6th WEDC Conference: March 1980: Water and waste engineering in Africa

RICHARD J OTIS

LESSONS LEARNED FROM U.S. EXPERIENCE WITH SEPTIC TANK SYSTEMS

INTRODUCTION

In the United States, many small communities are facing extreme financial hardships in providing adequate sanitation for their citizens. Conventional water borne sewerage consisting of gravity collection sewers and a central treatment plant that discharges to a surface body of water is the commonly accepted approach to sanitation. However, small communities often do not have the financial resources to construct and operate such a facility, nor do they have the skilled personnel necessary to maintain them. This has forced communities to investigate alternative technologies that provide the same reliable service at a lower cost. Some of the lessons learned may be useful in solving similar problems faced by small communities in developing countries.

SEPTIC TANK SYSTEMS AS COMMUNITY FACILITIES

Conventional sewerage has become to be considered the ultimate design of any public wastewater facility. If improved sanitation is to be realized in most small communities this notion must be overcome. In an analysis of costs of all public facilities constructed in the U.S., construction and maintenance of the collection system accounted for more than 65 percent of the average total annual costs (1). In small communities, sewers can be even more costly because housing is typically scattered (2). Therefore reduction or elimination of the collection system could provide substantial savings in the costs of small community facilities.

However, probably the greatest savings to the communities can be made by reducing the operation and maintenance costs. These costs can account for nearly 30 percent of the total annual costs (2).

Septic tank systems or other "onsite" systems offer a low cost alternative to conventional sewerage. Several treatment and disposal sites could be located within the community to keep costs of collection to a minimum by decentralizing the facility and treating and disposing of the wastes near where they are generated. This also can reduce treatment costs because the wastes would not be concentrated in one spot but dispersed over larger areas so that the environmental impact would not be as great.

The most extreme decentralized wastewater facility is one where each building is served by an individual onsite disposal system. Unfortunately, it is the failure of these systems to function properly which forces most communities into constructing conventional wastewater facilities in the first place. The cause of the failures can usually be traced to poor siting, design, construction and maintenance. Since regular and timely maintenance is a key element to the success of these systems, public management of the systems paid for through user charges would be necessary. Some communities could completely solve their problem by forming a public onsite system management district to rehabilitate and maintain all the individual systems within their jurisdiction at a very reasonable cost.

In many cases, though, the site and soil conditions on each lot preclude the upgrading of the existing onsite systems. Alternatives to the conventional septic tank system could be installed, but they are usually more complex and costly. In such cases, it may be more cost effective to serve a group of homes on a common or "cluster" system. Cluster systems have the advantage of economy of scale as well as the possibility of locating the system on a nearby site with site conditions suitable for a less costly treatment system. Again, public management would be necessary as an integral part of the system.

PUBLIC MANAGEMENT OF SEPTIC TANK SYSTEMS

Sound management of wastewater facilities is an essential component of an effective sanitation program. If community facilities are to be properly administered, operated and maintained, a public or private management institution must be established. This is common practice for central sewerage, but is a relatively new concept for managing onsite systems that may be located on private property. With sufficient powers, however, public management of onsite systems can be very effective.

Management institutions that are to provide sewerage services must have the authority and power to perform the following functions (3):

1. Plan, design, construct, inspect, operate, maintain and own all wastewater systems within its jurisdiction.
2. Enter into contracts, sue and be sued, and undertake debt obligations either by borrowing or issuing bonds for purposes of acquiring necessary property, equipment and supplies.
3. Raise revenue by fixing and collecting users charges and levying special assessments and/or taxes.
4. Plan and control how and at what time

wastewater facilities will be extended to those within its jurisdiction.

5. Make rules and regulations regarding the use of the system or systems under its jurisdiction and to provide for the enforcement of those rules.

FACILITIES PLANNING IN SMALL COMMUNITIES

Planning wastewater facilities that will meet water quality and public health goals at a cost small communities can afford requires a proportionately greater effort than is customary for larger communities. Each community can be quite different and no single solution will work for all. Individual onsite systems, clusters and alternative collection systems must be investigated to keep costs down. Maximum use must be made of the existing facilities and the natural resources of the community. This increases the need for detailed field work and public involvement. A systematic four step procedure outlined below is offered as a guide (4).

Preliminary Assessment

- Define scope of problem.
- Identify sources of information.
- Meet with community officials.
- Discuss potential alternatives.

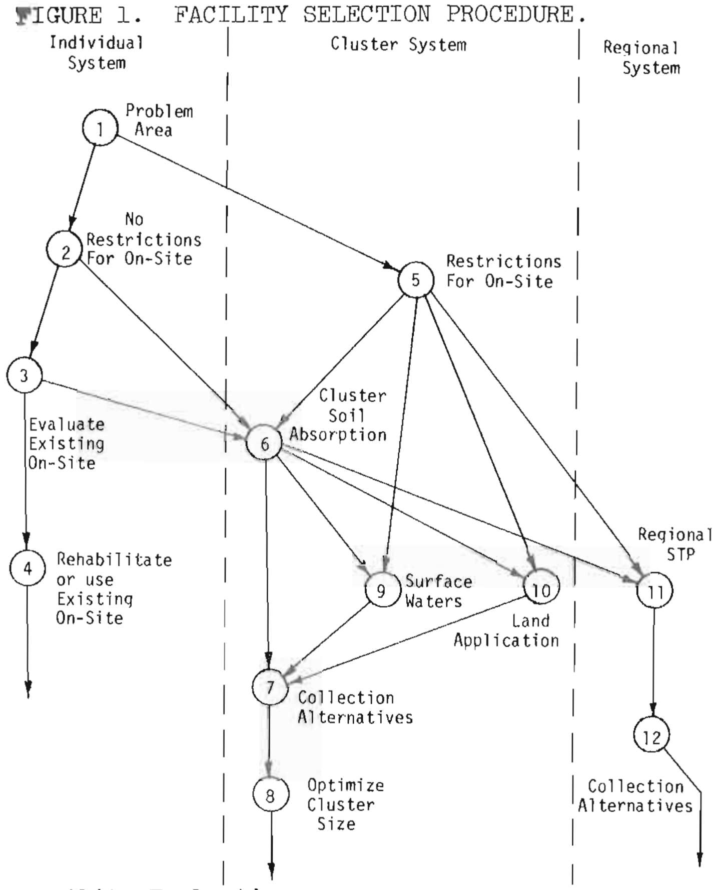
Problem Area Identification

- Identify areas requiring improved or new facilities.
- Evaluate existing private facilities.
- Distinguish between areas where off lot is only alternative and those that are feasible with rehabilitation.

Facility Selection

- Select alternatives for each area.
- Employ procedure (Table 1, Figure 1) to eliminate alternatives.
- Assumptions for Table 1:
  - Where no restrictions exist, subsurface soil absorption of septic tank effluent is the least expensive alternative.
  - Maximizing the use of existing septic tank systems minimizes the total costs.
  - Cluster soil absorption fields are less costly than individual fields where new construction or reconstruction is necessary for a number of lots unless collection costs are excessive because of economies of scale.

FIGURE 1. FACILITY SELECTION PROCEDURE.



Facility Evaluation

- Estimate costs for selected alternatives: construction, operation, maintenance, monitoring.
- Compare present worth of alternatives.
- Review local cost share based on funding available.
- Estimate assessment and user charges.

CASE STUDY

To determine if onsite technology could be employed under central management to significantly reduce the total annual costs of public wastewater facilities, a small rural community was sought for a demonstration study (5). The unincorporated community of Westboro, Wisconsin was selected because it is typical of hundreds of small rural communities that are in need of improved wastewater facilities but are unable

TABLE 1. FACILITY SELECTION DECISIONS CORRESPONDING TO FIGURE 1.

NODE	DECISION	ACTION
1	Do the developed lots have soil and site characteristics suitable for onsite subsurface soil absorption?	Yes - Proceed to Node 2 No - Proceed to Node 5
2	Do the undeveloped lots have soil and site characteristics suitable for onsite subsurface disposal? (If not, can the area be replatted to make each lot suitable?)	Yes - Proceed to Node 3 No - Proceed to Node 6
3	Are the existing onsite systems functioning properly? (If not, can they be rehabilitated easily?)	Yes - Proceed to Node 4 No - Proceed to Node 6
4		Determine costs of rehabilitation
5	Is a suitable area available for a cluster soil absorption system within a reasonable distance?	Yes - Proceed to Node 6 No - Proceed to Nodes 9,10,11
6	Does it appear collection costs will not be excessive?	Yes - Proceed to Node 7 No - Proceed to Nodes 9,10,11
7		Layout collection options and proceed to Node 8
8		Compare costs of various cluster sizes
9		Design low maintenance treatment works to meet water quality standards
10		Design low maintenance land application system to meet local design requirements
11		Investigate feasibility and local cost share of conveying wastes to a regional treatment plant
12		Layout collection options

to afford conventional sewerage.

Westboro has a population of about 200 people. Until 1977, the community of Westboro had no public wastewater facility. All the buildings were served by private septic tank systems. A survey by the Wisconsin Department of Natural Resources (DNR) showed that 80 percent of these systems were discharging wastes above ground. Consequently, DNR issued an order to the Town of Westboro to upgrade the existing septic tank systems or construct a public wastewater facility.

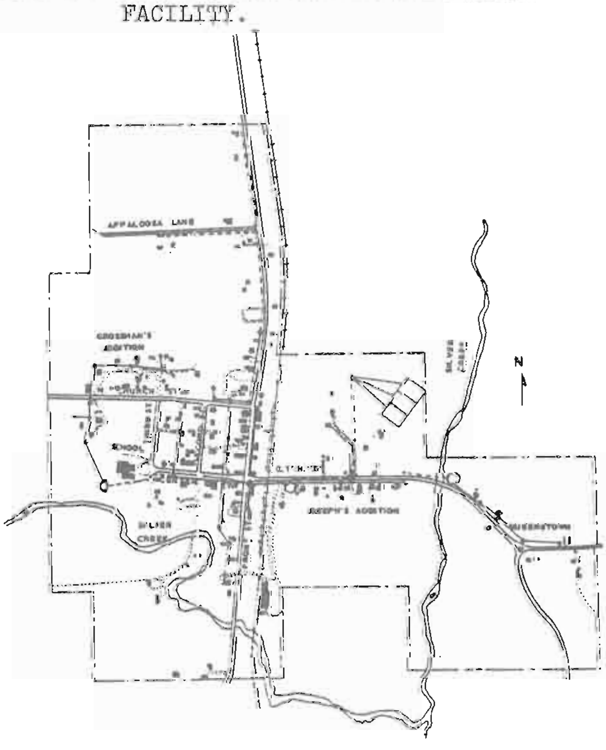
Because the soils and small lot sizes prevented the replacement of most of the failing septic tank systems, public sewerage was necessary. The Town Sanitary District #1 of the Town of Westboro was formed to incorporate all the buildings with failing systems which were endangering the water quality of Silver Creek. An engineering firm was hired to complete a facilities plan in cooperation with staff at the University of Wisconsin.

Selected Alternatives

In addition to conventional sewerage, six alternative facility plans utilizing individual and clustered onsite systems and alternative collection systems were felt to be viable. These alternatives are described elsewhere (5). Each of the alternatives was evaluated on the basis of reliability, cost and environmental impact. Following this analysis, the facility design recommended was a system of small diameter gravity sewers collecting the wastes from each cluster and conveying them to a single area for soil absorption northeast of town (Fig. 2). Homes not in the sewered area would be served by individual onsite systems, owned and operated by the sanitary district.

The District would be responsible for the operation and maintenance of all components of the facility, including those located on private land commencing from the inlet of the septic tank. The property owner would be responsible for providing and maintaining the lateral drain from his home or establishment to the septic tank and any power costs associated with lifting his effluent into the collection sewer if necessary.

FIGURE 2. PLAN OF THE CONSTRUCTED WASTEWATER FACILITY.



Design

Effluent Sewers: Experience with small diameter gravity sewers has been limited to Australia. Guidelines used for their design were ones developed by the South Australia Department of Public Health. These guidelines are summarized in Table 2.

Ten cm diameter mains were specified, set at a minimum gradient of 0.67 percent. Assuming a peak flow of 11.3 L/h per capita (6) this size sewer can serve approximately 600 persons flowing half full. Half full conditions are recommended by South Australia to maintain ventilation of the sewers. This is a very conservative design because peak flows are dramatically attenuated through the septic tank (6). Peak flows of 3.8 L/h per capita are more likely, which increases the design capacity of each sewer line to 1800 persons.

Manholes were placed at the upstream end of each line at junctions and at spacings up to 18 meters. Because settleable and floatable solids are excluded from the sewers, curvilinear alignments both in the horizontal and vertical plans were permissible.

TABLE 2. SOUTH AUSTRALIA GUIDELINES FOR SMALL DIAMETER GRAVITY SEWERS

Minimum Pipe Diameter	10 cm
Minimum Velocity (1/2 Full)	0.46 mps
Minimum Gradient	
10 cm Conduit	0.67%
15 cm Conduit	0.40%
20 cm Conduit	0.33%

Soil Absorption Fields: The soil absorption field was divided into three beds. Two are in service at any one time with the third acting as standby. Every Spring, the standby bed is rotated into service so that each bed receives wastewater for 2 years and rests for 1 year. The resting period allows the bed's infiltrative surface to dry out and rejuvenate (6).

Operating in this manner, the field should last indefinitely if not overloaded. However, if one of the beds unexpectedly fail, the standby bed would be rotated in immediately. The failed bed could then be chemically treated with hydrogen peroxide for immediate rejuvenation (6) or rested.

The total design capacity selected for the absorption field was 113.4 m^3/d. Each bed was designed to absorb half of this or 57 m^3/d. The design flow was estimated by assuming 0.94 m^3/d per home plus commercial flow. These estimates include infiltration. Undeveloped lots and vacant buildings were included in this estimate.

The application rate chosen for the absorption beds was selected based on a soil type which was sand and loamy sand. Long term infiltration rates into such soils loaded with septic tank wastes have been determined to be approximately .049 m^3/m^2d (7). Therefore, each bed required 1160 m^2. This was provided by 30 m by 46 m beds. Pressure distribution networks were designed to distribute the wastewater uniformly over the infiltrative surface to prevent local overloading and premature failure (8).

Three 25 cm siphons were installed, one for each bed. They are capable of discharging an average of 3.78 m^3/d at the design head. Two siphons are operating at any one time. They automatically alternate operation discharging approximately 30.2 m^3 per dose. At design capacity each bed will receive 2 doses per day. The third siphon is taken out of service by closing a ball valve installed in the siphon blow off vent.

Facility Construction

Construction began in April, 1977 and was completed in September, 1977. The soil absorption fields were constructed first. After they were completed, house connections were made and the wastes discharged into the fields as the sewers were installed. Before each connection, however, the septic tank was carefully inspected. All inadequate tanks were properly abandoned and new ones installed. To facilitate pumping of the tanks, some homeowners chose to relocate their tanks near the road. This usually meant reversing the plumbing in the home which was at the owner's expense.

Total project costs were $ 181,960 (1977). This represented about a 13 percent savings per connection over a conventional facility (see Table 3). This was not as great as hoped but the constructed facility serves every home in the district while the conventional facili ity would not have been able to serve 13 of the homes because of excessive costs.

TABLE 3. COMPARATIVE COSTS OF CONSTRUCTION FOR CONVENTIONAL AND ALTERNATIVE FACILITIES.

	Actual Costs of Alternative	Estimated Costs[1] of Conventional
Collection	$ 109,170[2]	$ 80,585[3]
Treatment	40,345	77,400
TOTAL	$ 149,515	$ 157,985
Cost/Connection	$ 1,800	$ 2,080
Number of Homes Served	83	76
Unserved	0	13

[1]Gravity collection/stabilization facility serving 75 connections.
[2]Includes septic tanks and house laterals.
[3]Includes customer hookup charges of $ 215.

Operation and Maintenance

The facility requires very little attention by the operator. All duties can be performed by an unskilled laborer within 2 to 4 hours weekly. The maintenance schedule is summarized in Table 4.

Design Modifications

The facility in Westboro is operating successfully after over 2 years of operation.

TABLE 4. FACILITY MAINTENANCE SCHEDULE

Daily

1. Check lift station alarm lights.

Weekly

1. Open lift stations for visual inspection of pump operation float control operation and debris.
2. Record total weekly flow from pump running time meters as per permit requirement.

Monthly

1. Sample lift station wastewater for BOD_5, suspended solids and pH as per permit requirement.
2. Inspect observation vents in each bed for ponded water. If the ponding is greater than 12 inches, take the ponded bed out of service.

Annually

1. Each Spring alternate resting bed into service and drain manifold of bed taken out of service.
2. Inspect the surface of the absorption field for holes and depressions. Fill in any that are found.
3. Pump 1/3 of septic tanks each year according to schedule.
4. Pump lift stations and siphon chamber to remove any sludge.
5. Jet any of the sewer lines which have a history of clogging problems.

The savings over conventional sewerage were not as great as hoped but experience gained thus far indicates that design changes that can be made which would substantially increase the savings in future facilities of this type. For example, it appears that small diameter gravity sewers do not need to be laid on a uniform grade. Since solids are not accumulating in the system, non-gradient alignments would permit simple trenching procedures reducing excavation and labor significantly. Other suggested modifications are discussed elsewhere (5).

DISCUSSION

The facility constructed in Westboro may not be directly applicable in many developing countries where water borne sewage does not exist. However, several aspects of the Westboro project may provide lower cost alternatives to conventional sewerage. First, public management of onsite systems whether latrines or septic tank systems may solve many of the existing problems without new construction. Second, small diameter sewers can be effectively used in staging public facilities. The lower cost sewers can be used to collect aqua privy wastes for soil absorption fields used for septic tank wastes where public water supplies are constructed. No further upgrading would be necessary. Finally, the planning methodology described can be employed to select the most appropriate sanitation facility for a given community regardless of the technologies considered.

References

(1) Smith, R. and R.G. Eilers, "Cost to the Consumer for Collection and Treatment of Wastewater", Water Pollution Control Research Series No. 17090, U.S. EPA, Washington, D.C. (July, 1970).

(2) Sloggett, G.R. and D.D. Badger, "Economics of Constructing and Operating Sewer Systems in Small Oklahoma Communities", Bulletin B-718, Agricultural Experiment Station, Oklahoma State University (April, 1975).

(3) Otis, R.J. and D.E. Stewart, "Alternative Wastewater Facilities for Small Unsewered Communities in Rural America", Small Scale Waste Management Demonstration, Phase III, Annual Report to the Upper Great Lakes Regional Commission, University of Wisconsin, Madison (July, 1976).

(4) Otis, R.J. and J.E. Kleinschmidt, "Guide to Wastewater Facilities Planning in Small Unsewered Communities", Small Scale Waste Management Project, University of Wisconsin, Madison(1980).

(5) Otis, R.J., "An Alternative Public Wastewater Facility for a Small Rural Community", Small Scale Waste Management Project, University of Wisconsin, Madison (1978).

(6) "Management of Small Waste Flows", University of Wisconsin, U.S. EPA, EPA-600/2-78-173, Cincinnati, Ohio (1978).

(7) Otis, R.J., G.D. Plews and D.H. Patterson, "Design of Conventional Soil Absorption Trenches and Beds", in Home Sewage Treatment, American Society of Agricultural Engineers Publication 5-77, St. Joseph, Michigan, 86-99 (1978).

(8) Otis, R.J., J.C. Converse, B.L. Carlile and J.E. Witty, "Effluent Distribution", in Home Sewage Treatment, American Society of Agricultural Engineers, Publication 5-77, St. Joseph, Michigan, 61-85 (1978).