Where appropriate, the building and site should be enhanced with special design features. These might include wood decks, terraces, and historical and geologic displays. Special features add interest and can serve as an extension of the building. Overlooks or interpretive areas take advantage of natural features of a site and can enhance the tourism potential of the area.

Site furniture is an important design element in rest areas. Picnic tables should be durable, comfortable, and well designed. Benches and waste receptacles should be attractively designed yet function efficiently. For example, barrels are not appropriate as waste receptacles because they are unsightly and function poorly. Benches that are built into other elements such as retaining walls or decks are encouraged. Drinking fountains and aesthetically pleasing information signs should also be provided. Wood signs with messages regarding use of the site are a good signing system.

Childrens' play areas that incorporate a simple play structure with a sand cushion beneath it are an important safety feature in a rest area. Walkways that encourage travelers to explore a site and stay away from their cars several moments longer will result in more-rested travelers. It is important that both adults and children be relaxed and refreshed before returning to the highway. States with these types of facilities report nothing but positive comments from travelers when rest-area usage surveys are taken.

Lighting plans should be carefully designed to provide varying illumination levels. Entry ramps and parking lots should have higher poles to broadly light these areas for safety. Areas along the entry walks and car parking lots can have lower mounting heights to provide a feeling of security. There should be enough light in the rest area so that it looks open and safe. Designers should select light poles and luminaires from one manufacturer for visual continuity. Careful selection of materials, furniture, and site elements enhances the architectural quality and consistency of the rest-area design.

Where tourist-related displays are developed, they should be integrated into the rest-area design. If covered displays are developed, materials and roof design should match those of other structures. These displays should be located so they fit the flow of pedestrians within the site.

FHWA has recognized the significant effect that properly designed wastewater disposal and water supply systems have on safety rest area success. These topics were of such importance to the development of rest-area programs that separate training manuals were prepared for each one [e.g., Wastewater Treatment Systems for Safety Rest Areas (2) and Manual for Safety Rest Area Water Supply Systems (3)].

The design process should also include preparation of site management plans that identify how the rest area should be managed once it opens. This attention to rest-area management and operation keeps the designer in touch with the rest-area system. Management tasks include building management, mowing and turf management, irrigation, fertilization, and vegetation maintenance. These plans should be formulated for a one-to-five-year period. They serve as the designer's final link between the initial concepts that motivated the original design and the operation and management of the rest area.

The overriding focus of the training manual and course we prepared is that rest areas are an essential part of the highway system. They promote safe travel and can be used to enhance state tourism programs. In order to be effective, safety rest areas must be designed with care and sensitivity to many factors. Quality rest-area sites and careful, thorough design procedures will result in successful safety rest-area systems that meet the needs of the traveling public.

ACKNOWLEDGMENT

We wish to acknowledge the efforts of many individuals who helped in the preparation of our design manual. The manual was prepared for the Office of Research and Development, FHWA. Robert D. Thomas of that office was coordinator for preparation of the manual and his work, as well as that of his steering committee, was appreciated.

The rest-area design staffs of nine states were interviewed for information on development and design of their rest-area systems. This information was very valuable in preparing the manual. The states interviewed included Virginia, North Carolina, Texas, Illinois, Nebraska, California, Arizona, Washington, and Michigan. Much of the material in the manual was developed through the experiences of MnDOT since 1967. MnDOT procedures were found to parallel the procedures of other states with successful programs.

REFERENCES

1. Safety Rest Areas: Planning, Location, and Design. Training Manual, FHWA, U.S. Department of Transportation, 1980.
2. Wastewater Treatment Systems for Safety Rest Areas. FHWA, U.S. Department of Transportation, Rept. FHWA-RD-77-107, 1977.
3. Manual for Safety Rest Area Water Supply Systems. FHWA, U.S. Department of Transportation, Rept. FHWA-RD-77-113, 1977.

On-Site Land Treatment Systems for Freeway Rest Areas

A.E. ERICKSON, M.L. DAVIS, R.T. SPRAGUE, D.P. BRATT, AND W.A. RUECKERT

This study evaluates the effectiveness of existing on-site sewage treatment systems used at freeway rest areas in Michigan. It also evaluates the effectiveness of land-treatment systems designed to polish and dispose of the partially treated effluents from septic tanks and lagoons. The selection of the proper system or combination of systems to match the physical constraints of a particular site can ensure quality effluents and dispose of them so that they will not harm the environment. Tile drain field, seepage pits, seepage beds, sand filters, overland flow evapotranspiration systems, and a modified barriered landscape water renovation system were studied. The parameters measured included total coliforms, fecal coliforms, total streptococci, fecal streptococci, biological oxygen demand, total organic carbon, total phosphorus, inorganic phosphate phosphorus, total Kjeldahl nitrogen, ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, and suspended solids.

The easiest solution to sewage treatment at freeway rest areas is to use nearby sanitary sewers, if available. However, because of the remoteness of most rest areas, this is not always an option, and a method of treating sewage and disposing of the wastewater must be developed on-site. In Michigan, the most common methods of primary sewage treatment at rest areas have been with septic tanks or lagoons. Disposal of wastewater has usually been to surface waters or to groundwaters through tile drain fields.

Environmental concerns and the Clean Water Act of 1972 (and its more restrictive effluent discharge standards) prompted this research between the Michigan Department of Transportation and Michigan State University. The purpose was to evaluate the effectiveness of existing on-site systems and to design and evaluate land-treatment systems that would polish and dispose of effluents.

Septic tank systems have been used when a continuous discharge can be tolerated, i.e., to a drain field. Lagoon systems have been used when a continuous discharge is not possible and where there are enough space and suitable soil conditions for lagoon construction. Land-treatment systems for polishing and disposing of these effluents have been designed to fit the site, taking into account conditions of soil, landscape, depth to water table, and land availability.

The various systems that have been developed and tested are discussed. Each system has been evaluated by sampling the wastewater before, during, and after treatment; sampling the soil at various depths; and sampling the water tables on, adjacent to, and at a distance from the treatment facility. Water samples were analyzed for total coliforms, fecal coliforms, total streptococci, fecal streptococci, biological oxygen demand (BOD), total organic carbon (TOC), total phosphorus (TP), inorganic phosphate phosphorus, (i-PO_4), total Kjeldahl nitrogen (TKN), ammonium nitrogen (NH_4-N), nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N), and suspended solids (SS) according to methods in U.S. Environmental Protection Agency manuals (1,2).

SEPTIC TANK-TILE FIELDS

The best septic tank-tile field design provides for a three-compartment septic tank that leads to a distribution box that in turn can feed into any of four separate tile fields. Each field is capable of supporting the entire sanitary requirements of the rest area. This design allows good flexibility in managing the system because it permits the complete rest of three fields while one is being used. Furthermore, the operator can open two fields should very high use be expected in special situations, such as a holiday weekend.

The multiple-field design has been used for the last 10 years in Michigan freeway rest areas and to date no system has failed hydraulically. One of these systems was evaluated for nutrient leakage for a period of two years. The soils on this site are loam texture with a water table at 25-30 ft. Wells for water sampling were placed adjacent to and on all sides of the drain field and at distances from the field.

It was found that i-PO_4, TKN, NH_4-N, and fecal coliforms do not appear in the water table; however, NO_3-N is found in the water table adjacent to the drain field in an average concentration of 25 parts per million (ppm). The concentration of NO_3-N varies in the well samples with the lowest well averaging 3.1 ppm and the highest averaging 66 ppm. This system, which could be considered conventional, failed with regard to NO_3-N removal, although the NO_3-N was rapidly diluted as it moved through the aquifer.

Septic Tank-Leaching Pits

The septic tank-leaching pits system consisted of a septic tank that had several leaching pits located at a site with variable soils, made up of granular pockets in fine-textured soils in association with rugged terrain, and a deep water table. Except for the failures of three leaching pits, located incorrectly in the adjacent clay soils rather than in the granular pockets, the system worked satisfactorily. The long, tortuous path to a water table at a depth of 80 ft appeared to polish the effluent as no nutrient leakage was found in the sampling wells.

Septic Tank-Sand Filter-Overland Flow Evapotranspiration

The septic tank-sand filter-overland flow evapotranspiration system was in a rest area that was located on a poorly drained clay loam soil with a high water table that would not allow the use of a conventional drain field. Treatment was with a septic tank because of space limitations. The effluent was pumped into an elevated sand filter that had tile drains at the base. A schematic cross section of this sand filter is shown in Figure 1. Intensive use of this facility during the summer season caused the overloading of the system with a breakthrough of nitrogen (N), phosphorus (P), and coliforms.

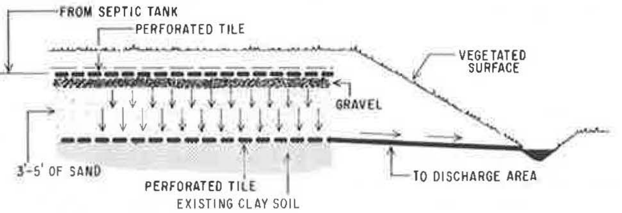
An overland flow evapotranspiration (OF-ET) system was designed as an alternate system for summer use. The OF-ET was placed in the median between the traffic lanes because the rest-area property could not be expanded. It was 20 ft wide and 1600 ft long with a uniform slope of 0.3 percent. Reed canary grass, *Phalaris arundinacea*, was planted on the OF-ET. The septic tank effluent, which had a very short retention time during the summer, was collected in a 1000-gal tank that was continuously ozonated to oxidize the volatile organics and to control odors. Thousand-gallon batches of ozonated effluent were pumped to the control structure at the top of the OF-ET. The adjustable notched weir on the control structure distributed the wastewater across the OF-ET. The grass grew well and produced a tortuous path for the shallow flow of effluent. The ozonation and aerated flow on the OF-ET controlled any potential odor problem.

The system was operated and studied for two months at an average loading of 5000-6000 gal/day, which was equivalent to 0.25 in over the whole OF-ET area. There were peak days in the operation when 12 000-15 000 gal/day were applied with no problems.

Measurements of the changes in quality of the wastewater as it moved down the OF-ET showed that all of the parameters except NO_3-N were greatly reduced when the effluent had flowed 400 ft. The NO_3-N concentration peaked at 30 ppm at this distance but declined beyond this point as the grass and denitrification at the soil surface removed NO_3-N from the system. The table below shows the efficiency of both the sand filter and OF-ET in reducing pollutants from septic tank effluent:

Pollutant	Sand Filter (%)	OF-ET (%) 200 ft	OF-ET (%) 800 ft
BOD	87	62	91
TP	70	75	89
Total nitrogen (TN)	28	55	98
SS	83		62
Fecal coliforms	99		99

Figure 1. Sand filter section above a clay soil.



The sand filter reduced TN by only 28 percent and TP by 70 percent, while the OF-ET did better than this at 200 ft. At 800 ft on the OF-ET, BOD was reduced by 91 percent, TP by 89 percent, and TN by 98 percent.

Most of the time the wastewater infiltrated the soil or was evapotranspirated so that it never reached the outfall at 1600 ft. During three heavy rains there was some outfall from the system, but only on one occasion was there enough to measure at the weir. This outfall amounted to 1700 gal, or one-third of one day's application, and had at least a 95 percent reduction in all parameters.

These two polishing treatment systems complement each other. During the winter season, when the sewage loading was low, the septic tank effluent was of better quality and the sand filter satisfactorily polished the effluent. During the summer season, when the bulk of the sewage was produced, the OF-ET did an excellent polishing of the poorly treated effluent with little discharge except during heavy rainfall.

LAGOON SYSTEMS

Lagoons have an advantage over septic tanks in that they also provide for storage during the winter season when land-treatment systems do not operate well. Recently constructed lagoons in Michigan are three-cell systems that have less than the recommended maximum of 20 lb/BOD per acre per year. They have the full flexibility of moving the wastewater to any cell and can be operated either in parallel or in series. Lagoon effluent is usually polished by an on-site land-treatment system with eventual discharge to the water table.

Lagoon-Seepage Beds

The lagoon-seepage bed system that was studied consisted of a three-celled lagoon system that discharged into seepage beds on a level, slowly permeable clay loam soil that had a high water table. The water table fluctuates from the surface in the spring to 5 or 6 ft deep in a dry summer. This area had adequate space so that the seepage beds could be constructed at the rest area. The seepage beds were designed so that the release of effluent from one of the lagoons would add between 1 and 1.5 ft of wastewater to the beds. This provided good aeration during the seepage process that proceeded at a rate of 0.5-0.6 in/day.

Sampling wells that reached the shallow water table were placed around the seepage beds and at a distance from them for control samples. Water from these wells was sampled throughout a two-year period with more frequent sampling during discharge. There were seasonal changes in NO_3-N in all of the wells, but the wells adjacent to the seepage lagoons were never different than the control wells.

These lightly loaded seepage beds filtered the organic matter and microbes, absorbed the phosphate, and converted the TN to NO_3-N. The NO_3-N was denitrified in the anaerobic zone just below the flooded soil surface of the seepage bed. Because the beds were used only once or twice a year, there was ample time for rejuvenation of the soil and vegetation before recharge. As long as these beds were used during the warm part of the year, when the natural water table was several feet below the surface, this system performed well.

Lagoon-Overload Flow Evapotranspiration

The lagoon OF-ET system was on one of the busiest information centers in the state. It was situated in the median with ample land but with an uneven landscape and variable soils, some of which have high water tables. The sewage was given primary treatment in two lagoons. An OF-ET was constructed on a 4-acre field that had soil with 1-3 ft of sand over clay and a slope of 4 percent. Figure 2 is a sketch of this OF-ET. The OF-ET had a 23 000-gal chlorination tank at the top. The chlorinated lagoon effluent was distributed across the top of the OF-ET by using perforated flexible plastic drain tile. Six level ditches were plowed across the existing slope to reduce channeling and to keep the water evenly distributed as it moved down the slope. Reed canary grass was planted over the original wild grasses.

Operation of the system during the eight-month open season involved operating the lagoons in series, pumping 23 000 gal of effluent from the second lagoon up to the chlorination tank for overnight chlorination, and allowing the chlorinated wastewater to discharge by gravity over the OF-ET system for a 6-h period. The system was usually operated five days per week but could be operated more intensively. Depending on the amount of rainfall, 10-20 percent of the added wastewater ran off the OF-ET and accumulated in the south catchments for recirculation.

Water from the ditches, catchments, shallow wells that reached into the perched water table on the OF-ET, and perimeter wells that reached the water table were sampled intensively for three months during one summer and analyzed twice a week. The data are summarized in the table below:

Pollutant	Concentration (ppm)	Reduction (%)
BOD	2.5	96
TOC	32.7	48
i-PO_4	0.09	97
TKN	1.9	97
NH_4-N	0.12	99
NO_3-N	0.45	0
TN	2.35	94
Water		87

The concentrations of all pollutants leaving the OF-ET were very low and the percentage reductions in BOD, i-PO_4, and TN were 96, 97, and 94 percent, respectively. Only TOC stayed at one-half its original concentration, but probably was this high because of the contribution of organic carbon from the dense grass cover. Nitrate-N remained at a constant of about 0.5 ppm, which was probably the limit that the grass could extract under these conditions. Microbiological studies showed that the lagoon and chlorination had effectively killed those microbes associated with human feces. Any fecal coliform populations in the OF-ET effluent were attributed to wildlife.

For this system to ensure complete evapotranspiration of the effluent, it should be 50 percent larger. However, the quality of the outfall exceeded any reasonable standards.

Figure 2. Plan view of overland flow evaportranspiration system.

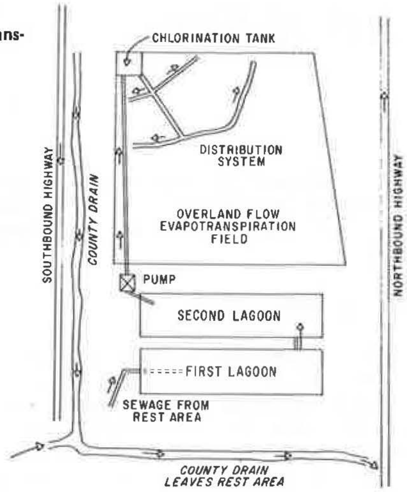
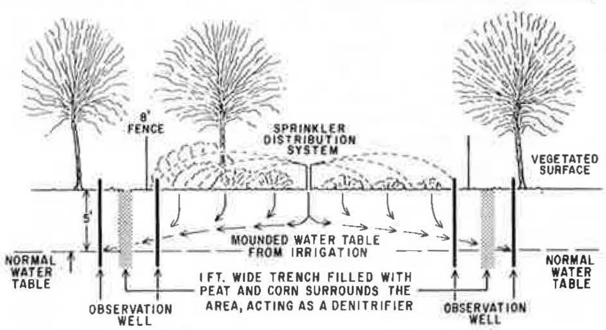


Figure 3. Modified BLWRS that uses a shallow water table as the barrier.



Lagoon-Modified Barriered Landscape Water Renovation System

The next information center has a two-lagoon system on a sandy loam soil with a water table 3-6 ft below the surface, depending on the season. In order to eliminate the discharge of the lagoons into a ditch that led to a river, a modified barriered landscape water renovation system (BLWRS) (3,4) was constructed in the highway median that used the natural water table as the barrier for the system.

The BLWRS is an efficient land-treatment system that uses all the properties of an aerated soil to decompose organics, nitrify N to NO_3, and absorb P. In addition, there is a barrier 4-6 ft below the surface to intercept the water, create an anaerobic environment, and direct the anaerobic water through a trench into which organic matter is placed. In this environment, the denitrifying bacteria will denitrify the NO_3 to nitrogen gas (N_2) and in this way remove N from the wastewater. The modified BLWRS is shown in Figure 3. The natural water table acts as the barrier to direct the anaerobic water through the peat-filled trench as it moves away.

In the operation of the system, lagoon effluent is taken from the second lagoon. The effluent is ozonated continuously in a 12 000-gal holding tank to reduce the odors. The ozonated effluent is spread on the two-third acre BLWRS with low-angle sprinklers operated at low pressure so as not to produce any aerosols. The spraying required 6-8 h.

Wells on and off the BLWRS were used to obtain water samples from the top of the aquifer for analysis. Soil samples from the BLWRS were also analyzed to monitor the movement of pollutants through the system. After 10 weeks of spraying during the summer of 1979, there was no change in the carbon (C), N, P, and microbiological parameters measured in well waters from wells adjacent to or at a distance from the BLWRS. All indications were that the system was operating as designed.

CONCLUSIONS

The wide range of conditions at the various freeway rest areas in Michigan required a variety of on-site treatment systems. Various land-treatment systems have proved useful in treating, polishing, and disposing of wastewaters in some cases. The selection of the proper system or combination of systems to match the physical constraints of a particular site can ensure quality effluents and dispose of them so that they will not harm the environment.

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REFERENCES

1. Methods for Chemical Analysis of Water and Waste. Office of Technology Transfer, U.S. Environmental Protection Agency, EPA-625/6-74-003, 1974.
2. Microbial Methods for Monitoring the Environment. Office of Research and Development, U.S. Environmental Protection Agency, EPA-600/8-78-017, 1978.
3. A.E. Erickson, J.M. Tiedje, B.G. Ellis, and C.M. Hansen. A Barriered Landscape Water Renovation System for Removing Phosphate and Nitrogen from Liquid Feedlot Waste. Proc., International Livestock Waste Conference, Columbus, Ohio, American Society of Agricultural Engineers, St. Joseph, MI, 1971, pp. 232-234.
4. A.E. Erickson, B.G. Ellis, J.M. Tiedje, A.R. Wolcott, C.M. Hansen, F.R. Peabody, E.C. Miller, and J.W. Thomas. Soil Modification for Denitrification and Phosphate Reduction of Feedlot Waste. U.S. Environmental Protection Agency, EPA-660/2-74-057, 1974.