1979 State of the Art Manual of

ON — SITE

WASTEWATER MANAGEMENT

National Environmental Health

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A 1979 State of the Art Manual of

ON-SITE WASTEWATER MANAGEMENT

By The National Environmental Health Association's
On-Site Wastewater Management Committee

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Lakewood, Colorado

Allan H. Young, Jr.
Williamsport, Pennsylvania

Advisors

Lawrence J. Krone, Ph.D.
Denver, Colorado

Nina McClelland, Ph.D.
Ann Arbor, Michigan

James F. Kreissel
Cincinnati, Ohio

Keith H. Dearth
Washington, D.C.

John T. Winneberger, Ph.D.
Berkeley, California

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INTRODUCTION

According to a 1975 report of the U.S. Environmental Protection Agency, "almost twenty million housing units, representing about twenty-nine percent of the United States population, dispose of domestic wastes through individual on-site disposal systems. About 85 percent of these systems are septic tanks and cesspools, which discharge approximately three billion cubic meters (800 billion gallons) of waste per year to the soil."

There is general agreement among most who are concerned with on-site systems that there is a rather urgent need for a national publication which will go beyond the scope of the "Manual of Septic Tank Practice."

There is active and encouraging national interest in the whole subject of wastewater management, stimulated partly by the requirements for federal financial assistance called for in the Clean Water Act (PL 91-250). In 1977, amendments to the Act further stimulated interest in the subject by authorizing federal contributions of 75 or more percent toward the cost of qualifying on-site systems for private homes, when the application is made by a qualifying public agency. New policies are necessitating careful cost-effectiveness studies to compare on-site systems with public sewerage and other alternatives, called for in the new Act, PL 95-217.

Increased environmental concern is bringing to focus the importance of protecting ground water supplies, preventing lake eutrophication, and avoiding the health hazards and nuisances from improper wastewater management.

Legislators, public leaders and businessmen and progressive environmental officials are no longer satisfied with past enforcement policies which blocked subdivision approval and issuance of building permits of unsewered properties because site conditions were not favorable for conventional septic tank and seepage systems. Research and development, demonstration projects and in-depth studies are resulting in acceptable alternative methods, equipment and designs for previously non-qualifying sites.

There has been much information developed by pioneers of the past, and this must be selectively incorporated into any "new" programs. Additionally, means are needed whereby federal, state, regional and local groups and officials have ready access to better regulatory policies and theories and the scientific data and experience on which they are based. It is with that concept in mind that the National Environmental Health Association organized its "On-Site Committee" and issued its charge to summarize available data and information.

The Committee includes representation from those who enforce regulations and guide planning and installation; authorities who do research and in-depth studies; specialists in environmental health, engineering, hydro-geology and other fields who do site and system evaluation; companies which make equipment and develop innovative systems; contractors who make the installations; contractors or others who maintain systems and dispose of or utilize the material removed from the treatment units. It is the primary objective of this Manual to recognize those who have much at stake, the owners of the homes and properties served by the systems.

The Committee recognized the vast amount of work and accomplishment of the many individuals and groups who have already developed excellent codes, guidelines and reports that were heavily drawn upon to produce this Manual.

It was also recognized that the field is so dynamic that new information, methods and systems are constantly being developed. For that reason, the Manual should be regularly and periodically updated to keep abreast of progress.

This manual concentrates on basic principles and fundamental methods. In areas where there is not general agreement among authorities, various viewpoints are presented with the scientific or experience basis for each.

This manual is not intended to substitute for an in-depth training manual but to include in various chapters much of the basic information which should be included in training manuals.

Recognition is given to the importance of knowledge of, and consideration for, variable regional and local conditions such as weather, geology, hydrology and especially *experience.* Encouragement is given to both those who develop new and innovative methods, systems and equipment and to those who participate in evaluating and supervising the controlled installation and operation of promising innovations.

Chapter 2

ADMINISTRATION OF PROGRAMS

A. Level of Government

1. Federal

The Congress has assigned important responsibilities for waste water management to federal agencies, particularly the Environmental Protection Agency. That Agency has manpower and funds to make and support studies to fill gaps in knowledge. Through its publications and Technology Transfer it helps to impart knowledge and provide training.

EPA has new responsibilities for stimulating and requiring cost-effectiveness evaluations to decide between financial aid for public sewage treatment and on-site alternatives. With governmental funding available to assist in financing on-site systems on private properties, EPA has a high stake in being assured that the systems will function properly.

Protection of the nations's water resources includes assuring that whatever system is installed will not result in serious degradation of these resources, including ground water. It is, therefore, apparent that the federal government has a role of greater magnitude than the advisory role played by the United States Public Health Service when it developed the *Manual of Septic Tank Practice (1967).*

The United States Department of Housing and Urban Development has a major stake in on-site systems for homes to minimize risk of system failures that affect their mortgage insurance. For this reason that agency has taken an active role in funding and securing research in this field. The policy requiring official approval of proposed systems as a condition of FHA and VA Mortgage Insurance has been an important factor in the continuous effort to provide higher standards for on-site systems.

2. State and Regional

State and regional agencies have the opportunity to play a dual role. They are authorized to act as the administrative, evaluative and recommending agency for many of the enforcement and fund allocating functions of EPA.

Additionally, as indicated by many excellent state programs, states have the resources, staff and breadth of responsibility to most effectively develop basic on-site systems codes or manuals; to provide the expert consultative services so often essential; to establish guidelines for review and approval of innovative systems; to work in close cooperation with universities and other research oriented organizations; and to provide leadership.

In states which do not have regional or local agencies that are staffed and prepared to enforce or secure compliance with acceptable standards, the state government must assume the responsibility as the enforcing agency.

States are also the logical agencies to develop educational publications, conduct educational and field training programs, administer regulations for licensure or certification of site evaluators and installers.

Water quality control programs, carried out in connection with the Clean Water Act, tie in closely with area-wide consideration of subsurface wastewater discharges and their potential effects on aquifers and surface waters. It is, therefore, recognized that such agencies have over-riding authority, especially where large numbers of on-site systems are considered for a development or subdivision of extensive area.

State lake and stream-shore regulatory programs commonly enforced at the local level, are basic to protecting such waters for contamination, including by nutrients. State authorities often provide the expertise necessary for on-site system planning. State real estate commission or regulatory agencies strongly support good review of on-site conditions as a condition for approval of or filing plans and sale of unsewered developments.

3. Local

There is general agreement that on-site regulatory programs are best administered by local agencies that have properly qualified personnel. For instance, the Minnesota Proposed Individual Sewage Treatment Systems Standards say, "...it is intended that the administration and enforcement of these standards be conducted by local units of government, since experience has shown that sanitary ordinances can most effectively be administered at the local level."

Administration at the local level involves a number of units of government, although in some jurisdictions they are all under a single agency administrator so as to simplify procedures for the public and to assure close coordination of the related programs.

B. Type Regulatory Agency

1. Planning Agency

The on-site control program at the local level begins with environmental input into land-use planning. Ideally there is a general plan advisory board, a subdivision review committee and, where state law requires such reports, an environmental impact advisory committee. The environmental health or control authority of local government should be a full member of all of those groups so as to assure adequate consideration of water supplies and sewerage, especially for areas where on-site wastewater systems are under consideration.

2. Water Quality Control Authority

Additionally, when the water quality, resources or environmental control agency is considering setting requirements for subsurface wastewater disposal, the local environmental health official should be involved in setting these requirements.

3. Local Environmental Health Official

In addition to participating in all of the processes outlined above, the local environmental health or control official is usually responsible for establishing requirements for on-site systems for all developments. Where conditions vary on a lot-by-lot basis, that official reviews conditions on each lot and approves specific plans for on-site systems. The functions include reviewing and checking on-site evaluation processes and conclusions; evaluating alternate methods and systems; considering special systems for such developments as mobile home parks, commercial and industrial establishments and other unusual type situations.

The local environmental official is usually responsible for regulating, and in some cases, licensing individuals and companies which service on-site systems, including those who pump systems and dispose of septage. This ties in with the over-all responsibility of evaluating the success or failure of various systems throughout the jurisdiction. Certifications are issued to mortgage lending agencies, real estate sales control agencies and others who require authoritative, official statements concerning acceptability of proposed methods of on-site wastewater management.

4. Building and Plumbing Officials

Building officials are generally encouraged or required to withhold building permits for unsewered lots unless authority for on-site systems has been approved by the environmental official or by a responsible agency whose approval includes an official on-site system approval.

There must be close collaboration between plumbing and environmental officials concerning on-site systems. In some jurisdictions, the whole on-site system approval is vested in the environmental official, while in others the actual inspection of installations is vested in the plumbing authority who enforces requirements established by or acceptable to the environmental authority.

C. The Private Sector

The private sector carries a large share of the responsibility for on-site system planning, design, installation, provision of equipment, operation, maintenance, and development of innovative systems, equipment and methodologies. Professional societies, such as NEHA and various other environmental associations, associations of equipment manufacturers and installers, groups like the National Association of Home Builders, and standards organizations like the National Sanitation Foundation are all important elements of the whole program.

D. Site Evaluation

1. There are at least three points in land-use regulation during which site evaluation is conducted:

   a. During development of general or master plan.

   At this stage, decisions are made between agricultural, residential, commercial, industrial and other uses of land. The plan usually includes projections concerning plans for public water supplies and sewers. Preliminary decisions are made concerning the intensity of land use; for instance, single family or multiple housing. Soil Survey, topographic and serial photographic maps are useful in broadly determining conditions which affect on-site wastewater management. Ideally, determinations are made at this point concerning areas where conventional on-site systems are not generally acceptable. Normally concentrated multiple family, commercial and industrial developments can take place only when public sewers or special wastewater management systems will be available.

Minimum lot sizes are indicated for areas where housing may be developed without public sewerage, and with or without public water supply systems.

Studies are made of the probable density of development as it may affect on-site wastewater discharges which reach the aquifers. Shore line developments are evaluated in terms of on-site wastewater effects on lakes and streams.

Details will be considered later, but at this stage basic geological, soil, topographic and hydrological maps and data are valuable. A certain amount of site evaluation is also indicated.

b . During review of proposed subdivisions or development plans.

Review of proposed unsewered subdivisions and developments involves quite extensive site evaluation. One question concerns responsibilities of the various concerned official agencies and the responsibilities of the applicant.

With the normal shortage of funds for local programs, there is merit in considering, as has been done in some jurisdictions, the concept of adding to the subdivision review fee an amount which covers normal basic costs for the environmental health agency's on-site evaluation program.

The subdivider or developer can justifiably be required to provide data from test and observation holes and percolation tests, soil analysis and hydrological findings, supplemented by bore-hole logs, contour maps and typical lot plans with special references to areas allocated for on-site systems, and such other information as may be requisite to site evaluation. The tests and evaluations should have been completed by professionally competent persons, other than the developer. Decisions must be made concerning the number and type of test holes or borings, percolation tests and other data which are required at this stage of development Less tests and bore holes are necessary where soil, topography, and ground water conditions are uniform or are not of concern. Where soil, topography, and ground water levels are likely to fluctuate widely, more detailed site evaluation is justified. In the latter type case, where each lot is not evaluated, it is customary to approve such subdivisions or developments only with the proviso that issuance of individual building permits is conditional upon a finding that a legally acceptable on-site system can be installed on each lot.

c . In connection with building permits.

For individual lots or sites, it is normally only necessary for the approval authority to determine that on-site systems are permissible in the area and to find that conditions are satisfactory for systems meeting all code requirements. Where sites are not suitable for systems meeting normal code requirements for conventional systems, the applicant may be afforded opportunity to show, to the satisfaction of the approval authority, that conditions are such that a specific, proven type of alternative system can be expected to function reliably and satisfactorily as required under code provisions, or as established by the environmental authority.

2 . Responsibilities for Site Evaluation

a . Related to basic land use planning

Site evaluation related to developing a general or master plan is normally a function of the governmental unit which supervises the jurisdiction's environmental aspects of on-site planning and regulatory programs. The actual work of digging test and observation holes and conducting soil permeability tests may be shared with a works or other agency which has the necessary equipment. In some cases, where the water supply authority operates wells in the vicinity, that agency is involved in site evaluations and approvals. Water quality control plans and restrictions are also reviewed.

The basin report may also be prepared by consulting firms which are equipped and qualified for such studies and site evaluations, but this should be done in close collaboration with and under approval of the environmental authority.

b . In connection with subdivisions or development planning.

Site evaluations in connection with subdivision or land use planning review and approval are commonly done by consultants engaged by the applicant or developer. Their reports and findings are subject to checking and approval by the environmental control agency, usually involving both office and field evaluation.

In some jurisdictions, especially where fees are charged for the environmental evaluation of proposed subdivisions or developments, the site evaluation may be done by the environmental control agency. There are some environmental authorities who do the entire review.

c . For individual lots or sites

The on-site system contractor is commonly the person who does the final site evaluation and submits plans for the actual installation. Consultant services may be utilized. The environmental control agency or the plumbing inspection unit reviews the data and plans and makes inspections of installations for locations, materials and methods.

d . Mixed jurisdictions

In some states the responsibilities are shared with a state or regional water quality control or environmental protection type agency. Some states require that plans for industrial, and sometimes other type occupancies must be signed by a registered engineer or registered sanitarians. As mentioned before, in some states the overall plans for on-site systems for subdivisions and substantial developments are subject to prior approval by the state water quality control agency. Also, in some states, shoreline developments are subject to special approval by planning or zoning officials, as well as by environmental and water quality control officials. Regulations are, in such cases, intended to protect against microbiological contamination and also against input of nutrients which are likely to contribute to eutrophication.

Chapter 3

QUALIFICATIONS AND TRAINING OF PERSONNEL, AND EDUCATIONAL PROGRAMS

A. Experience and Qualifications

The success of an on-site wastewater management program is heavily dependent upon the expertise of those who plan, design, install, maintain and supervise systems and the whole program. Few formal education programs provide the depth of special training to produce graduates who are expert in this broad field. What is usually required is an adequate basic education plus an extensive amount of qualifying experience and special study to learn the most practical way to apply the basic sciences to the on-site programs. There are, of course, persons of professional expertise in such related specialized fields as hydro-geology, geology, hydraulics and soil sciences who can contribute much to important aspects of the program. But all must have had qualifying experience and have studied the special subjects requisite to expertise in the broad field. Ideally, students in college and university environmental programs should have opportunity to take a full course that comprehensively covers the whole subject of on-site wastewater management.

It is not enough to specify that plans and reports be prepared by or under the direction of a registered engineer or a registered sanitarian. The site evaluators must build on a basic, relevant education, by experience and special study, to become expert. Similarly, many well qualified site evaluators and system installers without extensive formal education in the field, have had long and relevant experience and thereby have become successful; however, they too would usually profit from special studies of the theoretical and scientific aspects of their work, and many have done so.

B. Training and Accreditation for Site Evaluation

Training programs may be conducted in connection with registration or certification procedures for site evaluators and installers; however, since only a few states have such registration or certification programs, the most productive starting point would be to develop training programs both for persons in the business or profession and for those who officially supervise the programs. In many cases, the latter would function as trainers. Where examinations are required, they could participate in conducting the examinations, as well as the training program.

Excellent examples of training manuals, publications and code information are:

Wisconsin's Soil Tester Manual (1977)

This manual was prepared by the Department of Health and Social Services, Division of Health, Bureau of Environmental Health; and University of Wisconsin; and, U.S. Department of Agriculture, Soil Conservation Service.

Like other manuals, it emphasizes the importance of soil identification, classification, and characteristics as fundamental elements. It discusses soils in the various parts of Wisconsin, and is addressed particularly to persons who want be become certified. It begins with:

"Legislation has recently been enacted which requires certification of those persons who conduct soil tests and certify soil test data for proposed unsewered subdivisions and proposed sites for soil absorption systems for liquid waste disposal. This law. . . places responsibility for certification of soil tests with the Department of Health and Social Services and authorizes the adoption of administrative regulations covering certification."

The examination fee in Wisconsin is $15.00 and there is an annual registration fee of $10.00. The value and limitations of soil maps are discussed in the Wisconsin Soil Tester Manual and there is a state-wide map of "Soil Conditions in Wisconsin," which also shows large areas of high ground water levels; other maps show soil profiles and charts, and it discusses soil conditions in various parts of the state.

Study of soil profiles at road-side cuts and other excavations is advocated. As with most soil classification publications, the Manual discusses the U.S.D.A. "Textural Triangle" (Figure 1.) for classification of soil by particle size (% clay, silt and sand).

Figure 1.

GUIDE FOR USDA SOIL TEXTURAL CLASSIFICATION

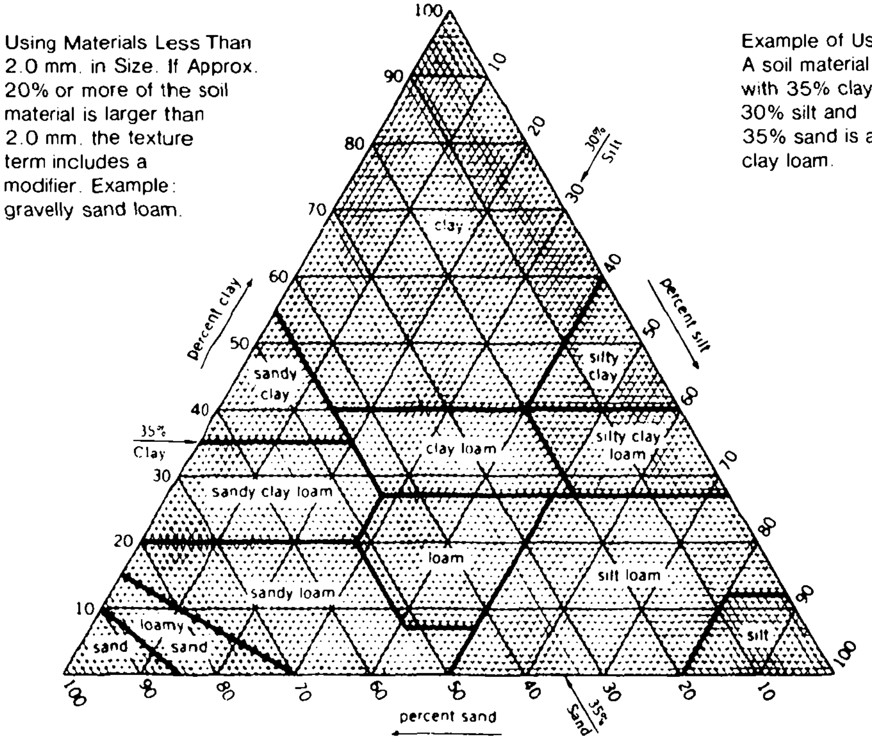


Table 1.

WISCONSIN'S EXPLANATION OF RELATIONSHIP OF SOIL CLASSIFICATION TO PERCOLATION RATES

General Soil Texture	Estimated Percolation Rate Range
1. Sand	Under 10 minutes per inch
2. Sandy loam	3 to 30 minutes per inch
3. Loam	10 to 45 minutes per inch
4. Silt loam	30 to 90 minutes per inch
5. Clay loam	Over 45 minutes per inch
6. Clay	Over 60 minutes per inch

Water tables and how they fluctuate with various soils, by months, are shown for Wisconsin conditions. It gives, among others, the following definitions:

"*Permeability:* Rate at which water moves between two points in soil."

"*Capillarity:* Action of water rising above horizontal plane of free water, ranges from 0.30 feet in soil, depending upon texture."

Soils are classified by:

1. Texture—Sandy, clay, loamy, and organic soils.
2. Color—Red, brown, yellow and black soils.
3. Landscape position—Upland, tallis, terrace, flood plain, and bog.
4. Origin—
   Alluvial (transported and deposited by water in recent geological time).
   Glacial till (transported and deposited by ice during glacial period).
   Aeolian (transported and deposited by wind-loess or silt).
   Residual (weathered in place, near or directly above bedrock).
   Lacustrine (deposited in lakes and ponds or generally quiet backwaters of glacial periods).
   Outwash—water transported and deposited during glacial periods.

The Wisconsin manual includes the basic U.S. Public Land Surveys and property description, methods of calculating slope, and a detailed description of the method for making percolation tests.

Pennsylvania's "Certification of Sewage Enforcement Officers" and Planning Program (1974)

In Pennsylvania, "A State Board for Certification of Sewage Enforcement Officers has the power and duty to schedule examinations, collect examination fees, and to review and pass upon the application for certification of Sewage Enforcement Officers. . . ." The Board also has the power to revoke or suspend such certifications, and to renew them every two years.

"The Act places major responsibility upon planning. Each municipality is required to submit to DER (Department of Environmental Resources), for approval, an officially adopted plan for sewage systems within its jurisdiction. Each plan must cover existing sewage systems in detail, proposed sewage systems (within the next ten years), and where no systems exist or are proposed, the plan must include a land classification system to prevent on-lot sewage disposal systems from being installed where soils are not suitable. Provisions are made under the Act for grants to help with such planning." Permits, approved by a Sewage Enforcement Officer must be obtained for all on-site systems except on "farms" of over 10 acres.

Lake County, Illinois

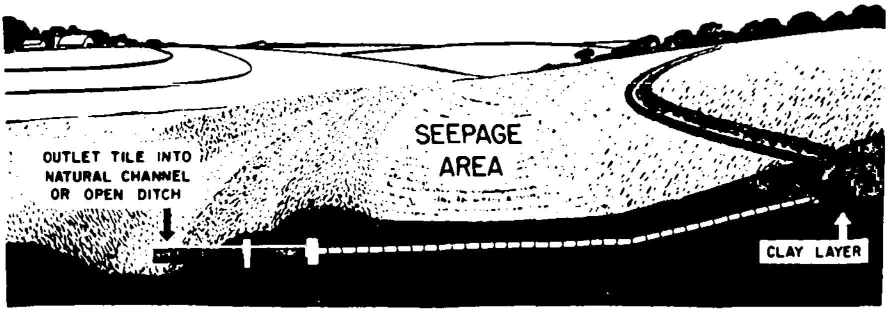
William L. Mellen of the Lake County (Illinois) Health Department has developed a comprehensive training program including a publication, "Identification of Soils as a Tool for the Design of Individual Sewage Disposal Systems." It was developed for a short term course for "professional people in the field of environmental health in the use of soils information for the design of individual sewage disposal systems."

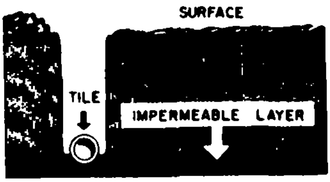
Like the Wisconsin manual, the publication stresses basic understandings, common technical nomenclature, soil classifications and geological and hydrological conditions with particular reference to the state and local areas involved. It gives practical procedures to help classify soils by feeling, examining, molding and determining grain size; methods of measuring the degree of slopes, and advice on the use of soil classification maps and their limitations.

A good "fill system" is described as suitable in certain areas which are not acceptable for conventional systems. Also, the publication shows the concept of installing curtain drains (a trench filled with rock and with a perforated bottom drain, installed up-slope from seepage trenches for the purpose of intercepting and lowering a high water table) (Figure 2). Maps and dicussion help in understanding legal descriptions of lands in Illinois.

Figure 2.

LAKE COUNTY CURTAIN DRAINS





Tile should be laid just on or just into tight soil, if possible.

Reprinted by permission from William L. Mellen, Lake County Health Dept., Waukegan, Ill.

The Lake County, Illinois, Manual says, "When rain falls on the land, part of it soaks into the soil and percolates downward until it encounters an impermeable layer causing it to flow laterally down the slope, reappearing in valleys or low lying areas. If this layer is within 48 inches of the surface, it may affect the operation of the seepage field.

"Curtain drains should be installed on all sites that have an impervious layer, at 30 to 36 inches. The curtain drain is installed above the field area to intercept the lateral movement of ground water and discharge it to a suitable area below the field. The tile must have an outlet into an existing tile system or into an open channel.

"If the lot is large enough, it can discharge onto the property a sufficient distance below the field so that it does not adversely affect the operation of the system.

"Some good general practices are:

1. After the tiles are laid, have the grade checked with a surveying instrument.
2. Fill the trench to within 2 to 3 inches of the surface of the gound and backfill with topsoil. A slight berm can be left on the downhill side of the curtian drain, thus causing surface water to infiltrate into the tile system.
3. Downspouts and sump pumps can all discharge into the curtain drain if available. For homes built without downspouts, the curtain drain can be installed directly beneath the drip line."

These examples illustrate desirable programs for training persons in the business and regulatory aspects of on-site systems. They also illustrate the importance of tailoring both training and regulatory programs to fit prevailing local conditions.

C. EPA's Technology Transfers

EPA's Technology Transfer Seminars and accompanying publications are excellent means of supplementing training and of bringing to the field results of research, demonstration and evaluation of innovative systems. Since they are usually conducted in collaboration with appropriate state and regional authorities, the programs provide a good means of tying together federal and state policies and procedures.

D. Public Education

Several states and local jurisdictions have prepared excellent pamphlets to advise the public concerning procedures for obtaining permits to install on-site systems, precautions to follow in securing a suitable installation, and for operation and maintenance which prolong the system's life. There are many pamphlets prepared by state and local agencies and some by system installers which provide important advice on care and maintenance of on-site systems.

Pennsylvania's Department of Environmental Resources has developed a good example, titled "Helpful Hints on On-Site Sewage Disposal System Construction, Operation and Maintenance."

Some local environmental control officials have developed their own public education programs. The Lake County (Illinois) Health Department's pamphlet, "Septic System: The How's and Why's," effectively answers most of the questions commonly asked by the public.

A more comprehensive type publicaton is the New York State Department of Health, Bureau of Sanitary Engineering's well illustrated, 34-page publications, "Waste Treatment Handbook—Individual Household Systems." This one is especially valuable to system designers, site evaluators, installers and regulatory officials, but is also of value to the property owner or developer who is interested in a more in-depth coverage than is provided by the pamphlets prepared primarily for the public.

William Mellen's 16 mm, color, sound, 15-minute film (1975), available from E. J. Clark Films, Brookfield, Wisconsin, is intended for contractors, regulatory officials and interested citizens. Mellen's newest film, available form the same source, is "Septic Systems and the Sanitarian" (1978).

E. Field Training

Some states are exerting effective leadership by providing training programs for local enforcement authorities. For instance, Michigan's Department of Public Health, Division of Community Environmental Health, through its Land Subdivision and Planning Section has developed what appears to be an exemplary program. State authority to conduct the Subdivision Control Program may be delegated to local health departments. Before such delegation, the capabilities, experience and knowledge of the individuals responsible for the local program are reviewed. That provides opportunity for input into staff training and for securing consistency in interpreting and application of the Subdivision Control Act. State staff members conduct informal training on a one-to-one basis in plan review procedures, including soils evaluating techniques, aquifer protection, utility extension, etc. That personal training is supplemented by formal training sessions in soils and water supply conducted by trained soil scientists from the Department of Agriculture as well as state environmental staff, including water supply engineers. Once the authority is delegated, the state continues in a consultative and advisory role.

There is need for a national program which would provide resource materials, up-to-date information, visual aids and modern teaching techniques to assist in training and up-dating the knowledge of both regulatory officials and those engaged in the business.

Also, periodic efforts by comparative field evaluations, are needed to determine that all who perform site evaluations use uniformly approved methods of soil examination, water level determinations, percolation tests and other elements important to site approval and system design.

Chapter 4

LEGAL AND ENFORCEMENT PROCEDURES

A. Applications and Required Data

1 . Subdivison and Development Policy

To minimize inconvenience to the public, on-site wastewater management is best considered as part of the total subdivision or development review process. The lead agency is usually the planning department. In jurisdictions having a comprehensive environmental control agency, that agency is usually responsible.

The lead agency obtains enough copies of the application, maps, data and other pertinent information to supply copies to each concerned unit of government, including the one responsible for on-site system review and approval.

Policies should be established to determine whether a public water supply and sewerage system is required. This depends, in part, upon the number and size of lots involved and partly upon current availability or planned future availability of public water and sewer services. In some situations, sewers will be available in the forseeable future but authority may be granted for on-site systems as an interim measure. In other cases, public water supplies may be available but no plans exist for providing or extending the public sewerage system.

Where both private on-site systems and individual wells are proposed, the on-site evaluation includes the additional factor of assuring an adequate separation of the on-site systems from wells on the same and adjoining properties. The distances will depend, in part, on topography, depth of wells, soil formation and other factors. Planning for the on-site system is also dependent upon many other factors, including the required size of systems, topography and proposed arrangement of buildings, paved areas and other improvements on each lot.

Because of the importance of assuring that all necessary requirements will be met, it is desirable to have the applicant provide typical plot plans showing areas reserved for the on-site system plus room for future expansion; the location of the well, if one is to be provided on the property or adjoining property; and the location of the home or other buildings that will contribute wastewater.

Other factors that are a necessary part of the application review process are the water quality control agency "Discharge Requirements." The policies of water quality control agencies may be overriding the approval process. An example is the policy adopted by the California Regional Water Quality Control Board—Central Valley Region. The Board calls for a thorough review of the feasibility of public sewerage before on-site systems are considered. The Board guidelines continue a policy of depending on local authorities to handle on-site applications in most cases; however, in the case of local jurisdictions that do not adopt the necessary ordinances incorporating

Board policies, the Board will withdraw such local authority and establish requirements for each application. The Board works closely with the environmental health directors of the region.

Among the requirements are specific minimum distance separation of the system from wells, streams, etc. Minimum percolation rates are also established.

Subdivisions of over 100 lots, and some with less lots if they threaten to impair water quality, will be approved only if a "public entity" is formed "with powers and responsibilities to plan, design, finance, construct, operate, maintain, and to abandon if necessary," all systems in the subdivision. Other of the California Regional Baords have set limits on the number of lots in a subdivision beyond which the Board assumes the jurisdiction for setting basic requirements.

These examples illustrate the fact that water quality control agencies are an important factor in on-site system approval.

Many jurisdictions have official subdivision review committees, including representation of the environmental control authority. This enables the applicant and his consultants and subdivision engineers to meet with all concerned agencies, and to present arguments in favor of his point of view.

Final decisions are sometimes made by planning committees but are frequently subject to approval by the elected officials of the concerned jurisdiction. The final approval process provides opportunity for appeal from requirements proposed by the environmental control authority.

To secure federal financial support for sewage treatment plants and related authorized allocations, cost-effectiveness studies are now required to compare all alternative wastewater management options, including on-site systems. This policy tends to further emphasize proper and thorough consideration of whether it is advisable to approve specific unsewered subdivisions and developments.

2. Individual Lots or Sites

A number of jurisdictions have developed exemplary forms to simplify the making and processing of applications for permits to install on-site systems. The forms include space for a plot plan showing lot lines, buildings and improvements, topography and space allocated for the on-site system.

Site evaluation data, according to processes described elsewhere in the Manual, are included on the application. The applications are usually accompanied by printed explanations and instructions.

B. Variance

Regulations should usually provide procedures whereby variances may be granted. An example is the Oregon regulations which have a special subdivision on variances. The Oregon rules require that the variance will only be granted for a system which "will function in a satisfactory manner so as not to create a public health hazard, or to cause pollution of public waters" and where "special physical conditions exist which render strict compliance unreasonable, burdensome or impractical."

The variance procedure is less necessary when regulations make specific provisions for alternate systems which have been approved for either trial or permanent installation.

C. Fees

As mentioned before, many jurisdictions have programs whereby fees are charged to cover part of the cost of the program. For subdivision and development review, these fees are usually added to the total cost of subdivision review and approval.

For on-site systems, the cost is commonly added to the plumbing inspection fees.

D. Pumping and Septage Disposal Regulation

To aid in assuring that equipment for pumping and hauling septage is designed and maintained to function effectively and in a nuisance-free manner, and to attempt to control the locations and methods of disposal, states commonly require the licensing or registration of such service vehicles and their operating company.

The disposal of septage involves close collaboration with officials responsible for operation of sewerage systems and treatment plants, operators of sanitary landfills (if they are used for septage disposal) and with works agencies or similar authorities that have the power to establish and operate septage disposal facilities.

Availablity of federal financing for tank trucks and equipment, and for disposal facilities, is leading to basic minimum standards requisite for allocation of such funds.

E. Final Inspection of Installations

The work of inspecting the laying of drain lines, installations of tanks and seepage systems and otherwise supervising the installation is commonly assigned to the official who inspects other plumbing installations. In any event, it is common to not allow a system to be used until the inspection shows it to meet requirements.

Ideally, the installer will leave at the property a scale drawing referencing the location of essential parts of the system to fixed objects.

Also, the installer should provide clear instructions covering use and maintenance of the system. The latter is important, but is essential for any system which utilizes mechanical and electrical equipment.

Chapter 5

SYSTEM PLANNING AND POLLUTION POTENTIALS

A. Basic Data and Alternatives

The usual policy is to require connection to the public sewerage system, if one is available within a distance that makes connection economically feasible. For developments in the path of anticipated sewer extensions, it is common to withhold approval until a sewer connection can be made.

Where lot areas are limited or where soil, topography or other conditions are not favorable for on-site systems, all available alternate systems are considered, including:

1. Connection to existing public sewers.
2. Development of a community service district for treatment and disposal of all sewage.
3. Discharge to a subsurface disposal system shared by several premises.

Among the alternative systems available are:

1. Pressure sewers of moderate diameter with septic tanks or other treatment systems at each property and disposal to a central sewer or treatment system. Some systems utilize grinder pumps at each home and provide central treatment. (One committee adviser expressed concern about the reliability and efficiency of grinder pump installations).
2. Vacuum sewers as have been installed at selected "demonstraton" sites.
3. Various innovative systems such as oil flushed toilets or low water using toilets with either central management or wastes stored in holding tanks and separate management of grey water.

Systems that appear to be feasible and are legally acceptable are considered on a comparative cost-effectiveness basis, including not only economic costs but environmental, convenience and reliability costs.

However, where site conditions are unsuitable for conventional on-site systems, there is special motivation and incentive to develop acceptable alternate plans, even though the unit cost may be high.

B. Responsibilities for Site Evaluation

Ideally the comparative and cost-effectiveness analyses are done as part of the planning for subdivisions and extensive developments. The subdivision engineer or planner, with the aid of consultants, would usually make the studies to the satisfaction of the subdivision approval agency, committee or board. The study would also be made to provide all information required by the water quality authorities and local agencies responsible for supervising system installations and for their operation and maintenance. Guidelines established by E.P.A. must be followed when qualifying for federal funding of on-site systems. In this, as in all other basic steps of site evaluation, the environmental health and plumbing regulatory officials have important responsibilities.

Alternative Systems

Figure 3.

Household Wastewater Treatment and Disposal System Configurations Installed in the Field

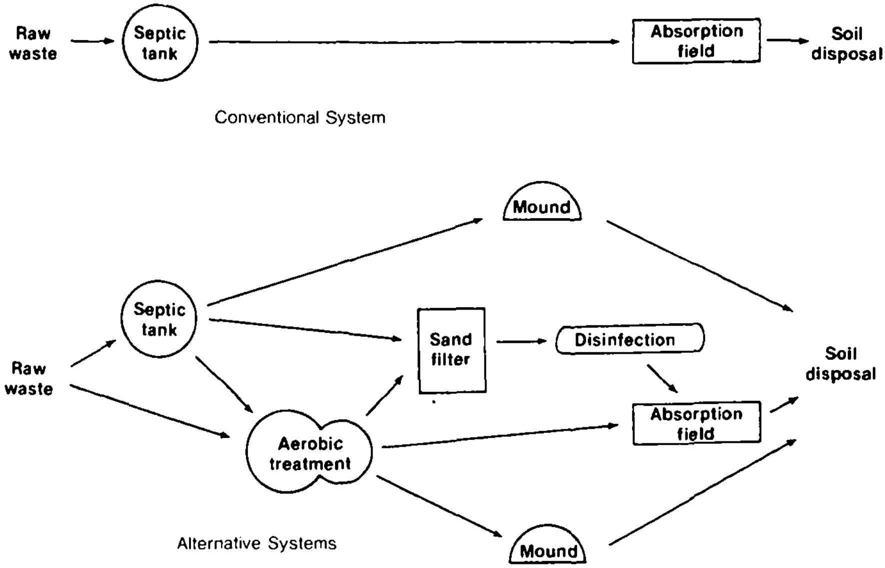


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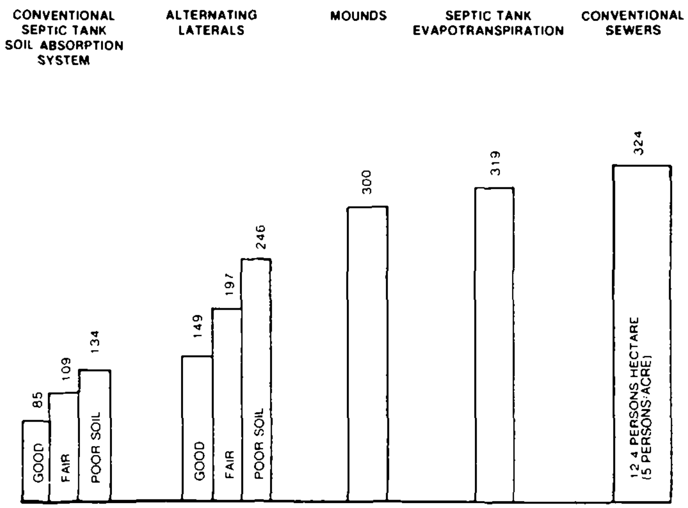
Figure 4.

Total annual costs of alternatives.



Reprinted from U.S. Environmental Protection Agency publication.

For scattered individual lots remote from sewers, the site evaluation study can be concentrated on individual on-site systems and the proposals and plans can usually be prepared and presented by the system installer.

C. Lot Size and Distance Separation

Some jurisdictions set a minimum lot size for all new on-site systems. However, simply requiring a stated number of square feet of lot area does not satisfy the needs of hill-side lots, unless a plot plan shows areas of proper locations and elevations (or pumping systems) are planned for the systems, and further that such space will be continuously reserved for the system.

A second factor to be considered is the size of system required, which is both determined by the size of the home or property to be sewered, the type of system and by the soil and other site conditions.

The type system to be installed is important. For instance, where seepage pits are authorized and where they will not pose a threat to an aquifer, the space requirements are considerably less than with conventional seepage trenches. Also, where seepage beds are authorized, even though their bottom

Figure 5.

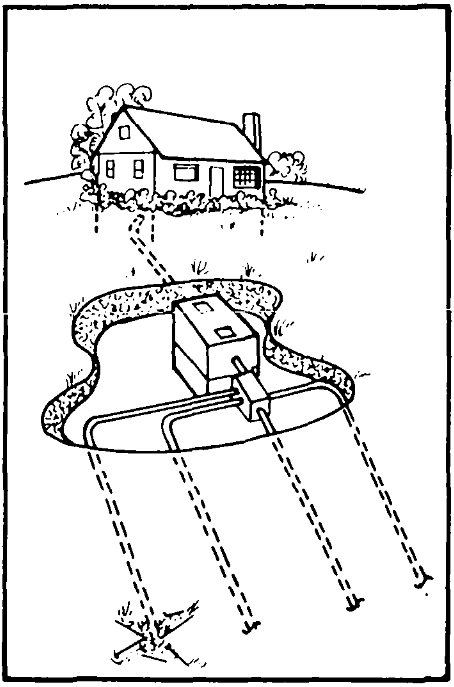


Figure 1. Layout of a Field with an Even Number of Trenches

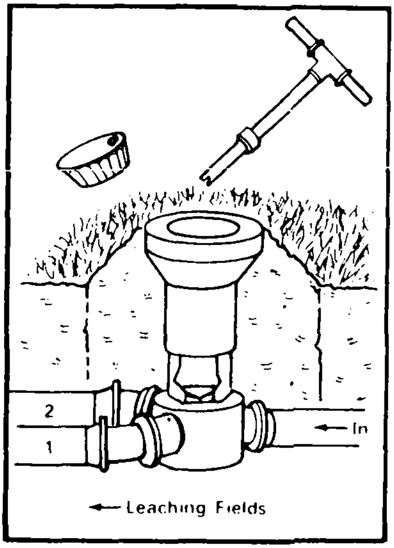


Figure 2. A Flow Diversion Valve with an External Regulatory Key

Source: Clayton, J.W., An Analysis of Septic Tank Survival Data from 1932 to 1972 in Fairfax County, Virginia.

areas must be 50% larger than trenches, their gross area is considerably less than with trenches.

Several innovative type systems also require less gross area than conventional trenches. For instance, there are indications that certain new type seepage systems, such as mounds, evapotranspiration and electro-osmosis, may require less lot area than conventional trenches. Where alternative systems like mounds or evapotranspiration are planned, plot plans can make specific provisions for such systems.

The area requirement for a valve alternating system would be about twice that of a single bed. In jurisdictions where such valve alternating systems are not required, there is jurisdiction for the common requirement that space will be reserved to enable 100% expansion of the seepage system to enable enlargement, replacement or provision of a valved alternating system.

A major factor in many areas is whether the water supply will come from a public source, or whether each lot will have both an on-site system and a well.

D. Quantities and Quality of Household Wastewater

Several studies have shown the normal household use of water is considerably less than the commonly quoted quantity of 100 gallons per capita per day. A study by Witt (1974) of the University of Wisconsin covered 11 rural homes and showed a range of 25 to 57 and an average of 43 gallons per capita per day (g/c/d). That was comparable to the data from a study in Colorado by Bennett, et al. (1974), summarized in Table 2.

The following table is from Witt's report:

Table 2.

WATER USAGE COMPARISON—PERCENTAGE

	USGS[8] 1962	HANEY HAMANN[5] 1967	LAAK[6] 1971	LIGMAN[7] 1972	WALLMAN[9] 1972	ONTARIO RESEARCH[3] 1973	BENNETT[2] 1973	THIS STUDY 1974
TOILET	41	45	43	41	27-45	38	33	22
LAUNDRY	4	5	16	19	18	12	26	25
BATH	37	30	19	26	18-36	34	20	23
KITCHEN	6	6	8	10	13	10	12	11
CLEANING	3	4	5	1	–	3	3	–
DRINKING	5	3	3	3	–	3	3	–
MISC.	4	7	6	0	6	0	3	13 Other 6 Water Softener
FLOW (gpcd)	–	–	41	45	30-50	–	44	43

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A study by Committee Member James C. Ault in 1961 covering over 10,000 residences in the vicinity of Nashville, Tennessee, revealed an average daily consumption of 193 gallons but the range was from 51 to 685 gallons per day (g/d. System design, therefore, cannot be based upon *average* rates but must approach the upper percentiles of measured rates.

A third table of Witt's shows possible reduction in water usage by various watersaving modifications. The main value of the table is to indicate reductions in water comsumption attributable to various watersaving type fixtures as appliances.

Table 3

POSSIBLE WATER REDUCTIONS
ALL VOLUMES IN GPCD

LOCATION	Average GPCD	With 3 Gal./ Flush	With Sudsaver @ 27.68 Gal.	With 15 Gal. Per Bath or Shower	With All Three Methods Used	% Reduc. Accomp. With Three	With Addition of Recyc. Bath/Laun. to Toilet	Total Reduction Using All Four Methods
A	56.73	53.84	54.13	49.68	44.18	22%	37.97	33%
B	25.43	23.61	25.43	23.18	21.36	16%	14.49	43%
C	38.85	38.32	35.80	36.22	32.64	16%	27.54	29%
D	41.05	41.05	39.83	37.69	36.47	11%	28.10	32%
E	41.46	38.36	36.70	39.60	31.75	23%	26.62	36%
F	33.74	31.67	33.74	31.91	29.83	12%	25.66	24%
G	29.78	27.76	29.78	28.16	27.75	7%	23.28	22%
H	49.68	47.38	47.45	49.20	44.67	10%	37.80	24%
I	41.81	38.93	41.81	39.77	36.88	12%	31.84	24%
J	45.11	40.67	43.09	41.35	34.90	23%	25.60	43%
K	56.93	54.81	53.40	53.45	47.81	16%	39.02	31%
AVERAGE (Weighted)	42.59	40.31	40.73	39.65	35.49	17%	28.62	33%

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It seems appropriate that the commonly accepted maximum household usage factor be the basis for system design, and this would appear to be 50 to 75 g/c/d. Several codes assume two persons per bedroom, so this would mean at least 100 gallons per bedroom per day. However, the requirement of several codes of assuming 150 gallons per bedroom per day provides a reasonable, additional factor of safety.

Additionally, many experienced system installers assume that practically all new homes will be equipped with garbage disposers which will add slightly to the water volume and considerably to the settleable solids and BOD of the waste, factors helping to justify calculations based on water usage figures that are somewhat higher than those shown by the figures for homes without garbage disposal units.

E. Distance Separation

1 . Travel and Fate of Microbiological Contaminants

Both microbiological and chemical contaminants from on-site systems are of concern.

a . Fort Caswell Studies

A classical experimental study was conducted by the U.S. Public Health Service in the 1920's and reported by C. S. Stiles, et al. in "Experimental Bacteriological and Chemical Pollution of Wells Via Groundwater, and the Factors Involved" (1927). Two of their study sites are of particular significance. One, at Fort Caswell, N.C., was in an area of very high groundwater in sandy soil, near the ocean. A trench 25 feet long, 1.5 feet wide and 0.6 to 2.5 feet deep (near the very high groundwater) was repeatedly dosed for 8 months with fecal material and dye (uranin). One hundred twenty two shallow "pipe wells" were placed parallel to the trench from 2 to 232 feet (with some test wells at greater distances) down-slope in the direction in which the groundwater was traveling at a rate of a few inches to a few feet per day.

The report's condensed Conclusions note that "*Escherichia coli* were recovered in 1,213 samples at a distance varying from 1 to 232 feet from the trench, and uranin was recovered up to 450 feet away. The report noted that the contamination was primarily concentrated in the interface between the groundwater and the capillary fringe. It is noted that the disposal trench was within about a foot of groundwater and no organisms were recovered from a foot or more below the water table.

"Both coliform and uranin traveled in one direction, namely in the direction of the groundwater flow." The report goes on to note that where the direction of groundwater flow is known, properly locating the source of pollution and the well in relationship to each other will provide maximum protection. Mention was also made of the fact that wells with substantial yields can affect both the direction of groundwater movement and lowering of the groundwater level. (This observation supports the principle of requiring greater separation for high yield public water supply wells than for wells serving single family homes.)

A series of tests conducted by placing fecal material flushed by a stream of water from a hose into a trench having a bottom which was more than 5 feet above the groundwater level resulted in recovery of coliform only up to 5 feet below the bottom of the pit. (This may be the basis of some code provisions calling for the bottom of seepage trenches to be at least 5 feet above the groundwater level. However, there are many situations where greater or less separation may be indicated.)

The authors of the Fort Caswell report were impressed with their observation that "*Escherichia coli* tend to filter out in the capillary fringe. . ." and note that this phenomenon takes place as the groundwater levels naturally rise and fall. They note this may be a factor in self-purification of soils and groundwater.

b . The Minnesota Problem

A report of "Groundwater Contamination in the Minneapolis and St. Paul Suburbs," by L. Woodward (1961) involved an area where 400,000 persons depended on individual wells or on-site sewage disposal systems, or both. The soil was favorable for on-site systems, but underlain by cracked limestone and dolomite, and well water was available from the limestone at depths of 20 to 70 feet. Samples representing 63,000 wells were examined for chemical and microbiological contaminants. "In younger communities 10 to 20% of the wells most seriously affected by sewage chemicals are also contaminated bacteriologically, as evidenced by coliform in the water. In older communities as many as 50% of all wells are so affected." The report supported a well accepted concept that sewage from individual systems can readily move into and through such type of rock formations. This case is an example of the hazards of on-site systems that can readily drain into cracked and creviced rock formations which are used for water supplies.

c . University of California Studies

A rather severe test by Ray B. Krone, et al. (1953) at the University of California consisted of discharging partially treated wastewater through an injection well, into a "3 to 5 foot thick aquifer about 95 feet below the ground surface through an injection well. . . ." The aquifer was in a pea gravel and sand formation. The pollution traveled principally only in one direction.

The report noted "Coliform bacteria quickly reach what may prove to be a maximum distance. In the investigation, this distance was 100 feet and no build-up of concentration occurred in 41 days of injection of the polluted water.

"The reduction of bacterial numbers with distance from the point of injection is extremely great. In the investigation the reduction was from 10^6 to less than 38 organisms per 100 ml. while traveling 100 feet in 33 hours."

d . The Virus Problem

Because certain virus particles withstand adverse conditions that remove coliform organisms, there has been concern that virus would travel farther in the soil than coliform. Eliasen (1967) noted that virus removal efficiency of soil is largely due to sorption on particles with a high clay content. However, Merrell (1967) reported good virus removal in gravel beds at Santee, California. The percolated water reached test wells in less than 48 hours. It was theorized that the removal may have taken place in the fine mat of soil where the water entered the gravel bed. Harold Wolf Dr. P.H. (1977) said the work at Texas A & M indicates virus removal in soil is usually sufficiently effective so conditions required for protection against other pathogens will also protect against virus. Otis, et al. (1977) in a publication prepared for an EPA Technology Transfer said "Removal of virus in soils occurs as the result of the combined effects of sorption, inactivation and retention. Upon entry into the soil, viruses are rapidly absorbed on solid surfaces. . . ."

In laboratory studies with packed sand columns, septic tank effluent was inoculated with more than 10^5 plaque-forming units (PFU) per liter of polio virus Type I. All viruses were removed in the 24 inch columns at a loading rate of 5 cm./day (1.24 gpd/ft^2) over a period of over one year.

Otis goes on to say that while removal efficiency was high in certain silt loams, "Channels in natural soil will reduce opportunity for virus absorption, and travel over long distances may occur when loading rates are high."

An excellent review of the literature on virus survival in soils is contained in EPA's "Management of Small Waste Flows"(1978).

e . Conclusions on Microbiological Contamination

From a review of literature it is concluded that with soils of sand or finer grains, 100 feet of separation, even down stream from a source of contamination is normally acceptable from the viewpoint of microbial contamination. It is also concluded that on-site effluents should not enter cracked or seamy rock, and possibly coarse gravels which do not have a sandy matrix. Sand filter beds or other pre-treatment should be designed to avoid the microbiological hazard, or systems should not be allowed where there is not a substantial depth of suitable soil separating the seepage system and such porous formations. In other words, the high purification capacity of dry, fine grained soils tends to remove the hazard of microbiological contamination, and would support the rule for a vertical distance separation of 3 to 5 feet between seepage systems and aquifers or porous rock formations.

The available data also support the position that, wherever subsurface wastewater absorption systems are installed over a relatively shallow aquifer, the shallow trench or bed is preferable to the deeper seepage pits.

2 . Travel and Fate of Chemical Contaminants

Of the chemicals normally present in on-site effluents, compounds of nitrogen are usually of most concern. Where eutrophication of lakes is of concern, phosphorous may also be a limiting factor, unless the soil is of a type which effectively removes phosphorous.

a . Effects of Wastewater from Home Regenerated Zeolite Softeners

Home regenerated zeolite water softeners may be objectionable in terms of increasing the total dissolved solids (TDS) concentrations of aquifers, by adding concentrations of sodium, and chloride salts to aquifers.

William Mellen (1973) noted that waste brine from backwashing should not be discharged into sub-surface disposal systems because "the sodium content of this water causes many soils to become impermeable."

Weickhand (1977) cited a paper by Brady which said "when sodium is a prominent absorbed ion, the particles are dispersed and a very undesirable soil structure results." He went on to say that calcium and magnesium ions produce flocculation and cause the opposite effect.

Weickhand also cites extensive tests at the Taft Engineering Center (Weibel, 1954) on silt loam soils of a type where the effect of sodium ions was assumed to be maximum. Their results showed the opposite effect, because "the salt effluent in every case caused less clogging of the test soil cores than normal effluent."

Corey, et al. (1977), at the American Society of Agricultural Engineers Symposium, said "reduction of hydraulic conductivity of soils receiving water with high sodium absorption ratio (SAR) and low salt concentration is due at first to swelling of the aggregates—and subsequently to aggregate breakdown and dispersion." They said their calculations "indicate that the salts in the waste waters from regeneration of water softeners create no HC (hydraulic conductivity) problems in septic tank seepage fields." They indicate this is due to calcium and magnesium salts discharged during the regeneration process and go on to say reduction in the hydraulic conductivity of the soil might result "if all of the house water were softened and if regeneration wastes were not allowed to enter the seepage field" because all of the divalent ions (calcium and magnesium) would be removed.

The effect on seepage systems of wastewater from softener regeneration is not clearly established to the point of supporting a prohibition of such waste from entering sub-surface disposal systems. The effect on soil permeability, if any, is limited to certain soils in which dispersion of particles and swelling is a factor.

b . Nitrates from On-Site Systems

E.P.A., W.H.O. and other drinking water standards limit the allowable amount of nitrates in drinking water to 45 mg/l as NO_3. The scientific basis for that standard is periodically questioned, but authorities, after reviewing all evidence, continue to adopt that value. It is, therefore, considered necessary that on-site system planning and control programs be established to avoid discharging nitrates which produce concentratons in groundwaters which exceed allowable limits.

The Otis report indicates that segregation of blackwater from household wastes results in from 68 to 99% reduction in total

Kjeldahl nitrogen and that blackwater wastes contribute about 87% of the total ammonium and nitrate nitrogen to on-site systems.

University of Wisconsin researchers L. J. Sikora and R. B. Corey say "*the predominant forms of N in home wastes are* ammonium—N and organic N. The N concentration ranges from 40-80 mg/l and an average family of 4 contributes about 33 KgN/year (73 pounds). The resulting N product after treatment in the septic tank is predominantly soluble ammonium (about 75%) and organic (25%). When the effluent leaves the tank, it undergoes further reactions in the bed and in the soil beneath the bed."

The ammonium nitrogen initially "undergoes adsorption to the soil particles almost immediately; however, under anaerobic conditions the soil would become equilibrated and the effluent would then move to the groundwater with its cation composition essentially unchanged."

However, "the authors say," "Nitrification is an extremely important reaction in septic systems. Nitrte (NO_3-) passes easily through soils." They go on to say that some nitrates may be taken up by root crops, but the amount removed by this process is minor.

The authors note that denitrification by reduction to nitrogen gas is another means of reducing the nitrate concentration. However, in sands, sandy loams, loamy sands and loams, aerobic reactions result in predominantly NO_3 as the end product from septic tank effluents. In the sandy loams and loams there may be a mixture of NO_3 and NH_4+, and in silty clay loams and clay the predominant form is NH_4+.

"From a pollution and public health standpoint, serious consideration *should be given to limiting the number* of systems in a watershed where sands, sandy loam, loamy sands and loams are the predominant soils. Silt loam, silty clay loam and clays would present a less serious problem because of the dentrification possibility as well as increased amount of NH_4.

c . Examples of High Nitrates from On-Site Systems

Areas on Long Island, in Florida and elsewhere, where unsewered population density has been rather high and groundwaters are shallow, have caused enough concern so studies have been made to evaluate suspected increasing nitrate concentration.

An example of such study is one made by the California Department of Public Health titled "Nitrogen Balance Study of the Verdugo Basin," a foothill area northeast of Los Angeles.

The report cited figures of 1.25 pounds of total nitrogen in the monthly discharge of sewage by the average individual (15 pounds per capita per year).

At the time of the study there was an unsewered population of 25,000 discharging a total of 3.65 x 10^5 pounds per year of total nitrogen, principally to the aquifer. The groundwater was in a relatively small, and partially closed basin.

Nitrate concentrations in wells in the basin rose rapidly in some cases. Well #6 rose from 9.2 mg/l of nitrates in 1952 to 64.0 mg/l in 1959. As a result, the recent Regional Water Quality Control Board "Basin Plan" and policies call for sewering the area to correct the problem.

Much of the area's soil is coarse sand and gravel and septic tanks with seepage pits or double cesspools function successfully for many years. As a result, building density is more like sewered metropolitan areas than would now be authorized for most unsewered subdivisions.

d . Dade County (Florida) Study

The United States Department of Interior Geological Survey report by William D. J. Pitt, Jr., et al (Open File Report 75-607) Talahasse, Florida (1975), contains 82 pages and is a comprehensive analysis of long-term use (15 years or more) moderately densely located septic tank systems. By 1970 Dade County had nearly 175,000 septic tank systems discharging about 40 million gallons per day into the Biscayne aquifer, which is also the main source of domestic water for the county. It provided 250 million gallons a day for municipal water systems in 1974. Thousands of families in areas served by septic tanks depend on individual wells for their water supplies.

The study was limited to areas where there were approximately four individual spetic tank systems per acre. Sampling was from wells which ranged from 10 to 60 feet deep. There were few reported incidents of microbiologically polluted well water before 1960, but since then, reports of such incidents have become more numerous.

Samples were also taken of groundwater from uninhibited areas to provide a baseline for judging effects of septic tank effluents. In the southern part of the country, the hydraulic conductivity is highest due to solution riddled limestone and sandstone. In the central and northerly portions, the content of sand in the aquifer increases, thereby reducing the overall permeability.

The report says that nearly everywhere in Dade County colific limestone forms the upper part of the Biscayne aquifer. Its average thickness is 20 to 30 feet and the maximum is 40 feet. Municipal wells penetrating the lower limestone yield up to 7,000 gallons of water per minute.

Septic tank effluent moves slowly from sandy areas but flows rapidly and for long distances in areas of high hydraulic conductivity.

The most significant and surprising finding is the low nitrate from septic tank sites (0.9 mg/l) and a total measured concentration of nitrogen of 2 mg/l. In other words, much of the 2 mg/l is due to a naturally occurring high nitrogen concentration in areas free of septic tanks.

The report said, "Dispersion, dilution, and various chemical processes presumably obliterate direct evidence of (nitrogen from) septic tank effluent at depths greater than 20 feet for all of the 65 water analyses employed in the investigation."

It is concluded that the Dade County Study further supports the position that on-site systems cause microbiological contamination of aquifers in areas of high hydraulic conductivity such as limestone and sandstones with solution channels.

e. Effects of On-Site Systems on Nitrates in Groundwater

The Dade County Study also shows where the hydrological and other conditions are favorable long-term use of septic tanks at a density of 4 per acre does not necessarily cause significant degredation of the chemical quality of ground water drawn from 20 or more feet in depth, nor cause noticeable increases in nitrates.

While the septic tank does not remove a major portion of the nitrogen compounds from the waste stream, a minor portion is retained in the sludge which is periodically removed. Probably an average of 25 to 30 kg. N (55 to 66 pounds) total per year per family of 4 leaves the septic tank. This figure could be utilized in the somewhat complex calculations necessary to estimate the density of sub-surface disposal systems which can be safely installed in various ground water basins.

f. Factors Related to Nitrate Concentrations Contributed by On-Site Systems

(1) Type soil, with the more permeable soils allowing highest percentages of NO_3 to reach aquifers.

(2) Amount of ground water available for dilution. This involves the amount of precipitation and irrigation water reaching the aquifer for unit area ground water basin volume flow of ground water.

(3) Depth of wells.

(4) Amount of NO_3 naturally present and amount contributed by other sources, including fertilizers and manures.

(5) Population density, using on-site systems.

Chapter 6

BASIC CONCEPTS AND REQUIREMENTS FOR SITE EVALUATION

A. Basic Planning Procedures

As stated above, on-site system planning is ideally part of a comprehensive land-use planning process for a whole political subdivision or region. It begins by considering all available alternatives, and the final decision on specific installation methods for on-site systems is usually made after it is determined that public sewerage or some modified community system is not a reasonable alternative and that conditions may be suitable for on-site systems. Planning for sewerage should be done as a companion to planning for water. This determines whether it is necessary to provide space for both water wells and on-site systems on the same lot. Also, prior determination of the locations of wells and formations from which they will draw water is important in evaluating the impact of on-site systems on such supplies.

B. Economic Evaluations and Cost-Effectiveness Studies

There are many factors involved in making economic assessments of various alternatives. There are also certain decisions which will normally be made regardless of the economic consequences, for instance, a prohibition of dense urban type development without public sewers.

Long range planning sometimes includes an evaluation of the effects on urban sprawl of lots large enough for on-site systems and the comparative economic and convenience aspects of more dense developments, in terms of urban type services.

Transitional areas on the outskirts of towns and cities are commonly developed with on-site systems, and when system failures become common on lots which are small or marginal in size, public sewers become a public health necessity. The property owner who paid or borrowed to install the on-site system must now pay premium contract prices to have streets dug up, to revamp a building or lot drainage system and to legally abandon the on-site system. These eventualities are part of a comprehensive cost-effectiveness study of such developments.

Establishment of significant numbers of special districts or other governmental agencies, as required to qualify for E.P.A. support for systems or to meet a growing local policy, will help provide cost data on adequate and regular maintenance fees for on-site systems. These can be compared with costs of public sewers, their maintenance, and of the total costs of the public wastewater management process. Public maintenance and provision or contracting for regular sludge or septage removal, servicing and other maintenance and operation programs will tend to significantly reduce the hazard of failure of on-site systems. The public will be largely relieved of the responsibility for system maintenance. Good system design, based on competent site evaluation, and with adequate loading rates, space for future expansion, and suitable procedures for assuring that innovative systems will function successfully, will all tend to increase the confidence of the public and of regulatory officials in on-site systems as an acceptable alternative.

Some good cost data are already available from studies in Wisconsin and elsewhere to compare system operation and maintenance costs, for instance septic tank vs. aerobic units, mounds and evapo-transpiration as compared with conventional sub-surface systems. Cost comparison would be made of the total capitalized cost, plus operation, maintenance and power costs, if any, for the on-site system, compared with the total capitalized cost of public sewer service including street sewer installation and connections plus fees or tax charges for public sewers and sewage treatment plant installation and operation costs.

C. Site Evaluation for Subdivision or Development

After all alternatives have been considered and it is determined that on-site systems will be acceptable if conditions on each lot or premises are acceptable, the detailed study of the application or proposal would usually involve the following:

1. Review of all available data for the area, including soil maps, hydrological maps and records showing groundwater levels, plus data from previous on-site evaluations of adjoining properties or sites within the area.
2. Review of data on existing systems in the vicinity.
3. Determination of number, location and type tests to be conducted on property, based on:
    a. Probable variability or uniformity or relevant conditions in various parts of the property.
    b. Evaluation of over-all suitability on basis of observed soil and known groundwater conditions.
    c. Consideration of topography as to slopes and features which affect on-site system location and suitability.
4. Proximity to wells, water courses, and lakes.
5. Proximity of proposed system to steep slopes, banks and retaining walls.
6. Decision on what test data will be required:
    a. Where soil is porous (sand or equivalent) and groundwater level is known to be well below the level of concern, practically no test holes or percolation tests may be required.
    b. Where soil is such as to necessitate an absorption area greater than the "minimum," a greater number of tests may be required, the number being determined in part by apparent uniformity or dissimilarity of soil and topography on the site.
    c. Where the groundwater level is or may be high enough to be of concern, the number of test holes may be based on the uniformity of data from preliminary tests at selected locations, and on knowledge of geology and hydrology of the area.
    d. Where conditions are marginal for on-site sytems due to soil

conditions, topography or groundwater levels, plot plans and tests on proposed system sites may be required for each lot.

e. Where the soil is especially porous (gravel with little sand) or underlain at shallow depths by cracked, seamy or cavernous rock, special studies are justified to determine effects of waste discharge on aquifers and near-by wells or streams.

D. Site Evaluation for Each Lot or Premise

1. Data Required:

   A good program includes easily understood forms and printed instructions to facilitate obtaining basic data similar to that required for subdivisions.

   The form would usually provide space for a plot plan on which the proposed system can be shown in relationship to all pertinent lot features and proposed construction or paving.

2. Test requirements for the final system design would be more complete than for a subdivision. The number of tests would depend somewhat on the same factors as are considered for subdivision. Where soil conditions are uniform, one or a very few tests usually are sufficient. Where soil is variable, the tests should be made to fully represent the whole seepage area, including space reserved for future expansion.

3. Where there are to be individual wells, the locations of the wells and on-site systems should be chosen to maximize distances and optimize directions from wells on these and adjoining properties.

4. Soil classification maps, if available, should be used, along with soil examination, to obtain preliminary information.

5. Experiences with existing systems in the area should be evaluated.

6. Except where it is known that groundwater is at such depth as to be of no concern, all readily available data should be obtained concerning groundwater levels during the wet season and, if possible, the highest groundwater levels of former years should be determined.

   Test holes and soil examination at the site should be required where this is considered necessary to determine maximum high groundwater levels or to aid in determining soil classifications, porosity and other pertinent factors; also to enable observations for mottling, soil color and other indications of seasonal high water levels.

Chapter 7

PERCOLATION TESTS

A. Site Evaluation Elements

As discussed in Chapter 3, persons responsible for making and/or reviewing site evaluations must have a comprehensive knowledge of related geological, hydrological, topographic, climatic and soil analysis to effectively perform their tasks. Too often the whole evaluation focuses on percolation tests. Perhaps this is partly due to the apparent simplicity of making routine tests according to any of many various procedures and utilizing a chart to determine the requirements.

Before considering the percolation test, the site evaluator should always consider the site from a broad and comprehensive viewpoint.

1. On-Site Systems or Public Disposal to Off-Site Treatment Systems

   It is necessary that developments will be within the limits of acceptable density of on-site systems and is well within the capacity of the soil and aquifer to accept wastewater discharges. This includes determining that enough lot area is provided for systems and for separation, as from water supply wells.

   Certain concentrated urban, high-density, commercial and industrial areas should be developed only with public sewerage.

2. Most authorities tend to not approve systems for installation in flood plains.

3. Topography is studied to assure systems will not be installed on too deep slopes nor too near banks or retaining walls.

4. Groundwater levels are determined to assure they are at least at minimum acceptable depths.

5. Surface drainage is studied to assure systems are not subject to periodic flooding.

6. Geological studies are made, and borings are logged, as necessary, to locate interfering imprevious barriers, solution channels or other factors which affect design and approval.

7. Soil examinations and analyses, as necessary, are made to enable comparison with the U.S.D.A. Textural Triangle or other acceptable guides to evaluate permeability.

8. Experience with existing systems at similar sites within the area is evaluated to obtain data useful in the site review.

9. Acceptability of the site for alternative systems is considered where evaluations indicate conventional systems are not likely to be acceptable.

10. Consideration is given to the uniformity or dissimilarity of various parts of the site in determining the amount of testing and boring which is required.

11. Recognition is given to the principle that there are usually less tests for development approval than for individual lots. Tract approval is to determine whether all or part of the development is suitable for properly designed systems on each lot or parcel.

    This involves recognizing that the final system design, especially on large lots, will depend on the plot plan that establishes locations of fixed construction and paving which will affect location of the on-site system.

12. Consideration is given to sites which may be acceptable with site modification, or use of alternative systems, including sand beds, mounds, curtain drains and other modifications which will enable use of sites which would otherwise have to be rejected.

13. Only after the above and other pertinent factors have been considered should the percolation test program be conducted. Then the number and location of such tests is based, in part, on the results of the complete site evaluation, so as to avoid unnecessarily large number of tests and to assure that enough tests are made to confirm data from soil evaluation and other site studies.

B. U.S. Soil Conservation Service Ratings

Sites are rated into the following four limiting categories:
Slight, moderate, severe and very severe.

For instance, *slight* would include slopes up to 12% while *moderate* would include slopes from 12 to 18%. Some regulations would limit slopes to 12% while others would permit up to 18% with special design and careful system location.

Severe conditions include slopes of 18 to 25%, somewhat poorly to poorly drained soils, subject to flooding for over 24 to 72 hours at a time, soil depth of 30 inches or less and, in some cases, very high permeability.

Very severe conditions are slopes over 25%, very poorly drained, subject to standing water for 3 or more days, and with a permeability of greater than 120 minutes per inch.

C. Conformance with Basin Plan

Review of proposed on-site system plans must include the determination that on-site systems are in accordance with the water quality control plans for the basin and region. Included in such a plan would be areas not acceptable for development until public sewers are connected. In addition, the plan includes reviewing special requirements for lot area and system design.

D. Value of Percolation Tests

Because of its common use, the percolation test deserves thorough study and evaluation. In theory, and as a handy administrative tool, it is ideal. Presumably, a standard prescribed method is used to accurately measure the time it takes for water to disappear in a standard test hole under prescribed conditions. The measured time is then simply applied to a chart or formula which gives the data needed for subsurface absorption system design.

One of the causes of widely divergent results of percolation testing is the trend toward using tables and charts like Ryon's which are based on reasonable correlation with long term system performance but using different size holes, depth of water and testing procedures. In using percolation testing, the following should be carefully considered.

1. Be sure that all tests are actually performed using the same methodology as was used in tests to develop commonly used charts or tables.
2. Evaluate the criticisms of the test reported in the literature.
3. Determine test weaknesses and recognize them in evaluating results.
4. Consider the test as providing information but not necessarily the whole sum of information available and required for making decisions and for system design.
5. Not necessarily require the test where adequate information is provided by soil analysis and other means.

E. Complicating Factors

Healy and Laak (1974) said, "....., research carried out by Healy and Laak, and Hill, has shown that the percolation rate can be very misleading and does not directly measure any soil characteristic that can be used in the rational design of a seepage field."

They also said, "Studies supervised by the writers indicate that seepage field problems, aside from those due to poor construction or lack of maintenance, could be separated into two categories: those fields that failed because of greatly reduced permeability of the soil interface due to biological growth and clogging by solids; and, those fields that failed because the ground surrounding the field could not absorb the liquid." They went on to say that "at some loading rates, decomposition would match accumulation and growth, and absorption could continue indefinitely under this long-term loading rate."

They made the surprising statement, which seems to conflict with the findings of Bouma (1971), that "There is little difference in the final long-term acceptance rate between a soil that is flooded continuously leading to anaerobic decomposition and the same soil that is flooded intermittently, allowing an aerobic decomposition."

"A hydraulic head of approximately 1 foot (0.3m) of water to push the nutrients and fluid into the soil leads to efficient operation of a seepage field."

They explained that the hydraulic conductivity of a seepage field (defined as the number of gallons of clear water that can be continuously absorbed by the field) is dependent upon such factors as the permeability of the soil, considered along with the geometry of the field and the position of any impermeable boundaries which may restrict the cross-sectional area through which the liquid must travel to escape.

Laak and Healy recommend that site evaluation includes determining the highest seasonal water level, depth of any impermeable strata which may be close to the seepage bed bottom elevation and the soil's permeability. They go on to describe the tube permeometer for obtaining undisturbed soil cores through which permeability is measured and the pit permeometer, used when the water table is less than 8 feet below the ground surface. The latter test is made by digging a hole to below the groundwater level, and by one of several means, measuring the rate at which the groundwater seeps into the hole.

Admittedly, the two alternate methods of getting data on permeability may have much merit in special cases where soil permeability is much influenced by such characteristics as solution and root channels. As with any test, there should be data to correlate test results with design factors for a successful system. There is not enough evidence available that either method is, under most normal circumstances, more accurate than the percolation test.

Bouma (1974) noted that "the capacity of a sub-surface bed to accept liquid waste cannot be adequately expressed by the percolation test." He advocated use of soil maps and analysis, and evaluation of hydraulic conductivity and moisture retention of the soil.

Many officials who operate under codes like the Uniform Plumbing Code of the International Association of Plumbing and Mechanical Officials (1976) make most of their determinations on the basis of soil examination and classification together with experience in the areas with which they are familiar. They use the percolation test only where they need further confirmation or sometimes for evidence to support their determinations which are based upon soil classification.

Many officials throughout the country have used the percolation test successfully as one of their major sources of information, along with other pertinent data. For instance Clayton (1974) in his "Analysis of Septic Tank Survival Data," said of the percolation test, "It is still essential for proper design of a sub-surface disposal system, but is not the only criterion to be considered. Of more concern is the groundwater table. . . ." He went on to explain that in 1950, in parts of Fairfax County, Virginia, the water table had risen into the drainfield areas resulting in literally hundreds of system failures and necessitating a $20 million sewer bond issue for sanitary sewers.

He then arranged for a soil classification survey of over 300 square miles of the county to be conducted by soil scientists of Virginia Polytechnical Institute and State University. A major outcome was that they were able to identify soil characteristics which indicate periodic high water tables (mottling of the soil with grey clay formations mentioned by Bouma, 1974 and others and other indicators.

The above references confirm the *Manual of Septic Tank Practice* (1967) statement which says, "The soil must have an acceptable percolation rate, without interference from groundwater or impervious strata below the level of the absorption system." It further says the bottom of the absorption system should be at least 3 or 4 feet above the seasonal high groundwater level and impervious layers. It is noted that a draft of the Glumb (1978) guidelines and several state and local codes accept 3 feet. Some require up to 10 feet, which is probably unnecessarily restrictive under normal circumstances.

F. Percolation Test Procedures

The *Manual of Septic Tank Practice (MSTP)* provides the well-known and commonly referred to instructions for conducting a percolation test, giving certain reasonable variations of methods to be followed under specified conditions. There are, however, some features of the instructions which should be restudied.

1. Water level during timing

   The MSTP calls for filling (repeatedly if necessary) to a depth of 6 inches above the 2 inches of gravel in the bottom of the hole and then measuring the number of inches the water level drops in 30 minutes. For more porous soils the prescribed measurement period is 10 minutes. The work of Laak and others has shown that head has a considerable influence on percolation rates. The test procedure can result in a head, on the test hole bottom, which varies from 8 inches to 2 inches.

   For this reason some regulations call for filling the hole in the same manner and to the same 6 inch prescribed depth and then measuring the time required for the water to fall 1 inch. Various ingenious devices are available to make accurate water level measurements. The alternate procedure has the advantage of providing both a uniform head and a more uniform soil-water interface per unit volume of water percolated. However, from a practical, field viewpoint, it is easier and measurements are more accurate when using the method of the MSTP. Some regulations, like Wisconsin's (1969) and the U.S. Public Health Service (1963), prescribe the "falling head" technique. Some advocate reservoirs designed to maintain a constant 6 inch head over the rock in the test hole, measure the volume accepted by the hole in a measured time, and thereby calculate the rate. However, the important point is to be sure that the method adopted has been proven to result in system design sizing factors equal to those determined by the method utilized in developing the table and charts.

2. Effect of various sized holes:

   The MSTP allows either a 1 foot square or a 4 inch round hole or other sizes in between. It has been contended that size of hole does not affect rate of drop in water level. That would be true if the sides of the hole were impervious and all water would have to pass through the bottom. However, it must be agreed that percolation takes place through all surfaces which constitute the whole water-soil interface.

   A few simple calculations are offered to provide a basis for proposing a single hole shape and diameter.

   Assume a 4 inch round hole is filled to 6 inches above the gravel or 8 inches above the bottom. The volume of water 1 inch deep, and 4 inches in diamter is 12.5 cu. in.

   The total side-wall plus bottom interface area is 8 x 4 x 3.1416 + 4 x 3.1416 = 112 sq. in. The interface area per cubic inch percolated, at the beginning of the test in the 4 inch round hole is 112 ÷ 12.5 = 9.

   For a 12 inch square hole, the volume of water one inch deep and 12 inches square is 144 cu. in. The interface area of a square hole 12 inches in diameter and 8 inches deep is 12 x 8 x 4 = 384 + 144 = 528 square inches. The interface area per cubic inch percolated at the beginning of a test in the 12 inch square hole is 528 ÷ 144 = 3.7. It is apparent that the smaller round hole has a much larger interface area per unit of water percolated than the larger diameter hole by a ratio of 9 to 3.7 or 2.4 times.

This tends to confirm Winneberger's (1974) plea for testing methodologies which produce the same results as the methods used by Ryon in developing the MSTP tables and charts for sizing systems.

G. Recommendations

It has been noted that percolation rates vary according to test hole diameter, water depth during testing, presoaking methods, procedures for hole preparation, and procedures for determining the rate at which the test hole accepts water.

There should be no significant variations from the originally specified percolation test method unless enough comparative tests have been run to demonstrate that application of a given correlation factor produces system design data which are equal to data obtained when the original method is used.

H. Test Holes, in Addition to Percolation Tests

1 . General Objectives

Except where soil is uniformly permeable and groundwater is not a factor affecting on-site systems, test holes should be used to:

a . Provide a log of soil formations and classification to a depth of at least 4 feet below the bottom of the proposed seepage bed.

b . Note whether groundwater is encountered and examine for soil mottling or other evidence which indicates the seasonal high groundwater level.

c . Observe the natural soil structure as it may be pertinent to percolation.

2 . Tests for Seepage Pits

Seepage pits are a subject of controversy, and some jurisdictions feel they are justified in not allowing them to be built. Others allow seepage pits when the top several feet of soil is relatively impervious but is underlain by a suitable porous material where there is no hazard to the aquifer and where the system will terminate 4 to 10 feet above the highest groundwater level. There is considerable justification for a policy of not accepting seepage pits in soil that is not sufficiently porous to produce the percolation rate of less than 15 or 30 minutes per inch recommended by Glumb (1978).

If necessary, test holes or "tentative" pits should be dug and further borings should be made to obtain the required soil, groundwater and percolation data. Where the soil is composed of layers of material with differing permeabilities, only layers with permeability rates equal to or more than 15 to 30 minutes per inch should be used. Such determinations are made by percolation tests in each such permeable zone. Some construct a bore hole and measure the rate at which the hole accepts water.

San Diego County, California, for instance, allows tests to be made in 1, 2 and 3 foot diameter pits. After a minimum of 10 hours of soaking, each pit shall accept in 2 hours:

1 foot hole — 35 gallons
2 foot hole — 70 gallons
3 foot hole — 105 gallons

An optional test is to construct a normal 4 foot diameter seepage pit and soak at least 10 hours. Then the rate of water acceptance shall be 1667 gallons per 24 hours, per pit.

Where suitable percolation tests are made for evaluating sites for pits, the percolation tests should be conducted as prescribed in the MSTP for seepage pits.

3. Tests and Observations for Various Alternative Systems

The enforcement agency should be fully authorized to require applicants for approval of alternative systems to provide all requisite test data from test holes, soil examination, soil structure, groundwater level and direction of movement, percolation or permeability tests, and anything else necessary to assure that site conditions are equivalent to those on which the alternative system has been proven successful.

For systems that depend in whole or part on transpoevaporation, the applicant shall provide all requisite data for the area of the site, including evidence that the system will not overflow during periods of maximum precipitation and other adverse climatic conditions that tend to reduce the rate at which water disperses so it is less than the rate of inflow from both the pretreatment tank, and infiltration.

I. Site Location and Drainage

System failures have commonly been traced to surface drainage, as from roof gutters and inadequate grading which causes flooding of the soil over seepage systems. Special care is advocated to assure diversion and drainage to minimize surface water soaking and drainage into seepage systems.

Chapter 8

PRE-TREATMENT SYSTEMS

A. Basic Objectives

With subsurface disposal of wastewater, it is assumed that the requisite removal of suspended solids and other pretreatment will be effectively accomplished and that additional purificaiton will take place as the liquid passes through the soil. As stated above, the commonly reported causes of failure in soils of assumed acceptable percolation capacities are from gradual plugging of the soil surface with suspended materials and biological slimes. One of the primary purposes of the septic tank is to effectively remove a substantial portion of the suspended solids.

It is contended that stablization of organics in the liquid, as indicated by an aerobic effluent with a low B.O.D., improves long-term performance and has other benefits.

Other objectives of aerobic treatment, sometimes with additional treatment and disinfection, is to enable reuse for such purposes as flushing toilets, irrigation of selected vegetation, and to meet requirements for discharge to water courses or drainage channels (where such discharges are authorized).

B. The Septic Tank

1. Objectives

The original subsurface systems were subsurface pits (cesspools) with open jointed walls and open bottoms into which wastewater was discharged for subsurface absorption. The septic tank was designed to remove a substantial portion of the solids, grease and scum which tended to cause plugging of the bottom and sidewalls of the cesspools.

The primary purpose of the septic tank is to permit separation of solids, grease, oil and scum by sedimentation and flotation. A secondary purpose is to afford opportunity for the removed material to anaerobically digest to reduce its volume, and possibly to change its character (such as breaking down grease).

A third function is to allow biological changes to occur in the liquid.

A fourth function is to provide capacity to hold a few years' accumulation of sludge and scum and, as necessary, kitchen waste solids and greases, thereby requiring pumping or cleaning only infrequently.

2. Basic Shapes and Arrangement

The original field and laboratory work which was done to develop the MSTP was concerned primarily with the question of size, shape and configuration of septic tanks to establish design characteristics which produce the best reduction in suspended solids.

The tests showed that there can be a considerable variation in shapes and configuration of tanks that produce reasonably satisfactory reductions in suspended solids. It was concluded that a single compartment tank with a suitable outlet arrangement will give acceptable performance but somewhat more consistent results were

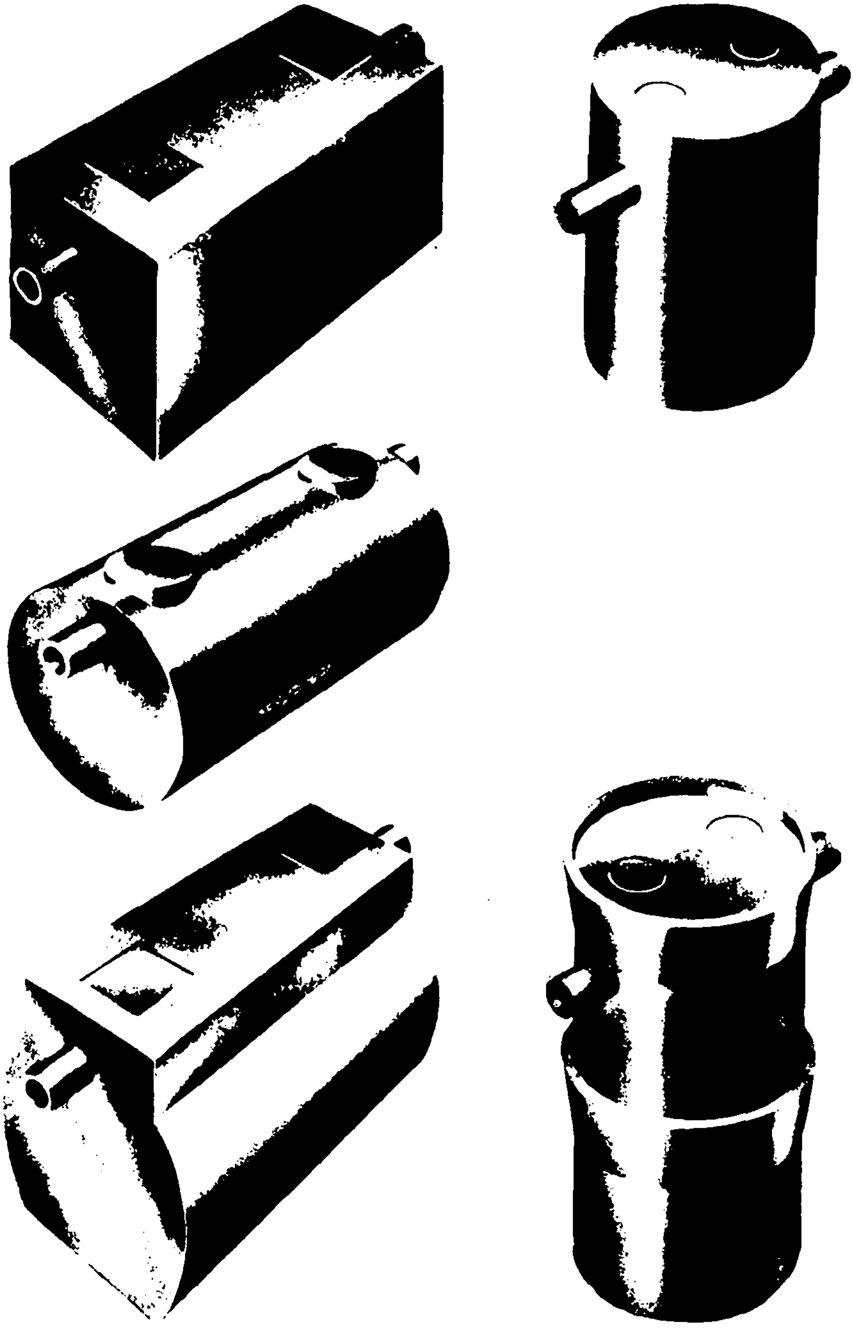


Figure 6

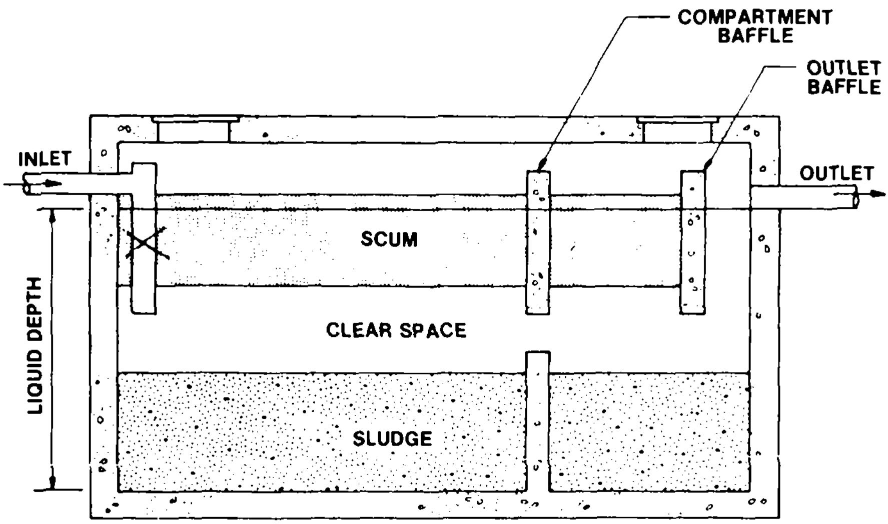
Typical septic-tank shapes

Reprinted from the U.S. Public Health Service's Manual of Septic Tank Practice.

attained with a two compartment tank, the first of which equals one-half to two-thirds of the total volume. This provided better suspended solids removal "which may be especially valuable for protection of the soil in the absorption system." Experience since the MSTP was developed appears to support the concept of a two compartment tank for households, with the inlet compartment being approximately twice the volume of the outlet compartment. Table 6 shows the sizes required in the various states. The tank design should facilitate separation of sludge, scum and grease from the liquid; provide for undisturbed storage of the sludge and scum; enable periodic removal of sludge and scum, and provide a sufficiently long detention period.

Figure 7

Typical Two Compartment Septic Tank



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3. Tank Design

a. Inlet and outlet arrangements:

Original U.S. Public Health Service studies showed that baffling of the tank inlet to the tank was not important. Experience has shown that inlet baffles, if used, should be designed to help avoid plugging and stoppages. That problem is particularly acute with "sanitary T" inlets, because paper and solids tend to become impacted in the bend, particularly in the vertical leg of such inlets. The type inlet baffles shown in the MSTP with either a smooth, sweeping inlet elbow or a baffle which extends across the tank, are acceptable. More recent studies show that suitable baffles help reduce the undesirable effects of surging action. Committee member Elmer Jones says most authorities favor an inlet arrangement which permits venting the space above the scum through the building stack; however, committee member Nix Anderson contends that the moist sewer gas is corrosive to some vent stack materials so many individuals avoid the vent.

The depth of the opening or slot in the baffle between the first and second compartments, shown in the MSTP as about 0.4% of the total depth, would normally be acceptable.

The functions of the outlet arrangement are to:

(1) Hold within the tank the floating scum, grease and other materials.

(2) Counteract the effects of surge and up-flow from sudden large loads and thereby minimize discharge of settled or floating solids.

Work toward minimizing undesirable surge action is illustrated by tests by the National Sanitation Foundation indicating a reduction of 35% in suspended solids in the effluent from a 1,000 gallon septic tank after it was fitted with a Capital Research Services Septic Solids Retainer and subjected to a 9-day simulated field test at a loading of 600 gallons per day.

However, the NSF report did not show compartmentation of the tank, and the effect of the Suspended Solids Retainer (SSR) or other especially designed outlet fittings may be much less significant with the two-compartment tank design commonly required.

b. Materials and Design:

Septic tanks and all other type pretreatment, holding or pumping tanks which are placed underground must be of material and design to withstand both corrosive action of the liquid and gases within the tank and the effects of surrounding soil. Additionally, building and safety officials have developed criteria by which structural engineers check the ability of the tank to withstand anticipated stress from earth backfilling and surface loading.

c. Access:

All tanks should have readily removable covers or manholes, of a size and location to enable complete maintenance operations. If buried more than a foot or two, it is common to require manholes of adequate size and location for effective maintenance and inspection. Tank and system locations should be accurately referenced to fixed objects on a plot plan left at the site so component parts can easily be located for maintenance.

d. Tank Capacity and Shape:

The main reason for large tanks is to provide space for storage of sludge and scum. This is assumed to be especially critical where garbage disposers are connected to the system and tank cleaning and pumping is infrequent.

Table 11 provides information which may be used in system design.

A substantial freeboard of at least 9 inches above the outlet level is desirable to provide space for floating scum.

The inlet connection is 2 to 3 inches above the outlet to prevent scum from backing into the inlet line.

MSTP and other studies showed there is little evidence to support the strict limitaitons on length-to-width ratios and depths.

Committee Member Elmer Jones provided his unpublished paper "Septic Tanks—Configuration versus Performance," in which he says, "Important factors in septic tank performance are volume, surface area, compartment, and inlet and outlet design." He gave the following for "ball park estimates" of suspended solids removal:

Single compartment tanks — % SSR $= \frac{7500}{v}$

Two-compartment tanks — SSR $= \frac{5625}{v}$

v = tank volume per person (200 to 275).

Assuming v = 200, the % removals are 62% for a single and 72% for a two-compartment tank.

(1) Inlet Design:

Jones said inlets should be nonfouling and the inlet should extend down about 33% of the tank depth.

(2) Outlet Design:

Jones discusses Weihel's studies and the MSTP statement that the outlet baffle should extend down to 40% of the tank depth. The 40% figure is based on tests of tanks receiving garbage and supports the 40% depth for such septic tanks, but Jones indicates 26% depth provides improved suspended solids removal in 1000 gallon tanks which do not receive garbage.

e. Comparison of State Standards:

The following tables, which also provide other valuable information are from Plews (1977).

f. Performance:

Richard J. Otis, et al. (1977) gave the effluent quality data in Table 11.

Table 4

BASIC PROGRAM ADMINISTRATION

States	Local	Regional	State	None
Alabama	X			
Alaska	X		X	
Arizona	X			
Arkansas	No Response			
California	X		X (Limited)	
Colorado	X		X	
Connecticut			X	
Delaware			X	
Florida	X		X	
Georgia	X			
Hawaii			X	
Idaho		X		
Illinois				
Indiana	X			
Iowa	X			
Kansas	No Response			
Kentucky	X			
Louisiana	X			
Maine	X		X	
Maryland	No Response			
Massachusetts	No Response			
Michigan	X			
Minnesota	No Response			
Mississippi	No Response			
Missouri				X
Montana	X		X	
Nebraska				X
Nevada	X		X	
New Hampshire			X	
New Jersey	X		X	
New Mexico	X		X	
New York	X			
North Carolina	X			
North Dakota				X
Ohio	X			
Oklahoma	X		X	
Oregon			X	
Pennsylvania	X?		X	
Rhode Island			X	
South Carolina	X		X	
South Dakota	X		X	
Tennessee	X			
Texas	X		X	
Utah	X		X?	
Vermont	X		X	
Virginia	X			
Washington	X			
West Virginia	X		X?	
Wisconsin	X			
Wyoming	X*		X*	X

44 — Responses

15—Local Control
18—Local - State
1—Regional Control
6—State Control
4—No State Involvement

*Per Nix Anderson

Reprinted from U.S. Environmental Protection Agency publication.

Table 5

ABSORPTION FIELD DESIGN

States	Setback Distance Drainfield To Well In Feet	Setback Distance Drainfield To Surface Water In Feet
Alabama	50-75	?
Alaska	50-100	50-100
Arizona	50-100	100
Arkansas		
California		
Colorado	100*	50
Connecticut	75	50
Delaware	50-100	50
Florida	75-100	50
Georgia	100	50
Hawaii	50	50
Idaho	100	100-300
Illinois		
Indiana	50-100	50
Iowa	100-200	25
Kansas		
Kentucky		
Louisiana	100	?
Maine	100-300	50-100
Maryland		
Massachusetts		
Michigan		
Minnesota		
Mississippi		
Missouri		
Montana	100	100
Nebraska	100	50
Nevada	100	100
New Hampshire	75	75
New Jersey	50-100	50
New Mexico	100	50
New York	100	100
North Carolina	100	50
North Dakota		
Ohio	50	?
Oklahoma	50-100	50
Oregon	50-100	50-100
Pennsylvania	100	50
Rhode Island	100	50
South Carolina	100	50
South Dakota	100	100
Tennessee	50	25
Texas	100-150	75
Utah	100	100
Vermont	100	50
Virginia	35-100	50-100
Washington	75-100	100
West Virginia	100	100
Wisconsin	50-100	50
Wyoming	100	50

*Local authorities require up to 200′ (Dan Tripton).

Reprinted from U.S. Environmental Protection Agency publication.

Table 6

SEPTIC TANK DESIGN

States	Septic Tank Capacity in Gallons By Number of Bedrooms 1	2	3	4	5
Alabama	1000	1000	1000	1200	1400
Alaska	750	750	900	1000	1250
Arizona	960	960	960	1200	1500
Arkansas					
California					
Colorado	750	750	900	1000	1250
Connecticut	1000	1000	1000	1250	1500
Delaware	750	750	750	1000	1250
Florida	750	750	900	1000	1200
Georgia	750	750	900	1000	1250
Hawaii	750	750	1000	1200	1350
Idaho	750	750	900	1000	1250
Illinois					
Indiana	750	750	900	1100	1250
Iowa	750	750	1000	1250	1500
Kansas					
Kentucky	750	750	900	1000	1250
Louisiana	500	750	900	1150	1400
Maine	750	750	900	1000	1250
Maryland					
Massachusetts					
Michigan					
Minnesota					
Mississippi					
Missouri					
Montana	750	750	900	1000	1250
Nebraska	750	750	900	1000	1250
Nevada	1000	1000	1000	1000	1250
New Hampshire	750	750	900	1000	1250
New Jersey	750	750	900	1000	1250
New Mexico	750	750	900	1000	1250
New York	750	750	900	1000	1250
North Carolina	750	750	900	1000	1250
North Dakota					
Ohio	1000	1000	1500	2000	2000
Oklahoma	1000	1000	1000	1000	1250
Oregon	750	750	900	1000	1250
Pennsylvania	900	900	900	1000	1100
Rhode Island	750	750	900	1000	1250
South Carolina	890	890	890	?	?
South Dakota	1000	1000	1000	1250	1500
Tennessee	750	750	900	1000	1250
Texas	750	750	1000	1250	1500
Utah	750	750	900	1000	1250
Vermont	1000	1000	1000	1000	1500
Virginia	30 Hour Detention — 100 Gallons Per Person				
Washington	750	750	900	1000	1250
West Virginia	750	750	900	1000	1250
Wisconsin	750	750	975	1200	1375
Wyoming	1000*	1000*	1000*	1250*	1500*

*Per Nix Anderson

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Table 7

ABSORPTON FIELD DESIGN

States	Minimum Percolation Restriction	Sizing Methods
Albama	None	Perc
Alaska	None	Perc & Soils
Arizona	None	Perc
Arkansas		
California		
Colorado	Yes	Perc
Connecticut	None	Perc
Delaware	Yes	Perc
Florida	None	Perc & Soils
Georgia	None	Perc & Soils
Hawaii	None	Perc
Idaho	None	Perc & Soils
Illinois		
Indiana	None	Perc
Iowa	None	Perc & Soils
Kansas		
Kentucky	?	Perc
Louisiana	None	Perc
Maine	None	Soils
Maryland		
Massachusetts		
Michigan		
Minnesota		
Mississippi		
Missouri		
Montana	Yes	Perc & Soils
Nebraska	No	Perc
Nevada	Yes	Perc
New Hampshire	None	Perc
New Jersey	Yes	Perc & Soils
New Mexico	Yes	Perc & Soils
New York	None	Perc & Soils
North Carolina	None	Perc & Soils
North Dakota		
Ohio	None	Soils
Oklahoma	None	Perc Test
Oregon	None	Soils
Pennsylvania	Yes	Perc
Rhode Island	None	Perc
South Carolina	None	Perc & Soils
South Dakota	Yes	Perc
Tennessee	None	Perc & Soils
Texas	Yes	Perc & Soils
Utah	None	Perc
Vermont	None	Perc & Soils
Virginia	None	Perc & Soils
Washington	Yes	Perc & Soils
West Virginia	None	Perc
Wisconsin	None	Perc & Soils
Wyoming	None	Perc

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Table 8

SPECIAL RESTRICTION

States	Required Soil Depth Below Bottom Of Trench in Feet	Allows Surface Discharge
Alabama	4	?
Alaska	4	No
Arizona	4	No
Arkansas		
California		
Colorado	4*	Conditional*
Connecticut	1.5	No
Delaware		
Florida	1.5	No
Georgia	No Minimum	No
Hawaii	No Minimum	Yes, Conditional
Idaho	4	No
Illinois		
Indiana	?	No
Iowa	1.5[a]	Yes
Kansas		
Kentucky	?	No
Louisiana	None	Yes
Maine	2	Yes
Maryland		
Massachusetts		
Michigan		
Minnesota		
Mississippi		
Missouri		
Montana	4	No
Nebraska[b]	?	No
Nevada	4	No
New Hampshire	4[a]	No
New Jersey	4	No
New Mexico		
New York	2	No
North Carolina	1	Yes
North Dakota		
Ohio	4[a]	Yes
Oklahoma	4	No
Oregon	1.5[a]	No
Pennsylvania	4	No
Rhode Island	3	No
South Carolina	6"	No
South Dakota	4	No
Tennessee	4[a]	No
Texas	4	
Utah	1	No
Vermont	4	No
Virginia	No Minimum	Yes
Washington	3[a]	No
West Virginia	4	No
Wisconsin	3[a]	No
Wyoming	4	Yes

a Allows less with special design

b Guidelines

* Per Dan Tipton

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Table 9

ABSORPTION FIELD DESIGN REQUIREMENTS AND SIZING METHODS

States	Minimum Spacing Between Lines	Minimum Soil Cover Over Trench In Inches	Range of Drainfield Width In Inches
Alabama	6	6	18-36
Alaska	6	12	12-36
Arizona	6	12	12-18
Arkansas			
California			
Colorado	6	12	18-36
Connecticut	6-9	6	18-36
Delaware	6.5-7.5	9	12-36
Florida	6-8	12	18-24
Georgia	10	12	18-36
Hawaii	6	12	18-36
Idaho	6	12	12-36
Illinois			
Indiana	6-7.5	12	18-36
Iowa	7.5	12	18
Kansas			
Kentucky	?	None	?
Louisiana	?	6-12	12-18
Maine	10	2-6	24
Maryland			
Massachusetts			
Michigan			
Minnesota			
Mississippi			
Missouri			
Montana	6	12	12-36
Nebraska	6	6	18-36
Nevada	6	4-6	12-24
New Hampshire	6-7.5	6	12-36
New Jersey	6-7.5	12	18-36
New Mexico			
New York	6	12	24
North Carolina	8	12	18-36
North Dakota			
Ohio	6	6	8-30
Oklahoma	8	10	24
Oregon	10	6	24
Pennsylvania	6	12	12-36
Rhode Island	6	12	18
South Carolina	10	9	18-36
South Dakota	6	?	?
Tennessee	6	12	18-36
Texas	7	6	18-36
Utah	6-7.5	12	12-36
Vermont	6	6	12-48
Virginia	6-9	None	18-36
Washington	6	6	18-36
West Virginia	6	12	12-36
Wisconsin	10	12	18-36
Wyoming	6-7.5	6-12	12-36

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Table 10

QUANTITIES

Type of Establishment	Gallons Per Person Per Day (Unless Otherwise Noted)
Airports (per passenger)	5
Apartments—multiple family (per resident)	60
Bathhouses and swimming pools	10
Camps:	
Campground with central comfort stations	35
With flush toilets, no showers	25
Construction camps (semi-permanent)	50
Day camps (no meals served)	15
Resort camps (night and day) with limited plumbing	50
Luxury camps	100
Cottages and small dwellings with seasonal occupancy	50
Country clubs (per resident member)	100
Country clubs (per non-resident member present)	25
Dwellings:	
Boarding houses	50
additional for non-resident boarders	10
Luxury residences and estates	150
Multiple family dwellings (apartments)	60
Rooming houses	40
Single family dwellings	75
Factories (gallons per person, per shift, exclusive of industrial wastes)	35
Hospitals (per bed space)	250+
Hotels with private baths (2 persons per room)	60
Hotels without private baths	50
Institutions other than hospitals (per bed space)	125
Laundries, self-service (gallons per wash, i.e., per customer)	50
Mobile home parks (per space)	250
Motels with bath, toilet, and kitchen wastes (per bed space)	50
Motels (per bed space)	40
Picnic Parks (toilet wastes only)(per picknicker)	5
Picnic parks with bathhouses, showers, and flush toilets	10
Restaurants (toilet and kitchen wastes per patron)	10
Restaurants (kitchen wastes per meal served)	3
Restaurants additional for bars and cocktail lounges	2
Schools:	
Boarding	100
Day, without gyms, cafeterias, or showers	15
Day, with gyms, cafeteria, and shower	25
Day, with cafeteria, but without gyms, or showers	20
Service stations (per vehicle served)	10
Swimming pools and bathhouses	10
Theaters:	
Movie (per auditorium seat)	5
Drive-in (per car space)	5
Travel trailer parks without individual water and sewer hook-ups (per space)	50
Travel trailer parks with individual water and sewer hook-ups (per space)	100
Workers:	
Construction (at semi-permanent camps)	50
Day, at schools and offices (per shift)	15

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Table 11

COMPARISON OF SEPTIC TANK AND AEROBIC UNIT EFFLUENT QUALITY

Item	Septic Tank	Aerobic Unit
B.O.D. (mg/1)	123	26
T.S.S. (mg/1)	48	48
Total Nitrogen — N (mg/1)	23.9	39.1
Ammonia — H (mg/1)	19.2	0.4
Nitrate — H (mg/1)	0.3	33.8
Fecal Coliforms (per/100 ml)	2.9×10^5	1.9×10^4
Total Coliforms (per/100 ml)	9.0×10^5	1.5×10^5

Ninety percentiles of B.O.D.$_5$ are 6 to 110 mg/1 for aerobic and 70 to 300 mg/1 for septic tank effluents.

C. Aerobic Systems

1. Performances

National Sanitation Foundation (NSF) Standard 40, as revised in November, 1978, covers basic design and performance requirements for individual "Aerobic Wastewater Treatment Plants." The standards provide for approval under "Class I" or "Class II" units. Units are normally tested at the NSF Special Test Facilty at Chelsea, Michigan, and the test normally takes at least six months.

For Class I effluents the arithmetic mean results should not exceed 20 mg/1 for B.O.D. and 40 mg/1 for suspended solids. For Class II sytems the values are 60 and 100 mg/1, respectively.

Studies have shown that effluent quality obtained under field conditions varies significantly according to the effects of "shock loading," sludge build-up and malfunctioning. The first factor is now incorporated into the 1978 NSF Standards. The latter two problems can be reduced by adequate maintenance, which is an element of NSF Standards and is usually accepted as a responsibility of reputable manufacturers. However, experience has shown that some form of public service agency and public financing is necessary to assure a satisfactory degree of maintenance.

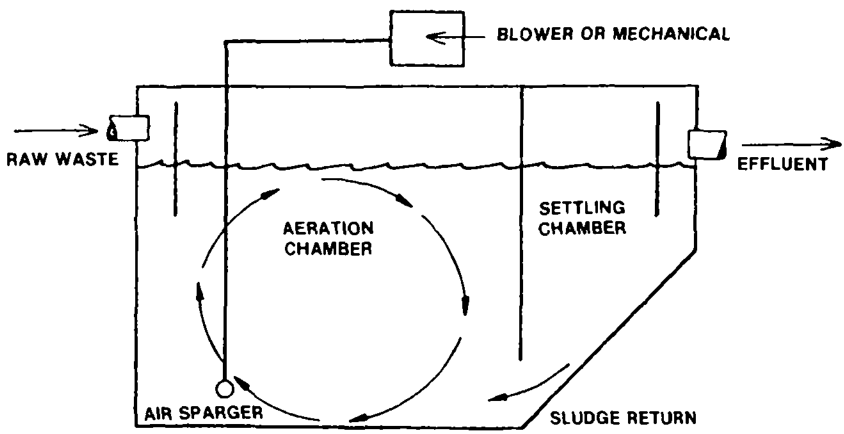
2. Design of Aerobic Units

NSF Standard No. 40 provides basic guidance for the design, materials and construction of Individual Aerobic Wastewater Treatment Plants. These are basically performance standards including such items as water-tight integrity, structure soundness, accessibility for inspection and maintenance, operation under various load conditions, and a standard performance evaluation method applied at the NSF test site at Chelsea, Michigan. Among the problems and needs which have come to the attention of the Committee are:

a. Malfunctioning when electrical contacts and elements are exposed to corrosive gases generated during non-functioning or malfunctioning of units.
b. Need to design so system will function as a septic tank during periods when aerator is not operating.
c. Desirability of alarms to warn of failure.
d. Need for ease of replacement of mechanical and electrical components and ready availability of such items.
e. Limit on noise levels of mechanical units.
f. Availability of competent maintenance service.

Figure 7A.

Typical Aerobic Unit



3. Advantages of Aerobic Systems

The report by McGauhey and Winneberger (1967), "A Study of Methods of Preventing Failure of Septic Tank Percolation Systems," noted that a major factor affecting the performance of percolation systems is gradual reduction that naturally occurs in the "infiltrative capacity, or rate at which water moves through the soil-water interface." They noted that one cause of severe reduction of the infiltrative capacity is the "deposition of ferrous sulphide 'slimes' which occur under anaerobic conditions." They also advocate alternate beds.

Some authorities assume that the stablilized, dissolved-oxygen-containing effluent from an aerobic unit would reduce this problem, and there is some evidence to support this theory.

Laak (1970) said:

"(1) Increasing the pretreatment of domestic wastewater prior to soil *absorption* application increases the service time of the soil surface."

"(2) Soil clogging failure loads should also be expressed in terms of T.S.S. and B.O.D. in the liquid. It seems that the service time of the soil surface is directly related to the sum total S.S. and the B.O.D."

Laak (1974) proposed the formula for the area of a sub-surface system.

$$\text{Adjusted Area Required} = \text{Area Required for Standard Septic Tank Pre-Treatment} \times \sqrt[3]{\frac{BOD_5 + T.S.S.}{250}}$$

Using data on aerobic system performance from Table 11, the Laak formula would permit reducing the soil absorption area by one-third, when aerobic systems are substituted for septic tanks.

Some studies are showing that aerobic effluents are more readily and continuously accepted in certain soils.

For instance, Merrill B. Glasser, Environmental Health Divsion, Maryland Department of Health and Mental Hygiene did a study of five aerobic unit installations in Barrett County, Maryland, where "the soil is rated as unsuited (severe) for sewage systems using filter fields because of the depth of bedrock, seasonal high water table, and slope. His 1976 unpublished report says, "The aerobic system becomes competitive in fair soils and is far superior in poor soils where clay or groundwater may be expected to be a problem.

At each of the test sites there had been experience of some degree of failure with septic tank systems, indicated by flooding of lawns and overflowing into a lake. After installation of aerobic units and new drain fields, both overflowing and odor problems were corrected.

The Brown and Caldwell Report (1975), on the other hand, noted that data on 65 mechanical aeration units in Colorado showed none was able to consistently meet EPA secondary treatment requirements for BOD and SS and for fecal coliform. About 60 were at single family homes. It was stated a "concerted effort was being made to have all surface-discharging units either modified to subsurface disposal or removed."

The major points of the State of Washington's Technical Review Committee's recommendations, adopted in May, 1978 as "Guidelines Governing the Design, Application and Operation of Aerobic Treatment Devices," are:

"Reliability and performance

a. The individual treatment device shall have been tested by a laboratory independent from the manufacturer of that device. The testing criteria and performance shall at least be equal to that specified and required in NSF Standard No. 40 for Class II certification.

b. An adequate form of positive filtration shall be required between the treatment device and the disposal component to prevent excessive solids from being carried over into the disposal component during periods of bulking. If a manufacturer of a process desires a variance from the filtration requirement, such variance may be granted if a financial guarantee for a period of seven years is provided for the potential replacement of a drainfield due to failure."

"Maintenance and operation

a. Continuous maintenance and operation shall be provided for the life of the system by an acceptable management entity. A management system which satisfies the criteria set forth in the 'Guidelines for the Formation and Operation of On-Site Waste Management Systems' would be a satisfactory example.

b. The management entity shall be responsible for monitoring both the performance and operation of the system.
   (1) Frequent inspections of the aeration equipment shall be provided during the first 90 day start-up period.
   (2) The routine inspection schedule shall be quarterly at a minimum.
   (3) Records, both of maintenance and performance, shall be kept and submitted annually to the local permit issuing agency.
   (4) The local permit issuing agency shall review the records and/or make an on-site inspection on the annual basis as a minimum.

c. All manufacturers of aerobic treatment devices shall provide a maintenance and operation manual which shall be followed. The manual shall contain detailed instructions on proper operation and maintenance procedures, including safety, a replacement parts list, public health considerations, limitations of the unit, how to detect when the unit may be malfunctioning, and what to expect from a well functioning unit.

d. Notification to the local health department shall be made as soon as possible if for some reason a unit fails to function properly."

A Washington report dated 1975 was based, in part, on review of 21 units. The report acknowledged that some data indicate "there may be advantages in providing aerobic treatment when ground disposal methods are utilized. However, a reduction in existing disposal field length or soil type requirements was determined to be not justified in the light of current information."

Hutzler, et al. (1974) of the Wisconsin Small Scale Waste Management Project concluded 2 years of field testing by saying "extended aeration units should be inspected and, if necessary, serviced every 2 months and excess solids removed every 8 to 10 months."

In laboratory soil column tests, Otis (1977) compared septic tank effluents with an aerobic effluent and notes, "More severe clogging occurred with the aerobic effluent." In reporting on subsequent studies, Otis said the septic tank effluent had 26 mg/l S.S. while the aerobic effluent contained 61 mg/l S.S. In that test, the septic tank unit effluent produced ponding in slightly less time than the aerobic unit.

4. Conclusions Concerning Aerobic Units

The new trend toward establishing on-site system maintenance districts or departments should do much to overcome the problems of poor operation and maintenance of aerobic units (as well as other type systems), and the mechanical problems of some units will hopefully be corrected. Continued studies and trials of aerobic units are justified. In the meantime further modifications of the processes are promising.

D. New Special Type Treatment Units

1. Batch Treatment

It is assumed that periodic high suspended solids in the effluent are due to bulking in aerobic units resulting from periodic surges and inadequate settling in the final sedimentation tank. To improve performance, some units are operated on a batch principle which causes the aerator to stop for several hours before the supernatant liquid is pumped to the disposal system. Further data may show that this system does result in a consistently lower S.S. in the effluent than conventional, continuous flow aeration units.

2. Special Filters

Special fabric filters have been installed so the effluent passes through what is sometimes called a special biological filter, and other types of strainers filter before discharge. Further data may show this to be a satisfactory arrangement.

3. Special Operation Cycles

At least one unit is timed to aerate only 5 hours at a time and then be off for 19 hours. The liquid remains aerobic and the long quiescent period seems to result in a low S.S. concentration. Other effects are a significant reduction in total organic nitrogen, possibly by nitrogen stripping during the anaerobic stage in the sludge during the 19 hours of quiescence, after nitrification by rather strong aeration for 5 hours.

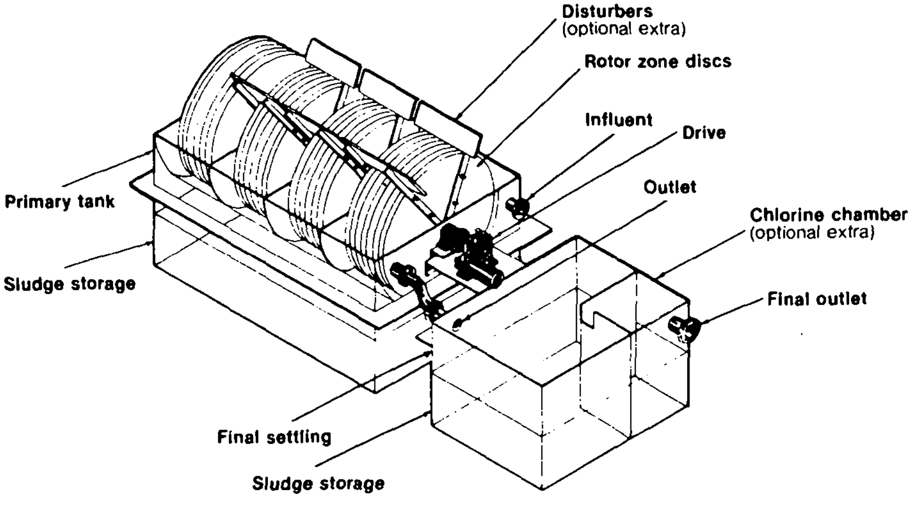
An unpublished San Diego County (California) study indicated that a strong hydrogen sulphide odor is normally liberated when the aerator starts; unless the system is tightly closed, this may cause a temporary odor nuisance.

4. Rotating Biological Discs

This system may become an acceptable candidate in the aerobic field since preliminary data indicate high BOD and SS removal and low sensitivity to shock loading. The Brown and Caldwell report (1975) indicated that units being marketed consisted of a septic tank followed by an aerobic tank with rotating discs, half under the liquid. The discs both aerated the liquid and became coated with an aerobic biological mass. When the mass became thick enough, it fell off and was removed in a final settling tank. The settled sludge from the final tank was partially circulated back to the aeration tank and partly to the inlet to the septic tank.

Figure 8.

ROTORDISK



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5. Conclusions

Improvements in design, operation, processes, maintenance and service all give hope of providing pretreatment systems which will be valuable for situaitons where conventional septic tanks do not produce an effluent which can be satisfactorily disposed of or utilized. For normal situations, the septic tank is the most inexpensive unit giving acceptable results with a minimum of maintenance.

Chapter 9

CONVENTIONAL SOIL ABSORPTION SYSTEMS

A. Basic Concepts and Objectives

Soil absorption systems are planned and designed to cause treated wastewater to percolate into the soil or to be utilized and removed by root-uptake, and by transpiration and dissipated by evaporation from soil and crops, or by a combination of processes.

The primary objective of the planner and designer of soil absorption systems is to utilize those methods and practices which maximize long term acceptance of the liquid into the soil, and to avoid those practices which have been found by experience to be detrimental to success.

There are many factors which influence the long-term acceptance of wastewater by the soil. In view of the wide utilization of the percolation test, its derivation and scientific basis should be restudied. The test presumably measures soil permeability to quantify long-term acceptance of treated wastewater in terms of unit volume per given area of effective system—soil interface per unit of time. The traditional test has, unfortunately been based on bottom areas only for seepage trenches and beds. Logic and experience dictate that both bottom and sidewall areas are valuable elements of the total infiltrative surface.

There is a significant difference between the percolation rate of clean water on a short-term test basis and performance throughout the many years of anticipated life of a soil absorption system. Henry Ryon's percolation test method resulted from comparing results of percolation tests with the size of systems which functioned satisfactorily.

The wide variation between the measured soil permeability and the long-term acceptance rate is illustrated by the following:

Assume a 3 bedroom home on a site with a percolation rate of 30 minutes per inch:

The graph of the MSTP would indicate a system with a surface area of 250 square feet per bedroom or 750 square feet.

The 30 minute rate would mean a percolation of 2 inches of water per hour or 48 inches (4 feet) per day. Each square foot would then accept 4 cubic feet or 30 gallons of water per day.

The 750 square foot bed would accept a total of 22,500 gallons per day.

Average measured quantities of wastewater produced per capita per day in typical households, as noted above, are about 50 gallons. However, to take into account the homes using more than average quantities of water, many codes call for 150 gallons per day per bedroom or 450 gallons per day for a 3 bedroom home.

The required size of the system would be $\frac{22,500}{450}$ or 50 times the actual volume of water which would normally enter the system. In other words, the interfering effects of the many factors are not thoroughly understood, and therefore a factor of safety of 50 was developed from the judgment, experience and studies of Ryon and those who developed the system sizing charts.

The change in liquid acceptance rates of various soils is variable. Obviously, coarse grained, hard, inert sand and gravels are much less likely to become plugged by suspended solids in the effluent, or by microbial growths and swelling than clays. Similarly, coarse grained soils are more likely to become and remain aerated than densely packed, fine materials.

Similarly, the rate at which chemical substances in the wastewater cause agglomeration and "cementing" of surfaces is related to soil structure, grain size and the chemical and electro-chemical nature of the soil.

Long-term wetting may influence permeability. Clays and shales, when relatively dry, may contain channels, cracks and openings through which water may pass. However, continuous wetting may cause swelling and produce a more plastic consistency which reduces hydraulic conductivity.

Certain decomposed granite soils become extremely hard and impervious when dry, but quite soft and permeable when wet.

All such factors are of major significance when making and interpreting percolation tests and other soil and permeability tests and observations.

It is well recognized that discharging wastewater to portions of systems which are below the groundwater surface not only may cause contamination of aquifers, but also greatly reduces the rate at which the wastewater can be absorbed by the soil.

In some soils the rate of flow of groundwater is extremely slow. For that reason several authors caution designers to ascertain that the volume of water that will pass through the system-soil interface will be able to flow away as rapidly as it is added to the soil.

Systems are often, and properly, designed to depend, in part, on evapotranspiration, as well as percolation. However, in such cases consideration must be given to the fate of wastewater during seasons of high precipitation and snow cover. Also, premises drainage design must divert surface flows, rain gutter discharges, and similar water from seepage system sites.

In some cases, where topography permits, subsurface or curtain drains can be installed to avoid seasonal high water tables which interfere with system design.

Test holes and knowledge of soil formations at various depths are valuable in system design so the percolation system maximizes utilization of the most favorable soil formations.

As stated in discussing prevention of contamination of aquifers and surface waters, consideration must be given to situations where soil and geological formations are such that microbiological contamination from wastewater will travel for considerable distances, as in areas where creviced and seamy rock or coarse gravel will readily absorb wastewater but microbiological contamination is a threat to water supplies.

B. Trench System Design

1. Conventional Trenches

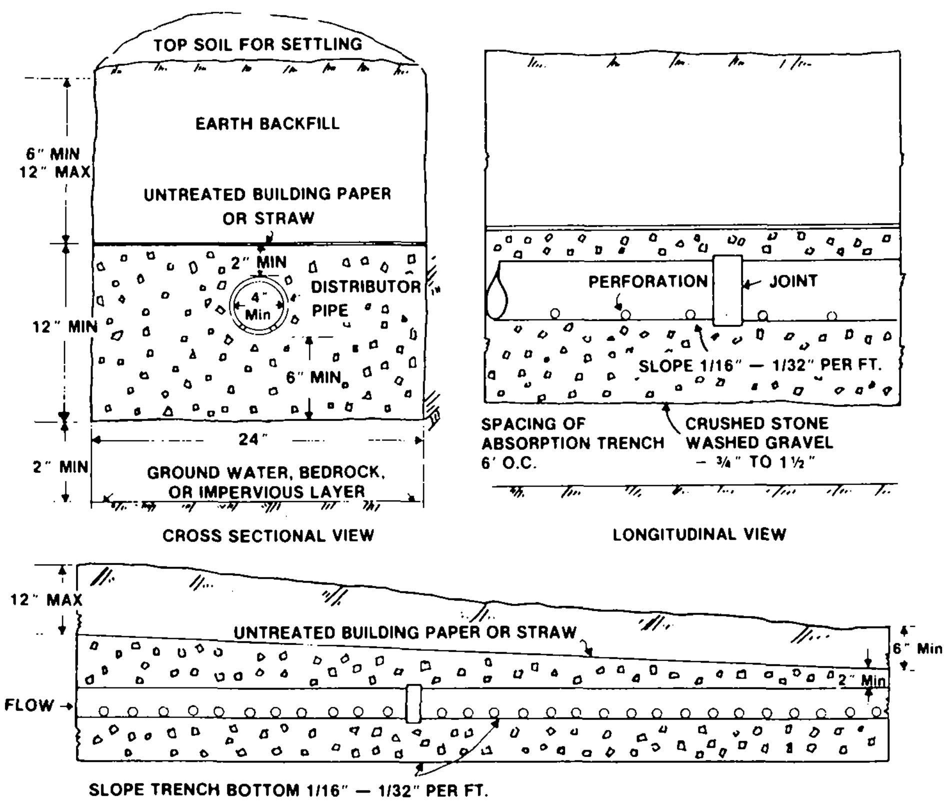
The most commonly accepted soil absorption system utilizes trenches in which perforated or open-jointed drain lines distribute treated liquid into a bed of crushed or graded rock, or a similar porous medium from which the liquid passes into the surrounding soil through the rock-soil interface of the sides and bottom of the trench.

There is some controversy concerning whether the interface between surrounding soil and the trench bottom or its side walls are of most significance; some regulations consider only the bottom surface, some the sidewalls and some allow for both.

The system sizing procedures of the MSTP are based on considering only the bottom area for trenches with a bed of porous rock (or equivent) which is 6 inches deep, below the drain line, with some exceptions.

Figure 9

ABSORPTION TRENCH DETAIL



TRENCH PROFILE

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2. Trench Depth

Allowance is made in the MSTP for reducing the calculated length of deeper trences by 33 to 87%. A similar provision is contained in some other codes. For instance, the Uniform Plumbing Code (1976) provides "for large, specially designed and approved systems; sidewall area in excess of the required 12 inches, and not to exceed 36 inches below the leach line, may be added....to the square feet of trench bottom area when computing absorption areas." This is justified by the fact that total permeable trench-soil interface beneath the leach line is effective. In addition, the deeper trenches provide a higher head.

These allowances are based on the assumption that the total interface of permeable soil in both bottom and sidewalls, with trench-wall interface, is a significant factor.

3. Hydraulic Head

Laak and Healy (1975) noted that "different hydraulic heads had been used in the cases reviewed by Healy, and Jones and Taylor, and showed that the long-term acceptance rate depended on the hydraulic head. These tests indicated that going from a few inches to several feet could double the long-term acceptance rate. . . ." There are indications that, with a proper rate of application to suitable soils, there is a long-term acceptance rate at which a seepage field may operate almost indefinitely. The soil acceptance appears to be increased when a hydraulic head (one foot—30 cm—as a minimum) is available to help push the liquid through the zone of reduced permeability at the soil interface.

This factor adds support for allowing reduced trench lengths for pressurized, pumped effluent systems. It also provides justification for authorizing smaller perforated distribution lines for pressurized distribution lines. However, care must be taken to avoid excessive pressures that cause wastewater to issue from the surface of the ground. In other words, it is desirable to design pressurized discharge systems so the total discharge head will not cause the wastewater to surface if the discharge rate exceeds the acceptance capacity. (Based on San Diego County experience with pressurized systems discharging directly into soils with poor permeability and observations in Santa Barbara County, California, where excessive pressures caused wastewater to surface on an evapotranspiration bed.)

4. Design to Maximize Evapotranspiration Effects

Where maximum use is to be made of upward passage of the liquid to the soil surface and roots, shallow trenches have merit. For sloping land, drop-box systems (advocated in William Mellen's films and the Lake County, Illinois, publication) enable keeping all lines at minimum depth for maximizing evapotranspiration and other beneficial effects. In such cases it is likely that maximum trench length and minimum depths are requisite to success.

5. Trench Width and Seepage Beds

Trench width is commonly limited to a minimum of 18 inches and a maximum of 36 inches. Both limits are difficult to justify. Probably 18 inches is the minimum *convenient* width in terms of digging and laying the lines. There is a practical limit to maximum trench width in terms of getting reasonably equal distribution over the entire trench bottom.

For those who favor giving the greatest consideration to side wall area, the minimum bottom width would be most economical and there would be little advantage in more than the minimum width for efficiency of construction.

Those who officially utilize bottom width to calculate total trench size but who also recognize side wall area as an important adjunct would have justification for limiting trench width so the ratio of side wall area to bottom area is significant.

Officials who accept seepage beds with the same bottom area as trenches would have no justification for limiting trench width, as long as the trench or bed is level and distribution pipes are properly placed.

A number of codes, including the Uniform Plumbing Code (1976), required a 50% increase in bottom area for beds, over that required for trenches. This appears to be justified by the very low side wall to bottom area of beds and possibly also to allow for the smaller gross surface area for evapotranspiration action with a bed compared to a trench system.

6. Trench Design and Specifications

a. Gravity Discharge:

In planning trenches, consideration is first given to deciding whether the discharge will be by gravity flow from the pre-treatment tank to the subsurface disposal system. Gravity flow systems have the advantages of avoiding mechanical and electrical components, power costs and additional maintenance. For conventional systems in permeable soils the gravity flow systems will continue to be the most common. The basic requirements of the MSTP should normally be followed, except as follows:

Since the manner of distributing the treated liquid to obtain optimum dosage conditions is important:

(1) Special provisions should apply to "dosed" or pumped, pressurized discharges.

(2) Maximum emphasis should be placed on perforated pipe in view of the fact that this is rapidly replacing the short lengths of drain tile and because it is easier to maintain line and grade with the longer lengths of jointed pipe.

(3) Each 100 ft. line (maximum) should utilize gravity distribution with practically horizontal lines; the objective is to avoid overloading the inlet ends of lines and consequently the progressive plugging of the soil. This length limitation would not apply to pressurized or specially dosed discharges, nor to special systems such as certain drop box and other designs found to function best with one continuous line.

(4) Consideration should be given to reducing the minimum depth of earth cover from 12 inches to 6 or 8 inches to allow maximizing evapotranspiration effects.

(5) The 18 inch preferred depth of cover had little justification, except under special circumstances. So this factor should be considered only under special local conditions.

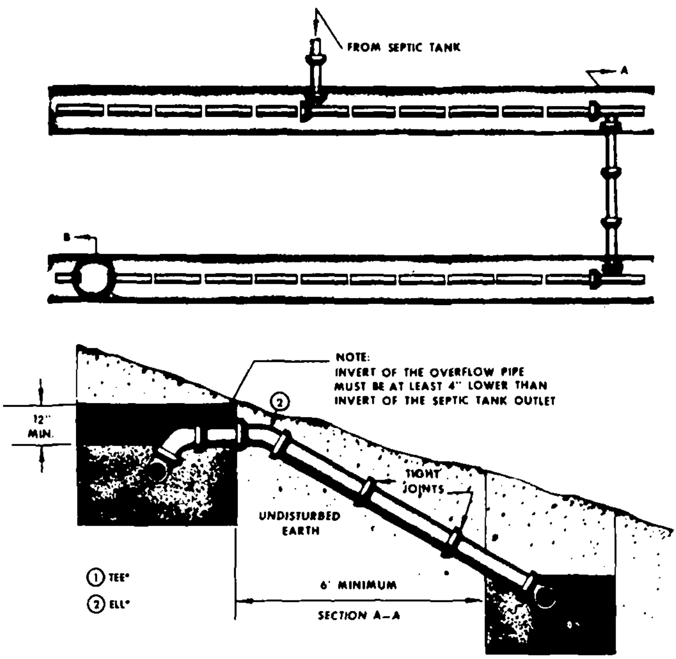


Figure 10.

SERIAL DISTRIBUTION DETAIL

Reprinted from the U.S. Public Health Service's Manual of Septic Tank Practice.

(6) The minimum grade of lines of 3 inches per 100 feet is not recommended as a firm requirement. Many experienced authorities favor level lines, even for gravity discharge.

(7) Minimum depth of filter material under and over drain lines should be modified for special systems so that pressurized systems may discharge directly into porous soil materials, as into the sand of mounds and evapotranspiration systems, and directly into porous soils in which such direct discharge has been demonstrated to provide long-term acceptance.

C. Conventional Seepage Beds

Jurisdictions which place maximum emphasis on trench sidewall areas would not normally accept conventional seepage beds. However, in permeable sand and sandy loam soils, beds have functioned well in many areas, so it is proposed that this Manual include guidelines for jurisdictions which accept them.

The MSTP says, "Studies sponsored by the Federal Housing Administration have demonstrated that the seepage bed is a satisfactory device for the disposing of effluent in soils that are acceptable for soil absorption systems. The studies have further demonstrated that the empirical relationship between the percolation test and bottom area required for trenches is applicable to beds." It is further noted that beds allow for conserving space and efficient use of earth moving equipment.

William Mellen observes that, the research cited in the MSTP (on seepage beds) was all done in sandy or sandy loam soils in which there is definitely downward movement, which is not affected by underlying impervious layers or a high water table.

"Management of Small Waste Flows" (1978) says, "Though beds often are more attractive than trenches because total land requirements, cost, and time of construction are less, trenches are more desirable in terms of maintaining the infiltrative and percolation capacity of the soil. This is particularly true in soils with significant clay content (over 25% by weight).

These observations tend to support the common recommendation of codes (Uniform Plumbing Code (1976), MSTP, etc.) that the bottom area of beds be greater than for trenches.

1. Bed Size

   The concept of requiring a 50% larger bed area than trench bottom area would be consistent with making certain allowances for trench side wall area and is considered sound.

2. Other Design Factors

   a. Grade of Bed and Lines:

      The bed and drain lines should be approximately level. This is consistent with requiring some slope for lines in trenches because lines in beds are normally considerably shorter than trenches.

   b. Depth of Gravel:

      The MSTP requirement of a total of 12 inches of gravel for a conventional bed, with 6 inches below the distributing pipe appears to be reasonable.

   c. Depth of Bed:

      The MSTP requirement of minimum 24 inches depth of bed to provide a 12 inch earth cover could be reduced to an 18 or 20 inch deep bed and 6 to 8 inch deep cover, to be consistent with the recommendations for depth of trench cover.

   d. Spacing of Distribution Lines:

      Spacing for distribution lines in seepage beds to be no more than 6 feet apart and 3 feet from the bed's side walls is good practice.

   e. Special Construction Precautions:

      Since it is convenient to excavate and fill beds by use of tractors, there is temptation to drive over the bed bottom. This can cause severe compaction and loss of permeability. Beds should not normally be constructed in rainy weather because of the effects of rain and ponding on the permeability of some soils (also somewhat true of trench construction).

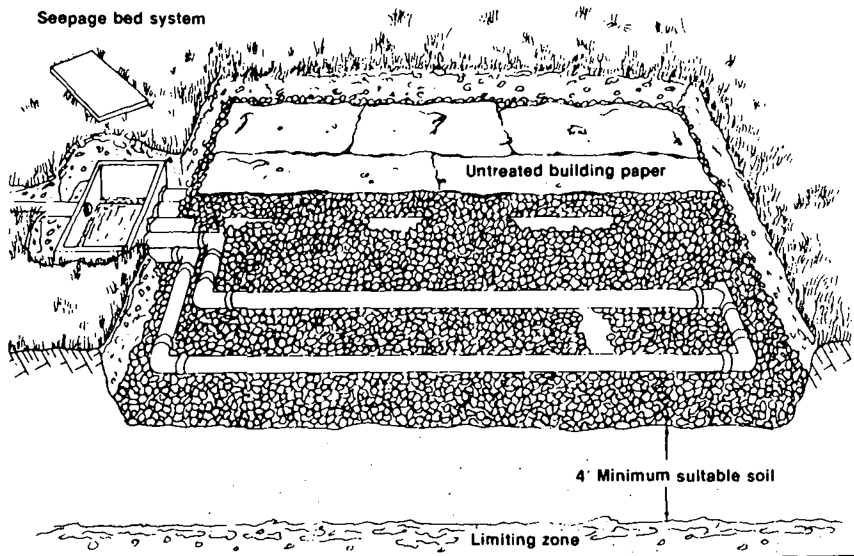
D. Distribution to Several Lines or System Elements

In conventional systems which consist of several separate elements such as trenches or seepage pits, the objective is to provide flow distribution so that each unit simultaneously receives a quantity proportional to its ratio of the total system design capacity. While distribution boxes, when properly designed and maintained, tend to accomplish this purpose, under certain circumstances, other means of accomplishing such equalized distribution, such as special "Y," control valves and alternate methods should be authorized, when they are of proper hydraulic design and accomplish the intended purpose.

Serial distribution on sloping land, with drop boxes or other arrangements which are properly designed and located, has been found to be successful in many installations. Sewage electro-osmosis systems appear to work best with serial distribution, as is true of some pressurized distribution sytems.

Figure 11

SEEPAGE BED SYSTEM



A seepage bed makes more efficient use of the space available for effluent disposal on a small lot

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E. Seepage Pits

It is recognized that some codes and regulations prohibit installation of new seepage pit systems. However, other jurisdictions have found that seepage pits provide satisfactory long-term service under the following conditions:

1. The seepage pit should be limited to soil with a percolation rate of 30 minutes per inch or less, or equivalent morphological soils.
2. The pit bottom should terminate at least 5 feet above anticipated high groundwater level.
3. Special study is recommended when considering pits penetrating different pervious strata separated by relatively impervious strata, to assure that such layers will afford adequate lateral flow. (Some cite advantages to serial arrangement.)
4. Where two or more pits are provided, they should be connnected in parallel and be fed by a distribution system which equalizes the flow.

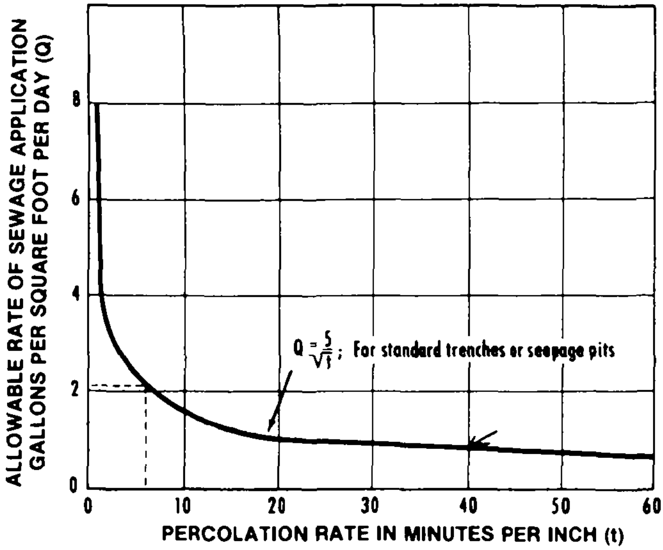
5. Where percolation test charts are used for sizing, only the side wall area below the inlet should be counted.
6. Other type sizing methods should be allowed, such as soil evaluation and measuring the amount of water accepted by holes of various sizes and depths, in a given time, or by measuring the rate of drop in water levels in such holes.
7. Multiple seepage pits should be spaced so as to avoid interference with functioning of other pits in the system.
8. Precautions should be taken to avoid placing pits close to banks or steep slopes and retaining walls. This is especially critical when the pits are underlain by an impervious layer or formation which would tend to cause surfacing of septic effluent.
9. While not totally accepted, some believe there should be a limit to pit depth.
10. Some guides (MSTP) advocate placing a layer of gravel between the pit liner and the surrounding soil. This is difficult to accomplish and unnecessary in caving sand and gravel soils and may not be necessary with soils having a percolation rate of less than 15 or 30 minutes per inch.

F. Establishing Size of Conventional Seepage Systems

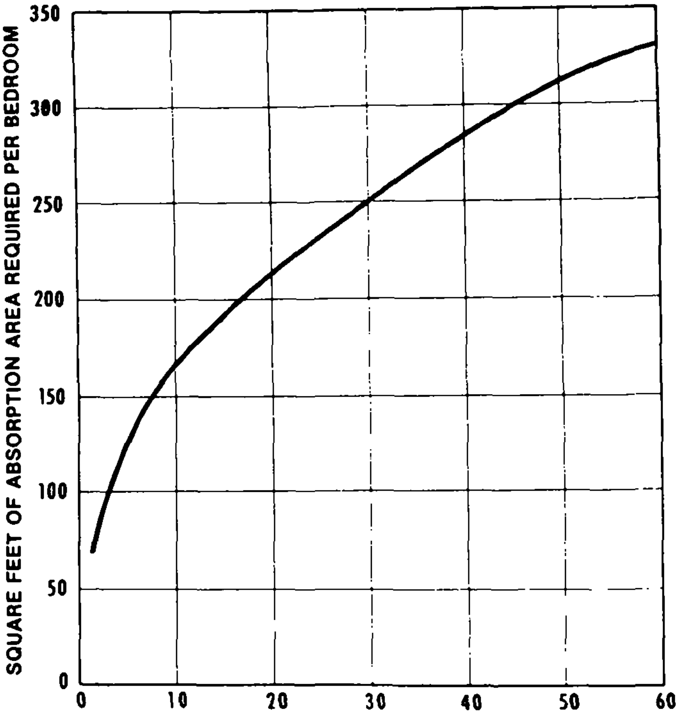
As stated, the size of seepage systems should be determined by study and evaluation of all potentially pertinent factors, including but not limited to total soil examinaiton and evaluation and permeability tests (most commonly the standard percolation test). Because the latter is most widely recognized, it will be used as a basis of comparison with other tests. The following charts, shown as Figures 3 and 19 in the MSTP, are suggested for situations where the percolation test is selected. However, where local experience has shown that other values should be used, these charts should not take precedence. For instance, in certain clay or shale type soils, the long-term acceptance rate may continually decrease. On the other hand, certain decomposed granite soils rapidly improve in permeability as they become well moistened.

G. Limitations

1. No conventional system should normally be installed where the percolation time is more than 60 minutes per inch and no seepage pit should normally be used if the time exceeds 30 minutes per inch except where experience shows that higher percolation times provide long-term acceptance.
2. Where other evidence, such as past unfavorable experience under similar conditions, indicates that a system meeting the conventional seepage test sizing criteria will not provide long-term service, alternative systems or system design may be required, or the site should not be approved.



Graph showing relation between percolation rate and allowable rate at sewage application.



Absorption area requirements for private residence

Figure 12

Reprinted from the U.S. Public Health Service's Manual of Septic Tank Practice.

Chapter 10

ALTERNATIVE SUB-SURFACE EFFLUENT DISPOSAL OR UTILIZATION SYSTEMS

Various alternative systems have been devised to enable use of premises where conventional systems are not authorized. Among those are the mounds systems, evapotranspiration, and electro-osmosis.

A. Mounds

Following the pioneering work in North Dakota in developing the "Nodak" mounds systems, much work and several thousands of installations were completed in Pennsylvania. The University of Wisconsin is doing much research on mounds, and a hundred or more mounds systems have been built in that state. Because of the fact that "mound" is, in fact, above grade, the tank effluent must normally be pumped.

1. Pennsylvania's Elevated Sand Mound

The Pennsylvania State University's "Alternate Methods of Effluent Disposal for On-Lot Home Sewage Systems" describes and illustrates methods of installing elevated sand mounds with either seepage-bed or trench effluent distribution for installation on either a level or a sloping site above a minimum depth of 20 inches of soil for which there is no percolation test required. If there is a limiting zone, it must be at least 20 inches below the natural grade, such as "seasonal water table, creviced rock, impervious strata." The mound is built with at least a 24 inch deep sandy fill, above which the wastewater is distributed into either a trench or bed of 12 inches of aggregate into which the effluent is distributed. The whole unit is then covered with at least one foot of earth, compacted at the edges to prevent lateral flow and the top mounded to effectively shed water.

Pennsylvania's literature says: "The effective size of the mound or the absorption area covered by the sand should be calculated on the basis of 330 square feet per bedroom or 1.65 square feet per gallon of effluent per day. If an aerobic tank is used, the basis is 220 square feet per bedroom or 1.10 square feet per day."

Special site preparation is necessary, including care to avoid soil compaction by the earth moving equipment. Further special construction precautions, including use of the most suitable soil materials at the lower side, are necessary to prevent surface discharge from mounds built on land with a considerable slope.

The October, 1976, minutes of the "Ten State Committee" quote Pennsylvania's Glenn Maurer: "He indicated that several thousand mound systems have been installed in Pennsylvania over the last few years and they have had reasonable success with the systems."

One typical Pennsylvania mound is illustrated in Figure 13.

Figure 13.

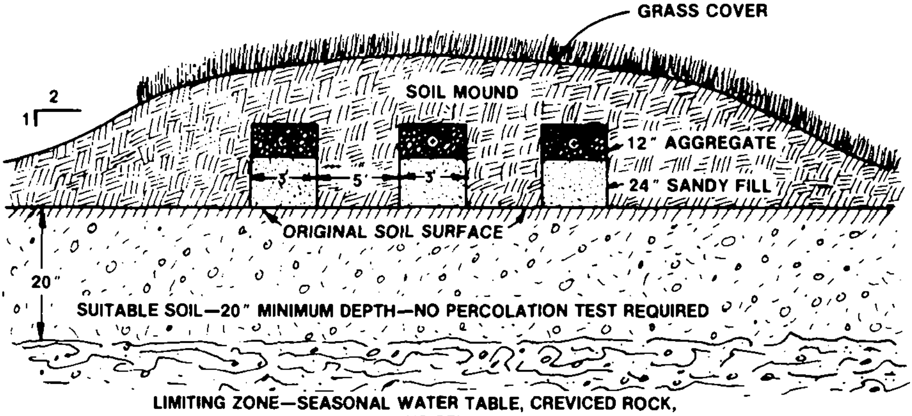
Elevated Sand Mound—Trench Distribution

Permissible Uses and Site Characteristics

1. New construction
2. Correct existing malfunctioning system
3. Limiting zone—20 inches below surface (minumum)
4. Maximum natural slope—12 percent

Non-Permissible Site Conditions

1. Flood plains (Soils group 13)
2. Poorly drained, high water table (Soils group 15)
3. Filled areas (fill in place less than 4 years)



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Committee Member Dale Krach, The Pennsylvania State University, reported a study is underway to evaluate "those (Pennsylvania) mounds presently installed." The information is not yet complete, but it is Krach's present opinion that it would be wise to emphasize the Wisconsin design as it appears to be a more viable alternative.

2. Wisconsin Mounds

The Wisconsin State Division of Health and the University of Wisconsin Small Scale Waste Management Project have cooperatively developed several alternate systems for effluent disposal, as described in the "Alternate Sewage Manual" (1975), including the mound system. Further important details on the design of mounds are provided by the publication, "Design and Construction Procedures for Mounds in Slowly Permeable Soils With or Without Seasonally High Water Tables" by James Converse, et al., (1975, Rev. 1976). The publication says, "necessary soil and site characteristics are: (1) Soil percolation rates: 60 to 120 min/in. in natural soil below 12 inches of top soil. (2) Depth of groundwater: less than 5 feet but greater than 2 feet. (3) Depth to bedrock: greater than 5 feet. (4) Slope: less than 6%. (5) Flood Plains: Construction in flood plains is not recommended."

Figure 14.

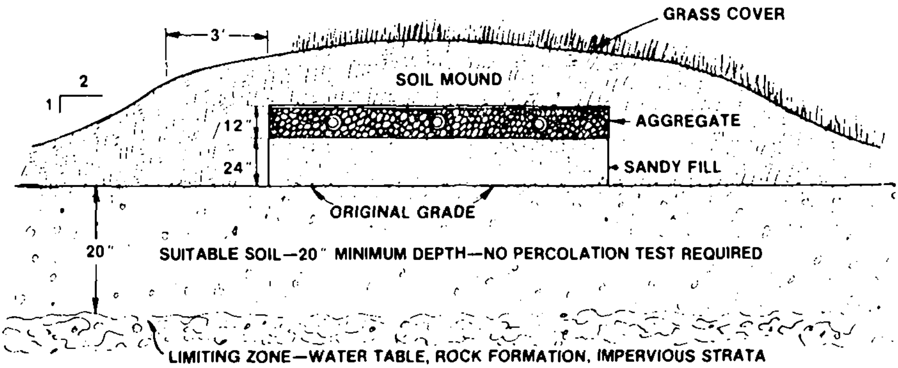
ELEVATED SAND MOUND—SEEPAGE BED DISTRIBUTION

Permissible Uses and Site Characteristics

1. New construction
2. Correct existing malfunctioning system
3. Limiting zone 20 inches below surface (minimum)
4. Maximum natural slope 8 percent

Non-Permissible Site Conditions

1. Flood plains (Soils group 13)
2. Poorly drained, high water table (Soils group 15)
3. Filled areas (fill in place less than 4 years)



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Flow rate estimates are based on 150 gallons per day per bedroom. For soils with percolation rates of 60 to 120 min/in. an infiltration rate of 0.24 gpd/ft^2 is used. The infiltration rate of liquid from gravel-filled trenches to the sand bed is calculated at 1.23 gpd/ft^2. A minimum depth of 1 foot of sand is required below the bottom of the distribution trench.

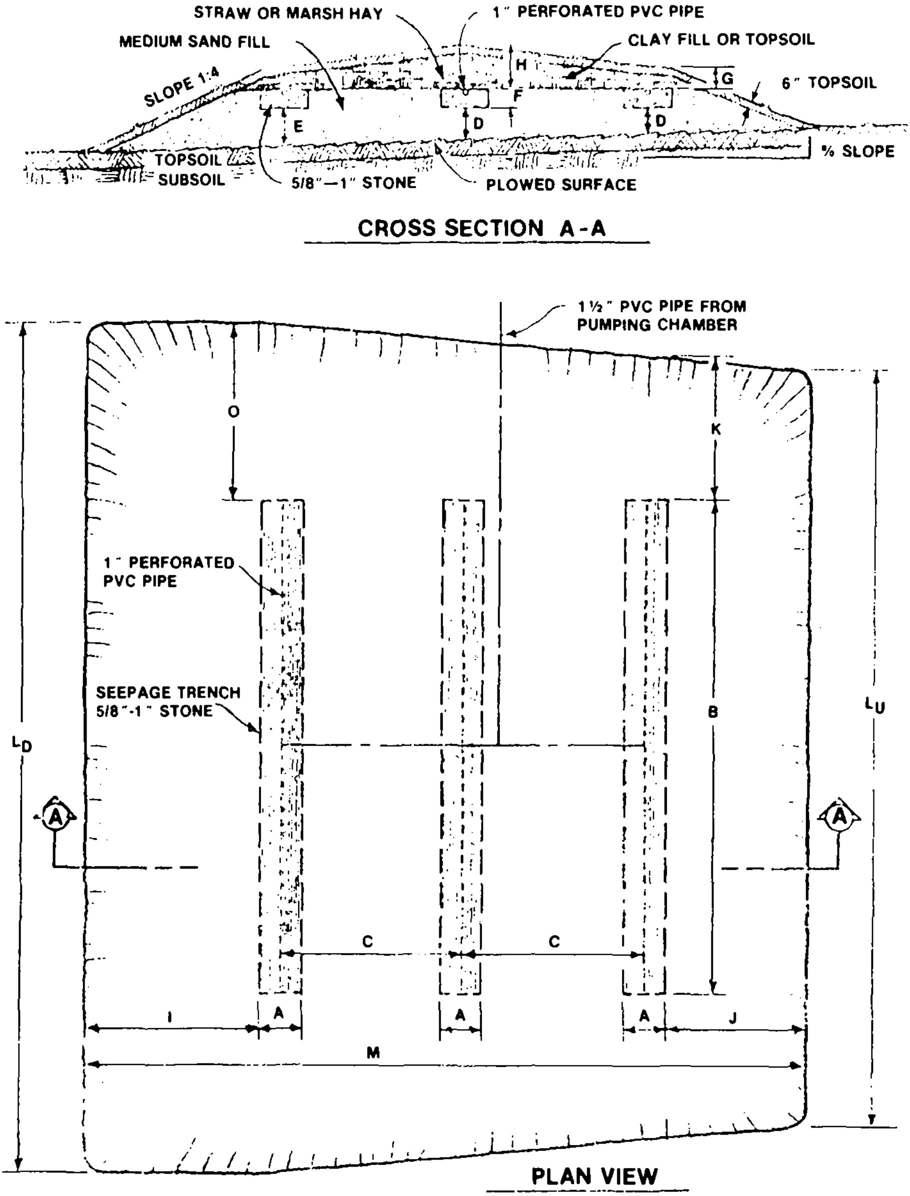
Using the above data for a 3 bedroom home, the area of sand bed would have to be at least 450 ÷ 0.24 = 1875 square feet and the minimum bottom area of distribution trenches would be 366 square feet.

The Wisconsin instructions, like those of Pennsylvania, stress proper soil surface preparation and avoidance of compaction during construction. No special allowance is made for aerobic systems. The septic tank drains to a pumping chamber of 500 gallons capacity for 1 and 2 bedroom homes and of 750 gallons for 3 and 4 bedrooms. Pump controls provide for dosing but once per day. The extra capacity of the pumping chamber is to provide storage for brief periods of power outages or pump failures. Pumps are designed for at least a 30 gallons per minute (gpm) discharge rate. PVC pipe with ¼ inch holes on the bottom is spaced 30 inches apart. Pump discharge pipe varies from 1½ to 2 inches and perforated distribution pipe is usually 1 inch.

(Note: The above are intended as basic information only. For more details, use the basic documents from which this information was taken.)

Figure 15.

A Mound System for a 3 or 4 Bedroom Home (67)
University of Wisconsin



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3. Major Differences Between Pennsylvania and Wisconsin Mounds.

Table 12

Item	Wisconsin	Pennsylvania
Limiting soil percolation rate	60-120 min/in.	May be used when soil conditions prevent use of conventional systems.
Maximum slope	6%	12%
Vertical distance to limiting zone	5′ (2′ some cases)	20 inches
Size Mound		
(sq. ft. per bedroom	150 g/d/br. and 0.24 g/d/ft² (for soil with 60-120 min/in. rate) = 625 sq. ft. per bedroom	330 ft.² per bedroom
Allowance for aerobic units	None	Reduce to 220 ft.² per bedroom
Pumping Systems	Size of "wet-well" and 30 gpm pumping rate specified	Not noted in available literature

It appears that Wisconsin's criteria are more conservative. Properly designed and built mounds provide a satisfactory alternate effluent disposal system for areas of relatively high groundwater levels or impervious strata and for soils with percolation rates up to at least 120 minutes per inch. Special attention must be paid to the degree of slope and to the design to minimize surface discharge from leaking under the down slope portion of the mound. System design includes both trenches within the mound and the mound itself. The usual precautions when selecting pumps are ease of replacement by quick-disconnect fittings, ready availability of replacements, and periodic service.

B. Artificial Beds and Cover

Pennsylvania's "Alternate Methods of Effluent Disposal" shows the following methods of providing sand-lined beds and trenches for shallow placement areas.

"The shallow placement absorption area (Figure 16.) as an alternate method of effluent disposal may be used for new homes constructed on sites where the limiting zone begins from 5 to 6 feet below the surface. This method cannot be used to correct the malfunctioning system of an existing residence. The percolation rate on the site must range between 6 and 60 minutes per inch."

The sand-lined bed or trench "may be used on sites with very well drained soils where the percolation rate is less than 6 minutes per inch or where the depth to excessively permeable rock fragments or a gravel bed is less than 4 feet below the surface."

Figure 16.

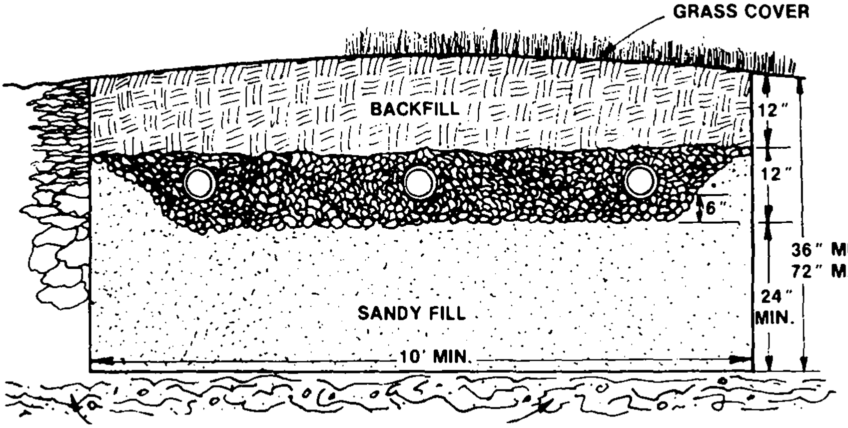
Sand-Lined Beds and Trenches

Permissible Soil Characteristics or Site Conditions

1. Sites having percolation rates less than 6 minutes per inch
2. Depth to creviced rock or gravel beds less than 4 feet

Not Permissible

1. Flood plains (Soils group 12)
2. Sites where ground water table or soil mottling appears at less than 4 feet below the bottom of aggregate



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1. Evaluation of Pennsylvania Sand Beds

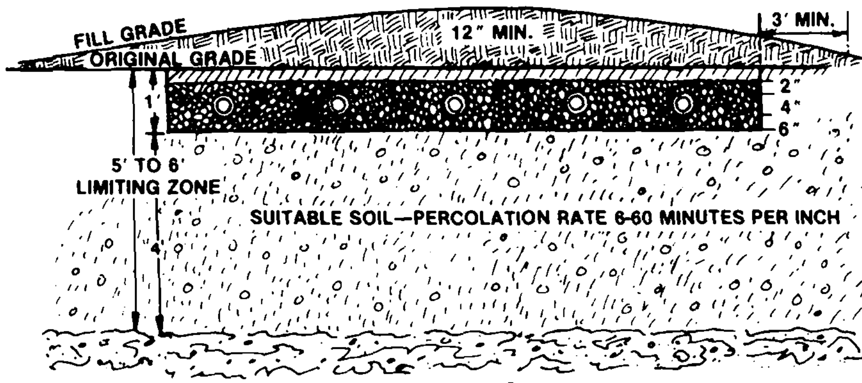
Committee Member Dale Krach also reported that Pennsylvania's artificially constructed sand beds are now being evaluated by The Pennyslvania State University and the Pennsylvania Department of Environmental Resources. In test situations, they are using various types of sand and sand-clay mixtures. Harry Steigman of Pennsylvania's Department of Environmental Resources confirmed these evaluations and reported that regular filter sands, and natural sands with an appreciable percentage of fines, have given indications of good microbiological results. Krach said that one study, utilizing different sands and sand-clay mixtures—has shown the fecal coliform and fecal strep organisms are greatly reduced after passing through sand and their numbers are further reduced in the soil.

Figure 17.

Shallow Placement Area

Permissible Site and Soil Conditions

1. May be used where limiting zone is between 5 and 6 feet below the natural surface
2. Percolation rate must range between 6 and 60 minutes per inch
3. Site must have at least 4 feet of suitable soil between bottom of aggregate and top of limiting zone
4. Aerobic tank required—septic tank not permitted



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C. Subsurface Sand Filters

At NSF's 1978 Annual Conference on Individual On-Site Wastewater Systems, David E. Barry of Erie County, New York, included subsurface sand filters in his report on successful on-site systems in his county.

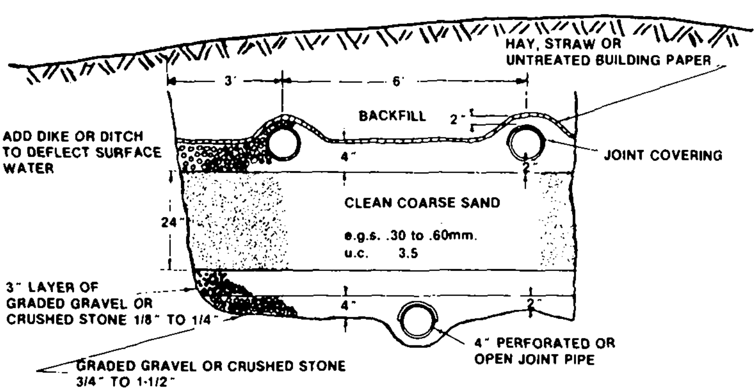

Figure 18.

NOTE

A normal application rate for subsurface sand filters is 1.15 GPD/FT².

A representative 2-pound sample of sand which is to be used in the filter must be submitted for approval prior to construction. The sand must be clean and coarse; all passing a ¼-inch sieve. The effective grain size should be between 0.3mm and 0.6mm and the uniformity coefficient should be 3.5 or less.

For installations having an area of 1,800 sq. ft. or more, or with 300 feet of distributors or more, a dosing syphon or pump is required.

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A Wisconsin suggested design is shown in Figure 19.

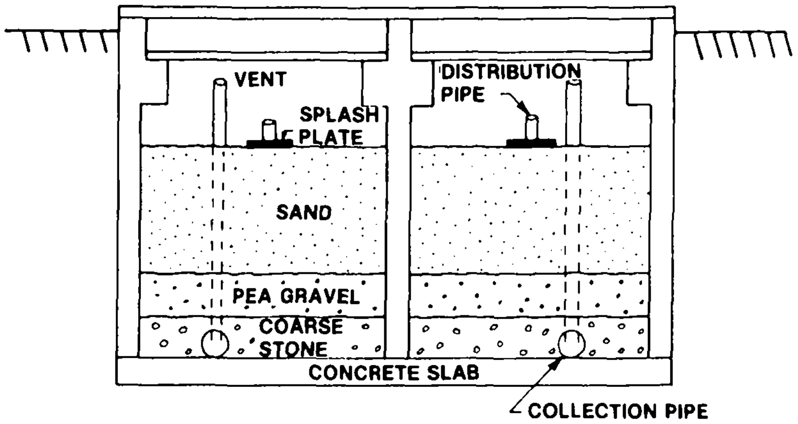

Figure 19.

Profile of Intermittent Sand Filter

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Wisconsin's studies have produced the following results with proper design and application rates with their intermittent sand filter.

Table 13.

Septic Tank-Sand Filter Effluent Quality Data

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	Septic Tank effluent	Sand Filter effluent	Chlorinated effluent
BOD (mg/l)	123	9	3
TSS (mg/l)	48	6	6
Total Nitrogen -N (mg/l)	23.9	24.5	19.9
Ammonia -N (mg/l)	19.2	1.0	1.6
Nitrate -N (mg/l)	0.3	20.0	18.9
Total Phosphorus -P (mg/l)	10.2	9.0	8.4
Orthophosphate -P (mg/l)	8.7	7.0	7.9
Fecal coliforms (#/100 ml)	5.9×10^5	6.5×10^3	2
Total coliforms (#/100 ml)	9.0×10^5	1.3×10^3	3

Note: Loading rate average: 5 gal/day/sq ft (0.2 m/day).
Effective size—0.45 mm; uniformity coefficient—3.0.

D. Evapotranspiration Systems

1. Objectives

Design to maximize evapotranspiration is desirable where soil porosity is marginal and where irrigation of lawns and selected vegetation can be accomplished with resulting water conservation.

Total evapotranspiration is a desirable concept where groundwater levels and impervious soil strata preclude conventional systems or where it is desired to prevent either microbiological or chemical contamination of ground or surface waters.

2. Experience with Systems

The literature includes a number of reports detailing problems and shortcomings of evapotranspiration systems and a few which tell of success.

Evapotranspiration systems must be designed to maximize the inherent concepts of evaporation and transpiration and minimize entrance of precipitation into the system. The system tends to fail when there is not enough volume provided to store the liquid which accumulates during periods when the total amount of wastewater and precipitation entering the system exceeds the loss from evapotranspiration. Some concern has been expressed regarding the anticipated build-up of salts from continuous evaporation of the liquid in a semiclosed system, but the significance of this problem has not been documented.

3. Basic Concepts

As with most on-site systems, the evapotranspiration system consists of a pretreatment unit which may be built as part of the liquid disposal unit or may be a separate unit. It may be an aerobic unit or a septic tank. The unit may be provided with a means of adding heat to help provide the energy needed for evaporation.

Even strong supporters of evapotranspiration, like Dr. Alfred P. Beinhard, do not favor creating a fully closed system unless particularly necessary. They advocate utilizing percolation plus evapotranspiration. (Figure 20.)

With a 100% evapotranspiration system, the unit is placed in an impervious lining, usually strong, nondegradable waterproof PVC plastic or equivalent, so all liquid must be disposed of and utilized by a combination of evaporation and transpiration. Dr. Harry Pence told the NEHA Annual Educational Conference in 1977 and 1978 of the importance of selecting material which will remain permanently watertight. He also expressed the concern of some investigators who feared penetration by burrowing animals.

The top of the bed is somewhat mounded or sloped so as to shed precipitation and thereby minimize the amount which seeps into the system.

There is usually built into the system a large volume of rock, coarse sand or equivalent coarse media to store the wastewater effluent until it can be dissipated through the plant roots and soil cover. If rocks are used, the rock bed must be rather shallow, or there must be wicks of finer capillary material extending from the bottom through the rock-filled space and into the sand and soil above, because otherwise the rock bed would simply be a dead storage space. The volume of the voids in the rock and sand actually constitutes the storage volume from which the wastewater can reach the upper soil. This must be sufficient to provide storage for the longest anticipated periods during which the inflow to the system from precipitation, melting snow, etc. approaches or exceeds the amount of moisture lost by evapotranspiration.

Some authorities advocate basing system design on "pan evaporation rates." These are the seasonally determined rates utilizing open pans so placed as to permit measurement of the difference between the depth of water accumulated from precipitation and the amount lost by evaporation. That criterion is "severe" in that proper slopes and cover material maximize surface run-off and minimize infiltration. The figure is commonly given in inches of water depth per year. However, it is usually more important to have data showing the excess accumulation from precipitation, over the amount lost by evaporation, during the months most unfavorable for loss by evaporation. There are also problem periods when some systems are covered by snow or are otherwise prevented from dissipating significant volumes of wastewater. Some plants are dormant during some seasons in some areas. Since much heat energy is required for evaporation, long cold seasons reduce the effectiveness of the concept.

A concept proposed by Dr. Pence, to cover unfavorable seasons, is to have rather large volume liquid storage tanks which accept the liquid during periods of low liquid loss and from which the liquid is pumped to the system when the evapotranspiration rate exceeds the inflow.

Tanner and J. Bouma (1977) discuss the "Influence of Climate on Sub-surface Disposal of Sewage Effluent" in a mimeographed paper from the University of Wisconsin's College of Agriculture and Life Sciences. They say, "Even in arid regions the net ET cannot be relied upon for disposal in cold, low radiation months. Therefore, sound design for disposal by drainage through the soil is mandatory." (There are several reports of successful ET systems in the areas of subfreezing seasons and appreciable precipitation indicating this statement is somewhat extreme.) Tanner and Bouma also note that "grass, flowers and deciduous shrubs that become dormant in the winter do not transpire." They say that in the absence of snow, this dormant vegetation shields the surface from radiation and advected heat and decreases transpiration.

Figure 20 is intended to show the concept of evapotranspiration (Bennett, 1975).

Additional suggested features are:

a. Top surface sloped to maximize runoff.
b. Gravel and sand bed large enough to provide large storage volume.
c. ET soil (or a wick of such material) is sand that will provide interstices for storage but has small enough grains to promote capillary action.
d. Some show a pipe extending vertically to a T connection with a perforated pipe at the bottom. (To measure water depth and for pumping, if necessary, to remove salts or surplus water.)

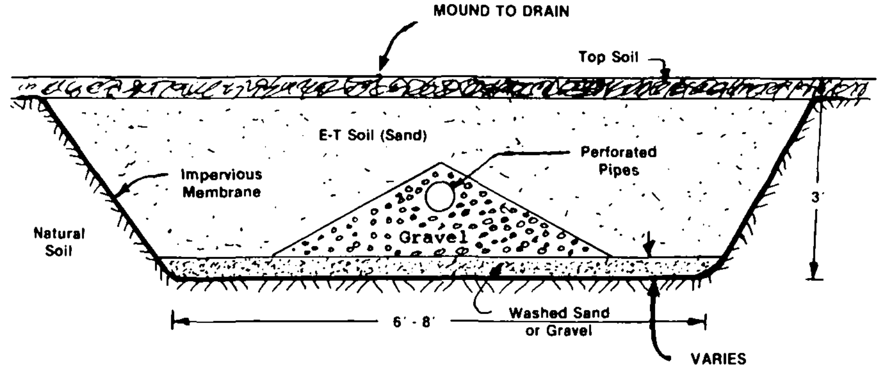

Figure 20.

Principles or Evapo-Transpiration

Most E-T systems have distribution pipes which discharge to a sand bed, to stabilize liquids which flow to beds of rock. They are covered by selected top-soil and vegetation.

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4. Field Studies

An unpublished paper, "The Applicability of Evapotranspiraton Systems for On-Site Wastewater Disposal in Idaho" (1975) by A. T. Wallace and Gary L. Trum of the Civil Engineering Department of the University of Idaho gives encouragement to those who favor evapotranspiraton. "Five evapotranspiration or combined evapotranspiration-infiltration systems were monitored in Idaho to determine their loading rates and performance." System design is usually based on the rate in gallons per day per square foot of bed, which can be discharged to a system.

They found systems were designed for evapotranspiration rates of 0.1 to 0.3 gallons per square foot which they noted were in the range of 0.12 $g/ft^2/d$ reported by Bernhardt for Southern Ontario, Canada, and his recommendation of 0.2 $g/ft^2/d$ for the Northern United States. They also noted 0.12 $g/ft^2/d$ allowed in Montana. From their own observations they determined ".... that evapotranspiration rates of at least 0.1 gallons per square foot per day and possibly as high as 0.3....are reasonable expectations for a properly constructed and maintained, lined evapotranspiration system." They stated that, "A loading rate of 0.2 $g/ft^2/d$ would require an ET system with 1500 square feet of surface area for a daily wastewater application rate of 300 gallons....

"In a system with a 1500 square foot surface area with a steady state water level of 18 inches below the system surface and a daily wastewater application of 300 gallons, the storage within the system ranges from 20 days for periods of zero transpiration to 50 days for periods of 0.1 gallon per square foot per day evapotranspiration, assuming the sytem materials contained 40% interstices."

They said, "If wastewater infiltration is not a potential hazard, the system may be left unlined and wastewater will be disposed of through a combination of infiltration-percolation and evapotranspiration."

Their system was shown as distributing the liquid through pipes near the top of a one foot layer of coarse sand. Below the sand was a 1 foot layer of pea gravel, over a 1 foot layer of 1 to 1½ inch rock. (Some authorities state capillary action will raise water as much as 2 feet in pea gravel.) The whole is sloped and covered with 6 inches or less of sandy loam top soil. In the center is a 6 inch or larger perforated pipe which serves as a vent—liquid measuring device— and an opening for pumping out the system, if necessary. The authors say, "there may be periods where the available system storage has been depleted due to temporary hydraulic overloading or prolonged periods of low evapotranspiration. At such times, the system may require pumping to prevent system overloading and the resulting seepage or ponding."

In his presentation at the NEHA Conference in 1978, Dr. Pence said the liquid in the storage space, even from a septic tank, has relatively low BOD, coliform concentrations, and close to 50% saturation with dissolved oxygen.

One contractor said he has had good success with sealed beds in a region of 40 inch annual rainfall and some winter snow. His two admonitions were:

a. To provide sand wicks which extend through the rock, to the bottom, in order to enable nearly complete emptying of the rock-filled area.

b. To carefully select a good top soil for surface cover to maximize evapotranspiration.

Other authorities stress choosing the appropriate type grass and vegetation to promote transpiration.

Field observations by the California State Department of Health, in Santa Barbara County, noted seepage through faulty walls of a system built of concrete block. Other observations were that the liquid distribution pipes were too shallow, that the velocity of the pumped waste discharge had uncovered some pipes, that the bed surface was, in one case, being used for growing strawberries and lettuce. The overall observation was that there must be better design and supervision of such systems. However, the Santa Barbara case is more an admonition for careful design that it is a condemnation of evapotranspiration systems.

Minutes of the Ten State Committee and reports from several states, including Washington and Colorado, indicate mixed success and a wait-and-see attitude before granting unqualified approval. Most are continuing observations to determine circumstances under which the system may be authorized.

The system should be used in regions where the climate is equivalent to that where such a system has proven successful.

Where the primary purpose of the closed bed is to minimize the possibility of chemical or microbiological contamination of ground water, it is possible to provide a moderately sized conventional seepage system into which the liquid would flow for disposal during periods unfavorable for evapotranspiration. This would then materially reduce the quantity of wastewater which would flow to the groundwater.

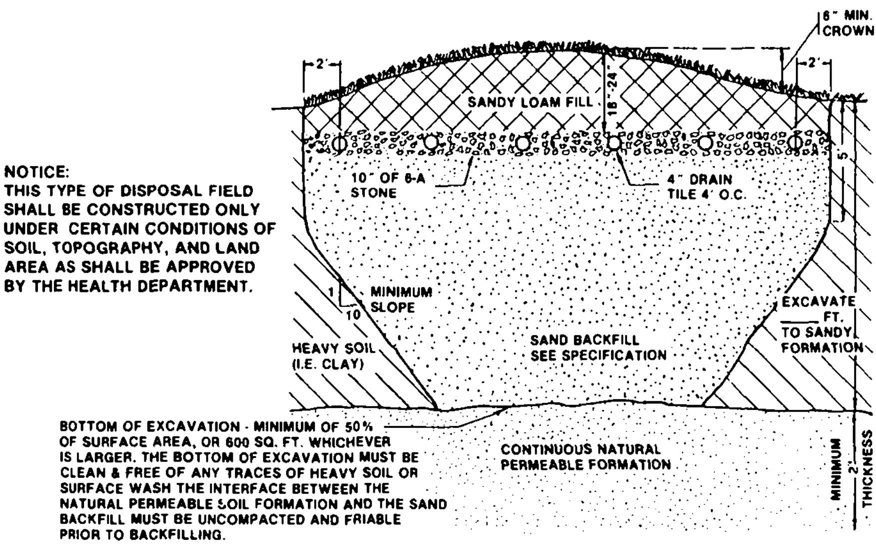
E. Deep Excavations

Where relatively shallow layers of impervious material overlay a permeable formation, it is often desirable to replace such material with sandy material. The design is intended to provide opportunity for the liquid to enter the permeable formation without creating special contamination hazards of aquifers. This concept is illustrated in the following Washtenaw County (Michigan) illustration: (Figure 21).

Figure 21.

CROSS SECTION

DEEP EXCAVATION DISPOSAL FIELD



Reprinted by permission from the Washtenaw County Health Department, Michigan.

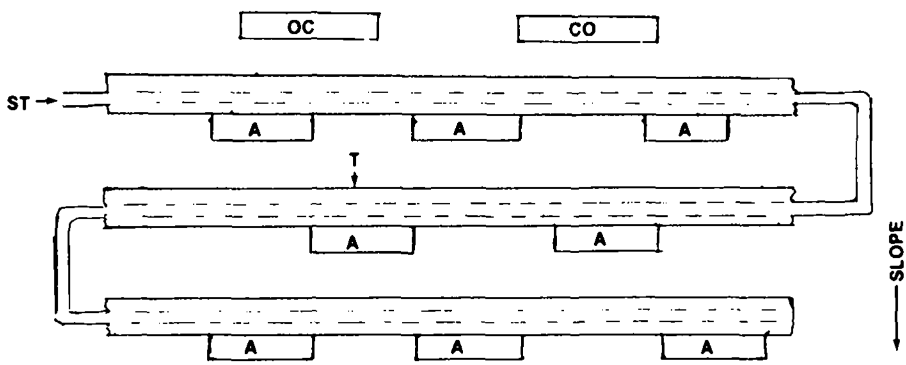
F. **Sewage Electro-Osmosis Systems** (Figure 22)

1. Definition and Explanation of Phenomenon

The *International Dictionary of Physics and Electronics* says: "Electro-osmosis: The movement of liquid with respect to a fixed solid (e.g. a porous diaphram or a capillary tube) as a result of an applied electrical charge."

A translation from Russian, in the "Illinois Geological Bulletin," gives a somewhat complex explanation of negative and positive charge on soil particles and the surrounding layers of tightly bound water, surrounded by free water. Upon application of an electrical potential to certain wet clay soils, "ions of different signs move in opposite directions. The moving stream of ions draws after it in the pores and capillaries the residual mass of free water." The article also said that, "besides electro-osmosis, direct current also produces hydrolysis of water and other physio-chemical processes in clayey soils. Gaseous hydrogen (H_2) is evolved at the cathode. . . . At the anode, oxygen (O_2) is evolved by the hydrolysis. The physio-chemical processes cause changes in the physical-mechanical properties of the soil, which are permanent if the current is applied for a long enough time." (The process has been widely used to stabilize soil, and the Russian article described how the process facilitated pile-driving.)

Figure 22.



PLAN VIEW
ELECTRO-OSMOSIS

T - Standard Leaching Trench
A - Rock Filled Anode
C - Carbon Filled Cathode
S.T. - From Septic Tank

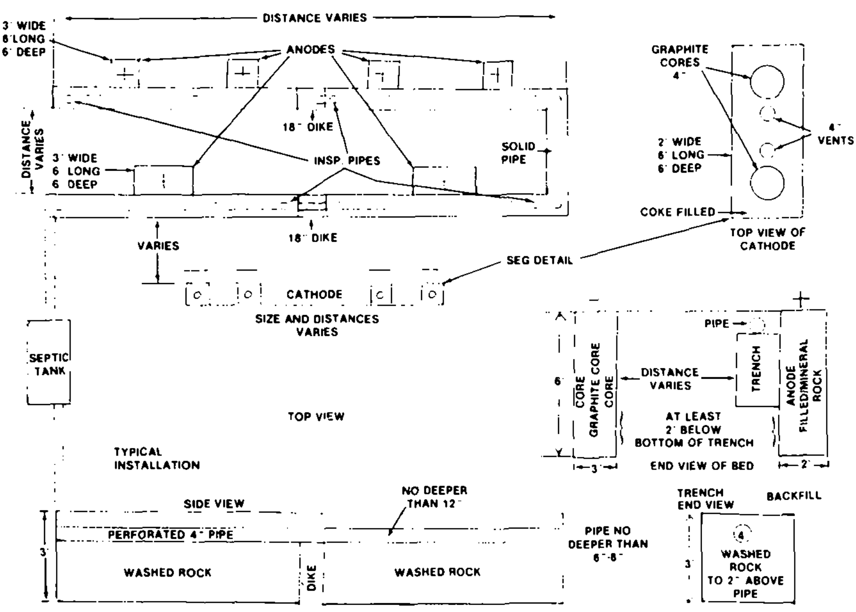
2. The Process Applied to Sub-surface Systems

The process has been successfully used in over 200 installations, principally in the Midwest and Wyoming, with a number of systems in California and elsewhere.

The effluent distribution line is usually laid in the same type gravel filled trench as is used for seepage trenches, as close to the ground surface as is acceptable. At various points along the line, and on its down-slope side, are built 5 or 6 foot deep short trench cells filled with a selected mineralized rock. These are the anodes. On the up-slope side of the disposal trenches are 6 foot deep, short trenches filled with coke and having graphite-filled cells, which are the cathodes. Repeated tests have shown that, when propertly oriented and installed, the cells produce an electrical potential of 0.7 to 1.3 volts across the disposal field. A significant current and a marked reduction in electrical resistance also results. The system causes the positively charged water which surrounds fine soil particles to be repelled by the anodes and be attached to the cathodes. This causes the wastewater in the trench to flow from the anodes (next to the seepage trench) and toward the cathodes. It tends to dissipate by downward seepage and by evapotranspiration.

For observation purposes, systems have vertical pipes built into the cathode, and in the disposal trench, to enable observing and measuring water depths.

Figure 23.



Reprinted by permission from Frank B. Coolbroth, President, On-Site Systems, Inc., Plymouth, Minn.

3. Field Experience

Practically all of the electro-osmosis systems have functioned successfully; some were built to replace conventional systems which had failed. Many were built at new homes where soil classification and percolation test results were not acceptable for conventional systems. Recent tests in Southern California demonstrated the systems do not achieve acceptable results in certain very dense clays, but they dramatically improved the percolation rate from 240 to 13 minutes per inch in a mixture of clay and fine sand.

4. Electro-osmosis System Design

Electro-osmosis systems function satisfactorily with septic tanks and gravity discharge to the seepage trenches.

Systems are installed by licensees who follow basic prescribed methodologies, including the usual tests to assure adequate separation from groundwater and impermeable rock or similar formations. Probes are used to measure the soil electrical restivity, voltage and current. In some areas of relatively uniform soil, the systems are installed without trial installation of cells. However, where necessary, special tests include installation of modules of anodes and cathodes to determine their effect on percolation rates and electrical characteristics of the soil.

In some cases, modules of the whole trench and electro-osmosis system are dosed for weeks by a metered supply of water to establish the relatively long-term liquid acceptance rate of the soil.

For larger systems, as at a California school and an industrial site, systems are designed with valving arrangements which enable separately and alternately using various sections of the system.

5. Limitations

   a. The system is not intended for sites where the seepage trenches would penetrate the groundwater.
   b. When installed on moderate slopes, the anodes are on the down-slope side of trenches and cathodes on the up-slope side to cause water to move up the slope.
   c. Because of the dependence of the system's performance on complicated soil—particle, groundwater and electrical phenomena—adequate tests are required to determine that the method will be effective in soils of types in which such test systems have not already been proven to be suitable for the process.

G. Pressurized Distribution Directly into Soil

There are a considerable number of demonstration installations at homes in California (and possibly elsewhere) where the effluent from a special type aerobic treatment unit is discharged directly into the soil through 1 inch, serially laid, shallow plastic distribution pipes. It appears that with an aerobic effluent which is low in suspended solids, certain permeable soils directly, without gravel beds, accept the pressurized discharge (based on up to two years of observation). The system maximizes evapotranspiration effects and is useful for lawn and similar subsurface irrigation. Two such systems are functioning well in decomposed granite in Riverside County, California. However, this type system illustrates the need for careful review of innovative proposals. Discussion with San Diego County's Environmental Director and review of a partial and incomplete field study of some 15 units, revealed several problems. Installations by home-owners or others who did not have proper experience and equipment, as well as faulty design, resulted in excessive flow rates and pressures in the one inch perforated subsurface distribution pipe. Also, attempts to distribute waste water directly in clay soils which could not absorb water at the required rate, caused the water to surface.

H. Advantages of Aerobic Treatment

The Garrett County, Maryland, experience indicates that in some soils in which conventional systems failed, properly installed and operated aerobic treatment systems result in long-term acceptance of the effluent.

The demonstration installations of many aerobic, on-site systems by the Appalachian Regional Commission indicated there are a number of advantages to properly maintained, on-site, aerobic units where discharge to surface waters is necessary or where surface discharge of septic tank effluent creates nuisance conditions.

In considering the experience with operation of on-site aerobic systems, the results are normally viewed in comparison with optimum results. The results should, in all fairness, be compared with other types of systems, ranging from conventional septic tank systems to public, centralized plants.

The failure rate of septic tank systems due to unsuitable soils or lack of maintenance is well documented. Poor operating results with small community systems are common. Keath Dearth of the U.S. Environmental Protection Agency told the NEHA Annual Conference in 1978, "If we are to have waste treatment in these communiites (small communities which cannot afford the cost of properly maintaining public sewerage systems) it must be with alternative systems, and the rules must change to accomodate them. I would note in this regard that centralized treatment systems were never a panacea so far as correcting problems goes. For years now less than half of the municipal treatment plants in the country have been properly operated."

I. Disadvantages of Aerobic Systems

Among the factors which affect the choice between aerobic and septic systems are the higher original and annual operating costs of aerobic systems; the energy consumption for aeration; the necessity for having available and securing maintenance service for both mechanical and electrical components; the removal of excessive sludge if and when it becomes necessary; the availability of spare parts in cases where components are manufactured specifically for one make of unit. The problems of securing adequate, periodic maintenance will become much less serious if the practice of establishing maintenance programs by public entities becomes more common.

J. Summary on Mounds, Evapotranspiration and Aerobic Systems

Favorable experience has shown that properly designed and located mounds systems will function satisfactorily in soils and at locations where conventional systems are not acceptable. The mounds tend to modify the yard topogrphy and somewhat restrict free use of the yard and free choice of vegetation to be planted. For large, properly planned yards, this is not a big disadvantage.

Evapotranspiration is an important element in the design of systems where downward percolation, alone, would not be suitable. Designs which totally prevent downward percolation are not recommended except where there are valid reasons for preventing such percolation, such as special reasons to prevent contamination of an aquifer or surface water. Current research and field studies should help in establishing design criteria to indicate where such systems will be successful and what design features are essential to success.

The situations and conditions under which there is sufficient advantage from the aerobic systems to justify their use continue to be studied. Opinions of experts are conflicting. There is already sufficient evidence to conclude that properly designed, installed and operated aerobic units are advantageous, under some conditions, as in the Garrett County, Maryland, study. The lower BOD and suspended solids in properly operating aerobic units, coupled with the aerobic condition of the liquid, should be beneficial in situations where soil and system clogging is due to anaerobic conditions. More data are needed on this point; however, where surface discharge is permitted, the systems have obvious significant advantages. The units are also proving to be useful in enabling recycling the effluent for toilet flushing and other uses, where such practices are authorized.

Problems of solids discharge due to bulking appear to be significantly reduced by filters which are integral parts of the units.

Chapter 11

WATER CONSERVATION AND ITS EFFECTS ON SUB-SURFACE DISPOSAL SYSTEMS

As mentioned before, the actual average measured quantity of water used in typical American homes with conventional plumbing fixtures and appliances is considerably less than has been commonly assumed. There are indications that new fixtures, valves, flow restrictors and appliances are tending to further reduce in-home water consumption. For sites where conditions are marginal for subsurface disposal of wastewater, water conservation is an important means of prolonging the useful life of existing sytems. In their system design requirements, some codes are providing reduced seepage areas and treatment tank sizes to compensate for such water conservation. However, this concept is being accepted slowly by authorities pending development of data from experience and applied research to more fully justify such reductions.

A. Water Conserving Toilets (Conventionals)

During periods of drought there have been flurries of activity to develop ways of reducing the quantity of water required per toilet flush. This led to adoption by some states of laws or rules restricting the allowable amount of water per flush to 3½ gallons for new toilets installed after a stated date (January 1, 1978, in California and Oregon, for instance). Many types and shapes of toilet tank inserts were marketed or supplied by water purveyors, to reduce the volume per flush of existing toilets.

Since on-site system requirements are often established for whole tracts and developments, it is not possible to predict the attitudes of future occupants toward water conservation. For that reason, allowances for water conserving programs should generally be reserved to those items which are inherently designed into the household plumbing and fixture system, and for those special systems involving toilets which use little or no water, including those which completely separate "black" and "grey" water. It would be reasonable to consider the new 3½ gallons per flush fixtures to be in the first category. Oil flushed toilets and those designed to use minimum quantities of water as well as compost toilets are in the second category.

There are at least two fairly comprehensive reports on residential water conservation. "Residential Water Conservation" (1976) by Murray Milne and "Demonstration of Waste Flow Reduction from Households" (1974) by General Dynamics Corporation. Both discuss water used for toilets and various fixtures. The reports describe various toilet tank and bowl designs, including the "shallow trap toilet." The Milne report says that water consumption of 3 to 3.5 gallons per flush reduces by one-third the amount of water normally used in flushing. "This would result in water savings of 15% of all water consumed in the home." This statement assumes the average conventional toilet uses 4.5 to 5.25 gallons per flush. The Milne report properly assesses the reduction in wastewater attained by oil-flushed and low water-using toilets.

Table 14 indicates that an average of 35% of all water used in the home is for toilet flushing. It is calculated that a saving of 33% per flush will mean saving one-ninth or 11% of all home water usage. That checks well with the following proposed Oregon regulations which allows a 10% reduction in seepage area for new buildings equipped with 3½ gallon-per-flush toilets. Maine's provision of allowing a 40% reduction in septic tank size and an appreciable reduction in seepage areas, where toilet wastes are segregated and handled separately, appears to be reasonable. (This should be the subject of careful comparative studies.)

Chapter 171, Oregon Laws, 1977 provide: "Proposed Amendment:" "(d) After January 1, 1978, subsurface sewage system construction permits issued for new hotels, motels, apartment houses, single family dwellings or other facilities which utilize 3½ gallon flush toilets, approved by the State of Oregon, Department of Commerce, shall provide for a *10%* reduction in the drainfield sidewall seepage area over the that required by these rules."

As soon as public acceptance of 3 to 3½ gallon-per-flush toilets is assured so there will be little tendency for them to be subsequently replaced with conventional units, a 10% reduction in the required seepage area would be reasonable.

B. Two or Less Quarts-Per-Flush Toilets

The Milne report describes the toilet manufactured by Microphor which employs a combination of not over 2 quarts of water and air pressure to evacuate the contents from a hopper located beneath the bowl and separated therefrom by a flapper-type valve. Operation is controlled by an air and water sequence valve.

Monogram Industries has developed a toilet which uses less than two quarts per flush and which utilizes a grinder to comminute the material so finely that flushing is accomplished with very little water. That unit is now used on Am-Track trains and is being modified for home use.

No doubt other low water use toilets will be available. The question of the effect of such units on system design is valid. At premises where toilets produce the major share of the wastewater, as at certain public toilet facilities, these units substantially reduce the amount of wastewater. This should be recognized by regulatory officials.

The proposed Oregon code would further provide: "(e) Subsurface sewage system construction permits issued for new hotels, motels, apartment houses, single family dwellings or other facilities which utilize two (2) quarts per flush toilets, approved by the State of Oregon, Department of Commerce, shall provide for 25% reduction in the drainfield side-wall seepage area over that required by these rules."

The Milne report indicates 2 quart toilets accomplish about a 90% reduction in water consumption compared to conventional toilets. If we accept the premise that toilets produce about one-third of the wastewater of an average home, 2 quart toilets could be expected to reduce the total wastewater produced in homes by 30%. Unless separate holding tanks are provided, the systems would not reduce the total amount of solids to be stored in the pretreatment system nor the total amount of BOD and suspended solids. Their effect on the BOD and suspended solids in the effluent of both septic tanks and aerobic units should be studied to determine whether concentrations significantly above those from homes using conventional and 3½ gallon per flush toilets affect subsurface disposal systems.

C. Other Water Conserving Type Toilets

This Manual indicates trends which need to be considered in developing on-site wastewater managment regulations.

The General Dynamics Corporation report (1974) describes a "dual flush" toilet system (Econo-Flush and Sink-Bob). These special devices provide for a low volume flush for liquids and a conventional flush for solids.

The Milne report describes a Vacuum Toilet System (Mansfield Sanitary) in which "suction of the vacuum aids in transporting of the wastes and thus decreases the volume of water necessary for that purpose." The material is conveyed from the toilet to a receiving tank which enables separate storage and disposal of "black water" wastes, so as to, in effect, provide separate "black" and "grey" water systems.

Various types of water reuse systems are described in both the Milne and the General Dynamics reports, and other such systems have been developed since those reports were written. Proposed National Sanitation Foundation Standard Number 4, "Waste Recycle Reuse and Water Conservation Systems" (November 1978) gives good descriptions and design criteria for a wide variety of alternative water conserving and reuse type systems.

Water conserving systems range from a system in which lavatory waste is discharged directly into the toilet tank to diatomite filter-chlorinator systems to prepare the water for reuse. The Milne report expresses a preference for reuse of grey water in preference to reuse of toilet wastewater or a mixture of all household wastewaters. Some aerobic treatment systems companies provide for the option of using their system's effluent for toilet flushing.

Control over cross-connections and accidental misuse for human consumption are problems which tend to discourage wide-scale acceptance of reuse systems in homes.

D. Separation of Black and Grey Water

Where home plumbing provides for managing toilet wastes separately, there is justification for modifying the sizing requirements for waste pretreatment and liquid disposal or utilization systems. Among types of toilet facilities used in such situations are:

Pit privies
Aqua privies
Recirculating oil flushed toilets
Various forms of chemical toilets
Low water flush toilets with holding tanks
Compost toilets
Vacuum toilet systems
Incineration type toilets, including those which function automatically.

1. Advantages of Separation

a. The following reduction in pollution loading is based on data from Otis, et al. (1977) and Siegrist (1977):

Table 14

Comparison—Coliform in Grey with Black Water

Source	Total Coliforms #/100 ml.	Fecal Coliforms #/100 ml.
Septic Tank	9.0×10^5	5.9×10^5
Bath	1.8×10^3	1.2×10^3
Laundry	2.1×10^2	1.1×10^2

Those data indicate that bath and shower wastes contain only 0.2% as many indicator organisms as septic tank effluent.

Siegrist's (1977) comparison of grey water with black water is as follows:

Table 15.

Comparison—Pollutants in Grey and Black Water

Pollutant	% of Total in Grey Water	% of Total in Black Water
Total Flow	65%	35%
BOD's	63%	37%
Suspended Solids	39%	61%
Nitrogen	18%	81%
Phosphorous	70%	30%
Pathogens	Very low	Vast majority

2. Reduction in Size of System

Data support reduction of 35 to 50% in septic tank size as contained in the Maine regulations or Monogram (1974) publications and an equivalent reduction in the size of seepage area. They would also support a more liberal attitude toward irrigation with grey water that has passed through a suitable separation tank, than would be authorized with septic tank effluent, partly due to the much lower concentration of indicator organisms and partly due to the lower nuisance value of grey water which has passed through a pretreatment tank, compared with conventional septic tank effluent.

As mentioned above, the percentage reduction in the size of pretreatment tank and effluent disposal system is much greater for sites where the principal use is for toilet purposes, such as parks and highway safety rest stops.

3. Need for Non-water Flushed Units

The cost of privies and certain other non-water-flushed systems is often far lower than for conventional plumbing. For weekend and temporary second-home occupancies, especially in cold climates, and at public toilet facilities which do not justify the cost of continuous heating, there is also an additional advantage because systems are nonfreezing. However, the odor commonly associated with privies has caused that type system to be in considerable disrepute. For that reason much effort has been devoted to development of more aesthetically acceptable, non-water flushed toilets. (In other countries more than in the United States, the aqua privy is well accepted.

4. Protecting Aquifers

In regions where conventional wastewater systems are prohibited due to potential contamination of groundwaters with microorganisms or chemicals, including nitrates, properly designed separated systems may make it possible to develop valuable properties so extra cost for more sophisticated separated systems may be justified.

E. Design of "Separated" Systems

1. Primitive Systems

The principles of design, location and maintenance of privies are well documented in publications such as the Wagner and Lanoix (1958) WHO publication "Excreta Disposal in Rural Areas and Small Communities," and various U.S. Public Health Service publications.

Wagner and Lanoix also describe aqua privies which are usually more acceptable to users than privies. These use a small amount of water for daily flushing and cleaning.

2. Compost Toilets

The need for an aesthetically acceptable, waterless (or nearly waterless) toilet which can be installed in living quarters, coupled with the desire of some people to utilize wastes for organic gardening, has resulted in considerable interest in, and rather large numbers of installations of, compost toilets. The movement is especially popular in Scandinavian countries, and a considerable number of such toilets are being marketed in the United States and Canada.

The basic principle is that aerobic composting is a relatively odorless method of stabilizing (and deodorizing) organic material. Compost is also a useful soil amendment. Therefore, the objective in designing a compost toilet is to provide means for producing aerobic action and mixing, both of which are essential to good composting.

Some companies advocate adding household garbage to the toilet, but leading manufacturers like Millbank now say that garbage can complicate the composting process and in some cases cause odor problems.

Commercially available systems are designed for either natural or fan type aeration and manual or semimechanical turning and mixing of the composting mass. In some the compost is heated.

Various do-it-yourself designs are proposed in a publication by the California State Office of Appropriate Technology (1977). That publication described tests made to determine whether the compost product from the toilets was free of pathogens and parasites. The findings were that, with the type of unit utilized, certain forms of parasites (helmiths) survived the composting process but were inactivated by long-term aging.

A newspaper account by columnist Barbara Riegel (1977) described the "Clivis Multrum" unit which is marketed by Abby Rockefeller. It told of mechanical and operational failures which may have been due to inadequate care in original installation and operation.

De Jounge (1976) reported in *Compost Science* that the Swedish compost toilet, Toa-Throne, has received wide acceptance. The unit has a "specially designed, stepped and perforated slanting to the decay chamber." The container is 66 inches long, 51 inches high and 39 inches wide.

De Jounge noted that the necessary microorganisms exist in toilet and kitchen wastes that are deposited in the unit. The design, with perforations, is intended to facilitate aeration. While the normal composting process generates heat, De Jounge stated that in colder climates the rate of microbial decomposition is materially reduced in the winter so provision for heating is necessary. He reported that Swedish authorities authorize use of the composted product for gardening but advised checking with United States state and local authorities for a ruling on this. The price was given as between $750 and $980.

De Jounge said, "The National Sanitation Foundation is working on a standard now."

The Mullbank "Ecolet" (Figure 24) was studied and approved by the French Ministry of Public Health in 1973 (translation supplied by Mullbank). Kajovaldmaa (1974) studied the Mullbank toilet and determined that the resulting compost, can be "acceptable as a sanitized product for use as fertilizer or soil amendment." That unit has both an electric coil to provide heat to facilitate composting and a fan for aeration.

Gary Plews of Washington State reports that studies are being continued and that such units are authorized under limited conditions. The Los Angeles Building and Safety Commission authorized an installation at the home of a lady who is active in organic gardening.

3. Low Water and Oil Flushed Systems

The Microphor low-water-flush toilet has been approved by the International Association of Plumbing and Mechanical Officials. The company representatives report that many units are in successful and satisfactory use.

In consulting for Monogram Industries, Committee Chairman, Charles Senn, made studies at a home with a family of four, where a Monogram Oil Flushed toilet was satisfactorily used for over four years in place of the usual water closet. Senn also found the units were well accepted by the public at parks, ski-lifts, highway rest stops and other places where Monogram provided a waterless system.

4. Evaluation of Special Systems

National Sanitation Foundation Standard Number 41 (1978) provides procedures for evaluation of "Wastewater Recycle/Reuse and Water Conservation Systems," ranging from units for recycling water for toilet flushing and other purposes, to compost and oil-flushed toilets.

Figure 24

Description of the Mullbank Toilet

1. Ventilation hood, with fly-proof mesh
2. Transformer and switch
3. Fan
4. Distributor for spreading the waste
5. Heating coil for heating and evaporating moisture
6. Thermostat for heat regulation inside the coil
7. Emptying tray
8. Scraper for use when emptying

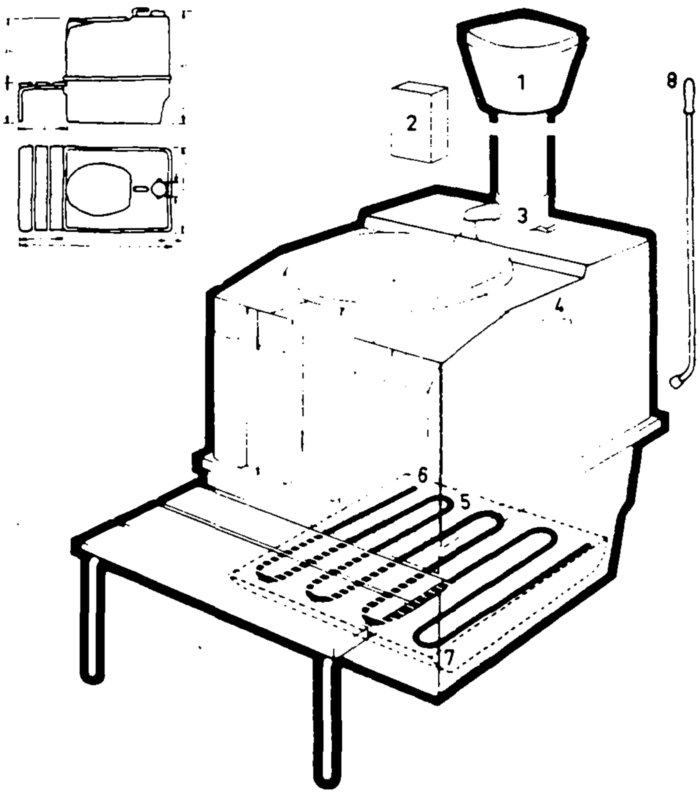


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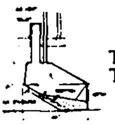
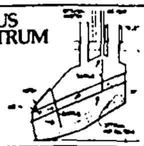
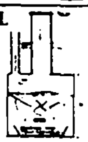
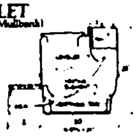
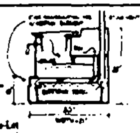
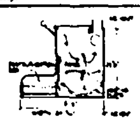
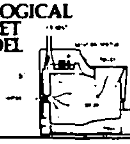
Figure 25.

GUIDE TO THE COMPOSTING TOILETS

TYPE	VOLUME	MATERIAL	PRICE AS OF Feb. 1, 1977	CAPACITY	ELECTRICAL REQUIREMENTS	FEATURES
 TOA-THRONE	Large volume	Polyethylene SIZE 39 × 66 × 51	$845-$1045 depending on accessories	4-6 persons; can handle overloads	Optional ventilating fan 110V-20W	Single waste chute insures layering of human & vegetable waste Produces nutrient rich humus No external power source necessary No pasteurization of humus required Ideal for new construction
CLIVUS MULTRUM 	Large volume	Fiberglas SIZE 45 × 101 × 79	$1400-$1685 depending on accessories	6-10 persons depending on number of midsections	Optional ventilating fan 110AC-46W	Produces nutrient rich humus No external power source necessary Insulated model available No pasteurization of humus required Ideal for new construction
BIOLOGICAL TOILET MODEL 75 + 75B 	Medium	Fiberglas SIZE 36 × 40 × 36	$1400-$1700 inclusive	2-4 persons (15 persons with optional evaporator)	2 fans 110V-46W Rotation motor 110V-180W Heating element 110V-1200W	Automatic mixing of waste to prevent compacting Internal heating elements Produces nutrient rich humus No pasteurization of humus required Ideal for new construction
ECOLET (same as Mullbank) 	Small volume	Polystyrene (plastic) SIZE 24 × 42 × 32	$736 inclusive	3-5 persons with occasional overloads	110V AC Transformer 110V Fan 42V-21W Heating element 42V-140W	Easy installation Internal heating elements Produces nutrient rich humus No pasteurization of humus required
 MULL-TOA (same as Bio-Let or Soddy Potty)	Small volume	Polyethylene (plastic) SIZE 21 × 30 × 28	$795 inclusive	2-4 persons with occasional overloads	110V-AC 250W 2 fans 2 thermostatically controlled heating elements Automatic leveler	Automatic mixing of waste Built-in hygrometer to indicate humidity Easy installation Greatest weight reduction of waste of comparable models Lowest volume of air evacuated of comparable models (9 liters per second) Internal Heating elements Produces nutrient rich humus No pasteurization of humus required
 BIO-LOO	Small volume	Polyphenyleneoxide (plastic) SIZE 24-3/16 × 31½ × 25-5/8	$795 inclusive	2-4 persons with occasional overloads	Fan 110V-23W Heating foil 110V 30W Pasteurization hot plate 110V-160W	Pasteurization box heats waste and kills pathogenic bacteria Manually operated harrow to mix waste Easy installation Internal heating elements Produces nutrient rich humus
BIOLOGICAL TOILET MODEL A 	Small volume	Polyethylene (plastic) SIZE 22 × 41 × 31	$980 inclusive	2-4 persons with occasional overloads	Fan 110V-23W Drum rotation motor 110V-115W 3 heating elements 300W(12ea apt.)	Automatic rotating drum mixes waste Easy installation Internal heating elements Produces nutrient rich humus No pasteurization of humus required

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Chapter 12

MAINTENANCE AND SEPTACE TREATMENT AND DISPOSAL

A. Maintenance of Septic Tanks

Even under ideal laboratory conditions, only a portion of the solids and grease are converted to liquid or gas by anaerobic or aerobic digestion. The undigested portion must be removed periodically or it will pass on into the leaching system. Fortunately, both anaerobic and aerobic digestion break down grease and materials which clog pores of the soil, so with the more granular and porous soils, carry-over of solids is not as serious as with undigested material. It is probably because of this digestion process that some septic tank and aerobic units ahve functioned for many years without removal of sludge.

The amount of sludge that accumulates is, of course, related to the amount of solids and grease that enter the system. That, in turn, relates to the size and habits of the family using the system. In addition, the use of garbage disposers may more than double the rate of sludge accumulation.

There is general agreement that excess sludge and scum should be removed from septic tanks periodically. Septic tank capacity was originally based on an assumed 24-hour detention period, with a 500 gallon per day maximum regular waste flow, allowing 25% of the tank capacity for sludge and scum storage. Enlarging to 1,000 gallon capacity was partly to provide storage room for extra solids. With the smaller size tanks, it was common to call for pumping at least every five years without garbage disposers and every two years with garbage disposers. Some advocate more frequent pumping of septic tanks. The actual frequency of removal is related to factors which influence the amount produced.

1. Type soil in seepage system

   Experience in coarse and porous soils has shown that septic tanks may function for many years without maintenance. As stated, microbiological digestion tends to break down grease and produce suspended solids which do not quickly plug pores in coarse soil. On the other hand, a number of authors cite lack of maintenance and resulting high suspended solids as a principal cause of failure in certain situations, usually in soils of finer texture.

B. Maintenance of Alternative Pre-Treatment Systems

The essentiality of maintaining pumps, aerators and other electrical or mechanical elements is obvious. Glasser (1974) said such maintenance inspections and service were indicated at least four times per year, for aerobic systems in his Maryland study. Some individuals say that the aerobic process modifies the suspended solids so that the discharge does not adversely affect the seepage system. Others advocate periodic removal of accumulated solids.

C. Education of Systems Owners in Maintenance

Several jurisdictions and installation companies have prepared excellent booklets to advise on system maintenance. This is important. Company prepared publications are especially valuable because they are specifically directed to their particular system.

The installer should always leave and preferably post a sketch showing the exact location of the pretreatment tank, distribution box, if any, and the various parts of the subsurface disposal system, including area to be reserved for future expansion.

In addition to calling for periodic pumping, as needed, of the pretreatment tanks and the solids collectors installed on certain aerobic units (or the whole system), the following may also be called for:

1. Periodic examinaiton of the distribution box.
2. Noting of water depth in various trenches or parts of the system.
3. Proper lubrication and other maintenance of electrical or mechanical parts.
4. Regular inspection and periodic raking of open intermittent sand filter beds.

D. System Features to Facilitate Maintenance

1. Inlet T's

   Use of "Sanitary T's" for septic tank inlet have been observed in the field. Paper and solids often become compacted in the vertical leg of the T; therefore, non-plugging inlets with more sweeping elbows or with regular baffles have merit. If inlet T's are used, they should be provided with an access opening extending to ground level, above the T, to facilitate removal of stoppages.

2. Mechanical and Electrical Controls

   Unless hermetically sealed, electrical motors and controls should never be installed where they will be subject to the corrosive action of hydrogen sulphide and gases which develop when septic conditions develop (even in malfunctioning aerobic units).

   Pumps and motors should usually be installed with quick disconnect fittings, and installations should permit replacement or repair without pumping out tanks or wet-walls.

   Preferably, motors and mechanical or electrical parts should be of a type readily available on the market.

E. Septage Removal and Disposal

1. Regulation

   Many jurisdictions properly license companies that pump pretreatment systems, seepage pits and cesspools. The purpose is to:

   a. Assure that equipment is properly designed to pump and haul in a sanitary manner.
   b. Assure a timely review and approval of all locations and methods of disposal.

(1) Public sewerage systems or disgesters at treatment plants.

(2) Controlled land application followed by plowing or discing.

(3) Sanitary landfills or hazardous waste sites.

(4) Special stabilization ponds.

Chemicals which could contaminate groundwaters or adversely affect biological processes in sewage treatment systems.

2. Special Disposal

Special precautions may be necessary with wastes from recreational vehicle dumping stations and for wastes from portable chemical toilets (as are used at construction sites). These may contain chemical compounds which would contaminate the aquifer or interfere with biological treatment processes. (Some regulations specify chemicals for use in such toilets which do not produce serious pollution problems.)

Chapter 13

FEDERAL PROGRAM FOR ON-SITE SYSTEMS

A. Publications and Technology Transfer Seminars

Among the recent E.P.A. publications which are fundamental sources of information are: Proceedings of "National Conference on Less Costly Wastewater Treatment Systems for Small Communities (1977). This publication provides data from several extensive studies of the effectiveness and cost of alternatives to conventional public sewers and sewage treatment for communities where the cost of such public facilities are unusually high. These include:

1. Pressure sewers

   The Douglas County, Oregon, demonstration of septic tank effluent being pumped from each home to a pressure sewer system which avoided high cost of deep trenches and large lift stations. Other installations have employed grinder-pumps and wet-wells to enable discharge of untreated waste to pressure sewers.

2. Clustered systems

   Septic tanks with "clustered subsurface disposal sites" at Fountain Run, Kentucky, cost $7.00 per family per month compared with $17.00 for conventional systems. These can be used with either gravity flow or high pressure or vacuum sewers. They can involve pre-treatment at each house or central treatment.

3. Re-cycling

   The Boyd County Demonstration Project, West Virginia, (Appalachia Project), utilized 6 different makes of aerobic household systems installed and managed by a maintenance district. One feature was recycling of the wastewater at 24 households. Many administrative and technical problems delayed the project, but the report emphasizes the need for effective maintenance and a "how-to-do" manual for all concerned.

4. Direct Reuse

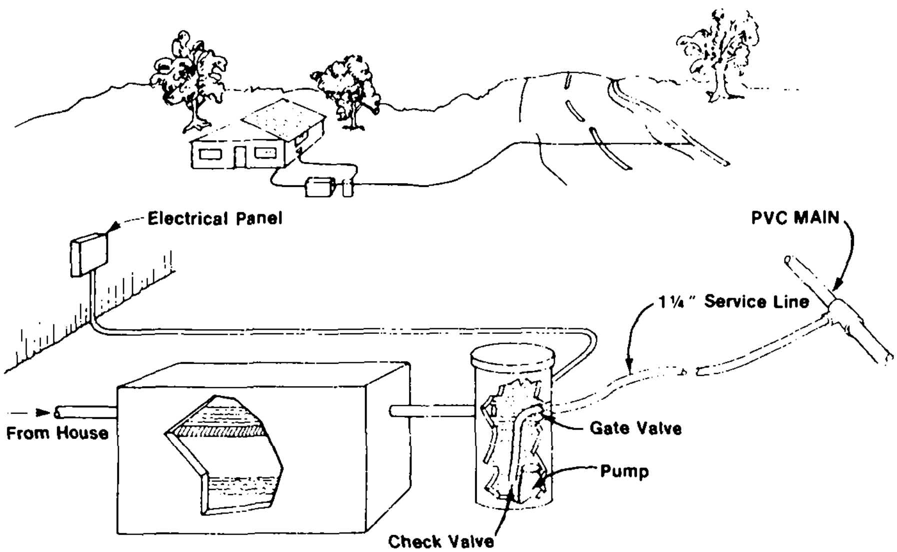
   Committee Member Dan Tipton reported successful "total recycling, sytems" in Colorado. He said, "One manufacturer (Pure Cycle) has been using the recycled water as a potable supply in their offices for two years or more."

5. Mounds

   The Westboro, Wisconsin, project which was conducted to find a most cost effective program for a small community, including "Wisconsin Mounds" is discussed in the EPA proceedings.

Figure 26

Pressure Sewer Service Connection Simplified



Reprinted from U.S. Environmental Protection Agency publication.

B. Other E.P.A. Publications

"Alternatives for Small Wastewater Treatment Systems" (Pressure Sewers/Vacuum Sewers) describes design criteria and other features of pressure and vacuum sewers.

Another publication in the EPA series with the sub-heading of "On-Site Disposal/Septage Treatment and Disposal" provides data from papers issued at the EPA Technology Transfer Seminars.

Another in the series, "Cost/Effectiveness Analysis," ties in well with the new federal requirement for such studies to be an integral part of new facilities planning (Figure 27).

C. 1977 Amendments Authorizing Federal Financial Assistance for On-Site Systems

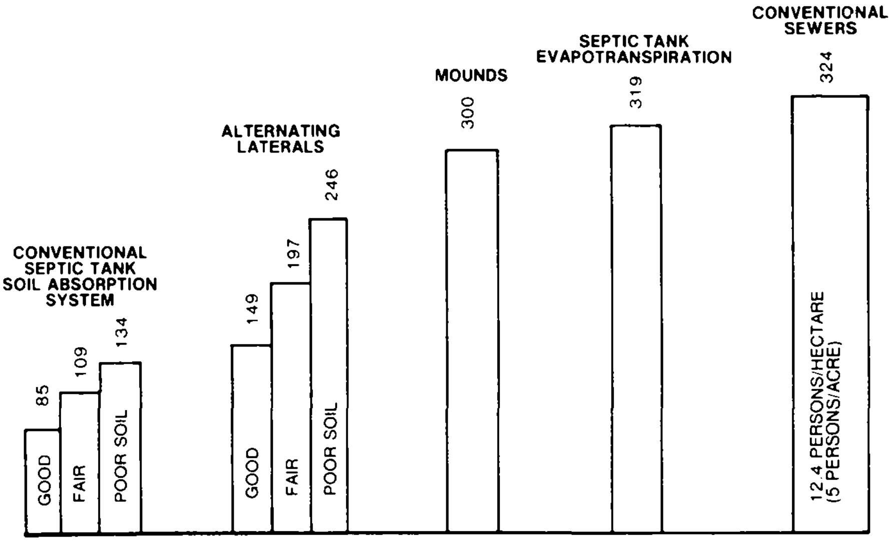
The Federal Register (April 25, 1978), contains EPA regulations which define conditions for awarding grants for on-site systems. More final and complete regulations are pending.

The key provisions concerning determining eligibility for funding of on-site systems are Dearth (1978):

1. A 4% set aside from allotments of rural states for alternative treatment systems in towns of 3,500 or less or dispersed areas of larger communities must be used in the rural states or the funds will be lost. A set aside of up to 4% is optional in the more urbanized states. A rural state is a state in which 25% or more of population is rural population.

Figure 27

Total Annual Costs of Alternatives



Reprinted from U.S. Environmental Protection Agency publication.

"Alternatives to conventional treatment systems are defined as systems other than the conventional gravity sewers leading into centralized treatment systems. Such alternatives include septic tanks with soil absorption fields, various add-ons or alternatives to septic tanks including mound systems, aerobic units, low-water or no-water toilets with grey water treatment systems and innovative sewers, including both vacuum and pressure sewers.

"These alternative systems have potential for greatly reducing costs to small communities when properly constructed, operated and maintained.

2. "A second related provision of the amendments make eligible privately-owned individual systems serving one or more existing residences or small commercial enterprises. To receive a grant for such systems, a public body has to apply on behalf of a number of units, a user charge system must be installed to recover operation and maintenance costs; commercial enterprises must pay back the federal share eventually; and the system must be less costly than a conventional system. The public body must accept full responsibility for the operation and maintenance.

   "EPA has determined on the basis of the new law that individual small systems which are publicly-owned and serve only one or a few homes would also be eligible for federal funding where similar conditions are met.

3. "A third provision of the new law provides for an increase in the federal grant from 75% to 85% of the eligible costs for alternative or

innovative systems. The agency interprets this increase to be available to all alternative systems that utilize the 4% set aside funds for sparsely populated areas.

4. "A fourth provision authorizes combined Step 2 and 3 grants for projects up to $2 million in towns of 25,000 or less (up to $3 million in high-cost states). This provision will cut down the amount of paperwork required of small communities.

5. "A fifth provision authorizes EPA to make a grant to states of up to 2% or $400,000 (whichever is greater) to assist with management of the construction grants program. These funds may be used to assist small communities in managing their construction grants.

6. "A sixth and final provision authorizes EPA to provide technical and legal assistance at the request of the grantee to help administer or enforce any contract related to the program."

D. On-Site Management Districts

Dearth (1978) said: "Planning for the program and its equipment is part of Step 1, the facility planning phase. Land for land treatment or ultimate disposal of residues is grant eligible as are sludge pump-out trucks and similar capital equipment and septage treatment works.

"To implement these new amendments and regulations will require substantial and, in some cases, radical reorientation of state level management of the construction grants program. Some states, like Illinois and California, have begun this reorientation.

"The kinds of changes involve regulation, oversight, assistance and public leadership. Many state laws and regulations must be modified to encourage (or even allow) alternative systems in small communities. For example, public health restrictions on septic systems and land disposal of effluents need to be reconsidered. In many cases, stringent restrictions are imposed because projects involving these alternatives historically were poorly planned, constructed and operated. Extensive evidence we have accumulated now indicates that these are the only systems which many communities can afford. If we are to have waste treatment in these communities, it must be with alternative systems and the rules must change to accommodate them."

Because of many common problems relating to on-site systems, a need developed to legally create public, local, official, tax or fee supported agencies to assume responsibility for solving the problems. Some of these problems are:

1. Improper original site evaluation
2. Faulty design of original system
3. Defective workmanship and failure to follow good practice in installation
4. Inadequate or totally neglected maintenance
5. Failure to provide trained service personnel and spare parts for equipment.
6. Lack of funds for repairs.

Management agencies are a prerequisite to receiving federal financial assistance and can be reaponsible for:

1. Original planning (facilities plan)
2. Planning, designing and supervising installation of new systems
3. Financing and handling financial matters
4. Organizing and managing, or arranging for managing and supervising of operation and maintenance of systems.
5. Providing for facilities including trucks, land and works for managing septage.

This does not mean that the work now competently done by private contractors, manufacturers and consultants must be assumed by governmental agencies, but that governmental agencies will assume responsibility to see that the services are provided, either under contract or by public employees.

Guidelines are available to assist in preparing suitable state-enabling legislation and as a guide to developing the legislation, regulations, and procedures under which local districts or agencies will operate.

An example is the California definition of a "Public Entity—A local agency, as defined in the State of California Government Code, (Section 53090 et seq.) which is empowered to plan, design, finance, construct, operate, maintain, and to abandon..." public sewerage facilities.

"In addition, the entity shall be empowered to provide permits and have supervision over the location, design, construction, operation, maintenance and abandonment of individual sewage disposal system within a land development and shall be empowered to design, finance, construct, operate, and maintain any facilities necessary for the disposal systems and to conduct any monitoring or surveillance programs required for water quality control purposes.

Chapter 14

FUTURE RESEARCH AND DEMONSTRATION NEEDS

A. Toward Longer System Life

1. Objectives

Some officials advocate the goal of nearly perpetual life of on-site systems. That goal could add materially to the cost of all systems and is not in keeping with the general practice of utilizing materials for siding and other elements of the house which need regular maintenance and painting or roofing which has to be replaced periodically.

This analogy applies to those system design features which add significantly to original costs but which may be more economically taken care of by an efficiently organized maintenance and, when necessary, replacement program.

The goal, then, should be toward systems with a high degree of reliability, a reasonably long life expectancy and with site and system planning which will enable such repairs or replacements as may reasonably be expected to be requried during the life of the property served by the system.

B. Health and Environmental Concerns

The associated health concerns range from microbiological contamination of ground or surface waters which may cause disease outbreaks to chemical contamination which may cause a whole aquifer to fail to meet primary drinking water standards. Obviously, facilities planning and site evaluation would be sufficiently comprehensive to avoid either.

C. Off-Site Surface Discharge

This Manual is intended to concentrate on systems which dispose of or utilize wastewater on properties where generated. It is not intended to exclude discharge to off-site channels or water courses where such practice is authorized. It is anticipated that the concept of new and improved treatment systems as mentioned in this manual in conjunction with competent maintenance district personnel will enable such systems to be used where they are needed. Among the systems now being used for off-site surface discharges are:

1. Aerobic systems meeting NSF standard 40 (Class I), with or without external filters, disinfection or additional treatment.
2. Intermittent sand filters as have been demonstrated and studied in Wisconsin and elsewhere, for either septic tank or aerobic unit effluents.
3. Lagoons have been used in North Dakota residences for years; in Illinois for highway safety rest stops and similar places; and at homes in a number of states in the South.

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