorption system clogging and decreased infiltrative capacity, thereby increasing the depth of ponding and accelerating the aging process.

   Septic tanks should be inspected and pumped every one to two years depending on use, age, size and configuration. Tanks which require more frequent pumping, (more than once a year) may be an early indication of soil absorption system failure. If during the pumping of a septic tank, repairs to the inlet or outlet baffles are required, or there is evidence of elevated flow or solids washout, the soil absorption system should be inspected.

c. Soil Absorption System Failure - The soil absorption system provides the bulk of the waste strength reduction of the septic system and is responsible for the highest incidence of reported system failures. Preservation of the infiltrative and purification capacity of the soil absorption system is the primary justification for requiring a mandatory inspection program with inspection reports submitted to the board of health.

   Failure of a soil absorption system should be considered to have occurred whenever there is evidence of surface ponding or surface water contamination, odors, or evidence of damp or wet soils above the soil absorption system.

FIGURE 25.1.6.1
METHODS OF SOIL ABSORPTION FIELD REHABILITATION



Ineffective treatment resulting in ground water contamination can occur as the result of the development of an inadequate unsaturated soil treatment zone (increased loading; infiltration of surface, perched or confined water; ground water rise into the treatment zone or mound formation), the formation of preferential pathways for pollutant transport, inadequate or non-uniform biomat formation, inconsistent waste distribution and application, or the disposal of improper, non-degradable, or hazardous materials. Soil absorption system failure will be considered to have occurred whenever there is evidence of, or just cause to believe, that contamination emanating from a septic system is causing degradation of the subsurface ground water or a surface water.

25.2 Conclusions and Recommendations

A review of the existing definitions contained in Title 5 and those contained in the regulations of other states was conducted in order to develop modifications and revisions to present definitions and to add new ones necessary to implement the recommended changes to Title 5. The following revised definitions are suggested to reduce some of the misinterpretations which currently exist and to add clarity to the regulations:

Bedroom - A room providing privacy, intended primarily for sleeping and consisting of all of the following:

a. a floor space of no less than 70 square feet;

b. a ceiling height of no less than 7'- 6" (mobile homes and older homes may have ceiling heights less than 7'- 6");

c. an electrical service, heat and ventilation; and,

d. a window.

Living rooms, dining rooms, kitchens, halls, bathrooms, unfinished cellars and unheated storage areas over garages are not considered bedrooms. The total number of bedrooms for single family residential dwellings may be calculated by dividing the total number of rooms (not including bathrooms, hallways, unfinished cellars and unheated storage areas) by two then rounding down to the next lowest whole number.

Cesspool - An excavation into which raw sewage is discharged and which allows the liquid portion of the sewage to seep into the surrounding soil while retaining the solids or organic material.

Deep Observation Hole - An open pit dug to a depth of at least four (4) feet below the bottom of a proposed leaching facility used to examine the soil characteristics and determine the mean annual high ground water table.

Impervious Material - Geologic substances having a percolation rate greater than 60 minutes per inch including bedrock, ledge, unconsolidated material and organic matter.

Lot - A parcel or parcels of land under the control of one person intended for the building of a dwelling(s), building(s) or development(s).

Contiguous land in common ownership shall be considered one "lot" for the purpose of these regulations. Further, a parcel of land which has been subdivided shall still be considered one "lot" as long as a common ownership of the subdivided land exists.

Multiple developments controlled by a single master deed, or other legal instrument, which allows for common ownership or use of certain common facilities by the developments, will be considered one "lot".

Mean Annual High Ground Water Elevation - The level of the ground water table which is not exceeded eight out of ten years. This level commonly, but not always, is reached during the months of December through April.

Percolation Test - A subsurface soil test taken to determine the water absorption capacity of the soil.

Project - Any construction activity involving the installation or repair of a subsurface sewage disposal system(s) for which a permit or approval is required pursuant to these regulations.

Watercourse - Any natural or man-made river, stream, pond or lake and/or any freshwater or coastal wetland as defined in M.G.L. c.131 s.40 "The Wetlands Protection Act".

The following proposed definitions should provide clarification of the Department's policies:

Bedrock - The solid rock exposed at the surface or overlain by unconsolidated gravel, sands and clays. This definition applies to all portions of various bedrock units, including any weathered or saprolitic components thereof. In Massachusetts, bedrock types are defined and their areal extent determined by the "Bedrock Geologic Map of Massachusetts" published by the Department of Public Works (1983).

Dwelling - Any structure or building, or any portion thereof which is used, intended, or designed to be occupied for human habitation purposes, including but not limited to houses, hotels, motels, apartments and condominiums.

Emergency Repair - A repair of a sewage disposal facility where immediate action is necessary to prevent sewage backup into a dwelling, surface breakout of sewage, or where an imminent danger to public health exists.

Failed Septic System - A failed septic system is one which does not adequately treat and dispose of sewage as intended so as to cause a nuisance or threat to public health and/or the environment as evidenced by, but not limited to, any of the following conditions:

1. the failure to properly accept sewage discharges resulting in a back up of sewage into the structure served by the private sewage system;

2. the discharge of untreated or incompletely treated sewage or septic tank effluent directly or indirectly to the surface of the ground, to a drain, or to any waters of the Commonwealth;

3. the introduction of untreated or incompletely treated sewage or septic tank effluent directly or indirectly into zones of saturation which adversely affects the operation of the sewage system, or results in impairment of the designated use as determined by the prevailing ground water classification;

4. any discharge which results in effluent rising to the surface resulting in ponding, surface breakout or damp soils above the leaching structure; or,

5. the onset of a circumstance in which the on-site disposal system does not comply with the standards set by this code in a way which immediately threatens the public health or safety, threatens to degrade the quality of the environment, causes or threatens to cause damage to property or otherwise creates a nuisance.

Family Mobile Home Park - A parcel of land upon which two (2) or more mobile homes are located on a continual or seasonal non-recreational basis, regardless of whether a charge is made thereof.

Maintenance - The cleaning out, on a regular basis, of accumulated liquid, scum or sludge from any septic tank, building sewer or any other component of a septic system and the servicing of any mechanical equipment.

Mobile Home - A transportable structure on a chassis and designed to be used with or without a permanent foundation as a dwelling unit. The phrase "without a permanent foundation" indicates that the support system is constructed with the intent that the mobile home may be moved from time to time.

Repair - Modifications or additions to a failing system which are necessary to allow the system to function properly, or must be made to eliminate a public health or pollution hazard.

Retirement Mobile Home Park - A parcel of land upon which two or more mobile homes, restricted to use by adults over the age fifty five years of age, are located on a continual or seasonal non-recreational basis, regardless of whether a charge is made thereof.

CHAPTER 26

MAINTENANCE PROGRAMS

When a septic system does not function properly it places the public health and the environment at risk. An effective way to minimize this risk is to develop and implement a rigorous management program geared toward ensuring that septic systems are properly operated and maintained.

There are a variety of means by which governmental agencies can ensure proper operation and maintenance of septic systems, each with its own advantages and disadvantages. Generally, the greater protection against system failures and ground water contamination a program offers, the more costly the program is to implement.

This chapter of the report discusses several approaches for controlling septic system operation and maintenance. These range from very simple procedures that promote sound operation and maintenance through public education to complex processes which subscribe to a total management concept where a public agency acts as the management entity. The chapter begins with an examination of the need for requiring proper operation and maintenance of septic tank/soil absorption systems. It identifies the regulatory techniques available to compel the required upkeep, and then examines how different states and localities are dealing with the problem. Finally, some general suggestions that might be used to improve the existing regulatory program are offered, along with recommendations on enabling legislation necessary to grant the authority to impose these controls.

26.1 Literature Review

Improper site selection, poor design and construction practices, inappropriate operation, and infrequent or non-existent maintenance have all been given as reasons for the failure of septic systems (Stewart, 1976). Although there is little information available concerning the precise number, or percentage, of system failures directly attributable to improper care or use, few people will dispute the fact that many septic system failures are either caused or exacerbated by incorrect operation and maintenance practices.

Sound operating procedures are simply a matter of controlling the amount and types of substances allowed to enter the septic system. Septic tank/soil absorption systems are designed to handle a certain volume of flow and to treat a particular type of waste. If a system user is not aware of these limitations, and operates the system beyond its intended use, system failure and/or ground water contamination may result.

In addition to following the prescribed operation practices, septic tank/soil absorptions systems need routine maintenance. Even a well designed and properly operated system will eventually fail if it is not suitably maintained. Septic tanks should be cleaned before too much sludge or scum (septage) is allowed to accumulate. If either the sludge or the scum approaches too closely to the bottom of the outlet device, particulate matter will be scoured into the leaching facility causing accelerated clogging of the soil absorption system.

Maintenance involves the monitoring, pumping, and hauling of sludge and scum from the septic tank to an approved disposal facility. Most tanks require pumping every one to two years. Frequent pumping is generally recommended to avoid excessive sludge compaction which makes complete sludge removal difficult.

Septic system additives, some of which include solvents, are sometimes used by homeowners and owners of commercial systems to minimize the amount of sludge and scum within the septic tank. Such products are typically ineffective and do not reduce the need for regular tank pumping. Even if the additives were effective in diminishing the sludge and scum build-up within the tank, they have the potential of creating more serious problems, including increasing both the solids load imparted upon the soil absorption system and the possibility of ground water contamination.

In instances where innovative or alternative systems are utilized, operation and maintenance factors become even more critical due to the increased degree of complexity of these types of systems. Most innovative and alternative systems employ some sort of mechanical device such as pumps or aerators which are dependent on regular maintenance. Unmaintained, these systems can pose an even higher danger of failure than a conventional septic tank/soil absorption system (Stewart, 1976).

Many homeowners are evidently unaware of the procedures for, and the importance of, proper septic system operation and maintenance. Huang (1983) reports that ninety percent of the people he interviewed stated that they employ proper maintenance procedures, but after further questioning only about half even understood the function of the system. In another case, it was reported that residents were not even cognizant of the fact that they have a septic system; believing instead that their dwelling was connected to a municipal sewerage system (USEPA, 198b). Therefore, septic system codes that merely recommend proper use are grossly ineffective in addressing the actual operation and maintenance requirements of the system (USEPA, 1986b).

Title 5 of the State Environmental Code falls within this category. These regulations simply require sewage disposal works to be maintained in a manner that will not create objectionable conditions or cause the works to become a source of pollution to any of the waters of the Commonwealth (310 CMR 15.02(20)). Although the code does not specify a maintenance standard, it is generally accepted that the septic tank should be inspected every one to two years and pumped whenever the combined depth of the sludge and scum equals one-third of the effective depth of the tank. This rudimentary standard is often ignored since there is no regulatory oversight or enforcement.

All too often the septic tank/soil absorption system is viewed by the owner with an out-of-sight, out-of-mind attitude. Winneberger (1974) suggests that this neglect by system owners may be due in part to the tolerance of septic systems to function for up to several years without any maintenance, and the fact that system design is not conducive to maintenance since it is buried and not visible.

Fundamental to the success of any septic system maintenance program is the satisfaction of two underlying premises. First, the location of the system must be known. This can be accomplished by requiring the actual location of the system be shown in adequate detail on a drawing of the lot where the system is constructed. The location should be referenced to the structure served, or other permanent fixture that can be used as a benchmark to allow ease of location after the system is backfilled. A filing and retrieval system should also be established to guarantee that this information about the system's location is available whenever future maintenance is to be performed.

The second element of a successful program is to provide a method of assuring that each system will be inspected regularly and maintenance performed when needed. This may be accomplished in one of several ways. Maintenance permit programs requiring system owners to periodically certify that a licensed septic maintenance firm has inspected, and if necessary pumped the septic tank, have become popular (Stewart, 1976). Other possible approaches include:

- educating the public on the needs and benefits of proper operation and maintenance;
- requiring a guarantee of permanent maintenance as a prerequisite to issuing a certificate of compliance;
- conducting periodic sanitary surveys to identify failing or inadequately designed septic systems;
- requiring pre-sale inspections for real estate transfers of ownership;
- requiring certification that the septic system is functioning properly prior to mortgage approvals; and,
- requiring governmental ownership of septic systems, especially the large or innovative systems.

Experience has indicated that the average citizen can not always be relied upon to perform the necessary maintenance of individual septic systems unless encouraged through incentives or threatened with sanctions. A malfunctioning system may present a health hazard, degrade the quality of the local ground or surface water and affect the value of neighboring property. In some cases this may not be enough of an annoyance to the homeowner at fault to cause him to remediate the failure (Robertson et al., 1974).

Since the general public has an interest in avoiding the presence of poorly functioning septic systems, consideration needs to be given to mechanisms by which adequate preventative maintenance might be enforced against flagrant violators. Measures for bolstering compliance with the program's requirements and prohibitions, including providing financial incentives and the imposition of penalties as sanctions, need to be evaluated as well.

26.1.1 Public Education

Septic system maintenance basically involves pumping the accumulated septage from the septic tank every one to two years. Since such service is an important part of protecting one's investment, theoretically no additional incentive should be necessary to have this relatively inexpensive work performed on a routine basis. In actuality however, this simple maintenance procedure is frequently neglected by the average citizen.

The Wisconsin Department of Health and Social Services surveyed septic system owners around eight lakes in the state of Wisconsin and found that there was an almost complete lack of servicing of the systems. They attributed this lack of servicing to the property owners' lack of knowledge concerning septic systems, many of whom could not even identify the location of their sewage disposal system on their lot (Wirth & Hill, 1967).

It may be that public education of the benefits to proper operation and maintenance is all that is necessary to effect compliance with the current septic system standards. This could involve the mailing of pamphlets reminding septic system owners of the importance of proper operation and maintenance as well as seminars and public service advertisements. Septic system users could be encouraged to follow sound operating procedures to ensure that their systems continue to function properly saving them the expense of repairing a failed system.

Guidelines for proper septic system operations could include the following reminders:

- DO NOT OVERLOAD THE SEPTIC SYSTEM.
  Septic systems are designed for a specified number of users and waste flow. If the number of users increases, the volume of waste flow will also increase and the septic system may eventually become overloaded and fail.

- DISPOSE ONLY DOMESTIC WASTE IN A SEPTIC SYSTEM.
  Standard septic systems are designed to handle domestic sewage from showers, washing machines, toilets, and sinks. These systems are not able to treat and dispose of other wastes, such as drain cleaners, pesticides and synthetic chemicals, that will pass through the septic system and may contaminate ground water. Even household cleaning chemicals can damage the bacteria needed to treat and degrade wastes within the septic tank.

- DO NOT DISPOSE OF COOKING FATS OR GREASE.
Grease congeals and solidifies in the septic tank and inhibits the bacteria that break-down the wastes in the tank. Over time, the grease will accumulate and may eventually clog the inlet and/or outlet to the septic tank.

- DO NOT DISPOSE OF WASTES FROM WATER SOFTENERS.
Salt and brine residues from water softeners may slow down the bacterial action in the septic tank. These salts are discharged from the septic tank into the leaching facility where they may cause soil clogging and ground water contamination.

- DO NOT DISPOSE SOLID MATERIALS.
Prevention of improper disposal of solids into the drains or toilets is an important maintenance procedure. These materials, including diapers, sanitary napkins, plastics, and cigarette butts, are apt to clog the septic system piping causing back-ups in the plumbing.

- DO NOT USE GARBAGE GRINDERS.
Ground garbage can severely overload the septic system. Results of experiments show that the amount of organic matter in septic tanks may increase by as much as fifty percent due to garbage disposal use. This increase in organic matter can have a detrimental effect on the soil absorption system.

- DO NOT USE CLEANERS OR ADDITIVES.
A properly functioning septic system does not need additives or cleaners. When problems occur, the problem itself should be addressed rather than providing a short-term solution. Additives and cleaners do not eliminate the need for pumping and may cause more costly problems.

- HAVE THE SEPTIC SYSTEM INSPECTED REGULARLY.
Grease and sludge accumulations should be measured every one to two years to determine when pumping is necessary. The septic tank, particularly the inlet and outlet tees, should be checked for damage and repairs should be made before major problems occur. The distribution box should be checked for signs of solids carry-over and if excessive solids are found, appropriate repairs should be made to the septic tank. The soil absorption areas should be examined for sponginess or other signs of surface breakout.

- HAVE THE SEPTIC TANK PUMPED AS NECESSARY.
Septic tanks should be pumped regularly. Pumping every one to two years is recommended to avoid the build-up of a compacted sludge layer which makes removal extremely difficult.

26.1.2 Maintenance Permit

One way to promote routine septic system maintenance is by instituting a maintenance permit program whereby periodic inspections of each system would be required as a mandatory prerequisite to the issuance of an annual permit. This program could be run as a simple office matter, where the clerical staff would issue a permit upon receipt of a completed application and fee. Owners of newly installed systems could be issued the first permit along with the certificate of compliance after the final construction inspection by the approving authority.

The program would entail a simple ticker file which would be used by the clerk to mail a renewal application form to each system owner as a reminder that the present maintenance permit expires in sixty days. The septic system would have to be examined by a licensed inspector who would then sign the application form indicating that the system was inspected, and the necessary pumping or other maintenance performed. The completed application form together with a fee adequate to cover administrative expenses would be returned to the issuing agent by mail.

Enabling legislation making it unlawful to occupy a building served by a septic tank/soil absorption system without a valid maintenance permit for that system, would have to be promulgated prior to implementing a program of this sort. Whenever an owner fails to renew an expired permit, he would then be in violation of the statute.

Enforcement would merely require evidence that the building is being used or occupied without a valid permit. It would not be necessary to prove that the system was not inspected, was not maintained, or is not functioning adequately. The simplicity of this program should encourage expedient enforcement and prosecution of offenders.

Depending on the authority granted by the enabling legislation, violators could be ordered to arrange an inspection of their septic system by a certified inspector at their own expense and to pay a fine or penalty. Also depending on the wording of the enabling legislation, it may be possible to establish a dedicated account, whereby the fines and penalties which are collected from violators could be used to support no interest loans for septic system maintenance and/or repairs to those demonstrating a financial hardship.

26.1.3 Conditional Certificate of Compliance

An alternative to requiring maintenance permits might be to make the certificate of compliance conditioned upon the performance of adequate inspection and maintenance. Under this program, septic system owners would be obligated to perform maintenance as a condition of approval for the installation of a new septic system or repairs to an existing one.

Enabling legislation would have to be adopted to void the certificate of compliance if adequate maintenance is not performed upon the system and to make it unlawful to occupy or use a building served by a septic tank/soil absorption system with a voided certificate of compliance. This aspect of the certificate would have to be explained in detail to the system owner and all subsequent purchasers.

The primary advantages of a conditional certificate of compliance lies in the fact that only slight modifications to the existing process would be required. Furthermore, additional staff would not be needed to implement the program. As a result, it may be easier to gain the necessary political acceptance of this program over one that requires the enactment a completely new regulatory process.

The proof of a violation under this program would be more difficult than that under a maintenance permit program since it would require producing evidence that the system was not adequately maintained. Additionally, this program would only apply prospectively to new systems installed after the date of the enactment of the program. This may act to discourage owners of existing systems to perform necessary upgrades or repairs.

26.1.4 Sanitary Surveys

Detection of the failing septic system is one of the most important aspects of any enforcement action against owners of problem systems. Inadequate operation of a particular system will frequently only be detected by the system users or their neighbors. The present regulatory program relies upon the concern of these individuals to either correct or report system failures. This procedure has proven to be relatively ineffective since most individuals are willing to put up with the inconvenience rather than face the potentially high cost of repairs.

Failures are usually made apparent by the appearance of, or odors from, partially treated effluent at the ground surface above the septic tank or soil absorption area. Less visible, but even more dangerous, is the contamination of nearby wells which may result from the disposal of inappropriate materials in the septic systems.

Legislation could be passed to grant authority and funding to state, regional, or local agencies to perform sanitary surveys to detect and identify failing systems. This would require a large commitment in terms of staff and resources; but this could be justified as surveys are effectual in determining which existing systems are failing.

Although this program would be directed toward isolating failed systems, it would also encourage proper operation and maintenance due to the severe consequences associated with the discovery of a problem system. Code violations could be recorded as an encumbrance on the title of the property. This would not only put the current owner on notice, but will have the effect of giving notice to potential buyers that sanitary violations or a failing system exists. This may also have the effect of lowering the price of the property since the seller does not have a clear title.

The regulatory agency may also be given the authority to directly abate or correct violations located on private property. The enabling legislation in this instance should provide that the cost of the work may be added as a lien on the lands upon which the violation occurred.

Retaining inspectors may be a financial burden to governmental agencies, especially local governments. Inspectors may be hired as full-time staff, or paid a stipend each time they perform an inspection. In some instances jurisdictions could pool their resources region-wide and hire a consultant to work for several municipalities or the county. In either case the cost for these services should be equably distributed to those who benefit from the program.

26.1.5 Real Estate Transfer Inspections

Requiring inspections of septic systems prior to the sale of property may be used as an alternative to the sanitary surveys by governmental officials (Steinbeck, 1984). Legislation could be passed to require either the correction of all violations before permitting a sale, or that the new owner would have a specified time period to effect the repairs before an encumbrance is placed on the title.

This would reduce the governmental role in policing individual septic systems which may be viewed an abuse of authority. However, unlike the sanitary surveys, this program would only identify problems on property subject to sale. Other code violations would continue uncorrected for extended periods should the property owner chose not to deal with them directly.

26.1.6 Certifications for Mortgage Approvals

Legislation could be passed requiring lenders to solicit a mortgage survey as part of the loan approval process for property involving on-site sewage disposal. These mortgage surveys, which would apply to residential and commercial mortgages, would require verification that a recent inspection of the sewage disposal system was performed by a licensed inspector, that the system was pumped, and any improvements needed to bring the system up to standards were performed.

26.1.7 Government Sponsored Inspections and Maintenance

Inspections of all septic tanks in a community may be conducted by the municipality or other governmental unit if issues such as right of access, authority to inspect, and liability for repairs are covered by ordinance or law. Communities may conduct septic tank pumping as a municipal service similar to trash pick-up or may contract for the services of a private maintenance firm (Robertson, et al., 1974; Stewart, 1976).

There could be various levels of governmental involvement under this scheme. For instance, the municipality may schedule the inspection and pumping directly with a septage hauler (and/or with Town forces) and simply notify the system owner when the unit will be serviced.

Alternatively, the municipality may select several firms and allow the system owner to chose the firm to perform the required maintenance and a time for the servicing. The inspector would then certify to the municipality that the septic system was in fact serviced. The municipality would keep track of the septic systems which have not been serviced within a specified time period; in which case, the municipality would make the arrangements for the septic tank to be serviced and assess an additional management fee on top of the typical user charges.

Under this program, the municipality would be assured a certain level of competency by licensing and certifying inspectors and pumpers. The organizational and administrative costs of such programs may be high. However, these costs can be minimized by requiring each owner to pay a fee for maintenance service.

26.1.8 Governmental Ownership

The concept of total management can be realized through the organization of special purpose agencies that provide all major functions related to on-site wastewater management. Under this program a governmental agency would, in effect, be the owner of the individual systems.

This agency could be an existing entity such as a town, county, or special purpose unit such as a wastewater management district. Legislation could be passed allowing the agency to impose a tax upon all property owners located in the district to pay for costs of construction, operation, maintenance, repair and replacement of septic systems and/or to impose a user charge to defray routine operation and maintenance expenses.

The district could employ trained personnel whose responsibility would be to site, design, construct, operate and maintain all on-site sewage disposal systems within its jurisdiction. Such a concept is similar to a water supply district which own and maintain quasi-public water distribution systems.

Implementation of management districts offer several advantages including:

- costly public sewers could be avoided by maintaining on-site systems in good working condition.
- if failures do occur, the district would be in a position to select the most cost effective, environmentally sound solution including the construction of new facilities at remote locations not just on-site repairs;
- more complex alternative systems could be used to serve homes in areas where soil and site conditions are unsuitable for conventional septic tank systems;
- adverse sites could be avoided by using nearby areas for joint systems to serve a cluster of homes;
- less costly facilities can be constructed because of economies of scale; and,
- unlike conventional sewers where areawide development is encouraged by the construction of a large central facility, growth can be controlled by providing service to only those areas of need.

In order to properly manage septic systems, the district would need powers even beyond those of the typical sewerage district. At a minimum, the district would need the authority to do the following (Otis, 1976):

- own, operate, manage and maintain all wastewater systems within its jurisdiction;
- enter into contracts to undertake debt obligations either by borrowing and/or by issuing bonds;
- raise revenue by fixing and collection user charges and levying special assessments and taxes;
- plan and control how and at what time wastewater facilities will be provided to those within its jurisdiction;
- make rules and regulations regarding the use of septic tank/soil absorption systems and provide enforcement through express statutory authority; and,
- meet the eligibility requirements for both loans and grants in aid of construction from both federal and state governments.

An overall wastewater management system of this sort was implemented in 1976 within Anne Arundel County, Maryland (Lombardo et al., 1987). All of the wastewater collection, treatment and disposal facilities, including individual on-site disposal systems, serving existing and future residents of the Mayo peninsula were placed under the direct control of the Anne Arundel County Department of Utilities (AACDU). AACDU was given the responsibility for the operation and maintenance of existing and future individual on-site disposal systems including providing periodic inspections, routine maintenance, septage pumping and disposal, and system rehabilitation and repair. Each property owner signed an easement granting AACDU the access needed to operate and maintain the systems and to allow the testing of individual water supply wells as necessary.

AACDU assesses user charges to owners of properties in its on-site service area based upon operation and maintenance of the systems plus future system replacement costs. A capital repair fund provides a self-sustaining utility fund which will be used to repair or replace problem on-site systems in the future (Lombardo et al., 1977).

A similar program has been implemented in the State of Illinois where legislation (P.A. 80-1371, Chapter 24, Parts 1401-1422) allows any corporate authority to develop wastewater disposal zones (USEPA, 1986b). Governing authorities have the right to impose a tax (or user fee) upon all property owners located in established zones to pay for the costs of construction, operation, and maintenance of septic systems.

26.2 State Regulations

Table 26.2.1 summarizes the maintenance standards of the other states. The majority of the states leave the responsibility of maintaining the sewage disposal system to the homeowner. Very few states suggest any minimum maintenance measures which the homeowner should follow. In fact, nineteen states do not even mention the maintenance of the septic tank/soil absorption system within their regulations.

Wisconsin provides one example of a maintenance program approach. Robertson et al. (1974) reports that Wisconsin is advocating regular inspections during the life of a septic tank/soil absorption system. In terms of maintenance, Wisconsin had been looking at four alternatives.

Homeowner Maintenance

Homeowner maintenance requires individuals to show proof that they have had their septic tank pumped at regular intervals during the life of the system.

Installer Maintenance

This type of maintenance requires a contract between the installer and the homeowner where maintenance would be provided on a regular basis.

County Franchise Maintenance

This type of maintenance program consists of the county subcontracting with a private company who would provide the required pumping and maintenance services for the systems in that county.

County Maintenance

In this system the county itself provides the required maintenance services for the systems in that county.

North Carolina provides for the proper operation and maintenance of large systems through a permit program which provides for the design and operation of the system in accordance with the design plans. Once an on-site system is placed into operation, the local health department must make routine inspections at least annually to determine if the system is performing satisfactorily and in conformance with the applicable permits. Also, monitoring reports are required to be routinely submitted to the local health department (Steinbeck, 1984).

Since the first step in providing the required maintenance to a septic tank/soil absorption system is knowing where the system is located, it is important that the location of the system is sufficiently plotted in relation to known benchmarks. At least seven states currently require that an "as-built" plan, showing the location of all components of the disposal system, be prepared and kept on the premises.

TABLE 26.2.1

MAINTENANCE PROGRAMS AND REQUIREMENTS

	AS-BUILT FILING REQUIRED	RECOMMENDED SEPTIC TANK INSPECTION FREQUENCY	RECOMMENDED PUMPING FREQUENCY	COMMENTS
Alabama				Owners responsibility
Alaska	Y			
Arkansas				(1)
Arizona		Annually(2)		
California		Every 6 Mos.	2-3 Yrs.	
Colorado				Owners Responsibility
Connecticut				(1)
Delaware				Owners Responsibility
Florida		Every 3 Yrs.(3)		
Georgia				Regulations unavailable
Hawaii	Y			
Idaho	Y(4)			
Illinois				(1)
Indiana				(1)
Iowa				(1)
Kansas				Regulations unavailable
Kentucky				Owners Responsibility
Louisiana				Regulations unavailable
Maine				(1)
Maryland				(1)
Massachusetts		Annually	Annually	
Michigan				Owners Responsibility
Minnesota		Regularly	As Required	
Mississippi				Owners Responsibility
Missouri		Annually	As Required	
Montana		Annually	As Required	
Nebraska		Regularly	As Required	
Nevada	Y(5)			
New Hampshire		Annually	As Required	
New Jersey				(1)
New Mexico				(1)
New York	Y(5)	Annually	3-5 Years	
North Carolina				Owners Responsibility
North Dakota			Every 3 years(6)	
Ohio				(1)
Oklahoma				(1)
Oregon				Owners Responsibility
Pennsylvania				(1)
Rhode Island	Y(5)			Owners Responsibility
South Carolina				(1)
South Dakota				(1)
Tennessee				Owners Responsibility
Texas			2-3 Years	
Utah				(1)
Vermont				(1)
Virginia				Regulations unavailable
Washington	Y(7)	Every 3 Years	As Required	
West Virginia				(1)
Wisconsin			As Required	(8)
Wyoming				(1)

(1) Maintenance requirements not discussed within regulations
(2) Inspection also required prior to sale of house.
(3) Yearly if garbage grinder is in use.
(4) If condition of construction permit.
(5) Must be kept on premises.
(6) More frequent if garbage grinder is used.
(7) Permanently filed by Health Authority.
(8) Counties may establish mandatory maintenance program to insure continued maintenance of private septic systems.

Washington's regulations specifically state that the as-built drawings shall be permanently filed by the local health officer. Washington's regulations also outline the role of the local health authority in the maintenance of individual on-site disposal systems. The health officers are responsible for developing a plan to inform homeowners of the proper operation and maintenance of their septic tank/soil absorption system. This plan includes notification every three years, at the time of sale of the property, and whenever the septic tank is inspected or pumped.

26.3 Local Regulations

At least three Cape towns, Barnstable, Brewster and Chatham, require pumping and an evaluation of the septic system whenever a property is sold. An additional off-shoot of this inspection is that some sort of upgrading may be required. There is no other evidence in the local regulations that any community requires any septic system maintenance prior to evidence of system failure.

26.4 Conclusions and Recommendations

There are many methods of promoting proper operation and maintenance of septic tank/soil absorption systems, each offering distinct advantages and drawbacks. We recommend that a combination of techniques be utilized instead of adopting a single method. This combined approach allows for a more comprehensive and adaptable program for meeting the states overall environmental objectives.

We believe that municipalities must be involved in developing their own programs which are tailored to the specific needs of their community. Large communities generally have a broader revenue base and therefore greater financial resources with which to undertake management options. Smaller communities may find it beneficial to rely on regional or county assistance. The state should set the basic framework for the management program and provide guidance to the cities and towns in establishing their individual management programs.

It has been noted that many owners do not know the location of their septic system. Obviously, this makes maintenance difficult, if not impossible. While some boards of health already require the filing of a plan of the finished septic tank/soil absorption system. To make sure that this standard is consistently implemented, we recommend that Title 5 be amended to require that each system owner file an "as-built" plan ofhis system, clearly referencing the location of the system components. Such a plan is invaluable when it becomes necessary to inspect or service the on-site system. A filing system which indexes these plans by street address should also be established by the boards of health so that the plans can be retrieved as needed.

We view public education as a critical component to our suggested program. Although maintenance functions can be monitored and enforced, the individual users must be trusted to properly operate the system. Septic system control programs are most effective when the public understands the relationship between ground water protection and proper septic system siting, design, installation, use and maintenance. Responsible property owners who are educated in proper waste disposal practices and maintenance practices and who are familiar with the consequences of system failures can make positive contributions to ensuring compliance. Education and outreach programs play an important role in septic system management and should be directed to wide audiences, including homeowners, and owners of commercial and industrial establishments.

We also urge that consideration be given to the adoption of a maintenance permit program to assure that all septic tank/soil absorption systems are checked by a certified inspector and that the septage is pumped when necessary. This would be akin to the automobile inspection program where registered motor vehicles are subject to annual safety and emissions testing by licensed service technicians. The homeowner would be mailed a maintenance permit application form and would be given sixty days to have a licensed pumper inspect and, if necessary, pump the septic tank. The pumper would sign one portion of the homeowner's permit application thereby certifying that the septic system was inspected and the required maintenance performed.

Perhaps the program could be phased in over several years beginning in those regions of the state where environmentally sensitive areas have been identified. New septic tank/soil absorption systems could be entered into the program immediately, while owners of existing systems would have a two to three year grace period to register their system with the municipal department responsible for implementing the program.

Legislation making it unlawful for any owner to occupy or use a building connected to a septic system without a valid maintenance permit for the system should be promulgated. The enabling legislation could also establish application fees, penalties for non-compliance, and provide the authority to order violators to take corrective action.

The state should establish a licensing procedure for inspectors that includes developing an exam, providing accompanying study materials, advertising, and notifying the applicant of the outcomes. The cost of these activities could be recovered through licensing, examination, and registration fees.

Sanctions to enforce the septic management permit program should include a combination of fines and corrective action requirements. Regulatory officials should have the authority to serve notices to property owners who own or operate septic systems that may damage the health of the general public or harm the environment. These notices should include a schedule for the property owner to take remedial action to upgrade or repair the septic system. If the repair deadline in the schedule is not met, the property owner should be subject to additional fines.

While establishing a program focusing on strict enforceable standards will help ensure protection of human health and the environment, in some instances the program may be so rigorous that it will overtax individual system owners not capable of implementing effective on-site solutions to their sewage disposal problems. Therefore, it may be necessary to establish wastewater management districts to deal with the existing septic system problems in certain areas. The management district could undertake the ownership of existing septic tank/soil absorption systems and construct new cluster systems for the repair of failed systems where on-site repair is not feasible.

The management district would build, or have built, the appropriate system or systems and provide the necessary maintenance. The cost of the systems would be assessed on an annual basis to the individual property owners based on actual operation and maintenance expenses, debt service and future replacement cost.

All the wastewater facilities serving both existing and future residents in the designated area will be under the direct control of the management district. The district would be responsible for performing periodic inspections, providing routine maintenance, arranging septage pumping and disposal and performing system rehabilitation and repairs.

The district will need to assume ownership of the individual on-site systems. These on-site septic systems could be acquired by gift, purchase, lease, or condemnation. Property owners will also have to grant an easement providing the management district access needed to fulfill its obligations.

CHAPTER 27

SEPTAGE MANAGEMENT

Individual subsurface sewage disposal systems have long been an effective means of disposing of sanitary sewage in areas where municipal sewerage systems are not accessible. There are approximately 600,000 of these individual systems currently operating in the Commonwealth of Massachusetts, with thousands more installed each year. Proper maintenance of on-site disposal systems requires periodic removal of residual scums, sludges and other accumulated solids. Finding cost effective, environmentally sound techniques for the disposal of these residuals has been a very troublesome and long neglected problem.

Several factors have played a role in encouraging the practice of improper septage disposal in Massachusetts and in making its regulation and management an extremely difficult task. Probably the largest single obstacle to proper septage management has been, and continues to be, the lack of readily available, approved disposal facilities. The widespread use of illegal septage disposal areas by many municipalities and several private concerns is a direct result of this lack of availability of adequate facilities to treat and dispose of septage.

Because septage disposal is typically handled by private enterprise, and therefore is profit oriented, it is difficult for private haulers using approved disposal facilities to compete in the marketplace. Because of the lower operating expenses and shorter hauling distances, the fees charged by septage haulers utilizing illegal areas are substantially lower than those charged by firms dumping at approved facilities. Consumer preference to pay the lowest possible price results in a reluctance to provide new treatment facilities and perpetuates the problem.

Inadequate resources allotted to regulatory agencies for inspections and enforcement of improper disposal facilities compounds this problem. The net result is a proliferation of septage disposal areas which provide little if any treatment, which are sited based on convenience, and which pose a serious threat to ground water quality. These sites are generally located in rural areas for which ground water serves as the primary source of public and private water supply.

With continued growth, particularly in areas without municipal sewerage systems, the Department of Environmental Protection is faced with the difficult problem of ensuring the availability of adequate waste disposal facilities. A delicate balance needs to be stricken between the competing needs for proper septage disposal facilities and maintaining adequate potable water supplies.

27.1 Literature Review

Septage is a mixture of the scum, sludge and grit which accumulates in an individual on-site sewage disposal system. It is a highly variable, pathogen rich, anaerobic slurry, commonly characterized by large amounts of grit and grease, an offensive odor, a high foaming potential, poor settling ability, and a high solids and organic content, often accompanied by an accumulation of heavy metals (Cooper and Rezek, 1977). Of recent interest are the various synthetic organic compounds now commonly found in septage.

Because the contents, loading rates, and holding times are highly variable from system to system, it is difficult to define a typical or mean value for the various chemical constituents and physical parameters of septage. This is illustrated in Table 27.1.1, which contains a listing of mean values compiled from several studies (USEPA, 1980b). As illustrated in this table, some parameters vary by almost two orders of magnitude.

The levels of heavy metals are generally low relative to municipal wastewater sludges, but exhibit a much broader range. Concentrations of pathogens and other bacterial indicator organisms are similar to those commonly found in primary wastewater sludge (Canter and Knox, 1985). Proper septage management is not only a matter of environmental protection but also a direct public health concern because of its potential to serve as a substrate for disease causing organisms.

27.1.1 Disposal Needs and Capacity

Periodic removal of the septage from the septic tank is necessary to maintain the system and to allow it to fulfill its primary function - the removal of settleable and floatable solids and the passing of partially clarified effluent to the soil absorption system. A crude estimate of the annual theoretical volume of domestic septage generated in Massachusetts is 268.7 million gallons per year. This is based on 30 percent of the households in the Commonwealth having septic systems, each with an average septic tank volume of 1,250 gallons (1,000 gallons minimum size and 1,500 gallons if there is a garbage grinder) that is pumped out every three years. Commercial, industrial and institutional facilities probably contribute another 10 percent, 26.9 million gallons per year, to this flow. Include the contents of grease traps, which is estimated to be approximately 2 percent of the septage flow, and the potential exists for the generation of nearly 300 million gallons of septage and grease per year.

The Department's preferred disposal method is co-treatment of the raw septage with sewage and other wastewater to reduce harmful chemical and bacteriological constituents, processing the remaining sludge by conventional dewatering and stabilization techniques and disposing of the residual cake by landfilling, incineration or alternative use such as compost. The choices for such co-treatment centers are traditionally limited due to physical, technical and economic reasons to the large (greater than 1 million gallon per day) wastewater treatment facilities, which are almost exclusively publicly owned treatment works.

There are 81 publicly owned treatment works in Massachusetts permitted to treat more than a million gallons per day. The cumulative capacity of these plants is approximately 1,110 million gallons per day (USEPA, 1987). Septage flows at these plants are generally limited to 1 to 2 percent of the total plant flow. Theoretically, this would yield a septage handling capacity ranging between 4 and 8 billion gallons per year. However, a 1986 summary by the Massachusetts Water Pollution Control Association indicates that there are only 51 plants currently receiving septage, and their annual intake is only 53.6 million gallons per year. Reasons for this large discrepancy include:

- lack of septage receiving facilities at some plants;
- plant locations beyond reasonable hauling distances;
- reluctance of towns to accept waste generated outside of their municipal boundaries;
- reluctance to accept such a highly organic waste for fear of plant upset and subsequent failure to meet effluent standards; and,
- most plants are already at or near (and some over) their design capacity.

Thus, there currently exists a shortfall of proper septage treatment capacity. Additionally, there are other wastes competing for this limited capacity such as small treatment plants sludges, industrial pretreatment facility sludges, industrial wastewater holding tank wastes and sewage tight tank wastes.

TABLE 27.1.1

CHARACTERISTICS OF DOMESTIC SEPTAGE

Parameter	Mean Values Reported in Several Studies mg/l
Total Solids	22,400; 11,600; 39,500
Total Volatile Solids	15,180; 8,170; 27,600
Suspended Solids	2,350; 9,500
Volatile Suspended Solids	1,770; 7,650
BOD	4,790; 5,890
COD	26,160; 19,500; 60,580
pH	6-7 (typical)
Alkalinity ($CaCO_3$)	610
TKN	410; 650;
NH_3-N	59; 100; 120
Total Phosphorus	190; 214
Grease	3,850; 9,560
Arsenic	0.16
Cadmium	0.1
Chromium	0.6
Copper	8.7
Iron	210
Mercury	0.02
Manganese	5.4
Nickel	0.4
Lead	2.0
Selenium	0.07
Zinc	9.7

Small wastewater treatment plants that handle domestic sanitary wastewater from apartment, condominium and office complexes generate a sludge that requires further treatment and disposal. Because of the inherent problems and high costs of handling sludge at small treatment facilities, sludges generated at these facilities are usually transported to large publicly owned treatment works for processing. This sludge is generally stored on-site with semi-annual removal to the selected disposal facility. There are approximately 200 small wastewater treatment plants presently on-line in Massachusetts generating a sludge disposal need of approximately 3 million gallons per year (Department of Environmental Protection, File Information). Industrial pretreatment sludge volumes are estimated at 2 million gallons per year.

Holding tanks for existing industrial wastewater discharges are generally approved for a limited time period until a sewer tie-in can be arranged or a treatment plant constructed. As more treatment plants come on-line and sewer lines are extended, this number should diminish. But, the recent concern for ground water quality and increased enforcement has increased the number of approvals for previously inadequate or untreated discharges. Statewide, there are currently 40 approved holding tanks accounting for a total flow of approximately 73 million gallons per year (Department of Environmental Protection, File Data).

When an existing, malfunctioning domestic septic system fails and cannot be rehabilitated due to site constraints, the sewage can be containerized in "tight tanks"; provided that no other feasible alternative exists. There are approximately 300 tight tanks in Massachusetts (Department of Environmental Protection, File Data). If it is assumed that each of these serves a three bedroom home, and flow is approximated at 110 gallons per day per bedroom (310 CMR 15.00), then the annual tight tank flow can be estimated at 36 million gallons per year.

When the combined total of all sludges and wastewaters trucked to disposal facilities across the state is examined, the magnitude of the septage problem becomes clear. There is a demonstrable need for additional treatment capacity. The current availability of co-treatment at publicly owned treatment works is limited, leaving a major shortfall in available treatment capacity. This shortfall can probably be accounted for by illegal disposal in lagoons and pits and by haulers that utilize out-of-state facilities.

Future population growth will push disposal capacity demands for septage from residential units to approximately 770 million gallons per year by the year 2000. It is estimated that there will be an increase in co-treatment capacity of approximately 272 million gallons per year at municipal wastewater treatment projects proposed for funding through the State Revolving Fund Program that are scheduled to be on line by the year 2000 (Department of Environmental Protection, File Information). This still leaves major shortfall in the future septage treatment needs.

27.1.2 Past Policies

Limited septage disposal capacity in Massachusetts is not a new revelation. There have been prior attempts at solving this problem. Unfortunately these attempts were far from successful, particularly when the effects on ground water from improper treatment and disposal are considered. The failure of these early stop-gap measures stem from a variety of causes, among which are poor planning, low funding, weak enforcement and a lack of commitment on the state and local levels.

The Department of Environmental Protection promulgated its first formal Septage Disposal Policy on December 11, 1981. This policy was formulated by a Septage Policy Team comprised of staff members from the various Divisions and regional offices within the Department. The policy states that "the preferred method of septage disposal in the Commonwealth is co-treatment of septage at wastewater treatment facilities for those communities within a reasonable hauling distance of a treatment plant capable of accepting their septage". Where co-treatment is not available, the Department considers proposals for "properly designed" septage treatment and disposal facilities of the following types:

- facilities for sole treatment of septage providing at least secondary treatment or its equivalent;
- anaerobic lagoons, land application and composting facilities consistent with the Department's regulations for each of these practices;
- utilization of selected wetlands as a treatment medium that are approved on a case by case basis; and,
- separate treatment technologies evaluated on an individual basis.

When the 1981 Septage Policy was released, 74 percent of the communities in Massachusetts could not meet the preferred co-treatment option (Department of Environmental Protection, File Information) because of the absence of a treatment plant in the town, lack of membership in a water pollution abatement district or the unwillingness of a neighboring town's treatment plant to accept their septage. Therefore, the immediate solution for most communities was the construction of anaerobic lagoons. Lagoons, which were instituted as a temporary method of septage disposal, provided communities with an economical alternative for their the immediate septage disposal needs.

The 1981 policy and guidelines expanded the design criteria of a previous memorandum and refined standards for siting and operation intended to ensure that septage facilities did not become a detriment to any waters of the Commonwealth. Specifications included a minimum of two anaerobic lagoons with inlet and outlet devices, followed by a series of percolation beds with defined hydraulic loading rates. In addition, there were requirements for bed slopes and grade, sizing, organic loading rates, detention times, the need for grease handling systems and a detailed hydrogeologic study. Although a hydrogeologic study has been specified since 1981, it was rarely performed before 1983. In fact, the major focus of any permit review or environmental notification was ensuring that certain setback requirements were met rather than developing an understanding of regional ground water flow.

There are still a number of these temporary lagoons in operation today. Provisions were made within the Guidelines for operators of lagoons and open pits to obtain Department approval in the form of a letter of interim status on a case by case basis. This provision was intended as a means of controlling illegal septage disposal sites and establishing compliance schedules for meeting the appropriate treatment standards. Some towns have yet to comply with these relaxed alternatives to co-treatment. Instead, they continue to provide nothing more than a simple hole in the ground or pit. These pits are oftentimes located at the town landfill and are used as disposal areas for septic tank and grease trap contents.

A statewide inventory of septage disposal practices completed in 1986 with the assistance of regional planning agencies identifies 56 operating municipal and private lagoon sites (Department of Environmental Protection, File Information). None of the sites had a valid discharge permit and only 10 had any form of Departmental approval for use on a temporary basis ("interim status"). All 56 sites were located in towns dependent on ground water as the primary (and in most cases the only) drinking water supply. Sixteen of these lagoons were located over the EPA designated "sole source aquifer" on Cape Cod. Most of the sites were located within municipal and community water supply zones of contribution. Hydrogeologic assessments have concluded that some leachate plumes attributable to septage areas are moving towards municipal wells (Rich, 1985, Gallagher and Nickerson, 1986); with arrival times at some wells on the order of a few to tens of years (Rich, 1985).

The 1981 Septage Policy and Guidelines were envisioned as a method of protecting public health while still providing an economical means for communities to modify their past uncontrolled practices. In retrospect, these guidelines failed on both accounts and have unfortunately created more problems than they have solved. Reasons for their failure can be attributed to several factors:

- inadequate enforcement by the Department;
- lack of commitment from communities to address septage problems until drinking water supplies are threatened or degraded;
- failure of local boards of health to enforce the septage requirements of Title 5; and,
- lagoons could not handle the large quantities of grease from seasonal operations (particularly restaurants on Cape Cod and the Islands).

Massachusetts recognized the need to ensure proper construction of household septic systems and formalized regulations in what was known as Article XI of the State Sanitary Code, later updated as Title 5 of the State Environmental Code (310 CMR 15.00). As waste loads increased or were merged in cluster housing projects, the Department of Environmental Protection promulgated regulations in 1983 for the Ground Water Discharge Permit Program. These regulations require a permit for any industrial or sanitary discharge greater than 15,000 gallons per day into the ground. Permit requirements specify that these waste streams undergo more rigorous pre-treatment prior to discharge.

Effluent limits for ground discharges are based on the U.S. EPA primary and secondary drinking water standards thereby assuring that discharges will not be detrimental to the most sensitive designated use of the ground water (in most areas that use is for water supply). Some, but not all, towns are concerned enough to delineate zones of contribution to their drinking water wells and to control the growth in these vulnerable areas through zoning or land purchase.

There has also been a change in how projects are reviewed at the Department level. New water source approvals and wastewater discharge applications undergo a far more rigorous review process than their predecessors. Discharge locations and water supplies are not viewed as isolated points on a map with their interactions limited to an arbitrarily defined, circumscribed area. Consideration of hydrologic parameters and hydraulic interconnections ensure that disposal facilities and wells are evaluated in the context of the entire hydrogeologic system.

Passage of the Administrative Penalties Bill in June 1985 gave the Department some much needed "muscle" to back up what were previously looked upon as "empty threats". The Department now has the authority to impose monetary penalties administratively without needing to go to court to have a judge impose the penalty. The enforcement vehicles now available to the Department include the following:

- **Permit Compliance Schedule** - the establishment of particular performance criteria on a defined schedule as a condition of the permit. A failure to meet a deadline is interpreted as a violation of the permit.

- **Notice of Noncompliance** - a statement of an act or omission by the violator in which a regulation or requirement was violated. It requests that the violator come into compliance and sets a deadline for compliance. It also puts the violator on notice that they can be subject to a penalty should they fail to comply with the conditions of the notice.

- **Penalty Assessment Notice** - an assessment of a monetary penalty for continued or willful noncompliance.

- **Administrative Order** - combines a notice of noncompliance and an order to remedy the continued noncompliance particularly if a pattern of noncompliance has been established.

- **Consent Order** - an agreement consented to by the violator which puts them on notice for a violation and sets a timetable for remediation of the violation.

- **Referral to the Attorney General's Office** - the turning over of an enforcement case for litigation purposes when there are significant environmental risks or impacts on ground water.

A stricter review process and an improved awareness of hydrogeologic factors effectively makes it more difficult to find an appropriate site for a septage disposal area, particularly one that will not have an adverse impact on ground water. Often the most suitable area is near the salt water interface on the coast, but disposal needs just can not compete with high priced beach real estate. Treatment costs are also high since discharges must meet the strict standards contained in the current Ground Water Discharge Permit and Classification regulations. Therefore, the high price tag for a septage or co-treatment wastewater plant is beyond the reach of most small communities.

Financial assistance for the capital costs is available through the Division's Construction Grants program. Originally, most of this money came from Federal sources. With the cutback and general phasing out of EPA money, Massachusetts recognized the need for continued financial assistance and instituted a State Revolving Fund Program to provide loans to communities for the construction of treatment plants. However, this process typically involves a long facilities planning phase and can take many years from initial project inception to final construction. The cost effectiveness for small towns and the Commonwealth to undertake such elaborate planning and construction is mitigated by combining flows from several towns and creating regional treatment plants. This is made possible by the fact that septage mobility is only limited by reasonable hauling distances, and is not dependent on sewering considerations. Affected land area and ground water impacts are reduced and significant savings can be realized by performing one, expanded facilities plan as opposed to two or more separate ones. A regional septage treatment plant at Wayland-Sudbury first came on-line in 1985. This facility has been successfully operated producing a high quality effluent. Two similar facilities have recently been completed to serve the Cape towns of Orleans, Eastham and Brewster, and Yarmouth and Dennis.

Facilities designed to pretreat septage prior to discharge into an existing sewerage system can offer a possible solution to the problem of inadequate septage treatment capacity within the State. Septage pretreatment can be used to reduce the strength of the wastewater to a range similar to domestic sewage. The pretreatment facility effluent is then discharged into a sewer system where it is transported to a municipal wastewater treatment facility for further treatment prior to its ultimate discharge. This option represents a viable solution in instances where a municipal plant has adequate hydraulic capacity, but is limited in its ability to accept the high organic loads associated with septage.

Private Septage Treatment Facilities provide an alternative to communities facing difficult fiscal times. Few private treatment facilities have been constructed due in part to the reluctance of local communities to provide assistance in the siting process.

27.2 State Regulations

Septage regulations in other states are often not included within the regulations for subsurface disposal systems. Therefore, the review of actual septage disposal alternatives for all other states was not possible. The states of Wisconsin and Pennsylvania primarily outline requirements for land disposal in their sewage disposal regulations.

The Environmental Protection Agency (1979) indicates that septage disposal is a problem in the New England States, the Southeast and the Pacific Northwest because of the number of septic systems and subsequently the volume of septage.

Review of the literature indicates that in almost all other areas of the country, whether septage volumes are high or not, land application in some form is the preferred method of disposal.

27.3 Conclusions and Recommendations

Limited septage disposal capacity in Massachusetts is not a new problem and prior attempts at solving the capacity shortfall have not been totally successful. Historically, the Department has been reluctant to take enforcement action against septage areas because of the inadequate capacity at acceptable facilities. That practice has only led to more illegal facilities.

The Department must meet the problem head on. A strong enforcement program backed by financial commitment to assist communities in constructing proper septage treatment facilities is necessary to bring Massachusetts out of the "Dark Ages" of illegal septage pits and limited public health protection offered by temporary lagoons (often at the expense of ground water resources).

Land application of septage in Massachusetts does not seem to be viable because of the large amount of land needed to be able to meet the groundwater protection standards and because septage is precluded from solid waste landfills by the Solid Waste Regulations. Composting may be possible if leachate generated in the process can be controlled and treated, but this would require the establishment of a fairly large market to be successful.

This leaves two options: increased co-treatment at existing or planned publicly owned treatment works or the construction of public and private septage only treatment facilities.

Co-treatment is currently being addressed in the design of new, and the upgrading of existing, treatment plants. Co-treatment is not sufficient to handle the amount of septage expected to be generated in many areas where large municipal treatment plants are not needed. Building regional septage treatment plants seems to be the best approach to solving the septage disposal dilemma in Massachusetts. It minimizes the land necessary for multiple treatment plant sites and disposal areas, as well as limiting the impacts on ground water supplies and environmental resources. Regionalization can also share the financial costs and financial assistance can be sought for the capital costs through the State Revolving Fund Program.

Another possibility is to encourage private entities to construct regional facilities to meet the septage disposal needs within certain areas. Towns should assist private enterprises in planning and siting these new facilities.

The Department of Environmental Protection has already initiated active enforcement against several municipal and private lagoon sites. The Department now needs to assume more responsibility to ensure that proper septage management is instituted across the state. It must evaluate problem areas and develop management plans to control the transportation, treatment and disposal of septage. The real key to unlocking the septage disposal problem is the correction of past policy weaknesses.

CHAPTER 28

SEASONAL USE OF SEPTIC SYSTEMS

One of the most difficult aspects of the present Title 5 program is dealing with the many thousands of existing vacation homes and cottages which do not measure up to current environmental standards. Solutions are needed to balance public interest in resource protection with the right of private individuals to use their property to its full potential. It is ironic that inadequate sewage disposal systems are adversely affecting the very resource which attracted much of this development in the first place.

There are two basic issues involving on-site sewage disposal problems associated with seasonal residences. First, is the ability of the sewage disposal system to provide an effective degree of treatment with only intermittent use. Second, some of the older seasonal dwellings have substandard sewage disposal systems. More and more, seasonal residences are being converted to year-round use without proper consideration given to the increased sewage disposal demands of the renovated structure.

One of the primary concerns associated with the design and usage of septic tank/soil absorption systems is the potential for inadvertently polluting ground water and surface waters. This concern is increased for systems serving housing units in sensitive resource areas. Ground and surface water degradation has occurred in many high density areas, with the degradation exemplified by high concentrations of nitrate-nitrogen, bacteria and viruses, and significant amounts of organic contaminants.

Degradation of surface water can occur when the capacity of the soil to absorb septic tank effluent has been exceeded and the wastewater added to the system is forced to exit onto the ground surface. A problem of greater significance in terms of both ground and surface water degradation, however, is when pollutants move too rapidly through soils. The existence of a low-permeability biomat zone is absolutely essential for proper physical and biological cleansing activity to occur and to induce unsaturated flow conditions in the underlying soils. Since it takes an extended period of continuous use for a soil absorption system constructed in soils with high permeabilities to develop a sufficient biomat, infrequent use of septic tank/soil absorptions systems in these instances may result in rapid movement of relatively untreated effluent from the soil absorption area to the saturated zone.

Inadequate systems, particularly those constructed close to or within the ground water, also represent a significant source of ground water and surface water contamination. Since Title 5's promulgation, the septic systems of newly-constructed seasonal dwellings have had to be designed in full compliance with the Code. A substantial number of existing seasonal dwellings, however, were built prior to the promulgation of Title 5. Many of these pre-code subsurface sewage systems are inadequate for seasonal use, let alone the more intensive use associated with year-round residency.

Requiring the property owner to upgrade pre-existing subsurface sewage disposal systems to meet current Title 5 requirements gives rise to a number of regulatory problems. For example, although Title 5 contains no expressed or implied "grandfathering" provision that exempts from its requirements presently functioning sewage disposal systems approved and in operation prior to the Code's effective date, there are no provisions within Title 5 requiring upgrading.

It has been the Department of Environmental Protection's practice, and that of most boards of health, not to require the upgrading of a pre-code sewage disposal system to Title 5 standards in instances in which there is no visible breakout of sewage onto the ground surface or where the owner has not applied for permits for alterations to the dwelling or septic system. Under this approach, septic system failure has been defined as surface breakout of sewage. This strategy fails to recognize that inadequate treatment leading to ground water contamination is also a form of failure posing a significant, albeit less visible, threat to public health and the environment.

Another difficulty arises when the lot size is too small to accommodate a standard system. Generally, seasonal dwellings, particularly those that predate current zoning bylaws, have been constructed on extremely small parcels of land. These problems are magnified by the fact that in many areas, especially areas used extensively for recreational activities, a substantial reliance on subsurface sewage disposal systems is paralleled by a reliance on private wells for drinking water supplies. Frequently, high ground water conditions are also prevalent in these instances due to the desirability of locating seasonal dwellings proximate to surface water bodies. This combination of physical constraints often makes the installation of a septic tank/soil absorption system in full compliance with Title 5 an extremely difficult, if not impossible, task.

The regulatory problems and the physical constraints associated with seasonal residences are also part of the larger problem of upgrading all substandard pre-Title 5 systems.

28.1 Literature Review

On-site sewage disposal systems fail for many reasons, including improper design for the particular site conditions, poor construction practices and insufficient maintenance. Failures are generally categorized as one of three types: (1) the system fails to accept all of the wastewater received; (2) the system fails to transfer all the wastewater to the soil; or, (3) the system fails to adequately treat the wastewater (U.S. Department of Commerce, 1986). The first type of failure is identified by a backup of sewage into the house or structure served by the disposal system. The second causes ponding in the yard or short-circuiting to surface water. This chapter of the report focusses primarily on the third type of failure which can result in significant contamination of ground and surface water resources. This type of failure is generally overlooked as it is often difficult to identify and trace.

The effectiveness of soil absorption systems depends upon several factors, the most important of which are the type of soil and the degree of saturation. These two factors are not always independent. Fine grained soils, while effective in removing contaminants such as bacteria and viruses from septic tank effluent, are more easily saturated and thus may lose some of their effectiveness (Peavy and Groves, 1978). In general, aerobic conditions are more favorable for conversion or removal of contaminants from septic tank effluent (McGauhey and Krone, 1967). Coarse soils usually promote aerobic conditions. However, should ground water tables be near the surface, rapid percolation through coarse material may result in short retention times in the aerated portion of the soil resulting in rapid transferal of contaminants to the ground water (Tyler et al., 1978). Pollutants have been found to move five to ten times further in saturated than in unsaturated soils (Romero, 1970). Research indicates that movement with ground water of some contaminants, notedly nitrate, does occur and that attenuation of these parameters is probably by dilution only (Walker et al., 1973; Viraraghavan and Warnock, 1976).

When wastewater is applied continuously to a soil for a period of time a biomat forms at the infiltrative surface. The biomat becomes a barrier to flow restricting the rate of infiltration. This clogging layer is necessary to enhance purification in rapidly permeable soils (Otis et al., 1977). Unsaturated conditions in the soil are created by the mat since the infiltration rate is reduced below the soil's saturated hydraulic conductivity. In unsaturated conditions, the septic tank effluent is forced to flow through the finer pores or along thin films covering the soil particles providing closer and longer soil-liquid contact for improved filtration, biochemical degradation and chemical retention of waste constituents. Studies have shown that 4 feet (122 cm) of unsaturated soils is generally adequate to remove nearly all fecal indicator bacteria and viruses[1]. If the soil is saturated or nearly saturated, as would occur in rapidly permeable soils where a sufficient biomat has not developed, removals become unacceptable (Tyler et al., 1978).

Studies of biomat formation under a variety of conditions have shown that clogging begins immediately with wastewater application and proceeds very slowly with time (Otis, 1980). High sewage application rates prior to full biomat development can reduce the treatment efficiency of a soil absorption system by allowing the liquid to percolate through the larger soil pores (Ziebell, 1975).

Studies have demonstrated that prolonged resting of the soil absorption system allows the accumulated organics in the biomat to be biochemically oxidized and the soil to dry and reaggregate (Thomas et al., 1966, Simons and Magdoff, 1979). Otis (1985) found that the biomat is significantly diminished when the system is allowed to rest for 6 months or more.

1 . An unsaturated zone of not less than 5 feet (152 cm) may be necessary for coarse sands and gravels with percolation rates less than two minutes per inch.

Intense seasonal use of a subsurface sewage disposal system has a dramatic effect on the ability of the system to provide effective treatment of septic tank effluent, particularly in uniform, well drained soils. The soil absorption system responds slowly to seasonal increases in the sewage application. Several months of continual use is necessary for the full development of the biomat clogging layer. By the time the system has adjusted to the increase use, the recreational season has generally ended and the biomat diminishes as the system's use decreases.

Cape Cod provides an excellent example of this fluctuation in use, although similar conditions can also be observed in coastal, lakefront and ski communities all across the state. Over 90 percent of the homes on Cape Cod use on-site subsurface systems for the disposal of sewage (CCPEDC, 1988). The Cape Cod Commission estimates the 1990 year-round population of Barnstable County to be approximately 190,000 with an increase to approximately 540,000 people during the peak vacation period (personal communication with personnel of the Cape Cod Commission). Along with this almost three-fold increase in population comes a drastic increase in the quantity of sewage discharged via subsurface sewage disposal systems. The magnitude of this increase in sewage flow during the summer months has been documented within the sewered area of the Town of Barnstable. The Wastewater Treatment Plant Operator at the Barnstable Plant reports that the average daily flows at the plant nearly doubles during the months of July and August (WPCF, 1988).

The porous sands of the Cape provide effective treatment only when sufficient biomat clogged layers have developed beneath the leaching structure. Therefore the sewage treatment taking place within the soils during the early part of the vacation season is not as effective as that which occurs during the final weeks of the season.

Another problem faced by Cape Cod towns, and communities all across Massachusetts, is the large number of existing substandard sewage disposal systems. Up until 1978 when Massachusetts adopted the current version of Title 5, many homes and cottages on the Cape were equipped with cesspools and other primitive types of disposal systems. Many of these systems are still in use today, even though they fail to comply with the requirements of the current code. For example, it has been estimated that over 50 percent of the subsurface sewage disposal systems in the town of Eastham predate Title 5 (CCPEDC, 1988).

It is not uncommon to find these old cesspools, particularly those serving waterfront cottages, to be situated within the ground water. These systems provide little to no treatment of the sewage due to the saturated soil conditions. Even those systems installed during the 1960's and early 1970's in accordance with the provisions of then prevailing regulations, Article XI of the State Sanitary Code, may be inappropriately suited for this hydrogeologic setting. Article XI allowed disposal fields to be constructed as close as two feet above the maximum ground water elevation in areas where the undisturbed soil beneath the leaching structure consisted of porous sand or gravel with a percolation rate of two minutes or less per inch. Recent research indicates that as much as five feet of unsaturated soils may be necessary to provide the proper treatment of septic tank effluent in areas where coarse grain sands and gravels are encountered.

Current Title 5 regulations require that new systems be designed for year-round use regardless of the intended use of the property (310 CMR 15.02(6)). This requirement eliminates the problem of having to upgrade systems built for seasonal dwellings once property owners decide to convert such dwellings to year-round use. This does not address the problem, however, of converting pre-code seasonal systems to year-round use.

Title 5 does not require substandard pre-code systems to be upgraded into compliance with the Code until such systems are altered or repaired (310 CMR 15.02(1)). The upgrading requirement is currently triggered by the requirement for a building permit, a foundation permit, a special building permit or a plumbing permit. Title 5 requires that these permits not be issued until a sewer entrance permit or a disposal works construction permit has first been obtained or unless the local board of health determines that the existing sewage disposal system is adequate (310 CMR 15.02(7)). Also, no additions to buildings may be occupied until the local board of health has issued a Certificate of Compliance. There are no specific provisions, however, which address the upgrading of pre-existing, substandard seasonal sewage disposal systems, nor does it address the potential ground water and surface water pollution problem due to an incomplete biomat.

In practice, building permits and other such permits are often issued for alterations and additions (as well as new construction) without board of health review of the adequacy of the existing sewage disposal system. The State Building Code provides that building inspectors shall issue a permit if they are satisfied that the proposed work conforms to the requirements of the Building Code and to all pertinent laws applicable thereto, but it does not specifically reference Title 5 (780 CMR 114.1). Likewise, the State Plumbing Code requires that a permit for the installation or alteration of plumbing shall be subject to express conditions set forth therein as to compliance with all of the applicable statutes and regulations, but does not specifically reference Title 5 (248 CMR 2.04(3)). Thus, when dwellings are expanded or converted to year-round use, there is the problem of enforcing the provisions in Title 5 requiring board of health overview.

The State Board of Building Regulations and Standards (the "Board of Building Regulations") has taken the position that Title 5 does not impose on the building inspector any restriction on the issuance of a building permit. The Department of Environmental Protection has on file correspondence with the Board of Building Regulations dating back to 1979 regarding this issue. The Board of Building Regulations contends that regulations adopted by other state agencies are not applicable to building inspectors; only the Building Code governs building inspectors. This view was published in "CODEWORD," the Board of Building Regulation's newsletter, on at least three occasions. The Department of Environmental Protection and the Board attempted a number of times to resolve this issue, but never with any success.

Among other things, the Department of Environmental Protection has considered the following solutions to this problem: (1) an amendment of the State Building Code to specifically include Title

5 requirements;[2] (2) amendment of G.L. Chapter 21A, Section 13 and G.L. Chapter 143 to incorporate the language of 310 CMR 15.02(7); and (3) issuance of a Joint Policy Statement by EOEA and the Executive Office of Public Safety concerning coordination of Title 5 and the State Building Code.

These efforts have been resisted by the State Board of Building Regulations and Standards for two reasons. First, building inspectors are concerned that the board of health may outright refuse to issue a disposal works construction permit. Of course, this is not a legitimate reason to resist amending the Building Code - systems which present a threat to public health and the environment <u>should not</u> receive authorization to convert to a year round use.

The other reason for blocking an amendment to the Building Code is the potential delay inherent in obtaining a disposal works construction permit. Many municipalities allow measurement of high groundwater only at specific times of the year. Thus, a person who applies for a building permit in July could have to wait until the following April or May to do a deep hole test and receive action on his disposal works construction permit. The limited time allowed for ground water measurements needs to be addressed it the Department of Environmental Protection is to secure the cooperation of the building inspectors in the matter of upgrades.

28.2 State Regulations

Most state regulations do not specifically address seasonal conversions. The few states with specific provisions addressing seasonal conversions all allow some deviations from the standard system design requirements. For example, Alabama exempts prior non-conforming seasonal systems from the minimum lot size requirements. Connecticut provides that a seasonal conversion must satisfy all current design requirements, except the requirement for a reserve area of at least equal capacity. Idaho allows new systems to be designed for seasonal use, but requires approval for any increase in flow beyond design capacity. Minnesota allows soil treatment systems to be designed for seasonal use but requires septic tanks to be designed for annual use. Additionally, Minnesota provides that conversions to year-round use must comply with all standard design requirements.

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2 DEP sought to have the following language added after paragraph 114.1 of the Building Code:

> No building permit, foundation permit, or special building permit, shall be issued until a Sewer Connection Permit of Disposal Works Construction Permit has first been obtained, unless the Board of Health determines that the existing sewage disposal system is adequate for a proposed alteration or addition to an existing building.

28.3 Local Regulations

Very few boards of health have addressed the issue of seasonal conversions. Predictably, those boards that have addressed seasonal conversions represent, for the most part, towns located on Cape Cod where such problems are more prevalent.

The Barnstable Board of Health has adopted a regulation that provides: "No person shall change the use of an existing building from seasonal to year-round use unless the on-site disposal system has the capacity to properly dispose of sewage generated by year-round use and unless the building conforms to minimum standards of fitness for human habitation." The Barnstable regulation provides that the conversion of a cottage, colony, hotel, inn or recreational camp to condominium-type ownership shall be deemed to be a change of use from seasonal to year-round.

The Brewster Board of Health has adopted a regulation which provides that a building "shall not be converted, altered or repaired so as to enable its year-round use and shall not change its use unless the present existing septic system" either complies with Title 5 or can be upgraded to comply with Title 5. The Board of Health has also adopted a "policy" which provides that, if the property in question is used seasonally, "the owner must agree that the use of the property will remain as seasonal and [be] recorded as such on the deed." It should be noted, however, that there are serious legal obstacles to the enforceability of such a provision.

28.4 Conclusions and Recommendations

The ground water and surface water contamination experienced on Cape Cod and in other towns across the Commonwealth have often been blamed on the inadequacy of Title 5. Most towns have attempted to deal with these perceived inadequacies by increasing the setback distances and other Code requirements. This approach has been generally ineffective in dealing with the existing contamination sources primarily because imposing more stringent standards on new septic tank/soil absorption system construction does not get to the real root of the problem.

The environmental impacts which result from inadequacies of the current Title 5 regulations are vastly overshadowed by the ineffectiveness of conventional systems to service the great influx of seasonal residents and the large number of existing substandard systems. Alternative sewage treatment and disposal systems in combination with a systematic upgrading process are necessary to resolve the problems experienced on Cape Cod and in other recreational areas of the state.

Current Title 5 provisions requiring year-round system design should be maintained. When seasonal dwellings with pre-Title 5 substandard systems are converted to year-round use, their on-site septic systems should be upgraded and brought into compliance with current day standards. It appears that the best method for ensuring that this upgrading occurs is to prohibit the issuance of a building permit for the construction work related to the conversion until the local board of health determines that the sewage disposal system is performing satisfactorily and is adequate for its intended use.

Ostensibly, Title 5 already provides this. Because of enforcement problems, however, we recommend that both the State Building Code and the State Plumbing Code be amended to specify that no building or plumbing permits be issued until the local board of health has determined that the existing system will serve the proposed structure adequately based upon current Title 5 concepts. To alleviate permitting delays, boards of health should be required to make this determination within a certain timeframe. The methods used for determining high ground water should be changed to allow for year-round determinations; with such information available a board of health has no reason not to act within a reasonable time period. It would also be helpful to inform building inspectors of their obligations through a state-wide mailing and/or an educational program administered by the State Board of Building Regulations and Standards in conjunction with the Department of Environmental Protection.

We also recommend consideration be given to including a provision in the regulations which allows the use of alternative design (e.g. systems with serial distribution, or "Wisconsin Mounds") and locational standards for repairs and replacements of existing systems. These alternative standards should be specifically designed to overcome site limitations frequently encountered on small lots with high ground water tables. This approach would provide a clear definition of what constitutes acceptable site modifications and design alterations under these conditions as opposed to the present method where boards of health issue variances under 310 CMR 15.20 on a case-by-case basis without the benefit of guidance from the Department of Environmental Protection.

Even with alternative design standards for repairs and replacements of existing system, there will be instances where it will be impossible to overcome specific site limitations and still provide adequate protection to public health and the environment. In these cases, the board of health should require a tight tank to be installed and, in conjunction with the building inspector, prohibit the conversion to year-round use. Although we realize the difficulty of enforcing such a prohibition, especially in determining the parameters of "seasonal" use, we view this as the most realistic alternative which would ensure the protection of public health and the environment. This is perhaps an appropriate application of a multiple-user system or a private sewage treatment facility.

CHAPTER 29

UPGRADING EXISTING INADEQUATE SYSTEMS

The provisions of Title 5 were designed to provide environmental protection by controlling the location of new sewage disposal systems, and to some degree setting the minimum density of development. The siting requirements have resulted in a number of unanticipated side effects, particularly where local boards of health have adopted more stringent setback requirements. Minimum distance requirements, some of which provide no significant environmental benefit, have severely affected the location or type and size of structure that a property owner may build on his land. This problem is particularly noteworthy in cases involving upgrades and additions to existing buildings.

The current Code includes a specific set of design and location requirements. These rigid provisions apply to all new installations regardless of site conditions. This inflexibility in the Code hinders the ability of property owners with pre-existing sewage disposal systems to upgrade their systems to current standards. This, coupled with the fact that the Code does not require owners of substandard sewage disposal systems to bring systems into compliance with the current regulations, has dissuaded many individuals from attempting to upgrade their existing sewage disposal system until the system totally fails.

The use of variances has been a common approach for accommodating unique site conditions where upgrades of existing systems are involved. Through variances, local boards of health can grant waivers from specified provisions in Title 5. These variances are granted on a case-by-case basis, when the board determines that a provision of the code is causing an undue hardship for a property owner by constraining the individuals utilization of his property and that the proposed system provides at least the same degree of environmental protection as a system that otherwise complies with the Code.

In order for variance provisions to be effective as a means for improving ground water protection, they must be administered with a high degree of commitment. Procedures and policies for thorough and consistent review of variance applications must be established and implemented. Moreover, these procedures and policies must reflect long-term community goals, particularly those involving protection of sensitive resource areas.

In some towns, variances have been granted too readily, compromising environmental protection goals for the sake of other short-term objectives. For example, when reviewing a variance request, some boards of health consider only the effects of the provisions on the individual parcel under review without considering how many other sewage disposal systems in the area have similar problems and whether the problem needs to be dealt with as a whole rather than individually. High densities in some areas have made it difficult to adequately achieve setbacks to on-site water supplies on all of the lots where subsurface sewage disposal system upgrades are undertaken. Rather than grant variances to the first few individuals who apply, and then require the others to install tight tanks, it may be advantageous to consider a single cluster system designed to service the entire area. This system could link a group of homes together through a central wastewater collection system. The wastes could then be pumped to a cluster type septic system or a central treatment and disposal facility.

Another approach to accommodating special site conditions is to include in the regulations varied siting requirements for upgrades under a number of different settings. This is particularly effective for dealing with lots situated adjacent to surface waters. Because lakes and other surface water bodies are sensitive to pollution from subsurface sewage disposal systems, special limits may be imposed in lieu of the traditional fixed horizontal setbacks to ensure that sufficient depth of soil is available on the lot to remove contaminants from the septic tank effluent before it reaches the surface water. These modifications to the standard setback requirements must, however, take into account the special hydrogeologic conditions found in the area.

29.1 Literature Review

Since World War II, housing developments have undergone unprecedented expansion in areas beyond the reach of public sewers. The past thirty years has seen a steady migration of the population to rural and suburban areas, accompanied by an increased reliance on individual, on-site sewage disposal systems. This is especially true in the case of urban fringe, rural residential and second-home recreational developments, where dispersed housing patterns and the absence of centralized sewerage facilities have made the use of subsurface sewage disposal systems the most logical and viable wastewater management alternative. Along with this trend, came the need for improvements in on-site sewage disposal technology. This need has been addressed by numerous research undertakings, resulting in substantial revisions of regulatory requirements. Much of the suburban land development has proceeded, however, without benefit of the knowledge and guidance provided by these technical advancements. Consequently, we are faced today with many developments which are poorly suited for on-site sewage disposal.

In Massachusetts, problems are particularly severe in water front developments and residential subdivisions created in the late 1950's and early 1960's, when there was insufficient understanding of on-site sewage disposal needs. Many of these areas, most notably around lakes and marine embayments are now experiencing an excessive number of septic system failures. Some home owners, desirous to implement improvements to protect the environment they enjoy, are stymied by poor soils, steep slopes, shallow ground water or other site limitations not previously recognized or taken into consideration when the home was first constructed. This poses a serious dilemma in which either severe financial hardships are borne by lot owners unable to improve (or in some instances continue to use) property which they have purchased in good faith, or the board of health is forced to relax the current standards and criteria for on-site sewage disposal systems by granting variances which may increase the risks to public health and water quality.

With attention increasingly focused on septic systems, we are beginning to realize that existing substandard systems may represent a major source of ground water and surface water contamination. Although solutions for upgrading existing, inadequate subsurface sewage disposal systems may be costly, and in some cases politically sensitive, these systems represent a substantial and continuing threat to public health and the environment that can no longer be ignored.

Inadequate sewage disposal systems represent a widespread problem affecting the quality of the ground and surface waters all across the Commonwealth. These systems can have a devastating impact on on-site water supplies, particularly where shallow wells are utilized in combination with old cesspools installed within or close to ground water. Surface waters supporting recreational and commercial uses have also been adversely affected including some areas at which these uses have had to be restricted or prohibited all together.

The problem has been found to be particularly severe in many of the shellfishing areas. Pathogenic bacteria and viruses from inadequate subsurface sewage disposal systems can be carried with the ground water concentrating in the bottom sediments of surface waters. The shellfish which inhabit these sediments further concentrate the pathogens rendering them toxic to humans.

The contamination of shellfish waters with bacteria and viruses has become an issue of great concern in Massachusetts and other coastal states. Many of these areas are not served by municipal sewers and therefore subsurface sewage disposal systems are widely used. During the last two decades, a sharp increase in closed shellfish areas has accompanied the increased development of coastal areas.

While some of the surface water pollution that has occurred in the coastal areas can be attributed point source discharges, the vast majority of the problems can be traced to inadequate system design and operation. Many of the areas closed to shellfishing are surrounded by older residences and cottages. For the most part, sewage disposal systems serving these dwellings were installed prior to the establishment of existing regulations. Some systems have been found to consist of dilapidated cesspools consisting of nothing more than an old perforated steel drum situated in soils that are flushed by tidal action (DEP personal communication).

Investigations conducted in residential developments along the North Carolina coast identified the mechanisms by which pollutants from septic systems constructed in unsuitable soils are delivered to shellfish waters during both wet and dry weather (Duda and Cromartie, 1982). Dyes, injected in septic tanks, were observed to travel laterally more than 50 feet (15.3 meters) to shell fish waters in times ranging from four to sixty hours depending on the site. High levels of fecal coliform bacteria were found with the dyed effluent and the pathogenic bacterium Salmonella was isolated from the tidal waters. In other investigations, enteric bacteria and viruses were recorded in surface waters more than fifty feet (15.3 meters) downgradient of existing septic systems installed in soils with severe limitations such as high ground water and confining layers (Sobsey and Scandura, 1980).

The problem is not isolated to coastal embayments used extensively for shellfishing. Drinking water supplies and recreational waters of all kind are also experiencing similar contamination.

29.2 State Regulations

Most states including Oregon, New Jersey, Minnesota and Kentucky do not allow the use of cesspools for new construction. Hawaii allows cesspools for public facilities only.

Most states do not have a standard upgrade policy. Both Maine and Maryland require that failing septic systems be upgraded to the current code. Oregon also requires that failing systems be upgraded wherever possible to eliminate threats to public health. In New Hampshire, design plans for a repair system are not required to be submitted unless the type of system proposed is different than the one currently in use. Rhode Island requires that any building that is altered in an environmentally critical area must first have its sewage disposal system upgraded to comply with current standards.

California has established On-Site Wastewater Management Districts (OSWMD). These districts determine the extent and nature of any problems and develop appropriate solutions. This may include investigating alternative systems, developing cluster systems with multiple houses tied into the same leachfield, or installing centralized collection and treatment systems.

29.3 Local Regulations

There are very few regulations adopted by boards of health which consider upgrading septic systems. Medfield, Natick and Carver prohibit cesspools for new construction. Lexington still allows cesspools in their regulations, while North Adams allows cesspools if they are used in conjunction with a septic tank. The town of Upton requires cesspools be replaced by septic tanks when repaired.

At least three Cape towns Barnstable, Brewster and Chatham require evaluation of the septic system when a property is sold and may require some sort of upgrading. In the Area Wide Wastewater Management Plan for Cape Cod (1978), The Cape Cod Planning and Economic Development Commission reports the following:

> "The town of Barnstable, each time a building permit is issued, upgrades the sewage system within reason. If the system is in a potential problem area, it is upgraded to a septic tank and leaching facility. If not in a problem area, we allow conversion of a cesspool with sanitary tees to a septic tank concept and allow an overflow leaching pit. This is done at half the expense of a full conversion. You can also solve the problem of overflowing cesspools creating an immediate health hazard more easily by allowing an overflow pit [sic] at a cost of about $400 rather than $1,000 for a tank and pit. We attended several 208 meetings and know that many ardent supporters have not converted their own systems from cesspools to septic tanks."

29.4 Conclusions and Recommendations

Title 5 regulations need to include provisions which specifically address upgrading of existing systems if effective protection of public health and the environment is to be provided. In addition to septic system review by the board of health before building permits are issued and prior to real estate transfers, schedules need to be established whereby all non-conforming subsurface sewage disposal systems must be upgraded to current Title 5 standards or alternative treatment and disposal techniques implemented. During the implementation of this program, emphasis should be given to sensitive resource areas, including wellhead protection areas, areas of critical environmental concern, swimming and shellfish areas.

Before upgrades of previously installed systems are mandated, however, certain allowances in the requirement for installing new septic systems should be made for instances where existing systems are extended, altered, repaired, or replaced. These allowances should include items such as increasing the maximum acceptable percolation rate, the use of retaining walls in lieu of meeting the sideslope requirements, and the use of mounded systems.

A comprehensive program designed to provide maximum protection to sensitive resource areas while allowing system owners an opportunity to make the best use of their property needs to be developed and implemented. This effort must include a detailed areawide planning initiative to determine whether upgradings are appropriate on a site-by-site basis or whether a district needs to be established in order to implement some form of joint solution such as a community septic system or treatment plant. This task could be undertaken by regional planning agencies or other county agencies in cooperation with the Department of Environmental Protection, the Department of Environmental Management, the Metropolitan District Commission, the Massachusetts Water Resources Authority, and boards of health.

Even with alternate standards for repairs and upgrades, there will be instances where both on-site and regional solutions are not feasible. In such instances where special design features and site modifications are not sufficient to overcome limiting soil and hydrogeologic conditions, tough actions may be required to protect sensitive resource areas for the benefit of the general public. This includes mandating the use of tight tanks, imposing restrictions on expansions and modifications, and enforcing prohibitions on rebuilding dwellings in cases where the structure is destroyed by fire or other natural causes.

CHAPTER 30

CLUSTER DEVELOPMENTS AND MULTIPLE LOT SYSTEMS

Cluster developments and other concentrated multiple lot residential developments have been considered desirable methods of preserving open space and lowering development costs. Title 5 currently prohibits the use of a subsurface sewage disposal system by more than one "lot", thus precluding the use of a community type subsurface sewage disposal system for multiple lot and cluster developments. The critical concerns underlying this prohibition relate to: (1) the long-term legal responsibility of a private, multiple lot system to ensure continued operation; (2) the related problem of assurance of proper operation and maintenance; and, (3) the need for appropriate contingency plans should the system fail. The legal and financial assurance questions presented by multiple lot septic systems are in many respects similar to those concerns applicable to privately owned sewage treatment facilities ("PSTF"). These concerns have been discussed in considerable detail in the Generic Environmental Impact Report on PSTF's (ICF, 1990).

30.1 Literature Review

Publicly owned and managed community on-site septic systems serving small residential developments have been encouraged by the United States Environmental Protection Agency (EPA) as effective, environmentally sound, yet less expensive alternatives to traditional sewage treatment plants, especially in rural and suburban growth areas (Train, 1976; Staudt and Niehaus, 1982). EPA's Construction Grants Program, established pursuant to the Federal Clean Water Act, provided funding for small community on-site septic systems (Deese and Hudson, 1980). EPA has encouraged public ownership of such systems because of the problems inherent in private ownership, which include lack of individual responsibility for a failed system, improper and inadequate maintenance, improper disposal of household wastes, and lack of alternative sources should the system fail (EPA, 1988). Nonetheless, a number of states have not only allowed but actively encouraged private, on-site multiple lot systems. When appropriately sited, designed, installed and maintained, multi-user systems have met with a high degree of success in many situations. The following sub-sections provide a discussion of the operation, management and financial consideration necessary to protect the environment and public health when large multi-user systems are utilized.

30.1.1 Cluster Developments

The chief characteristics of a cluster development under Massachusetts law are that it is:

- a residential development;
- on a parcel of sufficient size to permit construction of the contemplated number of buildings or units pursuant to the dimensional, density and use restrictions otherwise applicable in the district; and,
- on a parcel which is divided into (i) building lots, clustered into one or more groups, and (ii) open land, which separates the groups from adjacent property and from the groups within the development (Healy and Mack, 1989).

A cluster development provides a more flexible means of land development than traditional subdivisions. It reduces zoning requirements for minimum lot sizes, frontage and building setbacks, thus allowing a comparatively smaller portion of a development tract to be used, preserving a larger portion of the tract as "open" land. In addition to its value in preserving open land, a cluster development is considered a desirable land use because it also enhances recreational opportunities, reduces development costs and encourages construction of affordable housing (Rohan, 1987).

Perhaps the most important advantage of clustering is the preservation of open space to serve recreational, scenic and public service purposes. A very large part of a cluster parcel, often up to 70 percent, can be left undeveloped, and may be granted or otherwise dedicated to the municipality for use by the general public. The open land can also be used to enhance recreational opportunities through the construction of tennis courts and other types of playing fields.

A cluster development reduces the infrastructure (roads, sewers, water lines, etc.) which must be constructed. A major reduction in the amount of impervious surface is realized minimizing the quantity of storm water which must be managed. The savings available from clustering techniques can allow development of areas generally considered uneconomic (Rohan, 1987). The reduced cost also provides flexibility to communities struggling to find ways to enhance affordable housing opportunities.

Septic systems serving cluster developments have been utilized throughout the country. In the Midwest, the South, and California these systems are frequently used in rural waterfront resort communities (Hampton and Yahner, 1984; Steinbeck, 1984; Hantzsche and Fishman, 1982). In North Carolina alone, approximately 200-300 privately owned community septic systems were being constructed annually as of 1984 (Steinbeck, 1984). A community septic system allows construction of dwellings adjacent to the lakeshore, with the sewage effluent pumped to a septic tank and leaching facility located a sufficient distance from the water body to protect against pollution of the lake (Hampton and Yahner, 1984). In addition to new construction, such systems have also been used to replace or relieve failing individual systems.

Intermittent sand filter systems have recently been built in New York State to demonstrate that sand filters can serve as a low-cost wastewater treatment technology ideally suited for use by small clusters of homes (Perley, 1985). This study found sand filters to be adaptable for use under varying site constraints in close proximity to homes. The Environmental Protection Agency also published a brochure entitled "An Emerging Technology" on the use of intermittent sand filters as an alternative to conventional sewage disposal systems (USEPA, 1984).

19.1.2 Zoning Considerations

In Massachusetts, construction of cluster developments is governed by the Zoning Act, M.G.L. Chapter 40A, and municipal zoning by-laws adopted thereunder. Siting of a septic system in a multiple lot cluster development could prove problematic under the Zoning Act. Section 9 of Chapter 40A requires that when open land in a cluster parcel is not conveyed to the municipality or to a non-profit organization, a restriction must be recorded to the effect that the land is to be left in an open and natural state and cannot be developed "for accessory uses such as parking or roadways" (Chapter 40A, Section 9). While it is common practice to reserve easements in the open land for subsurface sewage disposal systems (as well as utilities and drainage) which are not visible and do not affect the value of the open land, the status of accessory uses other than "parking or roadways" in open land is unclear (Healy and Mack, 1989).

Municipal zoning by-laws and ordinances also complicate this analysis. Most local zoning provisions do not allow "accessory" uses on a different lot than the principal use. An accessory use is one which is dependent on and pertains to the principal use (See Needham v. Winslow Nurseries, Inc., 330 Mass. 95 (1953)). Individual on-site septic systems have not traditionally been considered accessory uses. Instead, septic systems, as well as utilities and wells, have been considered "integral" to the principal use of the land, and thus not subject to regulation as accessory uses. However, depending on the formulation of local zoning by-laws, it is arguable that community septic systems, due to their size and impacts, could be classified as "accessory" uses and thus subject to zoning controls. In at least one case, a PSTF has been classified as an "accessory" use subject to zoning controls (Dowie v. Planning Board of Sudbury, Land Court Misc. Case No. 125-8323, Dec. 9, 1988). If this conclusion were applied to a multiple lot septic systems, many municipal zoning by-laws and ordinances would have to be amended.

30.1.3 Assuring Proper Management

Private community septic systems in other states are usually owned and operated by a homeowners association. Such associations comprise the owners of dwellings which discharge sewage to the community system. The EPA has observed that these associations are notoriously poor managers of community septic systems (USEPA 1977). Regulators therefore generally require appropriate assurances that the system will be properly operated and maintained before a permit or approval is issued (USEPA, 1977).

One of the problems frequently associated with community septic systems is a lack of individual accountability for those substances discharged into the system. Standard septic systems are designed to handle domestic wastewater from showers, washing machines, toilets and sinks. These systems are not capable of treating and disposing other wastes, including pesticides, paints and thinners, and grease and cooking fats (USEPA, 1977). People are less likely to consider the effects of disposal of improper materials when they are not individually responsible. Further, many new homeowners in these developments will have previously lived in an urban environment with public sewers and as a result are simply not aware of the limits of what can be safely disposed of in a septic system. A first step, then, to proper management of a septic system is education of all system users (USEPA, 1977).

North Carolina requires that the purchase and sale agreement for a house which is part of a multiple lot septic system inform the owner of the system about his obligation to pay operation and maintenance fees. The buyer is required to sign an acknowledgement that he is aware of the septic system (Steinbeck, 1984). In addition to these requirements, a state could require that, at the closing, buyers be required to read and certify as to their awareness of the existence and operational requirements of the system. Signs warning of the effect of improper disposal of toxics could also be prominently displayed.

No educational program is foolproof. There is always someone who will ignore all the information presented to him and dispose of inappropriate materials through the subsurface sewage disposal system. A comprehensive educational program could, however, minimize such practices. The only certain way to determine individual accountability is to install monitoring devices on every building sewer. The cost of such monitoring could, however, prove to be prohibitive.

Regular maintenance of septic systems, particularly large systems, is also critical to their long term viability. Some states and municipalities have required that an operation and maintenance contract between the homeowners association and a qualified company be in place prior to start up of the system (Toxins and Hermanson, 1977; Stewart, 1976). This contract is a condition of the association's permit which must be renewed on a regular basis.

Another alternative is to require regular inspections and pumping of the system. Typically, such inspections would be required at least annually. The frequency of pumping depends on the size of the system but in no event should it exceed three years (Stewart, 1976). Monitoring reports are also required to be submitted to the local health authority in certain instances (Hantzsche and Fishman, 1982; Steinbeck, 1984).

Yet another alternative, which requires little or no oversight on the part of regulatory authorities, is to require an inspection and certification as to the proper operation of the system prior to transfer of any dwelling which is part of the system. This approach is somewhat problematic since the inspections are not conducted regularly, but instead as a function of a proposed sale of the residence. More importantly, inspections and certifications add to the cost and could significantly complicate the purchase and sale of residential housing.

An excellent alternative, which could be tailored to the needs and concerns of each multiple lot system, is to require the homeowners association to obtain a permit from the local board of health and/or the Department of Environmental Protection. This permit could set out a very specific schedule for regular inspections and maintenance, as well as arrangements for repair, education and financial security. This alternative would of course require considerable expertise and effort on the part of the local board of health or DEP. The necessary resources to negotiate, oversee and enforce such a permit are not likely to be available, particularly given the current fiscal constraints.

30.1.4 Financial Assurances

The homeowners' association, or other ownership entity, must have sufficient funds or other security to properly operate and maintain the system and to repair or replace it in the event of failure. The ownership entity should also have legal authority to impose liens for maintenance and repair of the system in order to be able to secure the necessary funds from the individual members of the association. The decision of the Department of Environmental Protection in the Willis Hill Trust, Ground Water Discharge Permit matter, (Mass. DEQE, 1988) in large part was based on DEP's concerns regarding the inability of a realty trust (or a homeowner association) to provide adequate long-term financial security for a PSTF serving multiple lots. Virtually identical concerns are applicable to a multiple lot Title 5 system. These issues have been discussed in considerable detail (in the context of PSTFs) in the PSTF GEIR (ICF, 1990).

There are a number of financial assurance mechanisms available which could be used to assure that a homeowners association has adequate financial resources to repair or replace a failing system. Because prudent planning would require consideration of the possibility that all systems would fail sometime, the ownership entity should be required to establish a segregated capital reserve account, which can be drawn on only for repair or replacement of the septic system. Approval by the Department of Environmental Protection or the local board of health should be a prerequisite to withdrawal from this account; either the Department or the board could be the trustee of the account. Funding of the reserve account must be sufficient to replace the septic system in its entirety at the end of its projected life.

There are a number of ways to assure sufficient replacement funding. One is to require that adequate funds to replace the system be deposited in the capital reserve account prior to issuing a certificate of occupancy for any of the dwelling units to be served by the system. The problem with this approach is that it significantly increases the capital cost of the system, at least initially. Another approach, which does not require the same amount of up-front capital, is to require that the capital

reserve account be annually funded in a sufficient amount to assure adequate funds at the end of the design life of the system.[1] The down-side to this approach is the administrative burden of assuring that each ownership entity is annually complying with this requirement.

The ownership entity should also be required to maintain insurance to protect against natural hazards. The Department of Environmental Protection or the local board of health should be named as beneficiaries of the policy, to assure that in the event of a covered loss the funds would be payable directly to the regulatory authority which would then contract for repair of the septic system.

One of the Department of Environmental Protection's stated concerns in the Willis Hills decision is the inability of a realty trust or a homeowners association to impose an enforceable lien on its members for common expenses. However, in the decision the Department stated that a condominium trust established pursuant to Chapter 183A was acceptable because it has the power to impose a lien on an individual member for any unpaid common expenses. Under the Massachusetts' Condominium Law, liens for unpaid common expenses assessed by the condominium association are superior to all other liens except municipal liens and first mortgages of record. (Chapter 183A, Section 6(c)). In order to assure the enforceability of a lien assessed for maintenance or repair of a multiple lot septic system, an analogous statute should be enacted before such systems are allowed.

30.1.5 Contingency Measures

The failure of a large, multiple lot septic system creates a much greater problem than failure of an individual system: there is a larger environmental impact; the system takes longer to repair; more people are affected; it is more difficult to recover funds from all affected users; and, in the event system repairs can not be accomplished, more families are rendered homeless. While failure of an individual system certainly presents an inconvenience to the homeowner during the system is replacement or repair, such replacement or repair in most instances should not take more than a few days. A large system, however, may take many weeks to repair or replace, inconveniencing all dischargers to that system for a lengthy period of time. It is therefore essential that any multiple lot system be designed and constructed to minimize the potential of significant "down time". Potential design requirements would include an alternating absorption system; increased reserve capacity; and, "dry" reserve distribution lines. Further, as discussed above, there must be sufficient financial resources to assure immediate action; such resources may be of less importance, or may not need to be as large, if an alternative system is already in the ground. There must also be a small group of individuals, or, ideally, one individual, with the power to make immediate, binding decisions.

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1 Cantor and Knox (1985) estimate that the design life of many existing septic systems is in the order of 10 - 15 years.

A written contingency plan addressing the following issues could also be required: (1) management of reserve funds; (2) how insurance would be paid and applied; (3) who is in charge; and, (4) the Department of Environmental Protection's and the board of health's role if the person in charge fails to act.

30.2 State Regulations

Most states' regulations do not include separate requirements for private multiple lot systems. Only Connecticut specifically prohibits multiple lot systems in all circumstances. Utah requires that a "body politic" be "responsible" for such systems. Maryland prohibits a septic system from serving more than one building unless special authorization is received. New Jersey prohibits such systems unless single user systems are "impracticable or impossible". Alabama prohibits multiple lot systems except for mobile home parks and multifamily dwellings. The regulations in a few other states (e.g. Indiana, Ohio) imply that multiple lot systems are not allowed, but do not clearly prohibit such systems.

A number of states, including Florida, Hawaii, Pennsylvania, Idaho, Minnesota, Montana, North Carolina, South Carolina and Colorado do have regulations which at least implicitly authorize multiple lot systems. Some states encourage the use of innovative or alternative systems, which apparently include multiple lot systems, subject to the approval of the state environmental protection authority.

Most states do not have extensive regulations governing multiple lot systems. The most common regulatory provision allows such systems, subject to size requirements applicable to all septic systems, with ownership of the system vested in an appropriate homeowners association. Utah, one of the few states which imposes specific design requirements, requires an additional 100 percent reserve capacity (for a total of 200 percent). In states which specifically allow multiple lot systems, a single legal entity (generally a homeowner association) is usually responsible for operation and maintenance of the system. Some, but not all states require appropriate financial assurances (bond, special account, adequate capital reserve, etc.) on behalf of the homeowners association.

Montana has published a circular which discusses multiple family systems. All such systems must be designed and constructed in accordance with the circular. Minnesota requires that all such systems be approved by the local authorities, and must address such issues as zoning, joint ownership of land, and easements. An alarm system for all pumping stations is required.

North Carolina has the most well developed multiple lot regulations. North Carolina requires a site evaluation by the local health department, as well as a design review by both the state and local health departments. The state also must approve the form of the following legal documents (1) purchase and sale agreements; (2) buyer's acknowledgment regarding obligation to pay assessment for the system; (3) homeowners association documents (by-laws, articles of incorporation; and (4) a tripartite agreement between the developer, municipality and homeowners association. Annual inspections of the system are required, and monitoring reports must be submitted regularly to the local health department. The state also has a variety of remedies including injunctions and administrative penalties for systems which are not in compliance.

30.3 Local Regulations

Since Title 5 prohibits multiple lot systems, local regulations do not address this issue.

30.4 Conclusions and Recommendations

Cluster developments provide a number of economic and environmental benefits, including the preservation of open space, reduction in impervious surface, and lower costs which facilitate affordable housing. Septic systems serving such developments have been used with success in other parts of the country. In Massachusetts, equivalent systems have been used to service condominiums and office parks on a single lot.

Multiple lot systems, however, present a number of potential risks since no one individual owns the "lot" where the septic facility is located, or is legally accountable for management of the system. These risks include: (1) an inability to ensure individual accountability for what wastes are discharged to the system; (2) inadequate maintenance and repair of the system; and (3) legal and financial accountability in the event of system failure. Most of these risks, however, can be significantly diminished through proper education and system management.

Despite the potential risks, we recommend that multiple lot systems be allowed, but only when there is some environmental or public policy reason associated with the development which justifies the risk. Cluster developments which preserve open space and/or facilitate affordable housing are an example of developments which should be allowed to construct multiple lot systems. Traditional subdivisions are an example of developments which generally should not be allowed to use multiple lot systems. Another example of when such systems should be allowed is to remediate a number of failing systems in close proximity, particularly in sensitive resource areas. An example of this would be the repair of existing substandard sewage disposal systems.

Of course, adequate financial and legal assurances must be in place for any multiple lot septic system. We therefore recommend the following:

- A new statute similar to General Laws Chapter 183A (the condominium statute) which gives homeowners associations or another management entity the power to assess liens for septic system assessments and also guarantees the enforceability of long term restrictions.

- A self-enforcing operation and maintenance requirement. This is probably most readily imposed as a condition precedent to a valid permit.

- An educational program designed to inform owners of the need to dispose of wastes properly.
- Financial assurances, including a segregated capital reserve account sufficient to replace the system at a projected failure date, say 15 years.

We also recommend that, due to the complex nature of the recommended financial guarantees and to the recommended revision in site evaluations for larger systems, approval of multiple lot systems be handled by the Department of Environmental Protection in conjunction with the local board of health.

CHAPTER 31

TIGHT TANKS

Tight tanks (holding tanks) are only allowed in Massachusetts at existing establishments for which it has been proven that there is no other feasible sewage disposal alternative. The use of tight tanks must be approved by the Department of Environmental Protection under 310 CMR 15.18(1).

The Department has adopted a tight tank policy which establishes review procedures and specifies minimum design standards for the use of sewage tight tanks. Under this policy, tight tanks are not allowed for new construction except in connection with the Department's marina licensing program.

There are a number of reasons for the Department's refusal to approve sewage tight tanks for anything but an existing establishment where there are no other means to remediate a failing sewage disposal system. This section will analyze these reasons and provide recommendations on modifications to the Department's procedures and standards for the use of sewage tight tanks.

31.1 Literature Review

A tight tank is a water tight vessel, usually a septic tank, which collects and stores sewage until it can be removed for disposal at another location. The sewage is removed by a licensed septage hauler for disposal at a municipal sewage treatment facility, a private or public septage treatment facility approved by the Department, or an out of state facility.

The cost to operate a tight tank varies depending on the availability of a disposal facility and distance the hauler must travel. It is not unusual to find costs of eight to twelve cents per gallon for pumping, transporting and disposing of the contents of tight tanks. Therefore, an owner of a three bedroom home generating 330 gallons per day could be faced with disposal costs of between one hundred and eighty five ($185.00) dollars and two hundred and seventy seven ($277.00) dollars per week.

Septage haulers are required to be licensed by the community in which they pump, all communities through which they travel and the community in which they dispose of the sewage. Unfortunately, as state and federal effluent standards become more stringent, the number of municipal treatment facilities that will accept sewage or septage from haulers is being reduced. Further, the Department of Environmental Protection has issued orders to all septage lagoons requiring them to either close or upgrade their facilities to include additional treatment processes required to meet current ground water discharge standards for the state's Ground Water Quality Standards (314 CMR 6.00). A number of the facilities have already shut down and it appears that most of the remaining facilities will also close rather than face the stringent siting requirements for a new facility. Septage haulers are finding it increasingly difficult to find locations to dispose of the waste, not only from tight tanks, but also from operating septic tank systems and grease traps.

The Department of Environmental Protection must determine whether perspective owners of tight tanks will be able to find a location to dispose of sewage at an affordable cost. The Department, in recognition of this problem, has taken the position that tight tanks should only be approved as a last resort. In a policy memorandum concerning tight tanks (Policy Memorandum # 87-7), the Department has indicated that all reasonable variances must be considered before approval for the use of a tight tank is granted. Compliance with this policy is extremely important in order to limit the amount of septage which is generated until sufficient facilities are available to provide proper treatment and disposal.

There have been a number of recent proposals for the construction of private septage treatment facilities. These proposals have been met with significant opposition at the local level and, to date, the only facility which appears to be ready for construction is a 50,000 gallon per day private septage treatment facility in the town of East Bridgewater. The communities where other facilities have been proposed have expressed fear that there are not sufficient controls to ensure that hazardous chemicals will not enter the facility and contaminate the ground water. Although the technology to construct a facility designed to properly treat septage is available, local communities are not convinced that adequate safe-guards can be built into the facilities to ensure protection to public health and the environment.

31.2 State Regulations

Table 31.2.1 presents the other state regulations concerning holding tanks. The majority of the states that allow the installation of holding tanks do so only for existing systems where the disposal system has failed and there is no other disposal alternative available, or when a municipal sewer system will be available within a specified time period. The majority of the states that allow their use do so only with State Agency approval.

The state of Wisconsin has conducted a significant amount of research relative to the use of tight tanks. Tight tanks are allowed for new construction throughout most of the state. The Wisconsin Administrative Code Section 62.20(6)(b) requires that septic tank sludge or septage be disposed of in the following manner:

"(1) Private sewer. By discharge into a public sewerage system where practicable. The point and method of discharge into the system shall be subject to the requirements of the municipality.

(2) Approved site. By discharge at a disposal site designated by the local governmental authority.

(3) Other. In the absence of a public sewerage system or designated disposal site by one of the following methods:

(a) By burial under 37 inches of earth on the premises on which produced at a distance of at least 50 feet from a well or if on other premises at a distance of at least 500 feet from a place of habitation provided that there is also at least 36 inches of soil between the buried sludge and the high ground water level or bedrock.

(b) By spreading on land, not used for pasturing livestock or for growing vegetables, at a distance of at least 1000 feet from a place of habitation or any stream, lake, pond or flowage."

A study conducted at the University of Wisconsin-Madison (Zilber, Harkin and Quigley) has indicated that septage disposal for holding tanks and septic tanks is being conducted by haulers with little or no regulatory control. Haulers are allowed to either bury or land-spread septage with no limits on loading rates. Since no enforcement is taking place, there is no guarantee that septage is not flowing overland into surface waters or wetlands. The study also indicates that many of the municipal sewage treatment facilities have refused to accept septage from haulers fearing that the waste will adversely effect their ability to meet federal discharge standards.

A second study at the University (Hanson and Jacobs) indicates that only 45 percent of the septage generated from holding tanks is actually removed from the property where it is generated. It is not possible to determine how much of that septage is disposed of properly. Based on this uncertainty, and the fact that operators of municipal sewage treatment plants are reluctant to accept the wastes, many of the counties within the state are beginning to either discourage or ban additional holding tanks.

Both studies also looked at the issue of costs of constructing and maintaining the holding tanks. The results indicate that the average cost to install a holding tank ($3,422) was only slightly more expensive than a conventional septic system ($2,815). Costs for pumping and disposing of the tanks' contents range from $0.0075 per gallon to $0.022 per gallon with an average cost of $0.01 per gallon. The reports suggest that these costs will increase if septage disposal regulations are strengthened and that the cost increase could lead to additional unauthorized disposal.

The Pennsylvania Department of Environmental Resources allows the installation of a holding tank for new construction if the municipality has an "Official Plan" to provide for:

- the scheduled replacement of holding tanks by adequate sewerage system;
- financial assurances that public sewers will be installed through bonding, public financing or other acceptable means;

- enactment of an ordinance in which the municipality assumes responsibility for maintaining holding tanks; and,
- requirements regarding the contract disposal of holding contents and standards for the construction of such tanks.

In addition the municipality, before approving a holding tank, must provide a time schedule for the replacement of the tanks which must be approved by the Department of Environmental Resources. Generally, the acceptable time schedule for a full time residence would be eighteen months to replace the holding tank with a sewer. The only exceptions to these requirements are when a holding tank is proposed to abate a nuisance or public health hazard.

Septage disposal costs in Pennsylvania have been estimated to be approximately $0.025 to $0.035 per gallon for disposal at an approved disposal area.

The state of Kentucky allows holding tanks to be installed for:

- single family residences, commercial establishments and public facilities when a municipal sewer system will be available within two years;
- for commercial and public facilities where the total wastewater flow is less than 200 gallons per day and no other method of disposal is available; and,
- for all residential, commercial and public facilities where immediate system installation is precluded but can be installed after allowing fill to settle for one year.

The state of Illinois allows the use of holding tanks for sewage disposal to serve a seasonal use such as a residence for use only on weekends, short vacations (and other similar situations) or as a temporary measure while awaiting the availability of a municipal sewer extension.

Delaware approves a holding tank for permanent use when all of the following conditions are met:

"(a) The site is not approvable for the installation of an on-site sewage disposal system; and

(b) No community or area-wide central sewerage system is available or expected to be available within five (5) years; and

(c) Isolation distances as required for septic tanks can be met; and

(d) A governmental unit or wastewater utility enters into a contract with the Department setting forth that the governmental unit or wastewater utility will provide hauling services, either directly or through a licensed private hauler, to the home(s), commercial establishment(s) or occupied structure(s) for the period the occupied structure is utilized or until connection can be made to an approved sewerage facility."

TABLE 31.2.1

HOLDING TANK REGULATIONS IN OTHER STATES

	USE ALLOWED	MINIMUM CAPACITY (Gallons)	APPROVAL BY	ALARM REQUIRED	COMMENTS
Alabama					(13)
Alaska	Y	1,000	State	Y	
Arkansas					(13)
Arizona					(13)
California	Y	2,000	State		
Colorado					(13)
Connecticut					(13)
Delaware	Y	1,000 or 7 x Daily Flow	State	Y	
Florida	Y	7 x D.F.			Flows <150 gpd only
Georgia					Regulations unavailable
Hawaii	N				
Idaho					(13)
Illinois	Y(1)		State		
Indiana					(13)
Iowa					(13)
Kansas					Regulations unavailable
Kentucky	Y(2)	7 x D.F.	State	Y	
Louisiana					Regulations unavailable
Maine	Y(3)	1,500	State	Y	
Maryland	Y(4)	7 x D.F.	State		
Michigan					(13)
Minnesota	Y(5)	5 x D.F. 1,000 or 400 × #br		Y	Commercial applications Domestic applications
Mississippi					(13)
Missouri					(13)
Montana					(13)
Nebraska					(13)
Nevada					(13)
New Hampshire	Y(6)		State	Y	
New Jersey					(13)
New Mexico	Y				Flows <375 gpd only
New York					(13)
North Carolina	Y(7)		State		
North Dakota	Y	400 gpd/br or 1,000			
Ohio					(13)
Oklahoma					(13)
Oregon	Y	1,500	Local	Y	Flows <150 gpd only
Pennsylvania	Y	1,000 Gal. or 3 x D.F.	State	Y	
Rhode Island	N				
South Carolina					(13)
South Dakota	Y	7 x D.F. or 1,000 Gal.		Y	
Tennessee					(13)
Texas					(13)
Utah	Y(8)	1,000 Gal. or 7 x D.F.	State	Y	
Vermont	Y(9)				
Virginia					Regulations unavailable
Washington	Y(10)		Local		
West Virginia	Y(11)	7 x D.F.		Y	
Wisconsin	Y(4)	2,000 or 5 x D.F.	State	Y	
Wyoming	Y(12)	7 x D.F.	State	Y	

(1) Seasonal use, temporary measure.
(2) Low-volume flush toilet required.
(3) Replacement systems or commercial flows <500 GPD.
(4) Case by case basis.
(5) Replace existing non-conforming systems or sites where no other system is feasible.
(6) As replacement or when sewer is imminent (1 year).
(7) 12 Inspections/year, requires certified operator.
(8) Existing dwellings with failed system, temporary system (1 year).
(9) Marine facilities only.
(10) Permanent controlled part time commercial use, emergency interim use, repairs.
(11) 6 Months maximum use.
(12) Intermittent use and failed systems only. No new construction.
(13) Holding tanks not discussed within regulations.

All of the states listed above have conducted research to determine the effectiveness of their tight tank requirements. Each of these states have definitive regulations in place to regulate the installation, operation, maintenance and use of holding tanks. With the exception of Wisconsin, however, none of the states address the issue of septage disposal in their regulations.

It is interesting to compare the cost of septage disposal in Wisconsin and Pennsylvania to the cost in Massachusetts. A review of the requirements placed upon disposal sites makes it clear that Massachusetts has taken much more of a protectionist approach to septage disposal.

31.3 Local Regulations

Several towns, such as Groton, prohibit the use of tight tanks. Gloucester allows temporary holding tanks, which must hold a minimum of 2,000 gallons or seven days of flow.

31.4 Conclusions and Recommendations

Tight tanks or holding tanks have been utilized in Massachusetts to remedy environmental and public health problems created by improperly operating sewage disposal systems. The Department of Environmental Protection has determined that tight tanks should only be used to solve an existing problem for which no other solution is possible. This policy is based on a number of factors including the lack of available approved treatment and disposal facilities for the tanks' contents. This policy, although not consistent with many states which allow tight tanks for new construction, is necessary until adequate septage disposal facilities can be permitted and constructed.

Tight tanks should be designed based upon the standards as outlined in the Department's current Policy Memorandum as modified below.

Tank Sizing

Most states require seven days storage but no less than 1,000 gallons. However, the current Massachusetts requirement that five days storage be provided has proven to be adequate. Five days storage allows sufficient time to schedule a hauler for removal and provides a sufficient volume for most pumper trucks. The size requirement should, therefore, not be changed and should remain as follows:

> Size - Tight tanks should be sized for 500 percent of the average daily flow from the facility being served, but in no case less than 2,000 gallons.

Plans

The current requirement should remain in order to ensure proper design and approval. The regulations should include the following provisions:

> Plans - Plans for tight tanks must be prepared by a Massachusetts registered professional engineer for approval by the Department of Environmental Protection.

Alarms

The majority of the states which allow tight tanks require alarms of some type. The Massachusetts requirement is adequate and allows sufficient capacity above the alarm to obtain the services of a hauler to pump the tank. The requirement should remain as follows:

> Alarms - Alarms with a bell and light set at the three-fifths capacity of the tank and located at a location manned 24 hours per day may be required.

Pumping

The application for the use of a sewage tight tank should provide details on how the tank will be maintained as follows:

> Pumping - The application for approval must indicate the method and frequency of removal of the contents.

Disposal of Tanks' Contents

This requirement is the most important part of the approval process. It is necessary for the Department to be aware of the disposal site for every tight tank in order to ensure that proper disposal of the waste is being accomplished. The Department has been requiring a contract for the hauler and disposal site to be submitted prior to approval of a tight tank. This policy should be continued and made a requirement in the Code. Copies of any approval of a tight tank should include the location of the disposal site and copies of the approval should be sent to the community where the tight tank is located as well as the community where the disposal site is located. The approval should require notification of the Department if the disposal site changes. The following requirement should be included in all tight tank approvals:

> Disposal of Contents - The specific location and manner of disposal must be indicated and be in a proper manner at a location approved by the agencies having jurisdiction.

Accessibility

Tight tanks must be accessible for routine maintenance. The accessibility and location requirements should continue to read as follows:

> Accessibility - All tight tanks must have at least one 24 inch diameter cast iron frame and cover at finished grade constructed so as to eliminate entrance of surface waters. Permanent suction piping may also be required.
>
> Location - The tank should be located so as to provide year-round access for pumping. - This requirement is obvious and should remain.

Permits

A permit for the use of a tight tank should be required. The requirement should read as follows:

> Permit - A permit to install the tank must be obtained from the local board of health under Title 5 of the State Environmental Code.

Monitoring

This requirement is, for the most part, ignored presently although monitoring should be a very important part of any tight tank program. It should be a requirement of any tight tank approval that the local board of health have a program in place to monitor the frequency of pumping of all tight tanks. The Department should give consideration to developing a regulation that requires every septage hauler to submit copies of hauling slips noting the location and amount pumped. Copies of these slips should be filed with the Board of Health of the community where the pumping takes place and the community where the disposal is located. The requirements should remain as follows:

Monitoring - The local board of health must certify that the system will be monitored by them to see that it is being properly operated and maintained. Additional monitoring will be provided by Department personnel having jurisdiction over subsurface sewage disposal on a spot check basis or complaint.

Ground Water

Tight tanks must be constructed to prevent ground water intrusion. The following standard should apply:

Ground Water - Tanks must be waterproof and watertight and should not be located below the water table without extensive testing to prove the integrity of the tank and be designed against uplift.

Odor Controls

Odor controls are applicable to very large systems in high density areas. These system should be handled on a case by case basis and therefore a specific regulation is not warranted. The Code should include the following general statement of authority:

Odor Control - Aeration or some method of odor control may be required.

Reports

The reporting system suggested under the requirement for monitoring should replace the current reporting requirement. Consideration should be given to developing a regulation requiring all septage to report monthly the locations and volumes pumped to each community that they service. This requirement could be as follows:

Reports - Monthly reports may be required to be submitted to the local Board of Health and/or the Department.

Certification

A certification requirement may be necessary in light of staffing shortages at both the Department and the local level. The standard should be as follows:

Certification - The tight tank should not be utilized until written certification that it has been constructed in accordance with the approved plan has been submitted to the Department and Board of Health. the certification must be from a registered professional engineer. This requirement is not intended to interfere with the right of the Board of Health to inspect construction at any time.

The Department of Environmental Protection's tight tank policy states that an escrow account may be required to ensure availability of funds for maintenance. Escrow accounts should be required for all tight tanks approved for non-residential establishments to allow the Board of Health or the Department to perform the required maintenance if necessary.

The current policy also states that any tight tank approval should indicate that there should be no change in use or ownership without a new approval. It is necessary to emphasis to no change in use or size of a facility served by a tight tank will be allowed without approval. However, a change of ownership should not require a new approval. Instead applicants seeking tight tank approval should be required to record a notice on the property deed to notify perspective purchasers that the premises are served by a tight tank.

The Department's tight tank policy has been effective in providing disposal alternative for existing malfunctioning subsurface disposal systems. The Department's policy that tight tanks will not be allowed for new construction should be continued. The requirements of the tight tank policy should be incorporated into the regulations with suggested changes. Further the Department should work with local Boards of Health to develop additional septage disposal areas and more sophisticated monitoring systems to ensure proper maintenance is conducted on all tight tanks.

CHAPTER 32

REGULATORY APPROACH

Across the country, state, regional and local governments play important roles in the regulation of septic systems. While each state's approach is unique, most regulatory schemes address the issues relating to the siting, design, construction and operation of septic systems, and are designed to ensure that septic systems do not affect public health or diminish environmental quality.

This section of the report evaluates the current Title 5 regulatory program and makes recommendations on additional or alternative requirements that should be included in the environmental review and permitting process. These recommendations are designed to make the regulatory process more effective in its ability to protect the environment and public health, and more manageable for regulators and the regulated community.

Recommendations for changes to the current regulatory procedure range from adding time frames into the regulatory review process to make it more predictable and efficient, to creating a code that ensures consistent and appropriate regulation of sewage disposal systems.

This section begins with a description of the key components of an effective approach to regulating septic systems. A discussion of the regulatory framework used in Massachusetts and other states follows. Lastly, recommendations for changing the current septic system regulatory process are provided.

32.1 Literature Review

Common Elements of Regulatory Approaches Used to Review and Permit Septic Systems

The regulatory process used to evaluate and monitor septic systems should ideally follow the life cycle of the septic system (Stewart, 1976; Steinbeck, 1984). Given this assumption, the regulatory process can be divided into three broad phases:

- **the initial installation phase** which encompasses designing, reviewing, permitting, and constructing the system;
- **the operation and maintenance phase** which includes monitoring and enforcement of permit conditions during the life of the project; and

- the project failure/replacement phase which includes the repair, replacement, alteration or abandonment of a septic system.

The EPA On-site Wastewater Treatment and Disposal Design Manual (1980) reinforces the life-cycle regulatory approach by describing a good regulatory program as having at least the following components:

1. site evaluation (phase 1);
2. system design review (phase 1);
3. construction and supervision (phase 1);
4. operation and maintenance certification (phase 2);
5. rehabilitation assistance (phases 2 and 3);
6. monitoring and enforcement (phases 2 and 3); and,
7. public education (all phases).

A well-designed regulatory process has several identifiable characteristics. It is a manageable process which is effective, efficient, consistent and produces the desired results. The paragraphs below describe each of these characteristics in more detail.

First, the process should create the outcomes intended by the regulations. For example, a well-designed regulatory system would create a set of standards for septic system designs that would protect public health and safety. Such a program would encourage the proper design, construction, operation and maintenance of the system. Additionally, the program would include provisions that allow failing septic systems to be easily and quickly identified, initiating an established procedure that assures appropriate remedial action is taken by the septic system owner.

These goals can be attained by using incentives to encourage or reward project proponents for complying with the regulations, using penalties for non-compliance with the regulations, or by a combination of incentives and enforcement actions. The program should establish levels of incentives or penalties reflective of the value of the desired outcome or the seriousness of the violation.

Second, the regulatory process should generate information that assists regulators and project proponents in realizing the goals of the regulations. For example, in Wisconsin, the septic system regulatory process enables state and county officials to identify the size and location of every septic system in the state (Stewart, 1976). This information helps state and local regulators better understand the environmental and public health consequences, including cumulative impacts, of septic system siting decisions. This data also assists state and local regulators in making decisions on land use, environmental issues and economic development projects.

Third, the rules of the regulatory process should be clear and consistent in their application. Project proponents need to understand what is expected in the environmental review, permitting and monitoring/enforcement process. They need to understand:

- what areas are suitable for their projects;
- what actions the regulators expect project proponents to take with regard to mitigation and on-going environmental protection efforts;
- what standards the project must reach;
- what criteria will be used to evaluate the project; and,
- who will evaluate the project and how will a decision about the project be made.

Ideally, project proponents should be able to assess the review and permitting process by which a project is judged to determine the likelihood of their project attaining a favorable outcome in the regulatory process.

In a well-defined regulatory process, all parties involved (the regulators, the project proponent, and the general public) understand the basis on which project decisions are made. All parties have confidence that the information presented in applications for approval meets well defined standards and that the people making the project decisions have the knowledge necessary to make informed judgements. For example, many states require that the basic data needed to make an informed judgement about a septic system project (soils data, percolation rates, etc.) be provided by certified consultants. In addition, many states have training and certification programs for state and local regulators charged with making the permitting decisions on septic system projects (Jacobson and Veneman, 1987).

The regulatory process should be efficient. Project review, permitting, and monitoring and enforcement actions should occur within a clearly defined time frame. There should be no backlogs or unreasonable delays in the regulatory system.

Finally, the regulatory program should be designed to evaluate "routine" projects easily and dispense with these cases quickly. For example, the Title 5 regulatory process might define a "routine" case as a small system, serving a residential use, that is not located in an environmentally sensitive area.

The regulatory system should also provide the flexibility to evaluate and take action on "unusual" projects. Many states have special review, permitting, monitoring and enforcement requirements for systems that have greater potential health and environmental consequences such as large, multiple-user systems, systems in environmentally sensitive areas, and systems with a potential for cumulative impact, etc. (Jacobson and Veneman, 1987).

The Current Title 5 Regulatory System

Statutory authority to regulate Title 5 systems is vested in both state and local governments. Under G.L. c.21A, s.13, the Commissioner of the Department of the Environmental Protection is required to adopt a State Environmental Code. The Code, which deals with matters affecting the environment, must include standards for the disposal of sewage. Section 13 of Chapter 21A also designates boards of health as the agency with primary enforcement responsibility under the Code.[1/] If the board of health fails to enforce the Code, the Department of Environmental Protection is authorized to act as the enforcement agency.

Statutory authority for the regulation of Title 5 systems on the local level is derived from several sources. Under Section 6 of the Home Rule amendments, Article 39 of the Amendments to the Constitution of Massachusetts, a municipality may adopt any ordinance or by-law which is not inconsistent with laws enacted by the legislative powers. G.L. c.111 s.31 provides boards of health with general authority to "make reasonable health regulations". Copies of all such local regulations must be filed with the Department of Environmental Protection.[2/]

G.L. c.111 s.127 further authorizes boards of health to make and enforce regulations for the public health and safety relative to house drainage and connection with common sewers. G.L. c.111 s.122 authorizes boards of health to "examine all nuisances, sources of filth and causes of sickness within its town", and to "make regulations for the public health and safety thereto. . ." Section 122 has been

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1) State authority over Title 5 systems is also potentially found in G.L. chapter 111, Section 127A, which provides that the Department of Public Health ("DPH") is required to adopt a state sanitary code. However, the authority of the Department of Public Health to regulate septic systems was transferred to the Department of Environmental Quality Engineering upon the creation of DEQE in 1975. See chapter 706 of the Acts of 1975. Included in the authority transferred to DEQE from DPH were several articles of the State Sanitary Code, including Article XI. Shortly after it was created, DEQE repromulgated Article XI pursuant to c. 21A, Section 13, and changed the name to Title 5 of the State Environmental Code. However, the legislature failed to amend chapter 111, Section 127A to clearly reflect that DPH no longer had authority over Title 5 systems.

2) Chapter 111, Section 31 does not explicitly require that board of health regulations be filed with DEP in order to be effective, but states only that such regulations "shall" be filed. As a result, many boards of health ignore this requirement.

cited as one of the sources for the "plenary power" of boards of health to adopt "reasonable health regulations" (See United Reis Homes, Inc. v. Planning Board of Natick, 359 Mass. 621 (1971)). Boards of health also have authority to review subdivision plans pursuant to G.L. c.41 s.81U.[3]

In general, boards of health have the primary responsibility for regulating Title 5 systems designed for discharge of less than 15,000 gallons per day on any one lot. The Department of Environmental Protection reviews projects which require variances to Title 5 or propose discharges greater than 15,000 gallons per day.

In cities, the three members of the board of health, one of whom must be a doctor, are appointed by the mayor, subject to confirmation by the board of alderman (G.L. c.111 s.26A et seq.) In towns, the board is usually elected. In towns which have not provided for the establishment of the board of health, Selectmen act in that capacity (G.L. c.41 s.1). Board of health members are not required to undertake any specific training or certification before making decisions on public health questions in their community.

Although never tested in court, the ability of boards of health to adopt stricter regulations than those contained in Title 5 has been the subject of some controversy. The Home Rule Amendment and the statutes cited above, as well as relevant case law, appear to give boards very broad general powers to regulate virtually any threat to human health. The preamble to Title 5, however, suggests that the Department of Environmental Protection believes stricter local regulations should be used sparingly:

> "Specific, identifiable local conditions may require more stringent regulations to protect these interests. However, in the absence of such specific conditions, the following Code when properly enforced, should afford adequate protection. In general, proper care and maintenance, rather than more stringent regulation, are the best means to assure that such systems will serve the purpose intended and prevent danger to public health and the environment" (310 CMR 15.00).

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3) Boards of health also have powers relative to the state sanitary code pursuant to Chapter 111, Section 127A, which provides:

> This section shall not be deemed to limit the right of any board of health to adopt such rules and regulations as, in its opinion, may be necessary for the particular locality under its jurisdiction; provided, such rules and regulations do not conflict with the laws of the commonwealth or the provisions of the [sanitary] code.

As noted above, however, since 1975 septic systems are regulated under the state environmental code, not the sanitary code. Accordingly, the provisions of Section 127A should not apply to the actions of boards of health relative to septic systems.

TABLE 32.1.1

Title 5 Environmental Review Process

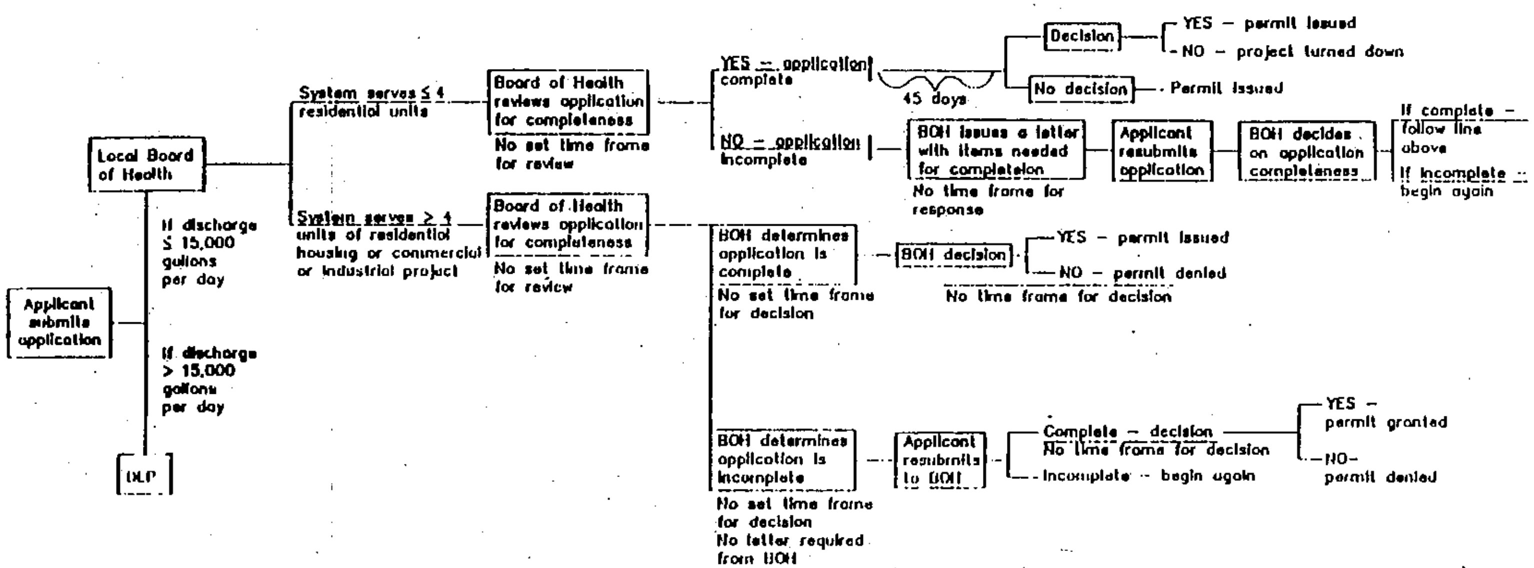

TABLE 32.1.2

ENVIRONMENTAL PERMITS ISSUED UNDER TITLE 5

Permitting Agency	Jurisdiction	Purpose of Permit
State	None for Title 5 Systems	
DEP	>15,000 gallons/day	
Boards of Health	Title 5 construction, repair and maintenance systems:	(1) Disposal works construction permit Terms/conditions for construction/ operations (2) Certificate of Compliance allows occupancy if Title 5 system built, altered, repaired in compliance with Title 5
	Persons allowed to work on Title 5	Disposal Works Installers Permit
	Persons allowed to handle septage disposal from Title 5	Septage Handlers Permit

TABLE 32.1.3

ENVIRONMENTAL MONITORING/ENFORCEMENT

	SYSTEM CONSTRUCTED/ BEGIN OPERATIONS	LIFETIME OF SEWAGE DISPOSAL SYSTEM	END OF USEFUL LIFE
Construction Permit Issued	Certificate of Compliance Issued	- nothing required during this time - possible scenarios: • regular maintenance • no maintenance • regular repairs • sporadic repairs • system failure (part) • system failure (total)	- possible scenarios • continue to operate even if environmental problems exist • replacement • enforcement action by board of health or DEP (if threatening water supply)

The current Title 5 regulatory program does not follow the life-cycle of septic systems. As illustrated in Table 32.1.1, the existing regulatory process is one which focuses primarily on the activities involved in the initial installation phase. The regulations contained within Title 5, however, allow involvement to occur in the three phases of the life cycle of a subsurface sewage disposal system as described below and shown graphically in Table 32.1.2; while, Table 32.1.3 describes the various permits issued for Title 5 systems.

Phase 1: Initial Installation

The regulatory process begins with some level of environmental review. Title 5 systems designed for less than 15,000 gallons per day do not require approval by the Department of Environmental Protection and do not trigger state environmental review under the terms of the Massachusetts Environmental Policy Act (MEPA) statute or regulations. Boards of health evaluate the environmental impact of the proposed subsurface sewage disposal system by analyzing the plans and specifications submitted by a project proponent for system construction, alteration or repair. The plans and specifications must contain all of the information set forth in 310 CMR 15.02(4) and (5) and the information required by G.L.c.111 s.31E. The statute and regulations require the project proponent to provide the board of health with at least the following information:

- the lot to be served;
- location and dimension of the system (including reserve area);
- design calculations;
- proposed and existing contours;
- location and log of deep observation holes;
- location and results of percolation tests;
- location of any streams, surface or subsurface drains, and wetlands within 100 feet of the sewage disposal system;.
- known sources of water supply within 200 feet of the sewage disposal system;
- location of any proposed well to serve the lot;
- location of water lines on the property;
- maximum ground water elevation in the area of the sewage disposal system;
- a profile of the sewage disposal system; and,
- any other information required by a board of health regulation.

Phase 2: Operation and Maintenance

The disposal works construction permit can set out conditions for the operation and maintenance of the sewage disposal system. However, as there is no explicit maintenance program contained within the Title 5 regulations, individual boards of health may determine the maintenance requirements and schedule for each sewage disposal system (310 CMR 15.02(19)). The regulations provide little guidance to communities regarding regular inspection programs for Title 5 systems.

Phase 3: System Failure

310 CMR 15.22 - 15.26 describe the enforcement provisions of Title 5. These sections specify that the provisions of 310 CMR 11.00 govern the enforcement of the Title 5 regulations, authorize the board of health or the Department of Environmental Protection to issue an order to remedy the failure when an inspection conducted according to 310 CMR 11.00 reveals a Title 5 failure, and set forth a hearing and appeals process.

32.2 State Regulations

Most states have regulations governing septic systems. For the purposes of this report, four general questions were explored:

- **Who regulates septic systems in each state?** If more than one governmental body regulates septic systems, what are their respective responsibilities? What is their relationship to each other?
- **How is the regulatory process structured?**
- **What is required of regulators and the regulated community in each state?**
- **What outreach or public education efforts are made to septic system designers and property owners?**

Table 32.2.1 summarizes the responses to these questions. This table was created by reviewing each of the state regulations as well as a report on state regulations (Jacobson and Veneman, 1987).

Septic systems are typically regulated by the states in conjunction with either regional or local agencies. The local or regional agencies are typically responsible for the review and permitting of septic systems as well as providing oversight of the septic system management programs. Generally the state's role is to ensure that the regulations are applied fairly, and to intervene on enforcement actions if needed. In some states, however, a state agency is solely responsible for the regulation of septic systems.

TABLE 32.2.1

REGULATORY STANDARDS

	MINIMUM STANDARDS	UNIFORM STANDARDS	EXPAND MINIMUM STANDARDS		TRAINING
			FREQUENTLY	INFREQUENTLY REQUIRED	
Alabama	X			X	X
Alaska					
Arkansas		X			X
Arizona	X			X	X
California					
Colorado					
Connecticut		X			X
Delaware	X			X	X
Florida	X		X		X
Georgia					
Hawaii	X				
Idaho	X		X		X
Illinois					
Indiana	X				X
Iowa	X			X	
Kansas					
Kentucky	X			X	X
Louisiana					
Maine	X			X	X
Maryland					
Massachusetts	X				
Michigan					
Minnesota	X			X	X
Mississippi	X			X	X
Missouri	X				X
Montana					
Nebraska	X		X		
Nevada					
New Hampshire	X			X	X
New Jersey	X		X		
New Mexico	X			X	X
New York	X		X		
North Carolina					
North Dakota					
Ohio	X			X	X
Oklahoma		X			X
Oregon		X			X
Pennsylvania		X			
Rhode Island	X			X	
South Carolina					
South Dakota	X			X	
Tennessee	X			X	X
Texas	X		X		
Utah	X			X	X
Vermont					
Virginia					
Washington					
West Virginia	X				X
Wisconsin					
Wyoming	X			X	X
Guam	X				

In many cases, a state agency sets the minimum standards for septic system design, construction, maintenance and/or operation. Some states grant regional or local governments the authorization to expand upon state regulations. Regional and local agencies in some states, for example Florida, New Jersey and Texas, frequently augment state regulations. In other states, including Alabama, Kentucky and Ohio, the local authority to supplement state regulation is infrequently exercised.
Arkansas, Connecticut, and Oregon, set uniform standards which apply to all communities in the state.

Many states have regulatory programs that, similar to Massachusetts, tend to focus on the Phase 1 activities involved with ensuring that septic systems are properly located, designed and constructed. These states do not place a strong emphasis on the Phase 2 and Phase 3 activities requiring on-going monitoring, repair and replacement of septic systems.

While the overall regulatory pattern is similar, several states have some unique components to their regulatory framework that may provide for more effective protection of the public health and safety. Wisconsin requires that septic system proponents file a plan with the regional and state government which includes the location and specification of the system. This allows the state to create a state-wide data base on the location of septic systems. This approach enhances the ability for decision-makers to assess the cumulative impacts of a project. North Carolina requires that a landowner prepare a number of legal documents that describe the condition of the septic system before a property can be transferred.

A number of states, including Wisconsin, North Carolina, California, Iowa, Kentucky, and Florida allow the creation of wastewater utility districts to oversee the operation, maintenance and eventual replacement of large, multiple user septic systems. These utility districts allow septic systems to be constructed at a lower cost than individual septic systems or a municipal wastewater treatment plant and its associated sewer collection system. The districts are better able to regularly monitor, repair and maintain their systems. They also typically have a financial mechanism to fund the eventual replacement of the system. Cluster development techniques, which help preserve open space and protect other environmental resources, are often used in developments served by large, multiple user septic systems.

Some states such as North Carolina have also begun to require more extensive monitoring reports (usually on an annual basis) for septic systems. North Carolina has begun a program to audit the monitoring and enforcement activities of local agencies to ensure compliance with the state's septic system and water protection regulations.

Training and certification of local and regional septic system regulators is required by more than 25 states. Many states, most notably Wisconsin, Ohio and Pennsylvania, have developed a number of publications designed to provide information to the general public about septic systems, how they work, and what a homeowner or small business person needs to do to keep them operating effectively. Understanding how septic systems work can translate into better homeowner maintenance practices. These two factors are critical in the successful operation of a septic facility (Huang, 1983; Staudt and Niehus, 1980)

32.3 Conclusions and Recommendations

The Title 5 regulations were developed to protect public health and environmental resources from the potentially deleterious effects of unregulated use of individual sewage disposal systems. Many steps can be taken to make the Code more effective at meeting its public health and environmental protection goals. The following discussion includes potential changes designed to strengthen the Title 5 program; to protect public health and environmental resources in the short and long term; to clarify the requirements of the regulatory process; to make the regulatory system more efficient by providing clear time lines for decisions by local and state regulators; to make the regulatory framework more consistent; to create regulations based on sound technical underpinnings; and, to help state and local decision-makers make more informed choices about subsurface sewage disposal systems.

The current regulatory process provides a high level of local control and influence over the location, and to some degree the density of development projects. Local officials can establish stricter standards than exist in the state regulations to account for unusual local environmental circumstances. When applied appropriately, these local standards can result in a greater level of environmental and public health protection than would occur through the application of Title 5 alone.

However, the current environmental review and permitting system also allows localities to create more stringent standards for sewage disposal systems without substantiating the need for the additional standards. Currently, neither the Department of Environmental Protection nor the State Department of Public Health have the authority to review or amend these local regulations. The results cut two ways. In some communities, individual sewage disposal systems are regulated to a higher standard than the environmental circumstances in that community warrant. Other communities, could benefit by adopting more stringent regulations specifically designed to address identifiable local conditions. The current Title 5 regulatory program is also ineffective in helping communities share their experiences and translate effective regulatory schemes from one community to another.

Over 180 local communities have chosen to exercise their right to adopt regulations that are more stringent than the state's requirements. While the ability to regulate according to existing local conditions is a valuable public policy tool, it creates, at the very least, a complex and often times confusing regulatory environment. It may also lead to inconsistencies among regulations where similar conditions exist.

Local officials also play a key role in requiring and enforcing maintenance provisions for Title 5 systems. Boards of health are in a better position than state officials to know the environmental conditions that exist in their communities and therefore can play a pivotal role in the early identification of system failures and subsequent enforcement actions. In communities where board of health members have a working understanding of Title 5 and the environmental conditions in their community, and a willingness to actively pursue the maintenance of sewage disposal systems, the current Title 5 regulatory structure can be effective in providing environmental resource and public health protection.

In the current environmental review process, boards of health evaluate the site specific impacts of a sewage disposal system. The current review process does not require an applicant to identify the location of other sewage disposal systems in the area of the project. Hence, regulators do not have the ability to assess the potential cumulative impacts of these systems on the area's natural resources.

The current application process requires a project proponent to identify the location of any streams, surface and subsurface drains and wetlands within 100 feet of the sewage disposal system; any known sources of water supply within 200 feet of the sewage disposal system; and the location of any proposed well to serve the lot. The current program does not require a hydrogeologic analysis of the ground water flow on or near the site, so that the potential impact of the sewage disposal system on these resources might be evaluated and understood, nor does the process require a project proponent to assess the impact of the system on other important resources in sensitive environmental areas.

Furthermore, the current review and permitting process does not have a mechanism in place to help gather the information from past environmental reviews and compile it in a useful form available to decision-makers evaluating a current project. For example, there is no comprehensive database that contains the location of sewage disposal systems across the state.

The Title 5 program is designed primarily as a construction permitting process which does not assure continuous monitoring and review necessary for successful environmental protection. Under this process there is no systematic way to evaluate whether the systems are functioning effectively during the course of their use nor to mandate that they are replaced when they are no longer effective. The lack of routine monitoring for problems with sewage disposal system and enforcement of maintenance provisions can lead to greater environmental degradation than might otherwise occur.

The current regulatory program also lacks a strong enforcement capability. Although boards of health and the Department of Environmental Protection are allowed by law to inspect septic systems for violation of environmental standards, there is little staff time or funding available for these inspections. There are few incentives, other than nuisance, for a property owner to identify problems with their septic system and to implement mitigative measures.

The current regulatory process could be made more effective by providing planning assistance and technical training to board of health members. Many boards of health lack the resources to identify the environmentally sensitive areas in their communities. As a result, it is very difficult to evaluate the appropriateness of siting a sewage disposal system in one location versus another location. Some board of health members also lack the technical understanding of sewage disposal systems needed to make an informed decision regarding location, specifications and short and long term impacts on the environment and public health.

The Title 5 regulatory program is not as efficient as it could be. While there are minimum standards for what needs to be included in a permit application, there are no definitive standards concerning what constitutes a complete application. There is no time frame for a board of health to make a decision about the completeness of an application. There is a time frame for decision once the application is considered complete, but this time frame only applies to residential projects of less than four units.

The Title 5 regulatory process makes no distinction between routine cases and exceptional cases. There is no differentiation in the environmental review and permitting process based upon system size (for all of those systems where less than 15,000 gallons per day is discharge on the lot), location, or type of use served by the project. This results in too much review of certain types of systems and too little review of other systems.

The Title 5 environmental review process could be strengthened in several important ways. First, the state could provide funding for Geographic Information System (GIS) services to boards of health to help boards identify the environmentally sensitive areas within their community. This assistance should be conditioned on the willingness of the community to identify appropriate areas for development as well as to take steps (such as zoning changes) to protect environmentally sensitive areas.

Second, the Department of Environmental Protection could seek the resources necessary to set up a statewide data base on sewage disposal systems. This data base could be used to compile the information provided through individual disposal works construction permit applications, and lead to improved decision-making, as there will be more data available on the cumulative impacts of multiple sewage disposal systems within a given area.

Third, the requirements for disposal works construction permit applications could be altered to include a hydrogeologic study as well as information on surrounding land uses, for all systems over 2,000 gallons per day so that the project may be reviewed in a regional context. Applicants may join together to share costs on a regional hydrogeologic study.

Fourth, the regulations could be rewritten to allow for greater discrimination between projects. It may be appropriate to differentiate the level of review required for small (under 2,000 gallons per day), medium (2,000 - 5,000 gallons per day) and large systems (over 5,000 but less than 15,000 gallons per day). The state should assist boards of health to review medium sized projects in environmentally sensitive areas; while, the state should review and permit projects involving large systems, regardless of location.

Fifth, the Department of Environmental Protection should seek the creation of a uniform code for the regulation of sewage disposal systems. Title 5 should be amended to prohibit local septic regulations unless approved by the Department. However, it is unlikely that the existing source of authority for Title 5, G.L. c.21A s.13, alone is sufficient to allow the Department of Environmental Protection to promulgate such regulations. While G.L. c.21A s.13 grants the Department broad powers to regulate septic systems, it also provides that nothing contained in the state environmental code "shall be in conflict with any general or special law". Accordingly, a regulatory provision which limits the power of boards to adopt more stringent regulations would probably conflict with G.L. c.111 s.31 as well as with Home Rule powers.

The courts have held that these statutes provide boards of health with "plenary powers" to adopt reasonable health regulations (United Reis Homes, 359 Mass. 624). Moreover, due to the breadth of Home Rule power, courts will not strike down local legislation, unless such legislation is clearly inconsistent with a state enactment (Bloom v. Worcester, 363 Mass. 136 (1973)).

The Department would have to obtain specific statutory authority to enact such a Code. This legislation could restrict boards of health from enacting supplementary Title 5 regulations until such regulations are approved by the Department of Environmental Protection or a specially established Board of Overseers. Such legislation could take the form of an entirely new statute, or could amend the provisions of G.L. c.111 to make clear that septic system regulations must be approved by the state.

Localities should continue to have the ability to establish stricter standards for local environmental conditions. The localities would be required, however, to have their local ordinance reviewed and approved by a state-level board. (This is a similar regulatory scheme to the Plumbing Code and the Building Code). This would help ensure that all local standards have a strong and legally defensible environmental or public health rationale. The uniform code model would also help better disseminate the experiences of local governments between local officials.

Sixth, the Department of Environmental Protection should require and provide training and certification of board of health members. The existing Title 5 Training Program offered to boards of health should be expanded to cover more advanced topics and a comprehensive handbook that explains technical issues involved with sewage disposal systems should be developed for board of health members.

Seventh, clear timeframes should be included in the regulations for board of health and the Department review of applications for completeness and for decisions on disposal works construction permits.

Eighth, a model application form and a list of required analysis should be created by the Department for use by boards of health. This will help ensure consistency between municipalities in the environmental review process.

The Title 5 regulations could be made more effective by including provisions for on-going maintenance and for more adaptable enforcement. Specifically, the Department of Environmental Protection should amend the Title 5 regulations to include specific requirements for maintaining subsurface sewage disposal systems. The Department should also consider seeking authority to allow the creation of wastewater utility districts.

The Department of Environmental Protection should explore ways to make the enforcement system more sensitive to the various types of sewage disposal problems. For example, the Department may want to consider having a sliding penalty for Title 5 violations based on the severity of the problem caused by the system and the willingness (or lack thereof) of the owner to remedy the situation. The Department could establish a low interest loan program, from fines collected from Title 5 violations, to help low and moderate income people and small firms bring their Title 5 systems into compliance.

PART VI

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STATE REGULATIONS FOR SUBSURFACE SEWAGE DISPOSAL SYSTEMS

1. West Virginia

- Chapter 16-1 Series VII 1983 effective Date December 1, 1983

  Division of Public Health Sanitation
  Room 507, 1800 Washington Street, East
  Charleston, West Virginia 25305

2. Washington

- Chapter 248-96 - July, 1983
- Guidelines for the use of Experimental On-Site Sewage Systems - October, 1986
- Procedure for the Review of Alternative Systems - May, 1980
- Guidelines for the Design, Application and Operation of Aerobic Treatment Devices - July, 1984
- Guidelines for the Use of Pressure Distribution Systems - September, 1984
- Guidelines for Alternating and Dosing Systems - January, 1985
- Guidelines for Vault and Pit Privies - July, 1984
- Guidelines for the Use of Composting Toilets - July, 1984
- Interim Guidelines Governing the Design, Application and Operation of Incineration Toilets - July, 1984
- Guidelines for the Use of Fill or Mound Systems - November, 1986
- Interim Guidelines for Sand Filters - May, 1981
- Design Guidelines for Larger On-Site Sewage Systems with Design Flows of Greater Than 3,400 GPD - 1987
- Graveless Disposal Systems - June, 1986

  Office of Environmental Health Programs
  Health Division LD-11
  Olympia, Washington 98504

3. Vermont

- Agency of Environmental Conservation, Division of Protection Chapter 7 Sewage Disposal

- Chapter 8 Sewage Treatment and Disposal

4. Utah

- State of Utah, Department of Health, Division of Environmental Health, Wastewater Disposal Regulations Part V Large Underground Wastewater Disposal System - Rev. April, 1986

- Regulations for Individual Wastewater Disposal Systems - January 5, 1984

  Utah Department of Health
  Division of Environmental Health
  Bureau of Water Pollution Control
  Post Office Box 16690
  Salt Lake City, Utah 84116-0690

5. Tennessee

- Regulations to Govern Subsurface Sewage Disposal Systems

  TN Department of Health and Environment
  Division of Ground Water Protection
  T.E.R.R.A. Building - 5th Floor
  150 9th Avenue, N.
  Nashville, Tennessee 37219-5404

6. Wyoming

- Part D Septic Tank and/or Soil Absorption Systems and Other Small Wastewater Systems

  Water Quality Division
  Herschler Building
  Cheyenne, Wyoming 82002

7. South Dakota

- Chapter 74:03:01 - Individual and Small On-Site Wastewater Systems

  Department of Water & National Resources
  Office of Water Quality
  Joe Foss Building, Room 416
  523 East Capitol
  Pierre, South Dakota 57501-3181

8. South Carolina

- Regulation 61-56 Individual Waste Disposal Systems - June 27, 1986

- South Carolina Department of Health and Environmental Control Standard for Determining Submersible Pump Effluent Requirements for Non-Pressure Individual Sewage Treatment and Disposal Systems - April, 1985

- Grease Trap Design & Maintenance

- Regulation 61-56.1 License for Contractors

  South Carolina Department of Health and
  Environmental Control
  2600 Bull Street
  Columbia, South Carolina 29201

9. Puerto Rico

  Estado Libre Asociado De Puerto Rico
  Oficina De Gobernador
  Apartado 11488
  Santurce, Puerto Rico

10. Pennsylvania

- Ch. 71 Administration of Sewage Facilities Program

- Ch. 72 Administration of Sewage Facilities Permitting Program

- Ch. 73 Standards for Sewage Disposal Facilities
  Technical Manual, Pamphlets

  Department of Environmental Resources
  Post Office Box 2063
  Harrisburg, Pennsylvania 17120

11. Oregon

- Ch. 340, Division 71 On-Site Sewage Disposal - December, 1986
- Oregon On-Site Experimental Systems Program - December, 1982

Department of Environmental Quality
811 South West Sixth Avenue
Portland, Oregon 97204

12. Oklahoma

- Rules and Regulations Governing Residential Sewage Disposal (ODM Bulletin #600) - April 2, 1987

Oklahoma State Department of Health
1000 Northeast 10th Street
Post Office Box 53551
Oklahoma City, Oklahoma 73152

13. Ohio

- Household Sewage Disposal Rules Ch 3701-29-01 to 3701-29-21 - July 1, 1977
- Home Sewage Disposal Drawing - June, 1980
- Limitation Evaluation of Ohio Soils for Sewage Effluent Absorption
- 3701-29-10 Installation Requirements for Soil Absorption and Percolation
- Ohio's Soil Manual for Sanitarians

Department of Health
Box 118
Columbus, Ohio 43266-0118

14. New York

- Appendix 75-A Waste - Treatment - Individual Household Systems Public Health Law 201(1)(L)

State of New York
Department of Health
Albany, New York 12237

15. New Mexico

- Liquid Waste Disposal Regulations - November, 1985

  State of New Mexico
  Post Office Box 968
  Santa Fe, New Mexico 83504-0968

16. New Jersey

- Standards for the Construction of Individual Subsurface Sewage Disposal Systems (CH. 199) - July 1, 1978

- Procedure for Piezometer Test

- Procedure for Pit-Bailing Test

  Department of Environmental Protection
  Division of Water Resources
  CN 029
  Trenton, New Jersey 08625

17. New Hampshire

- Subdivision and Individual Sewage Disposal System Design Rules - April, 1987

  State of New Hampshire
  Water Supply & Pollution Control Division
  Hazen Drive Box 95
  Concord, New Hampshire 03301-6528

18. Nebraska

- Title 124 - Nebraska Department of Environmental Control

  Department of Environmental Control
  Box 94877, State House Station
  Lincoln, Nebraska 68509

19. Montana

- Circular # 84-12 Individual On-Site Alternative Sewage Treatment Systems

- Ch. 16 Subdivisions

- Sewers and Sewage Treatment for Multi-Family and Non-Residential Buildings

- Septic Tanks

Department of Health and
Environmental Sciences
Cogswell Building
Helena, Montana 59620

20. Mississippi

- Regulation Governing Individual On-Site Wastewater Disposal Systems

21. Minnesota

- Use of Soil Surveys in the Preliminary Site Evaluation
- Recommendations for Checking Homes with Septic System Failures
- Chapter 7080 Individual Sewage Treatment System Standards

State of Minnesota
Municipal Wastewater Treatment Section
520 Lafayette Road
St. Paul, Minnesota 55155

22. Maryland

- 10.17.02 Sewage Disposal and Certain Water Systems for Homes and other Establishments
- Maryland Well Construction Regulations Comar 10.17.13
- Title 10, Subtitle 17 Sanitation, Chapter 03 Water Supply and Sewage Systems

Department of Health and Mental Hygiene
201 West Preston Street
Baltimore, Maryland 21201-2399

23. Maine

- Subsurface Wastewater Disposal Rules, Ch. 241 - July, 1980
- Department of Human Services, Rules for Site Evaluations

34. Florida

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35. Delaware

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North Brookfield
North Andover
North Adams
Northampton
Northborough
Northbridge
Norton
Norwell
Norwood
Pelham
Pembroke
Pepperell
Peru
Petersham
Phillipston
Plainville
Plymouth
Princeton
Provincetown
Raynham
Rehoboth
Rochester
Rockland
Rockport
Rowley
Royalston
Rutland
Sandisfield
Sandwich
Savoy
Scituate
Seekonk
Sharon
Shelburne
Sherborn
Shirley
Shrewsbury
Shutesbury
South Hadley
Southampton

DeFeo, Wait & Associates, Inc.

List of Towns with Local Regulations Filed with the Department of Environmental Protection as of July, 1990

Abington
Acton
Agawam
Alford
Amesbury
Amherst
Andover
Ashburn
Ashburnham
Ashfield
Ashland
Athol
Auburn
Barnstable
Bedford
Bellingham
Beverly
Billerica
Blackstone
Blandford
Bolton
Bourne
Boxborough
Boylston
Brewster
Bridgewater
Brimfield
Burlington
Canton
Carlisle
Carver
Charlton
Chatham
Chelmsford
Chicopee
Cohasset
Conway
Dartmouth
Dedham
Deerfield
Dennis
Douglas
Dover
Dracut
Dunstable
Duxbury
East Bridgewater
Easton
Edgartown
Fairhaven
Falmouth
Foxborough
Franklin
Georgetown
Gloucester
Goshen
Grafton
Granby
Groton
Halifax
Hanson
Hardwick
Harvard
Harwich
Hingham
Holden
Holliston
Holyoke
Hopkinton
Hubbardston
Ipswich
Kingston
Lakeville
Lanesborough
Leicester
Lexington
Lincoln
Littleton
Ludlow
Manchester
Mansfield
Marion
Marlborough
Marshfield
Mashpee
Mattapoisett
Medfield
Mendon
Merrimac
Middleton
Milbury
Milford
Millis
Monson
Nantucket
Nashoba Associated Boards of Health
Natick
Norfolk