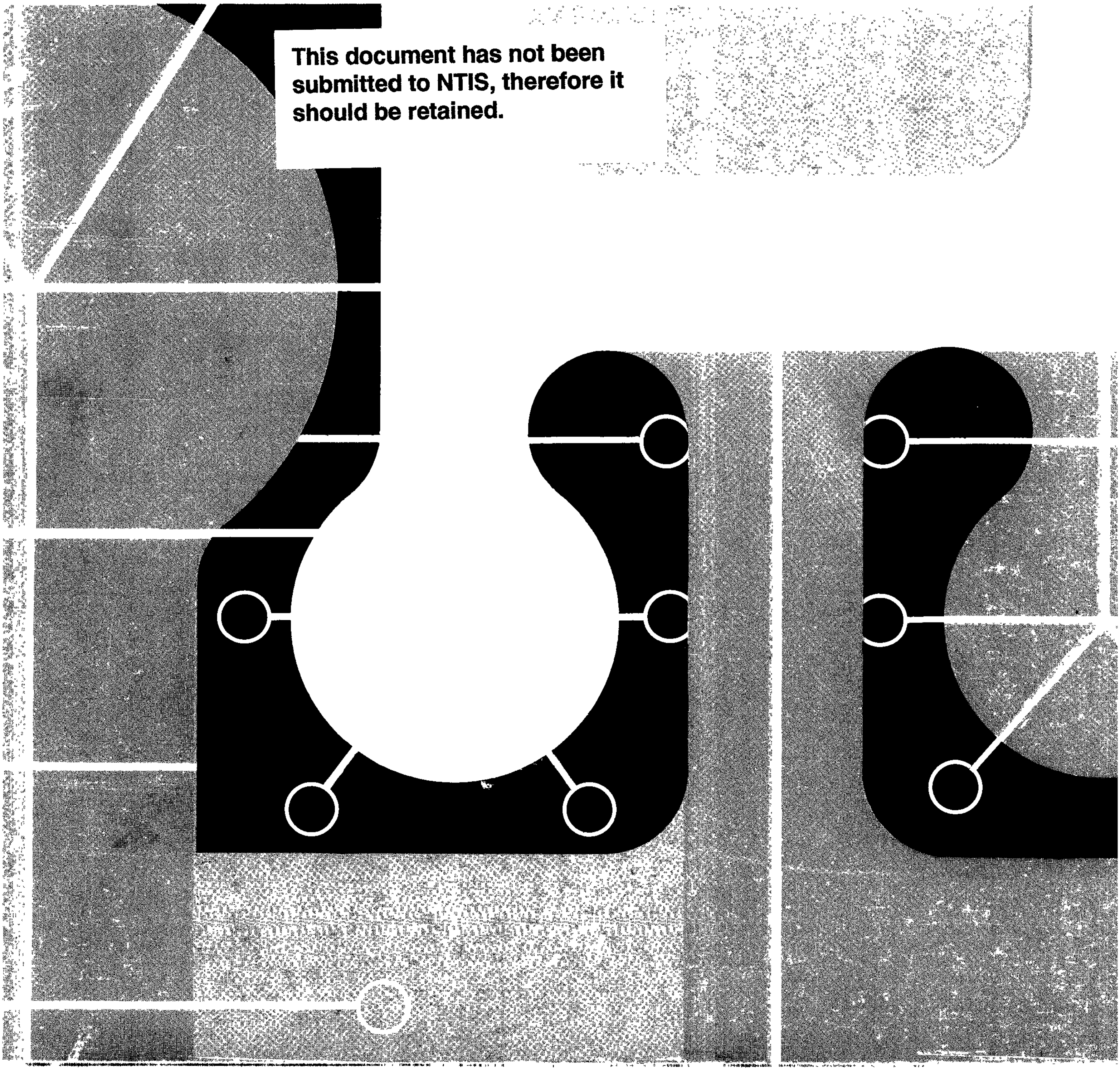
Alternatives for Small Wastewater Treatment Systems

Cost/Effectiveness Analysis

EPA Technology Transfer Seminar Publication



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ALTERNATIVES FOR SMALL WASTEWATER SYSTEMS

Cost/Effectiveness Analysis

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Chapter I

EVALUATING ALTERNATIVE WASTEWATER SYSTEMS FOR MUNICIPALITIES

In response to the increasingly acute financial problems presented to small communities and rural residential areas in the past 5 years resulting from pollution control requirements, new emphasis is being placed on examining the possible use of nonconventional sewerage systems. The mere proposal of conventional community systems, because of the magnitude of the cost to individual homeowners living in these areas, has quite often only served to delay taking any kind of action. For many years, research and development work has been accomplished on individual on-site treatment and disposal systems and on nonconventional systems (for example, pressure sewers). Nevertheless, the most recent work, initiated because of the high cost of the conventional systems, has only begun to become familiar to consulting engineers and public officials in the wastewater management field.

The objective of this publication is to present specific information pertinent to the cost/effectiveness analysis of sewerage systems for small communities and rural residential areas. Toward that end, procedures for use in determining the feasibility and desirability of using four on-site systems and four types of community collection systems have been included. The material herein does not emphasize procedures for the selection of community treatment systems.

The publication, in particular, includes sections describing the problem conditions that must be considered in selecting sewerage alternatives. It will also point out the advantages, disadvantages, and limitations of several on-site and community collection alternatives, a procedure for screening and analyzing costs of alternatives for individual homes, and a set of case histories taken from recent sewerage reports and facilities plans that show how and why some of the more nonconventional systems have been analyzed.

PROBLEM CONDITIONS

To evaluate on-site sewage disposal systems and nonconventional community collection systems, three basic premises should be borne in mind.

- If site conditions are suitable, the conventional septic tank-soil absorption system (ST-SAS) is the best type of on-site disposal system.
- If costs are reasonable, a conventional gravity sewage collection system is the best type of community system.
- A conventional gravity collection system is the accepted standard for community sanitation against which all alternatives should be measured.

It is recognized that there are situations in which the conventional ST-SAS would not work satisfactorily, and in which the cost of a conventional gravity system would be exorbitant. The problem is one of sorting out the alternatives in a rational manner and selecting a short list of alternatives that warrant detailed analysis. Fortunately, recent work in the area of alternative collection, treatment, and disposal systems for small flows has provided a background of information, which makes possible the initial screening of alternatives with a minimum of time and a high level of confidence. The screening process is effective because there is a range of available alternatives, each of which deals with certain specific problem conditions and each of which may be most cost/effective in a certain rather narrow set of circumstances. The starting point for the screening process, therefore, should be an inventory of the problem conditions encountered in the study area. The principal problem conditions may be grouped into four categories: soils, site characteristics, geology-hydrology, and climate.

Soils

Quite naturally, the nature of the surface soils has a major effect on the function of SAS's. There are three factors that are of particular concern.

Permeability. It is a well-recognized fact that SAS's will not work in soils that will not absorb water. Tight clays and other soils of low permeability as a rule preclude the consideration of SAS's. Often 60 min/in as measured by the percolation test is used as the lower limit of permeability for SAS's, but the authors believe this value to be unnecessarily restrictive, especially in light of the accuracy of the test. In a well-designed and properly constructed ST-SAS, a percolation rate of 120 min/in can be more than adequate to support the rate of infiltration from the disposal trench into the adjacent soil. Soils of very low permeability will also usually preclude the use of percolation-assisted evapotranspiration (ET) systems.

Depth to Impermeable Layer. Even though surface soils may have adequate permeability, an SAS will not work if a shallow impermeable layer prevents downward percolation of the wastewater. A shallow impermeable layer may lead to an accumulation of perched water that will flood the disposal trench and cause clogging of the trench infiltrative surface. An unsaturated soil column of about 3 feet is generally accepted as adequate for effective draining of fine-grained soils.

Depth to Creviced Bedrock. Experience has shown that unsaturated soil is an excellent medium for the removal of pathogenic bacteria and viruses. Wastewater, however, may flow for long distances through crevices in bedrock without such purification. One goal of an adequate SAS, therefore, is to achieve an adequate distance of travel through unsaturated soil before the wastewater enters crevices in underlying bedrock. A commonly accepted value for the minimum depth of unsaturated soil is 2 to 3 feet for fine-grained soils and up to 10 feet for coarser soils.[1]

Site Characteristics

Lot size and study area topography influence the selection of available alternatives for wastewater disposal.

Lot Size. The average lot size and corollary factor of distance between homesites influence the feasibility of both on-site and community sewerage systems. For example, a minimum lot size of about 1 acre is frequently required to accommodate an adequate ST-SAS with proper allowances for setbacks and for the house itself. It is not normally desirable to construct any subsurface discharge system on lots smaller than one-half acre. If water is obtained from individual wells, the minimum lot size should be about 1 acre.[2]

The cost of conventional community sewerage, on the other hand, increases rapidly as the distance between households increases and population decreases. For average lot sizes of 2 acres or more, community sewerage is not ordinarily the most economical solution. For lot sizes between one-half and 2 acres, particularly where the ST-SAS is not a suitable solution, a careful cost analysis may be required to select the most cost/effective method of wastewater management.

Topography. Although an adequate slope is necessary for gravity sewerage, excessively steep or irregular topography can limit the options available. A slope of about 25 percent is usually considered limiting for an ST-SAS, and construction of any on-site system is difficult at that slope. Irregular, hilly topography frequently requires numerous lift stations if a gravity collection system is installed. This is more likely to be true if the area was developed entirely on septic tanks, and roads were laid out without thought of later construction of sewers. Under these conditions, there is often a shift in the economics in favor of a community pressure sewer system. Vacuum sewers are not well suited for use in irregular, hilly topography, but may offer some cost advantage should there be no slope. This would be particularly true if soils are unstable.

Geology and Hydrology

Depth to bedrock, soil stability, and ground water hydrology are probably the most important group of factors involved in the selection of the best system for a small wastewater flow.

Shallow Bedrock. Bedrock within 5 feet of the ground surface forms an impervious layer, which rules out the use of the ST-SAS. Bedrock closer than 6 feet to the ground surface will probably result in excessive costs for any gravity collection system. Closer than 3 feet to the surface, bedrock probably rules out most on-site systems, except septic tank/slow sand filter/surface discharge systems, mound systems, or, in some cases, ET systems. Only pressure or vacuum collection systems are likely to provide community sewerage at a reasonable cost in an area with shallow bedrock.

Unstable Soils. Common examples of soil instability are sandy soils with a high water table, and fine sediments with a high water content such as those found in swamps and some tidal estuaries. Costs of dewatering, sheeting, and other measures necessary to construct deep sewers in unstable soils may cause a fivefold or greater increase in sewer construction cost. Some types of unstable soils can cause gravity sewer lines to shift after they are installed, changing slopes and adding high maintenance costs to high construction cost.

Seasonal High Ground Water Within 4 Feet of Surface. There is abundant documentation in the technical literature for the fact that high ground water has a detrimental effect on the function of an ST-SAS. Inundation of the infiltrative surface because of seasonal high ground water or perched water on top of an impervious layer leads to rapid failure of the SAS, which can be reversed only by an extended rest period. A commonly used limiting value for seasonal high ground water in fine-grained soils is 3 feet below the bottom of the drainfield trench. For coarser, granular soils a lower value may be acceptable. For a minimum-depth drainfield trench of 12 inches of gravel-fill with the top of gravel at natural ground surface and covered by a mounded soil-fill about 12 inches deep for protection, the limiting minimum depth to seasonal high ground water is about 4 feet. For higher ground water levels, a modified, mounded SAS must be used to raise the infiltrative surface above natural ground level.

Seasonal High Ground Water Within 24 Inches of Surface. Even with the use of a mounded system there is a limit to the acceptable ground water height. Water that flows downward from a mounded SAS must be able to flow laterally from under the mound into the adjacent soil mantle without surfacing at the edge of the mound. To prevent surfacing at the edge of the mound, the ground water beneath the mounded system should not rise to within 24 inches of the surface for any extended time period (the equivalent of 2 weeks or more). The seasonal maximum ground water height can be assumed to be an upper limit on any type of SAS.

Climate

Except for the special conditions that prevail in arctic climates, climatic factors have little effect on most community sewerage systems. Climate can, however, be severely limiting for certain on-site disposal systems.

Long, Cold Winters. Extended periods of severe cold will preclude the use of uncovered sand filters because of ice formation on the filter surface. A long, cold winter will as a rule limit annual ET to the point that ET units will not function properly.

Low Net Annual ET. Even in warm climates, excessive rainfall may limit ET to a value that will preclude the use of ET systems. Quite obviously, a unit relying solely on ET will not function in an area where the net ET is zero or negative. Units have been designed for combined ET and percolation rates ranging from 0.15 to 1.6 in/d.[3] As a practical matter, ET units should be evaluated very carefully in any location where the net annual ET is 24 inches or less. For a suburban family of five with a per capita water use of 100 gal/d, for example, a 24-inch net annual ET would require more than one-quarter acre to construct an adequate ET bed.

DESCRIPTION OF ALTERNATIVES IN COST/EFFECTIVENESS ANALYSIS

Eight separate alternatives for disposal of wastewater from individual homesites, listed in table I-1, are described briefly in tables I-2 and I-3. The alternatives are divided into two groups: on-site systems (table I-2) and community collection systems (table I-3). Each alternative included in the description and in the following screening process depends to some extent on the problem conditions described in the preceding section. Community treatment systems are not described, because only their cost, and not their use, depends on the specified problem conditions. In addition, because collection system costs are usually predominant in the total cost of a new sewerage system for a small community, the basic choice in a cost/effective analysis will ordinarily be between on-site systems and community sewers of one kind or another.

The alternatives are described in terms of the advantages, disadvantages, and limitations of each. Limitations listed for an alternative are those characteristics that would prevent the use of the alternative. Advantages and disadvantages are characteristics that determine the relative desirability of the alternative but do not bear directly on whether or not it can be used.

Table I-1.—*Alternatives in cost/effectiveness analysis*

Group	Alternatives
A. On-site disposal systems	ST-SAS ST-Mound ST-ET/ETA ST/sand filter/surface discharge
B. Community collection systems	Conventional gravity sewers Small-diameter gravity sewers Pressure sewers Vacuum sewers

Table I-2.—*Description of on-site disposal systems*

Group	Advantages	Disadvantages	Limitations
A.1. ST-SAS	Simple, minimum operation and maintenance requirements Relatively low construction cost Can operate in wide range of climates Chemicals not necessary Power may be required	Large space requirement Nitrate often discharged to ground water	Seasonal high ground water must be deeper than 4 feet Impermeable soil layer or excessively permeable soils must be deeper than 3 feet beneath trench bottom
A.2. ST-Mound	Can be used in some areas ST-SAS cannot, due to limitations of soils, hydrology, or geology Minimum operation and maintenance requirements Can operate in wide range of climates Chemicals not necessary	Larger space requirement than ST-SAS NO_3 often discharged to ground water Visual impact High construction cost Usually requires pumping from ST to mound	Must have 24 inches acceptable soil above: ground water, restrictive soils, excessively permeable soils Must be allowed by State regulations
A.3. ST-ET/ETA	Can be used in some areas where soil disposal systems cannot Chemicals not necessary Power usually not required NO_3 not discharged to ground water from *lined* bed Minimum operation and maintenance requirements	Very large space requirements in most areas Not operable in all climates Vegetative cover should be maintained in healthy condition Very high construction cost Must have water-tight bed lining in high ground water areas	Annual ET rate must exceed annual precipitation for lined beds Salt accumulation in bed may limit service life Must be allowed by State regulations Not generally applicable in very cold climates
A.4. ST/sand filter/surface discharge	Can be used where soil disposal and ET systems cannot NO_3 not discharged to ground water Small space requirement Operable in wide range of climates	Filter surface and disinfection units require periodic maintenance Disinfection necessary Pumping necessary State/Federal discharge permit may be required Sampling and inspection of operation may be required High construction and operation and maintenance costs	Must be permissible under State regulations Uncovered filters not applicable in very cold climates

Table I-3.—*Description of community collection systems*

Group	Advantages	Disadvantages	Limitations
B.1. Conventional gravity sewers	Can be used in any climate Pumping may not be necessary No ST pumping required Relatively low operation and maintenance Sewage generally not septic at treatment site Centralized control of wastewater treatment	High construction cost Deep manholes required Deep excavation may be necessary Pumping stations may proliferate in hilly areas (high construction and operation and maintenance costs)	None, if cost/effective
B.2. Small-diameter gravity sewers	Can be used in any climate Lower construction cost than conventional system Pumping may not be required Relatively low operation and maintenance cost if no pumping required	Septic sewage conveyed to treatment site Deep excavation may be necessary Every new home must have a septic tank Large manholes not necessary, but cleanouts must be provided Pump stations may proliferate in hilly areas (high construction and operation and maintenance costs)	Must be allowed under State regulations
B.3. Pressure sewers	Can be used in any climate Deep manholes not necessary Low construction cost No infiltration and inflow Shallow excavation	Pumping required Relatively high operation and maintenance requirement Septic sewage conveyed to treatment site Every new home must have a septic tank and pump or grinder-pump	Must be allowed under State regulations
B.4. Vacuum sewers	Can be used in any climate Deep manholes not necessary Low construction cost Minimum infiltration and inflow Shallow excavation	Vacuum must be maintained High operation and maintenance cost Difficulty in locating malfunctions	Must be allowed under State regulations Not applicable in extremely hilly terrain

PROCEDURES FOR EVALUATING ALTERNATIVES

The evaluation of alternatives for on-site systems and small community systems should begin with the basic assumption of equality in system life and performance. It makes little sense, for example, to compare a system of unquestioned reliability with a system that may be inoperative several weeks in the year. Similarly, a system having an anticipated life of 40 years should not be compared with a system with an anticipated life of 10 years unless allowance is made for fourfold replacement of the latter. Starting with this basic assumption of equality of service, the first step in evaluation should be a screening process to select the most suitable alternatives. The selected alternatives should then be compared in terms of life-cycle costs, and the length of the selected life cycle should be at least equal to the projected life of the structures that the system is designed to serve.

Screening of Alternatives

For practical application, there are two aspects to the determination of feasibility of alternatives: technical feasibility and administrative feasibility.

Technical Feasibility. Each of the problem conditions described earlier limits in some respect the application of certain sewerage alternatives. For each problem there is a probable best response in terms of selecting or discarding sewerage alternatives. Note the qualifying word "probable." There are, of course, varying combinations and degrees of problem conditions, which render any absolute judgment impractical. With this qualification, however, the available alternatives may be screened for technical feasibility in accordance with table I-4.

Administrative Feasibility. As a practical matter, no sewerage alternative is feasible unless its construction is approved by appropriate regulatory agencies. A mounded SAS may be the best solution to a particular problem, but if present regulations forbid its use, it is not a feasible alternative. That is not to say that modification and improvement of existing regulations should not be attempted, but that each decision must be made within the context of the regulations in effect at the time.

An example is the use of an on-site sand filter followed by direct discharge to a waterway. Research indicates that sand filtration of septic tank effluent, followed by chlorination and direct discharge to surface waters, is an acceptable individual on-site disposal system. Under current regulations, however, such a unit would usually require a specific National Pollutant Discharge Elimination System (NPDES) permit, and the system would possibly be discarded as administratively unworkable. The final step in screening alternatives, therefore, is the discard of those technically feasible solutions that cannot be implemented within the framework of existing regulations.

The engineer, in the course of the administrative screening process, must be alert to catch those alternatives that are technically feasible but not permitted and those that are permitted but are not technically feasible. As an illustration of the latter case, regulations governing ST-SAS's in many areas permit the installation of systems that are not recognized as substandard. A cost comparison of septic tank systems and community sewerage systems under such circumstances will violate the basic assumption of equality of service on which all alternative systems should be compared.

Cost Analyses

It is not the intent of this paper to set forth specific unit costs that should be used in evaluating alternatives for small community or on-site wastewater systems. The costs may vary significantly from community to community, and any professional engineer can prepare a more accurate cost

Table I-4.—*Technical screening of alternatives*

Problem condition	Probable best response[a]
Soils:	
Impermeable	Discard ST-SAS, ST-Mound, and ST-ETA
Sha''ow permeable layer over impermeable layer or creviced bedrock	Discard ST-SAS and ST-ETA
Site:	
Average net lot size 2 acres or more	Discard conventional gravity system
Average net lot size less than 1/2 acre	Discard ST-SAS, ST-Mound, ST-ET, and ST-ETA
Steep slopes	Discard ST-SAS and ST-Mound
Irregular, hilly topography that would require deep cuts or numerous lift stations	Discard conventional gravity collection system, small-pipe gravity system, and vacuum system
Geology-hydrology:	
Shallow bedrock	Discard ST-SAS, ST-ETA, and both conventional and small-pipe gravity collection systems
Unstable soils which result in high excavation costs	Discard conventional and small-pipe gravity collection systems
Seasonal high ground water within 4 feet of surface	Discard ST-SAS
Seasonal high ground water within 2 feet of surface	Discard ST-Mound and ST-ETA
Climate:	
Long, cold winters	Discard ST-ET
Low net annual ET	Discard ST-ET

[a]Septic tank with conventional soil absorption system. Septic tank with mounded soil absorption system. Septic tank with evapotranspiration-soil absorption system. Septic tank with evapotranspiration system.

comparison from local information than could be presented here. Rather, the purpose is to point out the fundamental alternatives in terms of equal life-cycle performance.

Any on-site system should be evaluated over a period equivalent to the life of the structure it serves. For a single-family dwelling, a reasonable life is 50 years, and all cost comparisons that include on-site systems should be compared over that period. To do otherwise is unrealistic. If a conventional ST-SAS is known to have a short life span in an area, it is not relevant that it may be the apparent best solution based on present capital costs. The owner in 10 years may be faced with the cost of an expensive sewerage project required for the protection of public health. In extreme cases, failure to plan a sewage disposal system for the life of the dwelling has resulted in people being forced to abandon their homes to avoid a serious health hazard. A utility function should not be allowed to govern the useful life of the dwelling. Furthermore, insofar as possible, the most economical system should be selected to serve the life of the dwelling.

The cost analysis, for community sewerage systems and for on-site systems, must include all reasonable operating and maintenance costs associated with the systems. Moreover, where appropriate, the cost of establishing and operating public agencies to supervise construction, operation, and maintenance of the systems should be formulated.

Costs for Septic Tanks. Each system that incorporates a septic tank should include an evaluation of other pertinent costs, as follows:

- The cost of an initial construction permit (the permit will also cover the effluent disposal system)
- Initial cost of the septic tank installed
- Cost of pumping the septic tank at intervals not greater than once every 4 years
- If the tank is steel, the cost of replacement at 15-year intervals
- The fee for a periodic inspection at intervals no greater than 2 years (the inspection will also cover the effluent disposal system)

Costs for SAS's. The cost of an SAS, either subsurface or mounded, may be assumed to vary almost directly with the amount of infiltrative surface area provided. As the infiltrative surface area required by regulation varies widely from State to State, and in many cases from county to county, some common basis is necessary for the calculation of life-cycle costs that can be reasonably compared with the cost of other alternatives. The lack of uniformity in regulations is matched by disagreement in the scientific community with respect to the basis for design of the infiltrative surface area. McGaughey, Krone, and Winneberger[3] recommended consideration of only the sidewall area of the disposal trench. Bouma,[4] on the other hand, recommends consideration of only the bottom area of the disposal trench. Healy and Laak recommend use of both the sidewall and bottom area of the disposal trench as a useful infiltrative surface area.[5] For the disposal trench configurations most commonly required by regulations, sidewall area is about equal to bottom area, and probably either can be used. In any case, the most important factor in the design of an SAS is the provision of sufficient infiltrative surface, and a current conservative approach would therefore use either sidewall area or bottom area, but not total trench area.

The life of the individual SAS's will vary for any given design, depending on the site characteristics, household water use, and attention to septic tank pumping. Some systems will fail early and some will last indefinitely. SAS's should be evaluated to determine if they will, on the average, provide a level of environmental sanitation equivalent to that obtainable from conventional gravity sewerage systems. One way to approach such an evaluation is to define a "median" or "control" system that can be expected to last 15 years, on the average, before failure. Using a control system as a basis for comparison, any set of regulations may be used to compare septic tanks in an area assuming the following:

- The life of a properly installed SAS is directly proportional to the amount of infiltrative surface area, provided that the soil percolative capacity is above a limiting value.
- A gravity-dosed absorption system in fine-grained soils, having 450 ft^2 of infiltrative surface area to each bedroom, is defined as a control system. It will last for 15 years. A proportionately shorter life will result from a system having an infiltrative surface area with a lower ratio.
- An SAS, supplemented after failure with a second identical system and an alternating valve, may thereafter be operated by alternately resting each half. It will last for the life of the dwelling.
- Systems having a ratio below that of a control system will have to be supplemented at shorter intervals until the total installed infiltrative surface equals that of two control

systems. Thereafter, the systems may be rested alternately, and they will last for the life of the dwelling.

- Coarse-grained soils that permit clogging in depth at the infiltrative surface will accept higher application rates.[5,6] It is assumed that a control system for coarse-grained soils may be defined as 250 ft^2 of infiltrative surface area to each bedroom.

The cost evaluation for SAS's, based on the foregoing assumptions, should include the following items:

- Initial construction cost of the absorption system
- Cost of constructing a supplementary absorption system in accordance with the foregoing assumptions on design life
- For systems in which the septic tank effluent is pumped to the disposal field:
  - Initial cost of installing the pumping unit, complete with electric power and controls
  - Cost of replacing the pumping unit every 10 years for the life of the dwelling
  - Cost of power and maintenance for the pumping unit (maintenance cost should include at least one service call each year)

Costs for ET Systems. Each ET system must be preceded by a septic tank, with cost estimates as set forth in the foregoing paragraph. A very careful cost comparison should be made wherever septic tank-evapotranspiration-soil absorption system (ST-ETA) units are considered to be certain that ST-SAS units are not more cost/effective.

ET units may be expected to work in favorable climates where impermeable soils or high ground water prevents the use of SAS units. Lined beds are usually required in areas with high ground water. To date very limited information is available for use in developing a reliable prediction of the average life of ET units, but for the purposes of this discussion it is assumed that problems with salt buildup and bed linings will require complete bed replacement every 15 years. This criterion is assumed in lieu of more definitive information.

Costs for Sand Filters. A sand filter is subject to the same limitations on its useful life as an SAS. Unattended, its infiltrative surface will eventually clog, and it must be renewed periodically by scraping and replenishment of the sand. The filter structure may be expected to last indefinitely as long as it is adequately maintained. Sand filtration and direct discharge are assumed to include effluent disinfection. This is a high-maintenance system that the individual homeowner cannot be expected to maintain, and its use, even where permitted by regulatory agencies, should be supervised by a qualified public agency. A cost evaluation of sand filter systems should include the following:

- Initial construction cost that would include fencing for mild climates and a complete cover for severe climates
- Bimonthly inspection of the disinfection equipment and replenishment of chemicals, if required
- Cost of power and chemicals for disinfection
- Semiannual rejuvenation of the sand surface

- Replacement of the chemical feed equipment every 10 years

- All costs for septic tanks as set forth earlier

- If pumping to the filter is required, all costs for pumping as described for SAS's

Community Systems. The elements of community collection and treatment systems are well known; the costs therefore need little explanation. Nonetheless, in comparing a community system with individual on-site systems, it is important that the comparison be made over a time period that represents the life of the dwelling, and that it include all costs to the individual homeowner. The comparison should include the following costs:

- The installed cost of the community system, recognizing that the elements of a community collection system, except for mechanical equipment, ordinarily have a life expectancy of 50 years

- The installed cost of all on-site components of the community system, such as house connections and septic tanks, where required

- For pressure systems and small-pipe gravity systems, all of the costs associated with septic tanks as listed in an earlier paragraph

Summary

It is believed that the foregoing procedures for evaluation will identify with a minimum effort and maximum uniformity the most suitable alternative for handling small community sewage flows. The procedures allow for variations in local regulations and permit consideration of alternatives on the basis of equality of function over the life of the system.

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Chapter II

CASE HISTORIES

Chapter I described problem conditions that should be considered in analyzing wastewater systems for small communities, alternative systems that might be used as tools to overcome particular problems, and a recommended procedure for ascertaining which system or systems would be best suited for any one of a number of conditions. A set of five case histories drawn from recent facilities plans are next presented to show why and how relatively innovative and nonconventional wastewater systems have been developed, analyzed, and in some cases selected as the most cost/effective solution to a sewerage problem in a small community. Although not all alternatives described earlier in this paper are represented in the case histories, they do provide an overview of responses to small-community sewerage problems. The case histories do not represent examples of the proposed cost-analysis procedure described in the preceding section but are included as sources of information and knowledge. They were discussed in the Technology Transfer municipal design seminars for small wastewater treatment systems.

GLIDE-IDLEYLD PARK

Glide-Idleyld Park is an unincorporated community in Douglas County, Oreg., with a present population of about 2,500. The area is without public sewers at present, and all wastewater is treated in septic tanks and disposed of through drainfields. Numerous drainfield failures have occurred, however, because of unsuitable soils and high ground water conditions. As a result of the problem, the Douglas County Department of Public Works undertook a study of wastewater management for the area in 1975. The material for the case history is taken from that study.[1]

Physical Characteristics

Glide-Idleyld Park is located in a scenic setting along the North Umpqua River on a highway leading to Crater Lake National Park. The area is noted for fine trout fishing and scenic beauty. There has also been increased interest in recent years in home building in the area. The sewerage study revealed the following information with respect to the physical characteristics of the area.

Climate. The region has a temperate climate with moderately warm summers and wet but mild winters.

Soils and Geology. Claylike soils are found throughout the study area, but outcroppings of rock occur near the surface in some areas.

Ground Water. High ground water is prevalent throughout the study region. Although abundant evidence of surface water pollution was presented in the report, the extent of ground water pollution as a result of failing drainfields was unknown.

Topography. The physical features of the study area are widely varied, which appeals to the many visitors to the area. The terrain varies from gently rolling fields to steeply sloping hillsides with solid rock in many places.

Site Characteristics. The total study area contains approximately 13,000 acres, is 11 miles in length, and averages 1.75 miles in width. At present, most of central Glide is divided into lots ranging from 20,000 ft^2 to 1 or 2 acres. Many of the lots do not lend themselves to subdivision. Present low-density residential areas have a preponderance of 1-acre to 7-acre parcels, few of which could be subdivided. Densities used for future planning were 1 acre for 1.5 homes for the more urban portions of the study area, and 2 acres for a home in the outlying areas.

Alternatives and Screening Process

Although no screening process is explicitly presented in the sewerage study, the following facts provide a basis for detailed analysis of the alternatives.

- Of the existing ST-SAS units, 60 percent are failing.
- Analysis of soils in the area showed that a very limited portion was suitable for installation of drainfields because of the predominance of claylike and rocky soils. In some areas, shallow surface soils overlie basalt bedrock.
- Three previous studies of the area had recommended community sewerage. The suggested design was conventional gravity sewers.
- Public response in surveys and at public meetings indicated that almost 80 percent of the residents favored installation of sanitary sewers.
- Cost had prohibited action on any of the initial three sewerage plans.
- In 1974 the County Engineer's Office had conducted a study of pressure sewers. The report contains the following paragraph in the opening discussion: "Though there are similar systems, such as vacuum sewers, or wastewater quantity reduction by reuse of 'grey water,' it is believed pressure sewers hold the most promise in difficult terrain and where a number of homes are of concern."[2]

As a result of the foregoing factors, the cost/effectiveness analysis in the sewerage study examined two methods of wastewater collection: pressure sewers and conventional gravity sewers. In addition, two types of treatment were considered, both disposing of final effluent by discharge to the North Umpqua River during the winter and by land application during the low-flow summer months.

Cost/Effectiveness Analysis

An analysis of cost/effectiveness of alternatives for community sewerage in Glide-Idleyld Park included the collection system and the treatment and disposal system. Emphasis in the study was given to the collection system, as it had been the most expensive item in previous studies.

Collection System. Construction costs and operation and maintenance costs are presented in the Douglas County report in terms of present worth.

Unit construction costs for the conventional collection system alternative were obtained from county, State, and Federal data, and information from two consulting engineering firms. Operation and maintenance costs were obtained from local sewerage agencies in terms of dollars per mile of line and dollars per person served. A detailed analysis of the required lengths and sizes of the conventional system components was conducted that include estimates of the segments of force main and the amounts of rock excavation needed. The resulting costs of the conventional system are shown in table II-1.

Table II-1.—*Cost of conventional collection system, Glide-Idleyld*
[Dollars]

Component	Present worth[a]		
	Construction	Operation and maintenance	Total
Gravity mains	2,523,400	104,900	2,628,300
Pressure mains	424,400	38,700	463,100
Rock excavation	169,000	0	169,000
Service connections	515,200	0	515,200
Mainline pump stations	772,000	118,000	890,000
Total	4,404,000	261,600	4,665,600

[a]Rounded to nearest $100 and calculated using 5.875 percent interest over a 20-year design period.

Unit construction costs for the pressure sewer collection system alternative were more difficult to obtain. The county gathered the costs from national suppliers of materials and local contractors to get the best possible data on labor and equipment needs for installing pipelines, pumps, septic tanks, and electrical instrumentation. The service connection at each home was laid out to include pumping of septic tank effluent from a small wet well to the local pressure collection sewer. In the design, 612 existing homes and small businesses were to be served by 568 pumps at an overall average cost of $1,155 per connection, excluding treatment and collection system costs. Operation and maintenance costs were obtained from agencies throughout the United States currently using pressure sewer systems, from suppliers of effluent pumps in Oregon, and from the local water supply agency. In terms of 1975 prices, each pumping unit was estimated to require $50 per year in maintenance, and the pipelines were estimated to cost $100 per mi/yr. The resulting costs for the pressure sewer collection systems are shown in table II-2.

A comparison of tables II-1 and II-2 shows that the total present worth of the pressure sewer system is almost exactly one-half the cost of the conventional collection system, a difference of $2.3 million. As expected, operation and maintenance costs for the pressure sewer system are higher than for the conventional system. The costs are more than 60 percent, or $166,000 higher, but the initial cost of the pressure system is only 44 percent of the initial cost of the conventional system, amounting to a savings of almost $2.5 million.

Treatment Plant. Inasmuch as treatment and reuse of effluent is not feasible in the Glide area and insufficient land is available to rely on land application as a year-round disposal method, treatment and river discharge with summer land application was chosen as the only practical alternative. Two methods of treatment were considered: extended aeration with effluent polishing by microstraining and aerated lagoons followed by intermittent sand filtration. As noted in the report, "The extended aeration option is common in Oregon and found to be generally acceptable. Lagoons, however, have not been generally accepted due to poor effluent quality." As no intermittent sand filters were in operation in Oregon at the time the study was being conducted, it was not known if the State Department of Environmental Quality would accept such a recommendation. Therefore, for the purposes of the study, extended aeration and microstraining were used for determination of user charges for a complete project. At the same time, the county stated its intention to continue evaluation of the cheaper lagoon-sand filtration alternative. Comparative costs for the two treatment systems are shown in table II-3.

User Charges

An assessment of user charges for the recommended project—collection by pressure sewers and treatment by extended aeration, microstraining, and summer land application—was also made. Components for the initial cost and the operation and maintenance costs for a single-family residence are shown in table II-4.

Table II-2.—*Cost of pressure sewer system, Glide-Idleyld*
[Dollars]

Component	Present worth[a]		
	Construction	Operation and maintenance	Total
Pressure mains	900,900	28,900	929,800
Service connections	853,700	374,300[b]	1,228,000
Rock excavation	126,000	0	126,000
Mainline pump stations	76,000	24,700	100,700
Total	1,956,600	427,900	2,384,500

[a]Rounded to nearest $100 and calculated using 5.875 percent interest over a 20-year design period.
[b]Includes both initial and future connections.

Table II-3.—*Comparison of glide area treatment costs*
[Dollars]

Process[a]	Construction cost	Annual operation and maintenance cost
Extended aeration plus microstraining	350,000	28,000
Stabilization ponds plus intermittent sand filtration	150,000	5,000

[a]Each facility sized for a 0.3 mgd design capacity.

Table II-4.—*User charges for a single-family dwelling, Glide-Idleyld*
[Dollars]

Item charged	Initial cost	Annual cost
Initial assessment for system cost and lot hookup[a]	1,500	–
Annual charge for initial assessment at 6 percent interest over 20 years	–	129
Annual operation and maintenance charges[b]	–	114
Total annual charge to initial singlefamily users	–	243

[a]Assessments for future hookups were estimated to be $1,800, or $300 more than for initial users.
[b]An annual charge for septic tank pumping is included in the annual operation and maintenance charge, based on local rate of $35 for pumping a single tank.

BELLEVUE

Bellevue is a community of approximately 550 persons located in south-central Idaho. The case history presents a cost/effectiveness analysis of the alternatives of either continuing the use of individual subsurface disposal systems or installing conventional gravity sewers in the community. The description and analysis are taken from a facilities plan prepared for Blaine County, Idaho.[3]

Physical Characteristics

The physical characteristics described in the report include climate, soils and geology, ground water hydrology and quality, topography, and site characteristics.

Climate. At an elevation of 5,200 feet, Bellevue has a long winter and a short, rather cool summer. The mean annual snowfall is approximately 100 inches, most of which falls between November and March. Mean daily minimum temperatures are usually below freezing from September through May.

Soils and Geology. As part of an ancient lakebed, the ground beneath Bellevue is composed of alternating layers of clay, sand, silt, and gravel. The soil in the vicinity of the community is characterized principally as a well-drained, shallow, gravelly loam. It has been described by the Soil Conservation Service as poor for subsurface disposal because of its coarse texture, creating a considerable possibility of ground water contamination.

Ground Water. Depth to ground water in and around the community is as a rule more than 25 feet. Ground water quality is excellent above and below Bellevue and is currently suitable for domestic and agricultural uses. Samples taken below Bellevue, particularly with respect to the direction of ground water flow, show that no perceptible change has occurred in ground water quality over the past 20 years.

Topography. The ground surface is quite flat within the present community and in the areas immediately adjacent to the present city limits. The maximum slope in the area is approximately 5 percent.

Site Characterization. Although the city limits enclose an area of about 500 acres, the sizes of existing lots were not available to the study. The cost/effectiveness analysis, however, considered a range of costs for various lot sizes.

Alternatives and the Screening Process

The two basic alternatives considered for Bellevue were: continuing the use of the ST-SAS's and installing community sewers followed by some form of treatment and surface discharge. On-site alternatives, other than the ST-SAS's, were not considered for the following reasons:

- Present ST-SAS's have experienced a low failure rate.
- No ground water degradation is noticeable in wells downstream of the community in samples taken 20 years apart.
- Population growth projections do not indicate that ground water degradation will be a future problem.
- Ground water depths and soil permeabilities are suitable for the use of the ST-SAS.

Cost/Effectiveness Analysis

An analysis of the cost/effectiveness of the use of the ST-SAS for the community of Bellevue is presented in two parts. The first part covers an analysis of total annual costs of a new ST-SAS compared to the annual cost of collection sewers for various lot sizes. The second covers the total annual cost of a complete sewerage system composed of collection and trunk sewers and three types of community treatment systems.

Homeowner Costs. The cost of septic tank-drainfield systems is relatively constant regardless of lot size, assuming that initially there is sufficient acreage to handle the required system and that the topography and soil types are suitable. In contrast, community sewerage cost to the homeowners varies directly with lot size. As the size of lot is reduced and as the proximity of the houses to one another increases, the overall cost of sewers to the homeowner is reduced, as the cost for the same length of sewer line is divided among an increased number of homeowners. It is therefore possible to compare the cost of septic tank-drainfield systems with the varying costs of community sewerage to determine the size of lot at which it becomes more economical to use a community waste treatment and disposal system. Nonetheless, comparison in terms of cost alone should not be the only factor in determining minimum lot size for septic tank systems. Although cost can be a limiting condition for planning purposes, other factors must be considered as, for example, availability of a public water supply and public acceptance of septic tanks. If all other factors are equal, public sewers should not be planned for residential areas if the overall cost is going to be more than for septic tank systems.

The cost of septic tank systems in Blaine County is presented in table II-5. Installation costs were obtained from local installers. The overall cost estimate is based on construction of a three-bedroom home, using Idaho regulations and assuming a percolation rate of 10 min/in. The resulting design criteria is 165 ft^3 per bedroom. The annual costs were computed for a 20-year period at 8 percent interest. Operational and maintenance costs included the periodic cost of pumping the tanks and the administrative cost associated with a proposed maintenance district. Operation and maintenance costs also include an allowance for a maintenance district. If the construction of such a district is either delayed or ignored, the cost to the homeowner will, of course, be less.

Costs of community sewerage consist of three basic items: construction and maintenance of collection sewers; construction and maintenance of trunk sewers; and construction, operation, and maintenance of some type of community waste treatment and disposal system. An estimate of the cost of collection sewers alone was made in terms of construction costs and assessment formulas, in two nearby localities in which community sewerage systems had been constructed within the past 5 years. The results of that estimate are shown in figure II-1.

It is apparent from a review of table II-5 and figure II-1 that at a 1-acre gross lot size, the annual cost of an ST-SAS equals the annual cost for local collection sewers alone. In developing areas, between 25 and 40 percent of the gross lot size is normally used for streets, schools, public facilities, and small commercial zones. An even smaller lot size is more economically served by septic tank systems, given the costs of trunk sewers, treatment, and disposal. The cost to the homeowner for the septic tank systems, however, may not be more than 10 to 25 percent of the actual cost, because of State and Federal grants. The break-even gross lot size may be as low as 0.25 acre if expensive forms of treatment and disposal are necessary. In these cases the governing factors on lot sizes for ST-SAS use will be setback distances and the possible requirement for a replacement drainfield. An estimate of homeowner costs for conveyance and treatment, excluding the influence of grant monies, ranged from $60 to $150 per dwelling, depending on the type of treatment. The lower value was for land application by infiltration-percolation and the higher value was for tertiary treatment and river discharge.

Community Costs. Costs determined for Bellevue in the study included initial construction cost, average annual operation and maintenance costs, annualized construction cost, and total

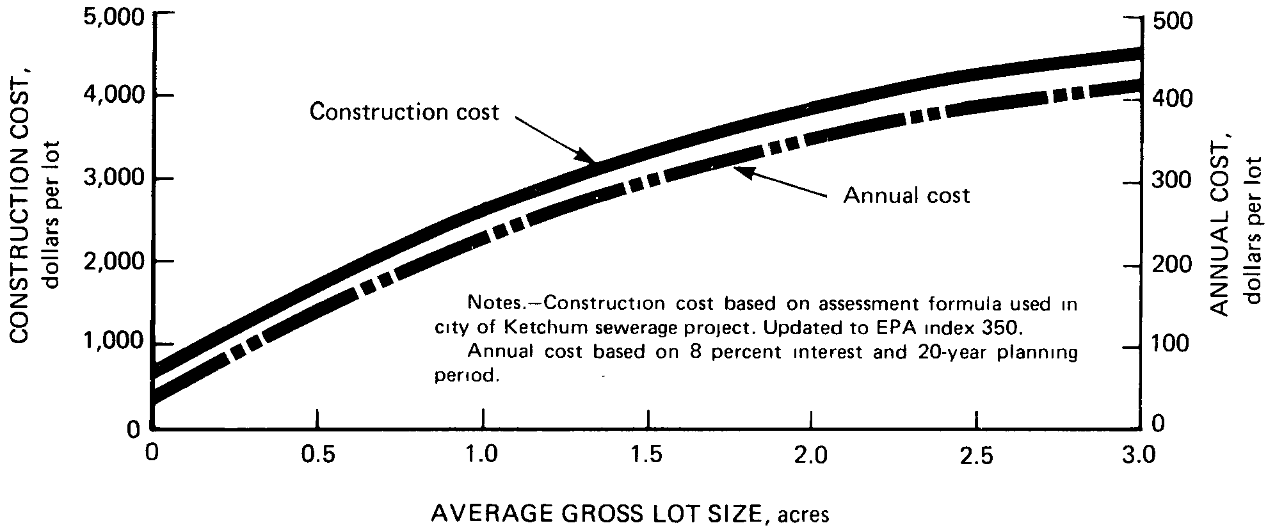

Figure II-1. Cost of sewerage systems, Bellevue.

Table II-5.—*Estimated construction and maintenance cost for individual disposal systems, Bellevue*
[Dollars]

Septic tank system costs	Construction cost[a]	Annual cost
Initial installation:		
Septic tank, 1,000 gallons	370	–
Drainfield, 250 lineal feet	1,250	–
Permit[c]	20	–
Total	1,640	150[b]
Replacement drainfield	1,250	38[b]
Operation and maintenance costs:		
Administrative cost of		
Septic tank maintenance district	–	30
Septic tank pumping ($80 every 4 years)[c]	–	20
Total	–	238

[a]All costs are based on an EPA index of 350.
[b]Based on 8 percent interest and a 20-year planning period. The replacement drainfield is assumed to be required after 10 years, and the economic life of the entire septic tank system is assumed to be 40 years.
[c]Based on information from the County Health District.

annual cost. The annualized construction cost was calculated on the basis of a 20-year period and an interest rate of 6.125 percent. Table II-6 shows cost comparisons of the continued use of the ST-SAS and construction of collection sewers that would include various types of treatment and disposal. In broad terms, use of the ST-SAS is 30 percent less expensive in total annual cost than the least expensive form of community sewerage. This would still hold true even if allowance were made for the conservative assumption of implementation of a maintenance district.

Table II-6.—*Community sewerage costs, Bellevue*
[Thousand dollars]

Waste management option	Construction cost	Annual construction cost	Average operation and maintenance cost	Total annual cost
ST-SAS	1,400[a]	115	44	159
Collection sewers, gravity	1,330	094	4	098
Collection sewers plus activated sludge treatment	2,720	203	52	255
Collection sewers plus activated sludge plus removal of nitrogen and phosphorus	3,430	270	87	357
Collection sewers plus conveyance plus lagoon treatment plus disposal by infiltration-percolation	1,910	144	65	209

[a]Includes new ST-SAS and drainfield replacement after 10 years for new homes. For existing dwelling units, only drainfield replacement cost is included.

Given the previously determined facts that there were no overriding detrimental social or environmental impacts, continued use of the ST-SAS was recommended for Bellevue.

WESTBORO

Westboro is a community of 200 persons located in Taylor County in northcentral Wisconsin. At present, it has no municipal wastewater collection or treatment system, and all buildings in the community are served by septic tank systems, 80 percent of which were found to be discharging wastes to the ground surface in 1971. Although a wastewater plan was developed in 1967, prohibitive costs and lack of available Federal funding have prevented implementation of a community sewerage system. In the interest of alleviating their sewage disposal problems, the Westboro residents agreed to cooperate with the Small Scale Waste Management Project (SSWMP) of the University of Wisconsin in an effort to develop an alternative plan that might result in a more cost/effective facility. The material for the case history is taken from the report of that investigation.[4]

Physical Characteristics

The Westboro Sanitary District encompasses segments of Silver Creek as it flows southward to the east of the town center and then turns westward along the southern edge of the community. The decline of the lumber industry reduced the population from 900 at the turn of the century to the present 200 residents. It left the community with a cheese factory, a small machine tool company, and a sawmill to provide local employment. A summary of the physical information reported by the SSWMP follows:

Climate. No specific climatic information was given in the project report, but Westboro is located in an area of Wisconsin that has, on the average, relatively short, mild summers and long, cold winters.

Soils and Geology. The soils in and around Westboro are primarily deep, well- to somewhat poorly drained loams and silt loams over sandy glacial till. The populated areas of the community are usually located on soils judged unsuitable for septic tank systems. Suitable soils can be found within the city limits, including thick deposits of well-graded sand in one location. Mucky peat soils predominate in the southern half of the community.

Ground Water. The report provides no direct information on ground water depths. The existence of the mucky, peat soils in the southern half of the community, however, indicates near-surface levels in that area, but ground water levels are apparently much lower in the northern half of town. Well monitoring since March 1975 has shown 7 of 30 wells sampled to be bacteriologically unsafe, one of which has also had nitrate concentrations consistently above the drinking water standard of 10 mg/l nitrogen.

Site Characteristics. There are no steep slopes in the community. The central area of Westboro, known as the Front Street area that includes the business district, is divided into small lots approximately 50 by 150 feet in size.

Alternatives and Screening Process

As a result of the sanitary survey taken in 1971, the Wisconsin Department of Natural Resources had declared the sewage disposal situation to be a nuisance and a menace to health and comfort. It had issued an order to Westboro to construct a community collection and treatment system or prohibit sewage discharge from private homes into Silver Creek. The initial 1967 study and the latest study were completed under this order. With respect to the screening process to develop alternatives, the SSWMP report revealed the following facts:

- Lot sizes and soils prevent the replacement of most of the failing septic tank systems, thereby eliminating the choice of alternative.
- The community was divided geographically into five separate areas.
- It was believed that two of the five areas were too sparsely developed for a collection system. Soils were judged suitable for either a conventional ST-SAS or an ST-Mound system. Individual systems were therefore recommended as the cost/effective solution.
- In two of the remaining three areas, physical conditions were also judged suitable for individual systems of some type, but it was decided that a common collection system offered the greatest advantage because of the density of homes.
- A collection system was also considered the best alternative for the fifth area, the central area that includes the business district and homes with lot sizes too small to permit the construction of replacement drainfields or other on-site treatment and disposal alternatives.

Several alternatives were to undergo cost/effectiveness analysis to ascertain their ability to serve the three areas considered worth sewering. Two areas (the Front Street central area and Joseph's Addition) were combined in each of the alternatives, because of the limited number of disposal sites available in each separate area. Alternatives for these two areas included using both pressure and small-diameter gravity sewers to convey septic tank effluent for disposal in a sand bank east of town along Silver Creek.

Four alternatives were considered for the remaining area (Grossman's Addition).

- Pressure collection of septic tank effluent and disposal with the Front Street and Joseph's Addition areas

- Small-diameter gravity sewer collection of septic tank effluent with the following disposal alternatives:

  — Pumping to the Front Street and Joseph's Addition gravity system

  — Soil Absorption

  — Sand filtration-chlorination and discharge to Silver Creek

Cost/Effectiveness Analysis

The analysis of the cost/effectiveness of the aforementioned conventional gravity sewer alternatives and the new alternatives included consideration of total cost at present worth, consideration of environmental impact, and a determination of system reliability. Cost analyses were based on a 20-year system life and 7 percent interest. Service connection costs were not included in the alternatives.

Conventional Alternatives. Costs of the alternatives analyzed in 1967, involving use of conventional gravity sewers, a community treatment plant, and surface water discharge, were updated. The cost of installing new individual systems in the two sparsely populated areas was added to each of the alternatives to permit comparison with the six new alternatives examined by SSWMP. The present worth of the two conventional systems is shown in table II-7. The two systems were 17 to 20 percent more costly than the least expensive new alternative analyzed subsequently, and neither conventional alternative was recommended for implementation.

New Alternatives. The present worth of the six new alternatives was determined and are given in table II-8. Of the new alternatives, alternative 5 is the least expensive, costing $266,416, or approximately $3,861 for a household. The cost for each household is significantly less than the cost of conventional alternatives 1 and 2 ($4,614 and $4,838, respectively).

The environmental impact of new alternative 5 was expected to be minimal. Only nitrogen in the form of nitrate was expected to leach through the soil to the ground water basin in significant amounts. Some of the nitrogen was also expected to reach Silver Creek owing to the short distance between the soil absorption field and the creek.

Table II-7.—*Cost comparison of conventional alternatives, Westboro*
[Thousand dollars]

Alternative	Present worth[a]			
	Collection	Treatment	Individual systems	Total cost
1. Conventional gravity sewers plus extended aeration package plant plus discharge to Silver Creek	136.3	170.1	12.0	318.4
2. Conventional gravity sewers plus raw sewage stabilization pond discharge to Silver Creek	136.3	185.5	12.0	333.8

[a]Includes both capital and operation and maintenance costs.

Table II-8.—*Cost comparison of new alternatives, Westboro*
[Thousand dollars]

Alternative	Present worth[a]				
	Grossman's addition (part A)	Front St. and Joseph's addition (part B)	Joint system[b]	Individual systems	Total cost
1. Part A: small-diameter gravity sewers to drainfield; part B: small-diameter gravity sewers to drainfield	124.5	145.2	269.7	12.0	281.7
2. Part A: small-diameter gravity sewers to drainfield; part B: pressure sewers to drainfield	124.5	185.3	309.8	12.0	321.8
3. Part A: small-diameter gravity sewers to drainfield; part B: small-diameter gravity sewers to drainfield	148.0	145.2	293.2	12.0	305.2
4. Part A: small-diameter gravity sewers to sand filter; part B: pressure sewers to drainfield	148.0	185.3	333.3	12.0	345.3
5. All small-diameter gravity sewers to single drainfield	([c])	([c])	254.4	12.0	266.4
6. All pressure sewers to single drainfield	([c])	([c])	294.2	12.0	306.2

[a]Includes both capital cost and operation and maintenance cost.
[b]Sum of costs for part A and part B.
[c]Individual cost not given in report.

Finally, in selecting new alternative 5 the report states:

> The reliability of this type of facility has not been established, but its selection is warranted because it is designed from extensive experience with smaller systems and its cost and environmental impact are a significant improvement over the conventional central facilities.

Since completion of the project report, decisions have also been made to serve the sparsely developed Queenstown and Appaloosa Lane areas of Westboro with small-diameter gravity sewers. In the Queenstown area, site investigation for possible design of ST-Mound systems showed that there was insufficient area on the occupied lots to construct the intended system, and adjacent land could not be purchased. In the meantime, the Westboro Sanitary District decided that it would also be beneficial to extend small-diameter gravity sewers to, and slightly beyond, the Appaloosa Lane area. At present, therefore, it appears that the entire community will be served by a sewerage system composed of individual septic tanks, small-diameter gravity sewers, and a community SAS.

FOUNTAIN RUN

The city of Fountain Run is located in Monroe County, in southcentral Ky. The planning area for the 201 Study is the area served by the Fountain Run Water District, including the city of Fountain Run and a portion of Monroe County. The study area is without a public sewerage system at present, and all wastewater is disposed through either ST-SAS's or privies. Of the existing ST-SAS units, approximately 20 percent are located on soils with permeabilities of less than 0.5 in/h. Moreover, an estimated 30 percent of the systems are, at least, producing surfacing effluent during the winter months. All material for the case history is taken from the facilities plan for the area.[5]

Physical Characteristics

The study planning area covers about 2,240 acres in the western portion of Monroe County. The population of the county and the city of Fountain Run declined significantly during the 1960's, leaving approximately 320 people in the city and some 440 in the water district. Detailed physical characteristics follow.

Climate. The climate in the Fountain Run planning area is temperate. Freezing temperatures occur on fewer than 85 days annually, and there are approximately 50 days with maximum temperatures above 90° F. The average annual snowfall and total precipitation depths are 10 inches and 50 inches, respectively. Estimated annual evaporation is 40 inches.

Soils and Geology. Bedrock in the study area is limestone, interbedded with chert and dolomite. The soil is described as predominantly deep, well-drained, claylike, and loamy. According to information provided by the Soil Conservation Service, a substantial portion of the area within the city limits has no limitations on subsurface disposal systems. As noted earlier, however, about 20 percent of the existing systems are located on soils with permeabilities of less than 0.5 in/h.

Ground Water. Limited information was available to the facilities plan investigators. One well located south of the planning area is reported to have a depth of 39 feet. The report contains no information with respect to ground water quality. No public water supplies use ground water sources, however, as they are inadequate, from a hydraulic standpoint, to sustain the withdrawal rates required for domestic consumption.

Site Characteristics. The planning area lies in the upper reaches of two small watersheds and contains gently rolling hills and moderate slopes having elevations from 700 to 850 feet. Lot sizes are usually over 0.75 acre. The smallest lot in Fountain Run is approximately 12,000 ft^2, or slightly larger than one-quarter acre.

Alternatives and the Screening Process

A separate, explicit screening process is not presented in the facilities plan for Fountain Run. The following facts form the basis for analysis of a limited set of wastewater management alternatives:

- Optimum operation of existing individual disposal systems was considered, but it was judged impractical to try to upgrade them to the level of current septic tank system technology.
- Implementation of any regional solution was also quickly rejected as the closest town, in a neighboring county, is 12 miles away, and an estimate of the capital cost of an interceptor system to deliver Fountain Run's sewage to the neighboring town exceeded $1 million and was nine times more expensive than any local alternative.
- A previous engineering report on sewerage for Fountain Run had been prepared using conventional gravity sewers with oxidation pond treatment. The data from that study were available to be updated as one alternative.
- A substantial portion of the soils within and adjacent to the city limits is suitable for disposal by soil absorption.

As a consequence of the preceding factors, four alternatives were considered. They are:

A. A conventional gravity sewer collection system with one of two types of treatment: (1) a package, complete-mix, activated sludge unit followed by soil infiltration-percolation and (2) an oxidation lagoon with infiltration-percolation disposal

B. Community-wide collection by an effluent sewer system consisting of individual septic tanks with siphons or pumps and small-diameter plastic pipelines carrying partially treated sewage by pressure and gravity; treatment in an oxidation pond and disposal by infiltration-percolation

C. The collection of septic tank effluent for clusters of houses in small-diameter pressure and gravity sewers; disposal in SAS's in suitable soils; individual septic tank systems used where appropriate

D. Completely individual on-site disposal throughout the community, with 20 percent of the systems forced to rely on nonstandard systems because of soil conditions

Cost/Effectiveness Analysis

An analysis of the cost/effectiveness of alternatives for sewerage in the Fountain Run Water District included detailed cost estimates of collection and treatment systems and an environmental assessment. All cost analyses were put in terms of present worth for comparison, using a 20-year design period and an interest rate of 6.125 percent. The salvage value of all capital expenditures was estimated and subtracted from total present worth (capital plus operation and maintenance costs) to determine net present worth.

Alternative A. The collection system for this alternative included over 20,000 feet of 8-inch line, 1,800 feet of 6-inch line, a pumping station, and 600 feet of force main. The total construction cost for the collection system was estimated to be $339,600, with an estimated annual expenditure of $9,000 for operation and maintenance. Net present worth of the collection system after subtracting salvage value, but including operation and maintenance costs, was determined to be $390,100. Two methods of treatment were examined and selected on the basis of the consultant's past experience with treatment systems for small communities. Net present worth of the 2-acre oxidation pond, including operation and maintenance costs, was $81,600, and that of the package activated sludge unit was $89,500. Three types of disposal systems were analyzed for alternative A: an intermittent sand filter system and effluent discharge, spray irrigation, and infiltration-percolation. Including operation and maintenance costs, net present worth of the three disposal systems came to $61,100, $74,900, and $53,900, respectively. Infiltration-percolation was therefore chosen as the disposal method used in alternatives A-1 and A-2 (shown in table II-9). Present worth for both alternatives is also given in table II-9.

Alternative B. The collection system for alternative B included about 20,000 feet of 2- to 4-inch plastic pipe without manholes. Some would be pressure lines, but most were designed to accept gravity flow. Also included in the collection system were some 3,800 feet of 8-inch gravity line, septic tanks with siphons or pumps, five larger main-line pumps, and one pumping station. Operating costs included in the net present worth of the collection system were pump operation and maintenance, septic tank pumping on a 5-year cycle, and flushing of small-diameter lines as needed. Net present worth of the alternative B collection system alone, including operation and maintenance costs, was estimated to be $246,900. Community treatment and disposal for the alternative B system was the same oxidation pond and infiltration-percolation basin combination used in alternative A-2. The component costs of alternative B are shown in table II-9.

Alternative C. Design criteria for the SAS's used in alternative C included an assumed average household wastewater flow of 200 gal/d and an application rate of 0.33 gal/ft^2/d (approximately 400 ft^2 per bedroom) to the trench sidewalls in each of two half-systems (600 ft^2 per half-system)

Table II-9.—*Cost comparisons of alternatives, Fountain Run*
[Thousand dollars]

Alternative	Present worth				
	Construction cost[a]			Operation and maintenance	Total cost
	Collection	Treatment and disposal	Combined collection, treatment, and disposal		
A-1	287.9	47.9	335.8	197.8	533.6
A-2	287.9	86.1	374.0	151.6	525.6
B	176.9	86.1	263.0	119.4	382.4
C	–	–	228.2	74.5	302.7
D	–	–	206.4	61.9	268.3

[a]Includes initial and 10-year expansion costs, less salvage value.

to be used in alternate years. Public management of all on-site and community wastewater facilities was considered critical to the alternative. Homes were grouped in several patterns before the final selection was made. The object was to achieve an optimum mix that would provide disposal to the most suitable soils by means of a low cost, simple operation. It should also be able to accommodate future growth. The resulting design included 22 individual on-site systems and 22 systems with two or more households or businesses using a common disposal field. The 22 community systems called for construction of 950 feet of 8-inch gravity sewer, 10,400 feet of 4-inch gravity sewer for septic tank effluent, and 1,200 feet of 2- and 3-inch lines for septic tank effluent. Operation and maintenance costs were assumed to include pump operation and maintenance, line flushing and repair, servicing septic tanks on a regular schedule, inspection of disposal field condition, repair and mowing of disposal fields, and periodic alteration of flow in the fields. The costs were estimated to total $6,110 per year. Components of the total present worth of $302,700 for the alternative are shown in table II-9.

Alternative D. Because on-site disposal was being used with some degree of success in the area, the consultant considered community management of individual on-site systems as an alternative. The cost analysis used construction costs of $1,200 for standard ST-SAS units and 50 percent more, or $1,800 per unit, for construction of nonstandard systems for the existing 20 percent of the systems located in soils described as having severe limitations for subsurface disposal. Total present worth of alternative D was determined to be about $268,300 as shown in table II-9.

Evaluation of Alternatives. The on-site disposal alternative (D) not only had the lowest total present worth of all alternatives evaluated, but was also given the highest rating with respect to environmental impact. The report also states, however, that the difference in estimated cost between alternatives C and D was probably less than the level of precision used in estimating alternative D. In addition, there was no significant difference in the environmental rating of any of the five alternatives. From the standpoint of implementation, alternative D was not recommended, because of uncertainty of the actual costs of systems required in areas with poor soils. Public opinion, including that of the Water District Commissioners, favored alternative C. Considering all factors, alternative C, community subsurface disposal, was selected as the recommended plan, and a user charge of $7.10 per month was estimated necessary to support the wastewater services provided by the selected plan.

EAST RYEGATE

The community of East Ryegate, Vt., is one of three villages that make up the town of Ryegate in the southeastern corner of Caledonia County, in the Connecticut River Valley. At the time the facilities plan for East Ryegate was being conducted, a small combined collection sewer system served the estimated 140 persons in the community and discharged raw sewage into the Connecticut River and into a small drainage channel. The NPDES permit compliance schedule for Fire District No. 2 of East Ryegate required that a subsurface disposal system be in operation by June 1, 1976. The report that serves as the basis of the case history is a revision of an August 1972 report.[6]

Physical Characteristics

Soils, ground water, and site characteristics of the study area are described below. Climate was not described in the facilities plan, as it did not bear on any of the alternatives evaluated.

Soils. Information taken from soil borings made during the investigation indicated that the soils beneath the village are composed of sandy loam, coarse sand, and silty gray clay. The clay layer appears to exist beneath the entire study area and varies from 2 feet below the surface in the western corner of the village to 12 feet in the village center. Percolation rates in most soil borings were less than 10 min/in; many were on the order of 1 min/in.

Ground Water. Ground water is found below the impervious clay layer throughout the study area. Test pits dug south of the community in October, 1973 showed ground water levels varying from a minimum depth of 4.5 feet to over 10 feet. The report contains no information relative to ground water quality. It can be assumed that present quality is adequate for domestic uses, as the community water supply well is located in the village center, and it supplies untreated water for domestic use.

Site Characteristics. Terrain throughout the village of East Ryegate is quite flat, with ground elevations ranging from about 470 to 490 feet above sea level. Although no specific lot sizes are described in the report, it does state that the 40 dwellings in the study area are located in a dense settlement and that many of the lots do not have enough open area to accommodate an 1,800-ft^2 drainfield.

Alternatives and Screening Process

The investigation selected four basic alternatives for study, one with five variations. The alternatives were as follows:

I. No action

II. Treatment and water reuse

III. Municipal extended aeration

IV. Septic tank and subsurface disposal

   a. individual private systems

   b. joint private systems

   c. individual-municipal system

d. municipal system-gravity flow

e. municipal system-force main

The screening process for the alternatives involved analyzing each from the standpoint of several questions.

- Does the alternative comply with State regulations and Federal guidelines?
- Does the alternative offer the best treatment process for the costs involved?
- Is the alternative capable of meeting the implementation schedule for the district as set forth by the NPDES permit?

Alternatives I and II were both eliminated in the initial screening phase, as alternative I does not comply with either State or Federal requirements and alternative II does not comply with the laws of the State of Vermont.

Cost/Effectiveness Analysis

Following elimination of alternatives I and II, those remaining were examined. Present worth analyses were based on the use of a 20-year design life and 7 percent interest.

Alternative III. This plan, proposed initially in a consulting engineer's report in 1970, would use an addition to the existing collection system to convey the community's sewage to a package extended aeration plant. It has two advantages: it would end the pollution of surface streams and it proposes a feasible treatment method, but in contrast, it involves high operation and maintenance costs and requires more power than any other alternative. Furthermore, the costs include extensive use of the existing collection system that the State Department of Water Resources subsequently determined to be inadequate on the basis of an infiltrative inflow analysis. Vermont's cost/effective solution was construction of a new collection system for sanitary sewage only and retention of the old system as a storm sewer. The actual construction costs of the collection system for the alternative are higher, therefore, than the $96,000 included in the total capital cost in table II-10.

Alternative IVa. Installation of private septic tank systems for each individual residence in East Ryegate assumes that every residence can be served by such a system. As a practical matter, the

Table II-10.—*Cost comparison of sewerage alternatives for East Ryegate*
[Dollars]

Alternative	Total capital cost	Average annual operation and maintenance cost	Present worth[a]
III. Municipal extended aeration	253,200	6,100	302,900
IVa. Individual subsurface systems	33,000	900	42,500
IVb. Joint private systems	38,500	900	48,000
IVc. Individual-municipal system	129,800	2,000	145,300
IVd. Municipal system-gravity flow	312,000	1,600	310,400
IVe. Municipal system-force main	271,700	2,000	274,300

[a]Present worth of salvage value deducted for all alternatives using community facilities.

report lists several obstacles to that assumption: the soils fronting on one of the four streets in the village overlie a clay layer less than 2 feet from the ground surface; only a few dwellings have as much as 1,800 ft^2 of open area in which to construct an ST-SAS; and if systems could be placed on all lots, the leachate from those in the central part of the village would flow toward the public water supply well. The costs shown in table II-10 assume that each residence can install a properly designed ST-SAS at a cost of $1,100.

Alternative IVb. In an attempt to improve the possibility of individual disposal, alternative IVb was developed. It proposes the combining of wastewater from several dwellings in small collection systems with disposal to lots that have suitable soils and size to accommodate the combined flow. It would therefore comply with State regulations. The disadvantages are that: there may not be sufficient suitable lots to serve all dwellings, and the issue of ownership and user's rights may be raised when neighbors start discharging wastes to one another's property. The difference in capital cost in table II-10 between the two alternatives, IVa and IVb, is attributed to engineering, land, and administrative costs.

Alternative IVc. An attempt to provide a communitywide system for those dwellings that cannot be served by Alternatives IVa or IVb prompted Alternative IVc. The residences that could use subsurface disposal would not be permitted to connect to the municipal system under this alternative. The community system would be designed to collect wastewater flows into an interceptor for conveyance by either gravity or force main to a municipally owned and operated ST-SAS. The time required for inspection of lots and for notifying owners of the decision that they are to construct an individual system or connect to the community system might exceed the time allowed in the NPDES permit compliance schedule. Moreover, the cost of the community system could be prohibitive for the small number of owners that would connect to it initially. Of the total capital cost shown in table II-10, about $83,000 is for collection and disposal, $12,500 for treatment, and $34,000 for engineering, land, and administrative costs.

Alternative IVd. Under this alternative, a low-lying area north of the village would serve as a subsurface disposal field for the entire community. Although use of the proposed disposal site would permit installation of a conventional gravity collection system, the disposal area itself would have to be filled with approximately 17,000 yd^3 of imported soil. State approval would have to be obtained for this plan, because of the proposed use of the fill system. At present, Vermont does not permit general use of the fill system. Capital costs in table II-10 are composed of the following components: collection and disposal system—$236,000; treatment system (septic tanks)—$26,400; engineering, land, and administrative costs—$49,600.

Alternative IVe. In this alternative, the collection system would consist of conventional gravity sewers conveying all wastewater to a pumping station in the northeast corner of the village, and a force main would operate from the pumping station to a municipal ST-SAS located south of the village. Soils at the proposed SAS site appear suitable. As noted in the facility plan, the cost of the system is nominal with Federal aid but prohibitive for the district without it. The total capital cost for the alternative is $271,700: $195,000 for the collection and disposal systems, $26,400 for the treatment system, and $49,600 for engineering, land, and administrative costs.

Evaluation of Alternatives. The results of the evaluation of the alternatives were as follows:

- Alternatives I and II were not recommended for the reasons given earlier.

- Alternative III was not recommended because of its high operation costs and power requirements, and because, as presented, it would use a portion of the existing inadequate collection system.

- Alternatives IVa and IVb were not recommended because data on soils indicate that subsurface disposal may not be feasible throughout much of the residential area.

- Alternative IVc was not recommended because of the high annual cost, which would have to be paid by the few users of the community portion of the system.

- Alternative IVd was not recommended because of poor soil and high ground water at the proposed disposal site, and because the extensive modifications required to make the site suitable may not be acceptable to the State.

- Alternative IVe is therefore recommended as the most cost/effective method of alleviating existing stream pollution.

REFERENCES

[1] Department of Public Works, Douglas County, Oreg., "Glide-Idleyld Park Sewerage Study, Douglas County, Oregon," Dec. 1975.

[2] Douglas County Engineer's Office, "Pressure Sewer Systems," Roseburg, Oreg., May 1974.

[3] Brown and Caldwell, "Wastewater Facilities Plan Project Report, Blaine County," A report prepared for Blaine County, Idaho, Nov. 1976.

[4] R. J. Otis and D. E. Stewart, "Alternative Wastewater Facilities for Small Unsewered Communities in Rural America," A report of the Small Scale Waste Management Project, University of Wisconsin, Madison, July 1976.

[5] Parrott, Ely, and Hurt Consulting Engineers, Inc., "Sewerage Facilities Plan, Fountain Run, Kentucky," A report prepared for the Fountain Run Water District, July 1976.

[6] Dufresne-Henry Engineering Corporation, "Facilities Planning Report on Wastewater Collection and Treatment," A report prepared for Fire District No. 2, Ryegate, Vt., Mar. 1975.

METRIC CONVERSION TABLES

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents*
Length	meter	m	*Basic SI unit*	39 37 m = 3 281 ft = 1.094 yd
	kilometer	km		0 6214 mi
	millimeter	mm		0.03937 in
	micrometer or micron	μm or μ		3 937 X 10^{-5} in = 1 X 10^4 Å
Area	square meter	m^2		10 76 sq ft = 1 196 sq yd
	square kilometer	km^2		0 3861 sq mi = 247 1 acres
	square millimeter	mm^2		0 001550 sq in
	hectare	ha	The hectare (10,000 m^2) is a recognized multiple unit and will remain in international use	2 471 acres
Volume	cubic meter	m^3		35 31 cu ft = 1 308 cu yd
	litre	l		1 057 qt = 0 2642 gal = 0 8107 X 10^{-4} acre ft
Mass	kilogram	kg	*Basic SI unit*	2 205 lb
	gram	g		0 03527 oz = 15 43 gr
	milligram	mg		0 01543 gr
	tonne	t	1 tonne = 1,000 kg	0 9842 ton (long) = 1 102 ton (short)
Force	newton	N	The newton is that force that produces an acceleration of 1 m/s^2 in a mass of 1 kg	0 2248 lb = 7 233 poundals
Moment or torque	newton meter	N·m	The meter is measured perpendicular to the line of action of the force N. Not a joule	0.7375 lb-ft 23 73 poundal-ft
Flow (volumetric)	cubic meter per second	m^3/s		15 850 gpm = 2,119 cfm
	liter per second	l/s		15 85 gpm

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents*
Velocity linear	meter per second	m/s		3 281 fps
	millimeter per second	mm/s		0 003281 fps
	kilometers per second	km/s		2,237 mph
angular	radians per second	rad/s		9 549 rpm
Viscosity	pascal second	Pa·s		0 6722 poundal(s)/sq ft
	centipoise	Z		1 450 X 10^7 Reyn (μ)
Pressure or stress	newton per square meter or pascal	N/m^2 or Pa		0 0001450 lb/sq in
	kilonewton per square meter or kilopascal	kN/m^2 or kPa		0 14507 lb/sq in
	bar	bar		14 50 lb/sq in
Temperature	Celsius (centigrade)	°C		(°F−32)/1 8
	Kelvin (abs.)	°K		°C + 273 2
Work, energy, quantity of heat	joule	J	1 joule = 1 N·m where meters are measured along the line of action of force N	2 778 X 10^7 kw-hr = 3.725 X 10^{-7} hp-hr = 0 7376 ft-lb = 9.478 X 10^{-4} Btu
	kilojoule	kJ		2.778 X 10^{-4} kw-hr
Power	watt	W	1 watt = 1 J/s	44 25 ft-lbs/min
	kilowatt	kW		1 341 hp
	joule per second	J/s		3.412 Btu/hr

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents*
Precipitation, run-off, evaporation	millimeter	mm	For meteorological purposes, it may be convenient to measure precipitation in terms of mass/unit area (kg/m^2) 1 mm of rain = 1 kg/m^2	
Flow	cubic meter per second	m^3/s		35 31 cfs
	liter per second	l/s		15 85 gpm
Discharges or abstractions, yields	cubic meter per day	m^3/d	1 l/s = 86 4 m^3/d	0 1835 gpm
	cubic meter per year	m^3/year		264 2 gal/year
Usage of water	liter per person per day	l/person/day		0 2642 gcpd

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents*
Density	kilogram per cubic meter	kg/m^3	The density of water under standard conditions is 1,000 kg/m^3 or 1,000 g/l or 1 g/ml	0.06242 lb/cu ft
Concentration	milligram per liter (water)	mg/l		1 ppm
BOD loading	kilogram per cubic meter per day	$kg/m^3/d$		0.06242 lb/cu ft/day
Hydraulic load per unit area, e g, filtration rates	cubic meter per square meter per day	$m^3/m^2/d$	If this is converted to a velocity, it should be expressed in mm/s (1mm/s = 86 4 m^3/m^2/day).	3 281 cu ft/sq ft/day
Air supply	cubic meter or liter of free air per second	m^3/s l/s		
Optical units	lumen per square meter	lumen/m^2		0.09294 ft candle/sq ft

*Miles are U S statute, qt and gal are U S liquid, and oz and lb are avoirdupois

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