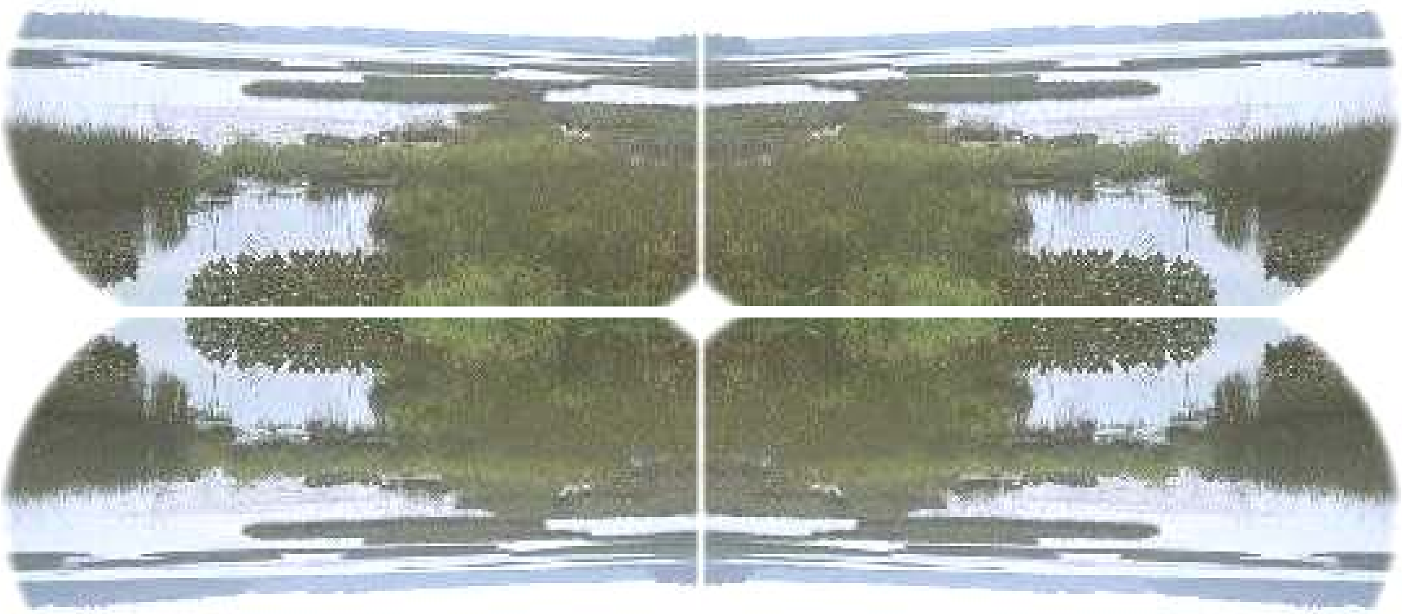
A Survey of Onsite Wastewater Treatment Systems



Identifying Alternatives Appropriate for Coastal Louisiana Based on Performance and Cost

November 1999

Barataria-Terrebonne
NATIONAL ESTUARY PROGRAM

A Survey of Onsite Wastewater Treatment Systems:

Identifying Alternatives Appropriate for Coastal Louisiana Based on Performance and Cost

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Acknowledgements

The Principle Investigator for this survey was Brent Ache, Battelle. Seth Wenger, a consultant to Battelle, was the primary researcher for the literature search and co-author of the document. Lynn McLeod, Battelle, also contributed to the document.

The lead technical reviewer was Dr. Kevin Sherman, Onsite Management Consultants, Inc., Tallahassee, Florida, and Executive Director, Florida Onsite Wastewater Association, Tallahassee, Florida. The authors extend special thanks to Ms. Lesley Garner, Director, Alabama Onsite Wastewater Training Center, University of West Alabama, Livingston, Alabama, for her efforts as a volunteer technical reviewer.

The BTNEP Action Plan Team provided technical direction on the project and reviewed the draft report. BTNEP and the authors thank the Action Plan Team members for their committed, volunteer assistance.

- James Antoon, Chief of Sanitary Services, Office of Public Health, LDHH
- Andrew Barron, Environmental Specialist, Nonpoint Source Pollution Program, LDEQ
- Teda Boudreaux, Sanitarian Regional Director, Region III, Office of Public Health, LDHH
- Jan Boydstun, Coordinator, Nonpoint Source Pollution Program, LDEQ
- Bill Branch, Louisiana Cooperative Extension Service
- Pat Breaux, Environmental Specialist Coordinator, LDEQ
- Greg DuCote, Coastal Management Division, Louisiana Department of Natural Resources
- Vickie Dufforc, Bayou Segnette Voters and Boaters Association
- Ken Hemphill, Oyster Water Monitoring Program, Office of Public Health, LDHH
- Tom Herrington, Co-Chair, GMP Public Health Focus Team, U.S. Food and Drug Administration
- Fred Kopfler, Co-Chair, Public Health Focus Team, USEPA Gulf of Mexico Program
- Al Levron, Director of Public Works, Terrebonne Parish Consolidated Government
- Frank Naquin, Sanitarian, Region III, Office of Public Health, LDHH
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- Kerry St. Pé, Director, BTNEP
- Mike Vidrine, Administrator, Individual Sewerage Program, Office of Public Health, LDHH
- Doug Vincent, Chief Engineer, Office of Public Health, LDHH

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Front Cover - USEPA (website); Page 1 - BTNEP (estuary location map), F. Kopfler (camps photo); Page 2 - Galveston County (TX) Health District; Page 4 - BTNEP (satellite image and bayou photo); Page 5 - BTNEP (small camp), F. Kopfler (large camp); Page 6 - LDEQ (two septic tank graphics), Hollomon 1997b (sand filter graphic); Page 7 - LDEQ; Page 9, LDEQ; Page 10 - BTNEP.

Citation

Ache, Brent W., and Wenger, Seth J. 1999. *A Survey of Onsite Wastewater Treatment Systems: Identifying Alternatives Appropriate to Coastal Louisiana Based on Performance and Cost.* A publication of the Barataria-Terrebonne National Estuary Program, Thibodaux, Louisiana. November 1999.

This project was partially funded by the Louisiana Department of Environmental Quality under grant number C9-996102-05-2. The contents of this document do not necessarily represent the views of the Department of Environmental Quality nor the Barataria-Terrebonne National Estuary Program Management Conference. The information represents the scientific findings and interpretations of the authors and is intended to provide background information for Management Conference deliberations. The mention of trade names or commercial products does not in any way constitute an endorsement or recommendation for use.

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List of Acronyms

ANSI	American National Standards Institute
BOD	Biochemical Oxygen Demand
BTNEP	Barataria-Terrebonne National Estuary Program
CDHS	California Department of Health Services
COD	Chemical Oxygen Demand
CW	Constructed Wetland
FC	Fecal Coliform Bacteria
FWS	Free Water Surface (constructed wetland system)
GAO	U.S. Government Accounting Office
gpd	gallons per day
gpm	gallons per minute
LDEQ	Louisiana Department of Environmental Quality
LDHH	Louisiana Department of Health and Hospitals
LPDES	Louisiana Pollution Discharge Environmental Standards
LUMCON	Louisiana Universities Marine Consortium
mgd	million gallons per day
MPN	Most Probable Number
MSD	Marine Sanitation Device
NODP	National Onsite Demonstration Project
NPDES	National Pollution Discharge Environmental Standards
NSF	National Sanitation Foundation
NSFC	National Small Flows Clearinghouse
PVC	Poly-Vinyl Chloride
SBR	Sequencing Batch Reactor
SCADA	Supervisory Control and Data Acquisition
SDGS	Small-Diameter Gravity Sewer
SF	Subsurface Flow (constructed wetland system)
SLT	Sand-Lined Trench
SRLA	Slow-Rate Land Application
STEP	Septic Tank Effluent Pump
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorous
TSS	Total Suspended Solids
TVA	Tennessee Valley Authority
USEPA	U.S. Environmental Protection Agency
UV	Ultraviolet

Executive Summary

The primary source of sewage pollution in the Barataria-Terrebonne estuary is runoff or discharge from inadequate or poorly maintained wastewater treatment plants, rural residences, unsewered communities, and waterfront camps (BTNEP 1996b). Onsite wastewater treatment and disposal using septic systems has been effective in many rural areas around the United States, but limited uplands, high water tables, and clay soils leave soil absorption -- the secondary treatment process of septic systems -- practically ineffective in many areas of the Barataria-Terrebonne estuary. Low density, rural development patterns along narrow upland ridges, prevalent in the southern portion of the estuary, make central sewer systems unfeasible simply due to cost. Moreover, extreme vulnerability to storms and flooding, especially in the southern portion of the estuary, make infrastructure investments in traditional central collection and treatment systems risky. Abundant recreational opportunities in the estuary have spurred the development of thousands of fishing and hunting camps, many built directly over the marsh. Regulated as periodically visited structures, wastewater treatment at these camps -- ranging from simple shelters to elaborate vacation homes -- creates a unique array of public health hazards and wastewater management challenges.

The suite of onsite wastewater treatment systems approved for use under the State of Louisiana Sanitary Code might not be appropriate for conditions found in coastal Louisiana. This situation highlighted the need for a survey of onsite wastewater treatment technologies, with the intent of identifying suitable alternatives appropriate for use in the Barataria-Terrebonne estuary. The demonstration of one or more of these technologies, if successful, might facilitate their introduction into the suite of onsite wastewater treatment options allowed by the Sanitary Code. This survey attempts to provide the scientific justification for the selection of technologies used in future demonstration projects by the Barataria-Terrebonne National Estuary Program, in partnership with the Louisiana Department of Health and Hospitals (LDHH) and the Louisiana Department of Environmental Quality.

The survey explores available onsite wastewater treatment technologies and evaluates specific components and systems for performance, cost, and suitability to conditions in the Barataria-Terrebonne estuary. It also reviews the current regulatory structure that dictates the use of onsite wastewater treatment systems in Louisiana. Armed with this information, the survey analyzes the potential to utilize alternative technologies in the following three applications common to the Barataria-Terrebonne estuary:

- Single-family, permanent residences
- Camps with continuous electricity and water under pressure
- Camps without continuous electricity (both with and without water under pressure)

Options, as they apply to the Barataria-Terrebonne estuary, for treating wastewater from small clusters of residences and camps, are also discussed. Three additional management considerations are explored simultaneously: (1) the necessity for proper onsite system maintenance; (2) options for greywater reuse/treatment; and (3) the benefits of water conservation.

The performance evaluation of onsite technologies assesses traditional wastewater treatment concerns -- biochemical oxygen demand and suspended solids -- but gives special attention to removal of enteric pathogens and nitrogen. Nitrogen is usually the limiting nutrient in brackish and marine systems (Loomis 1996), and excess nitrogen in wastewater can lead to eutrophication and reduction in oxygen levels. The Barataria-Terrebonne estuary is one of the nation's premiere oyster producing areas, and enteric pathogens can render shellfish contaminated and inedible.

Performance and cost information, where available, were analyzed for the following onsite wastewater treatment technologies:

- Septic tank with trickling filter
- Septic tank effluent filter
- Septic drainfields and variants
- Aerobic treatment plant
- Free-water surface constructed wetlands
- Subsurface-flow constructed wetlands
- Intermittent sand filter
- Recirculating sand filter
- Peat filter
- Marshland upwelling system
- Shallow-well injection system
- Spray and drip irrigation
- Overland flow
- Sequencing batch reactor
- Several proprietary aerobic biofilters and drainfield technologies
- Limited-use systems
- Composting and incinerating toilets
- Disinfection techniques

Based on the performance and cost data analyzed in this survey, and on input from state and local experts, there are a number of key opportunities for demonstration projects within the Barataria-Terrebonne estuary. Proposed projects fall into two categories. The first is evaluating the performance of several currently-implemented onsite technologies, to obtain baseline performance data. These demonstrations include:

- Evaluate the performance of effluent reduction fields, installed after mechanical plants, in different soil types prevalent in the Barataria-Terrebonne estuary to determine (1) the volume of effluent reduced and (2) the level of additional secondary treatment attained.
- Evaluate the performance of conventional limited-use systems (or "camp unit"), with and without consistent chlorine disinfection.
- Evaluate the performance of the HBO250 limited-use system, with and without consistent chlorine disinfection.
- Evaluate the performance of conventional limited-use systems in treating greywater.

The second category of demonstration project includes alternative technology evaluations and demonstrations of new wastewater management techniques within the Barataria-Terrebonne estuary, at individual residences, individual camps, and at small clusters of both residences and camps.

Key Individual Onsite Wastewater-Treatment Demonstration Opportunities

- With the intention of validating the ability of a marshland upwelling system to treat and dispose of primary-treated wastewater (*i.e.*, from a holding tank), begin a new camp demonstration in an area that directly impacts oyster growing waters in the Barataria-Terrebonne estuary. Determine an exact cost of installing the system. If this technology appears to provide effective and consistent treatment, develop techniques and assessment criteria to rapidly evaluate if a camp location meets the appropriate soil and salinity conditions for marshland upwelling. An alternative to beginning a new demonstration project is to continue evaluation of the Port Fourchon system, for unexplored parameters such as nutrient removal.
- Demonstrate the performance and management benefits of effluent filters, preferably filters with alarms that signal clogging, on septic tanks. Studies reviewed in this survey indicate a modest level of improved treatment with the use of effluent filters, and clogged filters can facilitate regular maintenance or indicate improper septic system use or function. Evaluate the cost of different effluent filter options. Consider testing effluent filters under a variety of septic tank loading conditions. Consider entering a partnership with owners/suppliers of proprietary technologies for a local demonstration project. There is a precedent for companies to donate materials for demonstrations of their technologies.
- Demonstrate the performance of effluent filters on conventional limited-use systems.
- To help ensure consistent chlorine disinfection in conventional limited-use systems and HBO250s, design and implement a targeted public information campaign to (1) inform owners about potential adverse impacts of untreated discharges from camps and (2) encourage proper chlorine tablet replacement. If resources are available, distribute free chlorine tablets at selected retail stores (those that sell bait, tackle, ice, hunting supplies, etc.) with "catchy" public outreach signs. In addition, design and print a public brochure to explain appropriate wastewater treatment options for various camp usage patterns.
- Test the performance and evaluate the cost of UV disinfection on one or several individual mechanical plant discharges in residential demonstrations. Adding UV disinfection to

mechanical plants installed without effluent reduction systems might provide excellent disinfection without great expense (possibly as low as $500).

- Test the performance of proprietary chamber and/or non-aggregate-mat drainfield technologies in a residential demonstration, and compare results to conventional stone-and-pipe drainfield performance. Evaluate and compare costs of these drainfield technologies. Consider entering a partnership with owners/suppliers of these proprietary technologies for a local demonstration project.
- Test the performance and evaluate the cost of a proprietary peat-filter system in a residential demonstration. Peat-filter systems have demonstrated good reduction in FC and the recent decrease in cost might make them more attractive to residents. Consider entering a partnership with owners/suppliers of these proprietary technologies for a local demonstration project.
- Test the performance and evaluate the cost of a proprietary aerobic biofilter in a residential demonstration, and compare results to common mechanical plant performance. Consider entering a partnership with owners/suppliers of these proprietary technologies for a local demonstration project.
- In the absence of a marshland upwelling demonstration, test the performance of UV disinfection, on one or more limited-use systems, at camps with continuous electricity. Select the UV disinfection demonstration project -- at a conventional limited-use system or a HBO250 unit -- taking into account the suspended solids loading. Adding UV disinfection to limited-use systems might provide excellent disinfection without great expense (possibly as low as $500).

Key Cluster-Based Wastewater Treatment Demonstration Opportunities

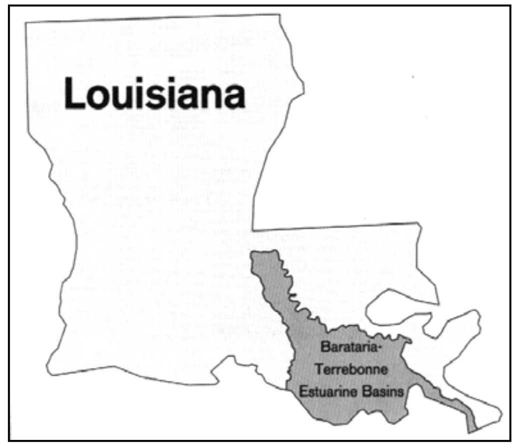
The foremost need in Louisiana is a well-planned and well-engineered demonstration of clustered residential wastewater treatment, an alternative collection system, and decentralized wastewater management. The one experience that Louisiana has had with these concepts was a complete failure and, justifiably, has soured many state and local officials. Officials might be more inclined to undertake a new demonstration project if it included significant economic incentives, access to technical leadership or expertise, and/or reputable private-sector partners.

Because there are such varied collection and treatment options at the cluster- and community-level, technologies should be selected on a site-specific basis. Therefore, the first challenge is to identify a small cluster of residents in the Barataria-Terrebonne estuary that is interested in participating in a decentralized wastewater management demonstration. The second challenge is to identify a private or public management district partner to perform the decentralized management responsibilities. One wastewater treatment and disposal method might be particularly appropriate for small clusters of residences, especially in upland-limited areas common to the Barataria-Terrebonne estuary -- the use of natural wetlands for secondary or tertiary treatment. While there appear to be significant regulatory and process hurdles using them for secondary treatment, natural wetlands are currently accepting secondary-treated wastewater from a public facility in Thibodaux, within the Barataria-Terrebonne estuary, and a number of other sites in coastal Louisiana (Day *et. al.* In review).

A similar decentralized wastewater management demonstration could be implemented for a small cluster of camps. For a cluster of camps in higher-salinity waters (greater than 10 ppt), a marshland upwelling demonstration seems very promising. Such a system has the potential to provide excellent treatment at a cost comparable or below the sum of the cost of several conventional limited-use systems. For a small cluster of camps on one side of a bayou, gravity could be used to route wastewater to a central holding/settling tank. A system could be readily designed for one large pump to deliver clarified effluent to several upwelling wells in a small field.

1.0 Introduction

The Barataria-Terrebonne estuarine system -- over 6,500 square miles of land, wetlands, barrier islands, bayous, and open water -- is located in the Mississippi Deltaic Plain of South Central Louisiana. From east to west, it consists of the Barataria Basin, bounded by the Mississippi River and Bayou Lafourche, and the Terrebonne Basin, bounded by Bayou Lafourche and the Atchafalaya River. The Barataria-Terrebonne estuary has and supports nationally significant resources of fish, shellfish, waterfowl, wildlife, oil and gas, sulphur, and salts (Laska *et al.* 1994). In addition, the estuary is home to more than 600,000 people, sustaining an old and unique culture, rooted deeply in the area's natural resources (BTNEP 1995).



Location of the Barataria-Terrebonne estuarine system.

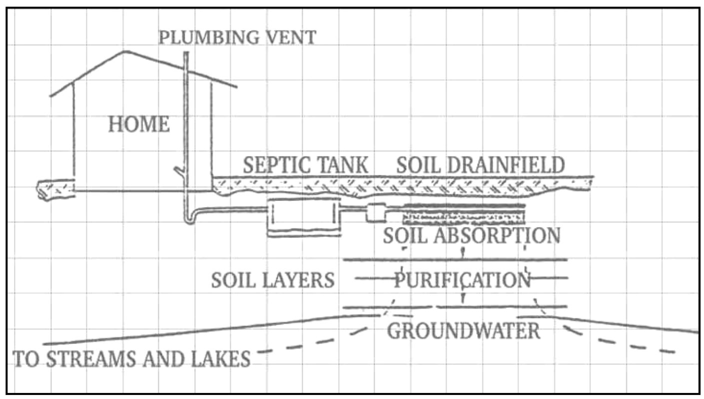
Limited uplands, minimal elevation, high water tables, and clay soils distinguish the Barataria-Terrebonne estuarine system, a result of its connection to the Mississippi River Delta. These conditions are often unsuitable for traditional onsite wastewater treatments, options that are effective in other areas of Louisiana and the United States. Low density, rural development patterns along narrow upland ridges, prevalent in the southern portion of the estuary, make central sewer systems unfeasible simply due to cost. Moreover, extreme vulnerability to storms and flooding, especially in the southern portion of the estuary, make infrastructure investments in traditional central collection and treatment systems risky. Onsite wastewater treatment and disposal using septic systems has been effective in many rural areas around the United States, but limited uplands, high water tables, and clay soils leave soil absorption -- the secondary treatment process of septic systems -- practically ineffective in many areas of the estuary (BTNEP 1996b).

Camps in the Barataria-Terrebonne estuary.

The abundant natural resources of the Barataria-Terrebonne estuary provide significant recreational opportunities, such as fishing, boating, hunting, and bird watching, to residents and tourists alike. These opportunities, combined with the enormity of the estuary, have spurred the development of thousands of fishing and hunting camps, many built directly over the water. Regulated as periodically visited structures, wastewater treatment at these camps -- ranging from simple shelter to elaborate vacation homes -- creates a unique array of public health hazards and wastewater management challenges.

Realizing limitations created by the physical landscape, unique human uses of the Barataria-Terrebonne estuary, and constant resource constraints for activities such as enforcing regulations, local and state officials have worked hard to ensure that wastewater generated at residences and camps is properly treated. In the past decade, the Louisiana Department of Health and Hospitals has increased its efforts to ensure the installation of approved onsite wastewater treatment systems at new and existing residences and camps. From January 1996 to July 1998, approximately 2,500 approved systems were installed in the Barataria-Terrebonne estuary, providing treatment and disposal of almost 1 million gallons of raw sewage each day (T. Boudreaux, pers. comm.). Despite these efforts, the primary source of sewage pollution in the Barataria-Terrebonne estuary is runoff or discharge from inadequate or poorly maintained wastewater treatment plants, rural residences, unsewered communities, commercial and recreational vessels, and waterfront camps (BTNEP 1996b).

The result of inadequate treatment is the discharge of partially treated or raw sewage to the estuary's waters, which may have a variety of adverse impacts. Because sewage-related pathogens in the wastewater remain viable, there is an increased risk of illness from swimming in contaminated water and from consuming shellfish harvested from contaminated waters. Elevated concentrations of sewage-related pathogens can cause shellfish harvesting restrictions, which can hurt local and regional shellfish harvesting, processing, and distributing businesses. In the recent past, emergency harvesting closures have damaged the State of Louisiana's image as a national provider of high quality oysters. Discharges of partially treated and untreated wastewater can also cause an overabundance of nutrients and organic matter in the receiving water. Nutrient-rich waters can cause algal blooms, low dissolved oxygen concentrations in the water column, and fish kills.



Wastewater treatment using a septic system.

The suite of onsite wastewater treatment systems approved for use under the State of Louisiana Sanitary Code might not be appropriate for conditions found in coastal areas of Louisiana, such as the Barataria-Terrebonne estuary. This situation highlighted the need for a survey of alternative onsite wastewater treatment technologies that have been developed and demonstrated throughout the United States, with the intent of identifying suitable technologies appropriate for use in coastal Louisiana (BTNEP 1996b; Action Plan EM-10, M 5.00). It is generally agreed that the demonstration of one or more of these technologies, if successful, might facilitate the introduction of other suitable technologies into the suite of onsite wastewater treatment options allowed by the Sanitary Code.

This survey explores available onsite wastewater treatment technologies and evaluates specific components and systems for performance, cost, and suitability to conditions in the Barataria-Terrebonne estuary. It also reviews the current regulatory structure that dictates the use of onsite wastewater treatment systems in Louisiana. Armed with this information, the survey analyzes the potential to utilize alternative technologies in the following three applications common to the Barataria-Terrebonne estuary:

- Single-family, permanent residences
- Camps with continuous electricity and water under pressure
- Camps without continuous electricity (both with and without water under pressure)

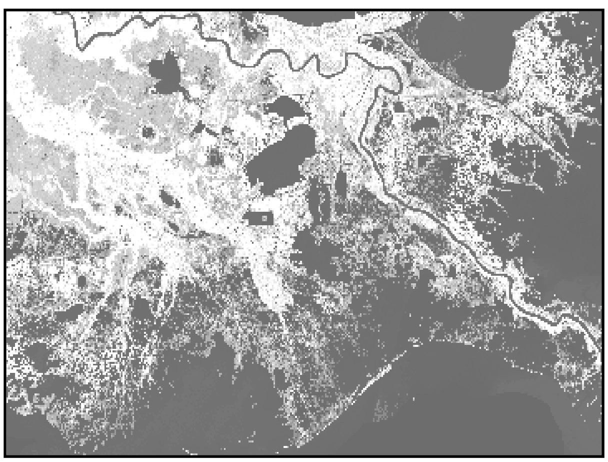
In investigating the issue of utilizing onsite wastewater treatment technologies in coastal Louisiana, it became evident that four management considerations needed to be explored simultaneously: (1) the necessity for proper onsite system maintenance; (2) options for combining wastewater treatment and disposal operations for small clusters of residences or camps; (3) options for greywater reuse/treatment; and (4) the benefits of water conservation.

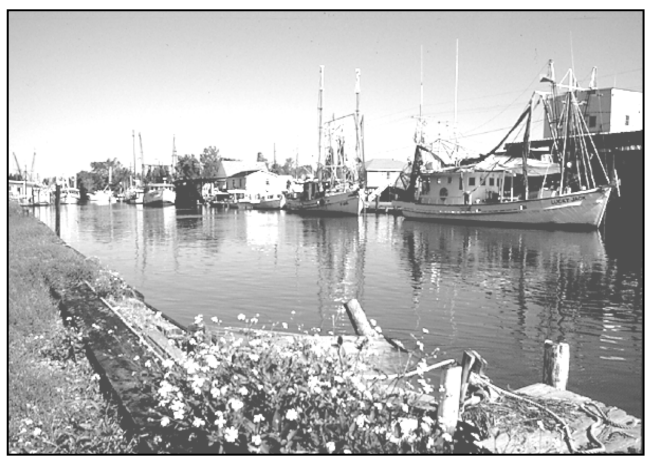
Where an approved system has the capacity to provide proper wastewater treatment, lack of maintenance and service -- such as neglecting to pump out septic tanks, clogged drainfields, broken aeration systems, lack of chlorine disinfection in limited-use systems -- often renders the system inadequate (BTNEP 1996b). In fact, improper maintenance can readily become the limiting factor in both conventional and alternative onsite wastewater treatment system performance. The survey recognizes the importance of this issue, and discusses management options, including adequate enforcement, for ensuring proper maintenance. In certain applications, combining the wastewater treatment needs of small clusters of residences or camps might provide the opportunity to effectively treat wastewater and ensure proper system maintenance, at costs comparable to onsite wastewater treatment. This survey briefly reviews the concept of decentralized wastewater management and available alternative sewer collection systems. Lastly, in certain situations, the reuse, or the separate collection and treatment of greywater might provide more effective wastewater treatment at comparable costs; this survey recognizes the existence of greywater reuse and treatment technologies and the benefits of water conservation practices.

2.0 Onsite Wastewater Treatment in the Barataria-Terrebonne Estuary

2.1 Development within the Barataria-Terrebonne Estuary

The Barataria-Terrebonne estuarine system is located in the Mississippi Deltaic Plain of South Central Louisiana. Its 6,500 square miles of land, wetlands, barrier islands, bayous, and open water, is bounded by the Mississippi River in the east and the Atchafalaya River in the west. Sediment deposition from hundreds of years of annual overbank flooding formed natural levee ridges that border the Mississippi River and various bayous within the estuary. These levee ridges are several thousand feet wide in the northern part of the estuary, but decrease in height and width to the south until they disappear beneath the saltmarsh. Development, including residences, commercial buildings, and fishing camps, follows these levee ridges along both sides of most major bayous. The high ground, provided by the silty clays and silty sands of the levee ridges, rapidly disappears when moving perpendicular to the bayou, becoming soft clays and organic marsh deposits in the inter-bayou basins.





The satellite photo shows the natural levee ridges adjacent to the various bayous in the Barataria-Terrebonne estuary. Development follows these natural levee ridges.

To protect development from flooding in the more vulnerable southern portion of the estuary, forced drainage districts have been established around higher-density communities. Forced drainage district are encircled by a levee, constructed with sediments taken from a borrow canal, positioned just inside the levees. To complete the levee system, there are flow control structures on the bayou that divide the developed area. A number of large pump stations keep the water level in the borrow canal at an acceptable level, by pumping rain runoff over the levee and into the adjacent marsh.

Wastewater treatment within the forced drainage districts is a mix of traditional central wastewater collection and treatment, septic systems, and mechanical plants; the majority of residences, businesses, and camps are served by onsite wastewater treatment. Within this leveed area, poorly treated or untreated sewage discharges flow to one of two places, depending on the location of the outfall with respect to the highest point on the natural levee ridge. Where bayou-ward of this high point, effluents flow to the bayou; when on the other side of this high point, effluents flow to a system of drainage ditches that eventually empty into the borrow canal. Sewage contaminants, fecal coliform bacteria and other enteric bacteria and viruses can, therefore, concentrate both in the bayou and in the borrow canal. These contaminants reach the adjacent marsh by flowing to the end of bayou or being pumped over the forced drainage district levees.

Typical camps found in the Barataria-Terrebonne estuary.

Seaward of the forced drainage district's levees, development usually consists of both large and small camps and a few permanent residences. In several instances, there are also a number of commercial buildings outside of the forced drainage districts. For example, in Cocodrie, near the end of Bayou Petit Caillou, there are restaurants, a hotel, a marina, oil and gas support facilities, two seafood processing facilities, and a large Louisiana university system laboratory. Development in this area is not protected from storm surge or other flooding. Only newer development in these areas stands on pilings to meet minimum first-floor elevations required by the National Flood Insurance Program.

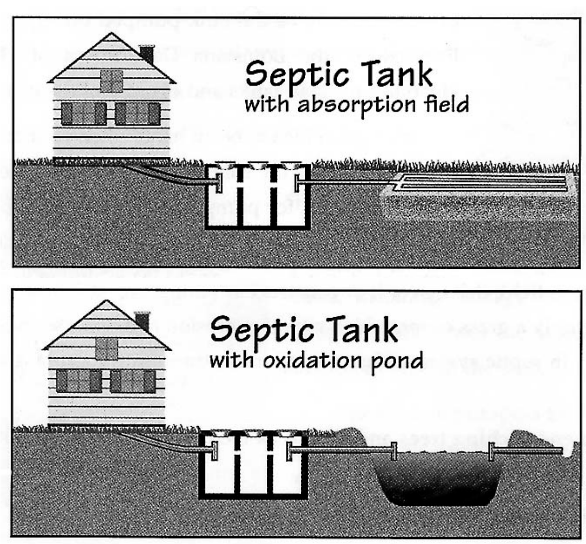
Most development outside of the forced drainage district is served by onsite wastewater treatment. Because the natural levee ridges are much smaller here, poorly treated or untreated sewage discharges flow directly into the adjacent marsh.

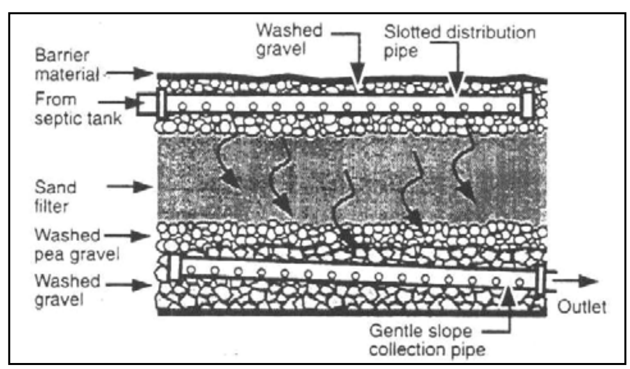
2.2 Status of Onsite Wastewater Treatment in the Barataria-Terrebonne Estuary

Approved Onsite Wastewater Treatment Systems

The Barataria-Terrebonne estuary is largely rural with many unsewered communities (BTNEP 1996b), and a variety of onsite wastewater treatment systems -- septic systems, mechanical plants, and limited-use systems -- are regularly utilized. Septic systems normally consist of two main components, a primary treatment unit -- the septic tank -- and a secondary treatment and disposal unit. A properly designed septic tank is a buried, watertight, multiple-compartment tank, equipped with scum-control baffles. Septic tanks are designed to allow solid materials to settle to the bottom of the tank and oils to float to the top, leaving three levels of waste: bottom solids or sludge, floating scum, and partially clarified wastewater in between these layers. Bacteria in the wastewater feed on nutrients in the solids, and anaerobically digest and decompose most of this material. Because not all solids are broken down, periodically it is necessary to physically remove, or pump out, the solids and scum from the septic tank. Intervals between pumpouts generally range between three to seven years (Smith 1998).

The partially clarified wastewater, called effluent, is then discharged from the septic tank to some secondary treatment and disposal process. Where an absorption drainfield is used, wastewater is distributed to a system of perforated pipes in the ground. Wastewater percolates into the soil, where naturally occurring microorganisms feed on the nutrients and bacteria in the effluent. Where an oxidation pond is used, effluent volume is reduced by evaporation, and exposure to sunlight and oxygen enables aerobic bacteria to digest organic matter. In coastal Louisiana, oxidation ponds are infrequently used in single-unit residential situations because of limited uplands and the exposed nature of the effluent. Where a sand filter is used, wastewater is distributed through a bed of sand, where solids are filtered and the effluent is exposed to microorganisms in the sand. Because the sand substrate for these filters must be imported to coastal Louisiana, sand filters are not commonly utilized.



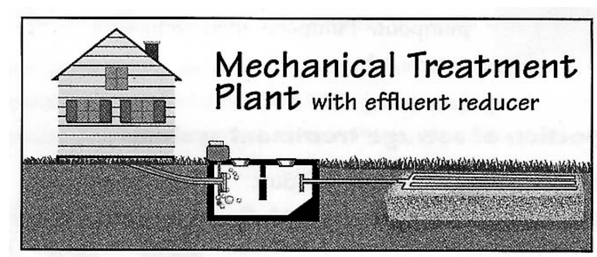


Secondary treatment of septic tank effluent through a sand filter.

As a general rule for satisfactory treatment of septic tank effluent through an absorption drainfield, a 2- to 4-foot layer of well-drained soil is required (K. Sherman, pers. comm.). This condition is only found along the highest bayou ridges in the northern portion of the Barataria-Terrebonne estuary. The silty clays and high water tables prevalent in the southern portion of the estuary offer soils that have minimal capacity for absorbing septic tank effluent. In this case, untreated effluent would ultimately find its way into the bayou or the back levee canal or, in some instances, would remain on or near the surface in front lawns or pools in adjacent drainage ditches, resulting in an unsanitary, foul-smelling neighborhood.

The State of Louisiana Sanitary Code provides an alternative for situations where soil permeability or lot size will not allow the installation of an absorption drainfield. Mechanical plants, a type of aerobic treatment plant, are designed to provide both primary and secondary treatment of wastewater within one unit. Organic matter is broken down and digested by injecting air into the wastewater with an electric pump or motor. Normally mechanical plants discharge directly to a ditch or surface water. An effluent reduction field -- a modified absorption drainfield (*i.e.*, a shortened version of a septic system drainfield) -- is required for mechanical plant installations on small lots or where offsite drainage is an obvious problem (*e.g.*, where site visitation indicates that adjacent ditch elevation would cause standing water). While it varies greatly from parish to parish, it is estimated that, statewide, 5 to 10 percent of mechanical plants discharge to an effluent reduction field (M. Vidrine, pers. comm. 9/15/99).

Currently, the Sanitary Code specifies two effluent limits for mechanical plants: 45 mg/L total suspended solids and 45 mg/L biological oxygen demand (BOD). While disinfection requirements have been incorporated into several onsite system permits, there are no statewide effluent limits for fecal coliform bacteria.



Not all mechanical plants currently approved by the Louisiana Department of Health and Hospitals (LDHH) carry certification by the American National Standards Institute (ANSI). However, recent regulatory revisions established a program of third-party ANSI certification of mechanical plants. As of January 20, 1999 all new mechanical plant models must function at ANSI Class I effluent criteria levels (described in more detail below). Beginning on January 1, 2001, all mechanical plant models, including existing models, must acquire this certification. Even small changes in a proprietary system will require re-certification. Another benefit of this program is that it removes LDHH from the mechanical plant approval process. Currently-approved mechanical plant models include: Aqua Klear, Aqua Safe, Cajun Aire, Clear Stream, Delta Environmental, Econo HP, Jet, Jet Aire, Mo-Dad, Mud Bug, Multi-Flow, Norweco, Old Ham, and Southern Aerobic Systems (M. Vidrine, pers. comm.).

ANSI certification requires that the installer/manufacturer of an aerobic treatment plant provide a 2-year maintenance agreement with the user of the system. Recognizing the benefits of this requirement, the January 20, 1999 revisions of the Sanitary Code will require and monitor regular maintenance of mechanical plants in Louisiana. It will be the installer's responsibility, on behalf of the manufacturer, to provide a service contract to inspect and maintain the mechanical plant. Inspections are required every six months for the first two years. After this initial period, the plant owner must sign an affidavit agreeing to continue maintenance through a service contract, normally for a period of 1 to 5 years. The service provider must report results of inspections to the plant owner and LDHH. LDHH will then conduct spot checks of inspections and serviced mechanical plants. The service contract requirement will be applicable to all new systems after January 1, 2001. The requirement currently applies, and will continue to apply, to existing mechanical plants cited for malfunction. Normal inspection upon legal property transfer also grandfathers an existing mechanical plant into the service contract requirement.

Proposed regulations were published in the Louisiana State Register on August 20, 1998 to establish specifications for a number of effluent reduction systems, most of which are considered alternative technologies. While these did not pass and were not promulgated in the January 20, 1999 revisions to Chapter XIII of the Sanitary Code, it is possible that some form of these regulations could be included in future revisions (T. Boudreaux, pers. comm.). The following is a summary of these proposed regulations:

Effluent Reduction Field
Uses absorption and evaporation to reduce effluent volume from mechanical plants. The system is not visible above ground. Effluent reduction fields cannot be driven over, paved, or built upon.

Treatment Capacity of Sewerage System (gpd)	Minimum Total Length Per Field (ft)
500 or less	100
501 to 750	150
751 - 1000	200
1001 - 1500	300

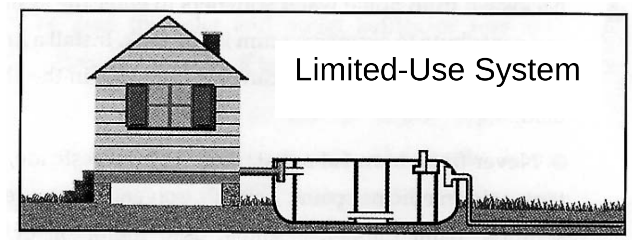
Rock Plant Filter
Uses evapotranspiration to reduce effluent. A type of constructed wetland that looks like a garden and requires similar maintenance. Large 2- to 3-inch diameter gravel must be utilized.

Treatment Capacity of Sewerage System (gpd)	Rock Plant Filter Size (sq. ft.)
500 or less	150
501 to 750	225
751 - 1000	300
1001 - 1500	450

Spray Irrigation
The spray irrigation system uses an electric pump that distributes the effluent to the yard through sprinkler heads. The effluent from the treatment system collects in a pumping chamber. At a predetermined level, a float switch activates a pump that forces the effluent through piping to pop-up or elevated rotating sprinkler heads. Evaporation and soil infiltration of the dispersed effluent should prevent any runoff from occurring.

Overland Flow
When the size of the property is three acres or more, an overland flow may be utilized. The discharge through perforated pipe must be distributed in such a manner as to confine the effluent on the property owned by the generator.

The Sanitary Code contains special provisions for onsite wastewater treatment at structures occupied three days per week or less and located in the marsh, in a swamp area, or over water. These provisions allow the use of limited-use wastewater treatment systems at the thousands of fishing and hunting camps -- which very in size from simple shelter without windows to large multi-bathroom vacation homes -- found in the Barataria-Terrebonne estuary. Conventional limited-use systems have a four-compartment treatment unit and discharge directly to the receiving water. Disinfection is provided by chlorine contact in the fourth chamber of the unit. Because the user must manually add chlorine tablets, conventional limit-use systems should be equipped with an automatic cutoff to prevent flow from the third chamber if the chlorine supply is exhausted.



In August 1999, a new type of limited-use system manufactured by Houseboat Outlet, Inc. -- the HBO250 -- was approved for use by LDHH. The HBO250 provides aerobic treatment using an AC or DC blower (the blower can be powered with batteries, where camps do not have access to continuous electricity). Other approved limited-use systems include mechanical plants, in cases where the lot is at least 12,000 square feet, and a Type-II or Type-III Marine Sanitation Device (MSD). The Coast Guard regulates MSDs. MSDs are designed to only treat blackwater (*i.e.*, the sewage component of household wastewater); where MSDs are used at a camp, a greywater treatment system would also be required. The Sanitary Code also has provisions for non-waterborne systems, such as composting toilets, that would be applicable to overland camps where there is no access to water under pressure.

The Louisiana Department of Environmental Quality (LDEQ) also has a role in regulating sanitary discharges in the Barataria-Terrebonne estuary. One general permit -- and its associated effluent limits for biochemical oxygen demand, total suspended solids, fecal coliform bacteria, and pH -- exists for sanitary discharges under 5,000 gpd, but does not apply to discharges from individual residences. However, it is applicable to discharges from an onsite system treating sewage from two or more residences, or a privately-owned community wastewater treatment system (G. Aydell, pers. comm.). This permit has provisions for additional restrictions on fecal coliform bacteria concentrations in discharges to "oyster propagating areas."

Another LDEQ general permit applies to discharges from individual residences that went online from September 1, 1989 to August 31, 1994 (G. Aydell, pers. comm.). This general permit is implemented on a compliant-driven basis, after first yielding the complaint to officials at LDHH (G. Aydell, pers. comm.). No fee is collected by LDEQ for this permit. LDEQ has plans to create a new general permit applicable to sanitary discharges from individual residences (G. Aydell, pers. comm.).

Estimated Failures of Onsite Wastewater Treatment Systems

Evidence suggests that environmental conditions prevalent in the Barataria-Terrebonne estuary can significantly impair the treatment process of existing septic systems. Evidence also suggests that the lack of proper septic system maintenance, such as periodic removal of solids from septic tanks, maintenance and repair of mechanical plants, and regular replacement of chlorine tablets in limited-use systems, regularly leads to onsite wastewater treatment failure. In addition, anecdotal information suggests that wastewater from a few residences and camps is not treated by any type of community or onsite system.

The LDHH Sanitarian Regional Director, Region III, maintains a database of wastewater treatment systems and their approved/unapproved status for several parishes within a portion of the Barataria-Terrebonne estuary. For the area from Chauvin to Cocodrie, along Bayou Petit Caillou in Terrebonne Parish, LDHH has cataloged a total of 2,104 onsite discharges from residences, businesses, and camps. Some of these structures are within the forced drainage district, as, for example, those within the community of Chauvin, while many others, including most of the camps, are not within any protective levees. These discharges are characterized as follows:

- 179 residences are connected to 1 of 12 community sewage treatment systems
- 74 businesses are connected to extended aeration plants
- 670 residences are connected to individual mechanical plants
- 481 residences are connected to septic systems or are not connected to any system
- 300 camps have approved limited-use systems
- 400 camps have unapproved limited-use systems or no system

Given the approved/unapproved status of these systems, LDHH estimates that approximately 485,200 gpd of partially treated or untreated wastewater are discharged directly or indirectly to Bayou Petit Caillou and surrounding marsh and surface waters (T. Boudreaux, pers. comm.).

A survey conducted by the LDHH Oyster Water Monitoring Program for a 1990 Shoreline Survey identified a total of 338 structures – 299 camps, 31 residences, and 8 commercial buildings – along a section of Bayou Petit Caillou in Terrebonne Parish (roughly from the Robinson Canal to just north of the intersection of Bayou Petit Caillou and the Houma Navigation Canal). Approximately 46 percent of the camps and 42 percent of the residences were observed to have some sanitation discharge-related violation, such as a raw sewage or washwater discharge, an obvious onsite wastewater treatment system failure, or no treatment system (Kilgen and Kilgen 1990).

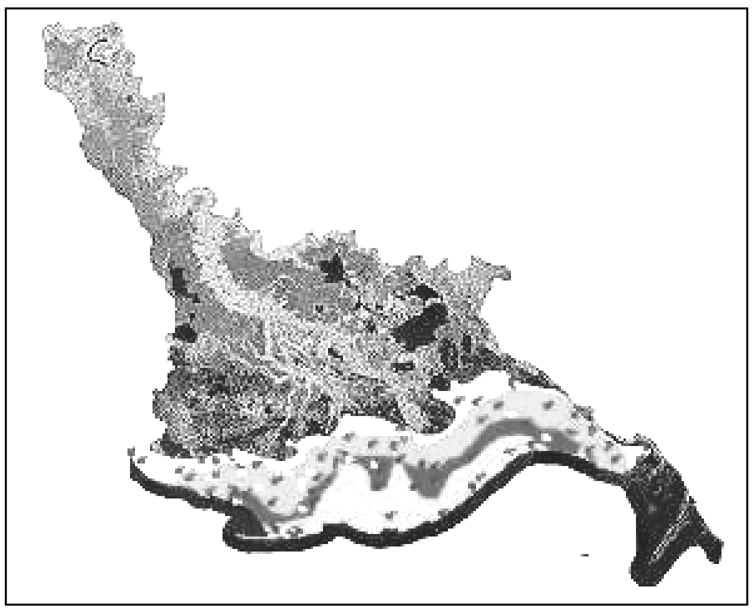
The impacts of failing onsite wastewater treatment systems are compounded by high densities. The Sanitary Code states that community sewerage systems are required for all new subdivisions and developments where lots are sold or leased. There are several allowable instances, all of which are detailed in the next section, where onsite wastewater treatment systems can be used instead, for example, where fewer than 125 lots are involved. Anecdotal information suggests that the requirement for community sewerage is sometimes subverted by incremental development of large tracts of land. Where conditions may not be appropriate for approved onsite wastewater treatment systems, as can be the case in the southern portion of the Barataria-Terrebonne estuary, this practice can lead to large numbers and high densities of failing onsite systems.

Potential Consequences of Failed Onsite Wastewater Treatment

The result of inadequate wastewater treatment is the discharge of partially treated or untreated sewage to ground and surface waters. These effluents can accumulate and stand in drainage ditches, or concentrate in canals and bayous. Because sewage-related pathogens can remain viable, there is an increased risk of illness from swimming in contaminated water, accidental ingestion, or consuming shellfish harvested from contaminated waters. Typhoid fever, cholera, dysentery, infectious hepatitis, and poliomyelitis are diseases that may be transmitted by inadequate wastewater treatment. Hookworm and other intestinal parasites are also associated with improperly treated wastewater.

Nutrients, such as nitrogen and phosphorus, are essential for healthy and productive freshwater, estuarine, and marine environments, but discharges of partially treated and untreated sewage can cause an overabundance of these nutrients and organic material. Nutrient-rich waters can cause algal blooms that block sunlight necessary for growth of submerged aquatic vegetation. Further, when algae die, their deterioration removes life-supporting oxygen from the water column, eventually resulting in fish kills. In addition to being unsightly and smelly, some algal blooms are directly harmful to human health because of toxic substances that they produce.

The Barataria-Terrebonne estuary is one of the nation's premiere oyster producing areas. The LDHH Oyster Water Monitoring Program is required to monitor fecal coliform bacteria (as an indicator of other enteric bacteria and viruses) concentrations in oyster growing waters and restrict or prohibit harvest from these waters based on certain threshold concentrations. The Program redraws a “seasonal classification line” four times a year based on monitoring results, and oyster harvesting landward of this line is prohibited or managed. Poorly treated or untreated sewage discharges contribute to high fecal coliform bacteria concentrations in oyster growing waters and affect the location of this line (*i.e.*, upstream sewage discharges increase fecal coliform concentrations in downstream oyster harvesting waters, thereby causing the seasonal classification line to be located farther seaward).



The shaded bands in the lower part of this map of the Barataria-Terrebonne estuary represent areas where oysters are harvested.

Large sectors of the Barataria-Terrebonne estuary economy are supported by businesses that harvest, process, and distribute oysters. Onsite wastewater treatment failure and the consequent elevated levels of sewage pollution in the estuary's waters can contribute to the restriction or closure of areas where oysters can be harvested. In addition, recent emergency harvesting closures caused by sewage pollution have damaged the State of Louisiana's image as a national provider of high quality oysters.

State of Louisiana Task Force on Individual Wastewater Treatment Systems

On January 31, 1997, the Governor of Louisiana signed Executive Order No. MJF97-9, establishing the Task Force on Individual Wastewater Treatment Systems (LDHH 1999). The Secretary of LDHH was directed to chair the Task Force. Noting that "serious environmental and health threats may exist due to the individual wastewater treatment systems in use in both urban and rural areas of the state which are inadequate or malfunctioning," the Task Force was given the following duties:

- Prepare a preliminary report which identifies potential health and environmental problems associated with individual systems, defined as those with a capacity less than 1,500 gallons per day; review relevant regulations in use by southern states; and present a plan to study the identified problems.
- Compile information on the current use of individual systems.
- Prepare a final report on the impact of individual systems on the environmental and public health, and the need for uniform statewide regulation of such systems.
- Recommend legislation and/or regulatory provisions (LDHH 1999).

The *Preliminary Report of the Task Force on Individual Wastewater Treatment Systems* was submitted to the Governor on January 22, 1999.

The initial focus of the Task Force was to identify potential health and environmental problems associated with individual wastewater treatment systems. The Task Force's Problem Identification Committee submitted a November 1997 Problem Identification Report, with the following conclusions:

- Reducing individual system effluent run-off, to the maximum extent possible, can minimize citizen exposure to pathogens and contaminants (proposed requirements for effluent reduction systems were developed and submitted as part of the January 22, 1999 report to the Governor).
- Regulatory agencies lack empowerment and funding to ensure the proper design, installation, and maintenance of individual systems.
- Emphasis on and installation of community sewage treatment can make inspection and regulation of discharges much more manageable and can improve the quality of the effluent discharged.
- The major problem in the onsite wastewater treatment industry can be identified as the lack of an effective management system and regulatory infrastructure for onsite wastewater treatment systems for septic and aerobic modalities. This can be more clearly defined as a:
    1. Lack of a basic code containing sufficient requirements and criteria for wastewater treatment technologies as it pertains to development, testing, manufacturing, installation, and maintenance;
    2. Lack of effective, approved, and affordable disposal methods appropriate for Louisiana soils;

3. Lack of adequate education and training programs for installers and maintenance providers;
4. Lack of effective enforcement authority for LDHH/Office of Public Health against inadequate, unapproved, or failing systems. This applies to manufacturers, installers, and homeowners/operators;
5. Lack of funding for LDHH/Office of Public Health administrative and field personnel who are well trained in wastewater treatment technologies and science;
6. Lack of funding for management of wastewater program by LDHH/Office of Public Health;
7. Lack of indigent family assistance for the purchase and installation of approved wastewater treatment systems;
8. Lack of homeowner education programs for onsite wastewater treatment systems as to their installation, use, and maintenance; and
9. Lack of improved evaluation by LDHH/Office of Public Health for new wastewater treatment technologies, and to change existing approved technologies (LDHH 1999).

The next focus of the Task Force was to review regulations concerning individual wastewater treatment systems, and devise a plan to study and address the identified health and environmental problems. The Regulation Review Committee studied regulations governing individual wastewater treatment systems for the states of Texas, Mississippi, and Louisiana. The Committee's report, submitted on May 1, 1998, recommended the following actions:

- Accept and support the revised Chapter XIII of the Louisiana Sanitary Code (the revisions to Chapter XIII were accepted and promulgated on January 20, 1999).
- Form a Phase II Regulation Review Committee to conduct further recommendations.
- The Task Force supports legislation for:

1. A tax credit for installations of individual sewage systems,
2. An individual indigent family fund, and
3. A tag fee increase for individual sewage system.

3.0 Applicable Regulations and Standards

3.1 Text Summary of the State of Louisiana Sanitary Code, Chapter XIII: Sewage Disposal

This summary is based on Sanitary Code, Chapter XIII regulations as revised and approved on January 20, 1999 (Louisiana, State of 1999).

Chapter XIII of the State of Louisiana Sanitary Code contains regulations for the treatment and disposal of sanitary sewage, any and all human waste, and/or domestic waste. The regulations specify whether a community or individual sewerage system is acceptable for a residence or subdivision, specify the types of individual sewerage systems allowed for use in Louisiana, and specify the treatment performance of all sewerage systems.

General Requirements

All premises with plumbing fixtures installed as prescribed in Chapter XIV of the Sanitary Code must be connected to a community sewerage system whenever feasible. If it is determined by the State Health Officer to be unfeasible, an individual sewerage system may be installed as long as its installation and operation are not likely to create a nuisance or public health hazard. No person shall allow, directly or indirectly, discharge of plumbing fixtures or sewerage systems into any road, street, gutter, ditch, water course, body of water, or onto the surface of the ground. No sewerage system should be installed where contamination of groundwater supply will occur.

Requirement for Community Sewerage Systems and Allowable Instances for Individual Sewerage Systems

A community sewerage system refers to any sewerage system that serves multiple connections, and consists of a collection and/or pumping/transport network and treatment facility. Community sewerage systems are required for all new subdivisions and developments where lots are sold or leased. Community systems are also required for use by pre-existing structures in any area where they become available and where there is ample water supply.

In order to build a community sewerage system, the operator must receive a permit from the State Health Officer prior to the start of construction. The review and approval of plans and specifications submitted for issuance of a permit will be made in accordance with the design standards presented in "Recommended Standards for Sewage Works," 1990 Edition, promulgated by the Great Lakes and Upper Mississippi River Board of State Sanitary Engineers. The system must be constructed, operated, and maintained at all times as specified in the permit. Once the community sewerage system is in operation, the operator must maintain continuous compliance with the effluent limitations and standards established by the State Health Officer for that facility. At a minimum, effluent from community sewerage systems must meet the Secondary Treatment Standard (see sidebar box).

Instances exist where individual sewerage systems, in lieu of community sewerage systems, may be authorized. The regulations specify that, in the following cases, the State Health Officer may authorize an approved individual sewerage system:

> *Secondary Treatment Standard* means a sewage effluent water quality standard which prescribes a maximum 30-day average concentration of biochemical oxygen demand [five day basis] (BOD_5) of 30 mg/l and a maximum daily concentration of BOD_5 of 45 mg/l. The 30-day average concentration is an arithmetic mean of the values for all effluent samples collected in the sampling period. The analyses to be performed for the purpose of determining compliance with these effluent limitations shall be in accordance with the 18th edition of the "Standard Methods for the Examination of Water and Wastewater," published by the American Public Health Association.

1. Subdivisions that have less than 125 lots and the developer submits a comprehensive drainage plan and proposal for restrictive covenants, which detail requirements for perpetual maintenance of drainage.
2. Total anticipated design flow to the sewerage system does not exceed 1,500 gpd and no food service is involved.
3. Large lots, with an area of 1 acre and having a minimum frontage of 125 feet.
4. Lot or plot with a minimum of 22,500 square feet and a minimum frontage of 125 feet.
5. Subdivisions that meet Criterion #4 for 85 percent of the lots and the other 15 percent have a minimum frontage of 60 feet, and width of each lot is at least 125 feet.
6. Where parish governing authorities have enacted and enforce a formal sewerage permitting system, and lots meet the following criteria:
   - Minimum area of 22,500 square feet and minimum frontage of 80 feet
   - Minimum area of 16,000 square feet and minimum frontage of 80 feet and where an approved individual mechanical plant is to be utilized
   - Minimum area of 12,000 square feet and minimum frontage of 60 feet and where an approved individual mechanical plant is to be utilized with a 50-foot modified absorption field
7. Where "lots of record" are combined to create a larger, single lot, and no re-subdivision of the property is involved.
8. Single lots or sites, regardless of size, remaining in substantially developed, previously established subdivisions, when, in the opinion of the State Health Officer, a hazard to the public health will not result.
9. Single lots or sites, regardless of size, when the property owner proposes to replace or renovate a pre-existing sewerage system and the State Health Officer determines a public health hazard or nuisance will not result.

Single commercial structures, where less than 1,500 gpd total flow is expected and where the connection to a community sewerage system to serve other loading sources is not required, may utilize either an individual or commercial sewerage system, provided minimum lot-size requirements for the use of individual sewerage systems are met. A commercial sewerage system shall be installed for business establishments where the preparation of food and/or drink is the primary business activity. Apartment complexes, condominium complexes, hotels, motels, and other such complexes shall be connected to a community sewerage system; a commercial sewerage system shall be installed when no existing community sewerage system, capable of accepting the additional loading, exists.

Requirements for Approved Individual Sewerage Systems

A permit must be obtained to install and operate an individual sewerage system. A permit is issued after an onsite inspection of the system determines that system has been installed in compliance with regulations. Individual sewerage systems will be installed and operated according to regulations detailed in Appendix A of Chapter XIII, *Regulations Controlling the Design and Construction of Individual Sewerage Systems* (each approved system is described below). Individual sewerage systems, other than conventional septic systems (*i.e.*, a septic tank followed by a subsurface disposal system), shall comply with all provisions of the LDEQ Wastewater Discharge Permit.

Specific Regulations on Approved Individual Sewerage Systems

Several options are available for individual sewerage system design. All individual sewerage systems, with the exception of limited-use sewerage systems, must generate effluent meeting the Secondary Treatment Standards described above. Appendix B of Chapter XIII of the State Sanitary Code provides sewage-loading criteria for determining the average daily design flow and organic loading of individual sewerage systems.

Septic Tanks

Conventional individual sewerage systems begin with a watertight, corrosion-resistant septic tank. The septic tank may be square, rectangular, or cylindrical and may have one large compartment or have several compartments, although two or three compartment systems are encouraged. The minimum required total septic tank liquid capacity is 500 gallons or 2.5 times the estimated average daily design flow, whichever is greater. The use of septic tanks in series is encouraged; in these cases, the first tank must have a 500-gallon liquid capacity and subsequent tanks must have a 300-gallon liquid capacity. Septic tanks should provide primary treatment to household wastewater. After the effluent has passed through the septic tank, it must be delivered to an acceptable device for secondary treatment. Approved methods include absorption trenches, oxidation ponds, or sand filters.

Solids that settle out in a septic tank are acted upon by bacterial decomposition and are largely transformed into liquids or gases. The remaining residue in the tank is a sludge that must be periodically removed from the tank.

Absorption Trenches

Absorption trenches are earthen-covered, gravel-filled trenches into which septic tank effluent is distributed via a network of perforated pipes; the liquid wastewater seeps through the gravel and into the underlying soil, allowing soil-associated microorganisms to decompose the organic matter. Although this is the most commonly used form of secondary treatment, sufficient space and satisfactory soil conditions must exist for absorption trenches to be effective. Sufficient space to install absorption trenches is determined by the volume of effluent, soil conditions, and proximity to drinking water supplies and property lines. Satisfactory soil conditions are determined by measures of soils permeability, percolation rate, and groundwater level. A "Percolation Test" is used to determine soils acceptability and size of the required absorption trench system. Once the size of the absorption trench system has been determined, the actual design of the system will depend on the size and shape of the property. Minimum requirements for trench length, width, and proximity to each other are specified in the regulations, along with specifications for pipe, aggregate, and cover material.

Oxidation Ponds

Another form of secondary treatment consists of a shallow pond designed specifically to treat wastewater through natural purification processes under the influence of sunlight and air. Oxidation ponds rely on bacteria and algae to render the effluent harmless and odor free. The bacteria digest and oxidize the wastewater, and the algae use the products from bacterial degradation to produce oxygen needed to sustain the bacteria in the treatment process. The main obstacles to utilizing oxidation ponds are their large size and proximity to buildings and property lines. At a minimum, the oxidation pond must be 400 square feet and 4- to 5-feet deep for systems up to 400 gpd. If input to a system is greater than 400 gpd or if the input has a high BOD loading, the size of the pond must be increased. In addition, the oxidation pond must be surrounded with a fence to keep animals and unauthorized persons from accessing the pond. The regulations specify requirements for wall construction, materials, inlet and outlet placement and design, and maintenance procedures.

Sand Filters

Sand filters remove solids in septic tank effluent and utilize microorganisms in the bed of sand to break down these solids. The sand filter consists of a layer of coarse gravel over a bed of sand, at a minimum 24 inches deep; the entire bed must be a minimum of 12 feet wide and 25 feet long. Septic tank effluent is distributed through perforated pipes placed at the top of coarse gravel. In order for this particular system to work, the bed must be completely drained and the sand must be continuously exposed to air. This may require that the bed be raised above natural ground level. Specifications on system cover material, gravel, and sand size are given in the regulations.

Mechanical Plants

Mechanical plants provide primary and secondary treatment of sewerage in one unit, using aerobic bacterial action sustained by mechanical means. Mechanical plants can only be used when it is determined that conventional septic systems can not be utilized. The regulations specify that any new mechanical plant design must be certified by an accredited certification program testing/evaluation facility (third party), as meeting NSF 40-1996 and ANSI/NSF 40-1996 Class I standards (described below). The regulations require that each manufacturer of mechanical plants must annually inspect at least 10 percent of its authorized installers in Louisiana, for proper installation procedures.

Manufacturers/sub-manufacturers/installer must provide a minimum 2-year service policy to the purchaser of a mechanical plant. The service policy requires four inspection visits over this

2-year period, to service and adjust electrical and mechanical components of the plant. The service policy also contains provisions for an effluent quality inspection, consisting of a visual assessment of color, turbidity, and scum overflow, and an olfactory assessment for odor. Lastly, manufacturers/sub-manufacturers/installers must make available an extended service / maintenance agreement to owners of mechanical plants; it is the owners responsibility to provide proof of an extended service contract. The service provider will notify the State Health Officer whenever an extended service contact has been negotiated. An "Individual Mechanical Plant Initial Warranty Inspection/Service Report" must be submitted to the State Health Officer after each inspection is completed by the service provider, and will become part of the permanent record for each mechanical plant.

Requirements for Limited-Use Sewerage Systems

There are special provisions for structures, occupied three days per week or less and located in a marsh/swamp area or over water, to utilize a limited-use sewerage system. Where a community sewerage system is not available, a limited-use system, consisting of three septic tanks in series (or an acceptable three-cell or three-compartment tank), followed by an automatic chlorination system, may be utilized. The first cell shall have a minimum liquid capacity of 500 gallons. The second and third cells shall each have a minimum liquid capacity of 250 gallons. The chlorination system shall be provided with a contact chamber of a minimum of 100 gallons, and shall be equipped with an automatic cutoff to prevent flow from the third cell if the chlorine supply is exhausted.

Non-Waterborne Systems

Non-waterborne systems include pit toilets (or privies), vaults, pails, chemical toilets, incinerator toilets, or composting toilets. A non-waterborne system may be used in situations where the State Health Officer determines that (1) it is impractical or undesirable (for example, water under pressure is not available) to either connect to an existing community sewerage system or to install an individual sewerage system and (2) the system will function without creating a health hazard or nuisance.

Consideration and Approval of Innovative or Experimental Sewerage Systems

The State Health Officer may consider for approval, on an individual basis, proposals for developments that are of a unique nature (*e.g.*, development over water or in an irregular configuration) where individual wastewater disposal is proposed, in cases where the development is clearly not addressed by the current considerations of the Sanitary Code.

Where a person proposes innovative processes or design features, other than those described in Appendix A of Chapter XIII of the State Sanitary Code, a limited number of experimental or developmental installations may be approved where either failure of the installation or insignificant benefits to performance and costs is not expected, based on current engineering data and literature. The total number of such installations shall not exceed three throughout the State and shall be approved under the following conditions:

- Each installation shall be installed only in accordance with plans and specifications and testing procedures which have been specifically approved for each installation as a part of a permit issued by the State Health Officer prior to the installation.
- The permit for each installation shall be for a period of 1 year and may be renewed.
- Should an innovative process fail, the owner of the premises and the person proposing the innovative process shall upgrade or replace the installation to bring it into compliance.

The approval of a proposal to utilize a proprietary device may only be granted by the State Health Officer. Proprietary devices include all devices designed to reduce, process, and treat all or a select portion of wastewater generated within the individual home, such as water recycling and reuse devices, water conservation devices, composting units, and other devices intended to reduce the volume of waste generated or water consumed.

Other Requirement in the Regulations

Chapter XIII also contains regulations on sewage hauling, licensing procedures for installers and manufacturers of individual sewerage systems, and pumping stations; none of these subjects is detailed in this text summary of the regulations.

3.2 Text Summary: ANSI/NSF Standard 40 - Residential Wastewater Treatment Systems

The purpose of American National Standards Institute (ANSI)/National Sanitation Foundation (NSF) International Standard 40 is to establish the minimum criteria for the materials, design and construction, and performance of residential wastewater treatment systems handling 400 to 1500 gpd. The standard is directed towards manufacturers who are designing or building residential wastewater treatment systems, and lists general materials, design, construction, and testing specifications that must be incorporated into all systems. For example, materials used to construct the system shall be durable, capable of withstanding assembly and operational stresses, and not adversely affected when used in the environment. The Standard lists general specifications in the following areas:

- Infiltration and exfiltration resistance
- Mechanical components
- Electrical components
- Access ports
- Failure sensing and signaling equipment
- Dataplate and service labels
- Limited warranty
- Product literature
- Service-related obligations

Standard 40 also specifies maximum noise levels, flow design, and performance testing and evaluation criteria. The maximum noise level allowed for a correctly installed system is no more than 60 dbA within 20 feet of the system. The system will be designed and built with a specific flow path so that, at no time during normal system operation or component malfunction, shall wastewater be discharged from an opening external to the designated flow path. The performance testing and evaluation portion of the standard gives specifics for system assembly, influent water characteristics, hydraulic loading, and schedules.

Standard 40 lists requirements for system operation evaluations. New systems are evaluated over 26 consecutive weeks with the system being dosed 7 days a week. The first 16 weeks are performed under normal operation conditions, followed by 7.5 weeks of stress loading, then another 2.5 weeks of normal operation. Included in the stressed-operation tests are examples of a laundry day, working-parent schedule, power/equipment failure, and vacation. The Standard gives specifics on the amount and type of influent water used during each test, and a schedule of when the stress days will be run. The normal-operation wastewater used is specified as having a 30-day average carbonaceous five-day biochemical oxygen demand ($CBOD_5$) of 100 mg/L to 300 mg/L and a 30-day average total suspended solids (TSS) level of 100 mg/L to 350 mg/L.

Table 1. ANSI/NSF Standard 40 Minimum Effluent Criteria for Class I and Class II Wastewater Classification.

Parameter	Class I	Class II
$CBOD_5$	30-day average ≤25 mg/L[a] 7-day average ≤ 40 mg/L[a]	Not more than 10% of the effluent values shall exceed 60 mg/L
TSS	30-day average ≤30 mg/L[a] 7-day average ≤ 45 mg/L[a]	Not more than 10% of the effluent values shall exceed 100 mg/L
pH	Between 6.0 and 9.0	Not specified
Color	≤ 15 units	Not specified
Odor	Non-offensive	Not specified
Oily film and foam	Not visually detected	Not specified

a – System performance shall not be considered outside the Class I limits if, during the first calendar month of performance testing and evaluation, 7-day average and 30-day average effluent $CBOD_5$ and TSS concentrations do not equal or exceed 1.4 times the specified limits.
Source: NSF International (1999).

During systems operation testing, effluent samples are evaluated for pH, $CBOD_5$, and TSS, as well as color, odor, and the presence of foam and oily film. Samples are collected randomly during the three phases of testing (normal [weeks 1-16], stressed [weeks 17 – 23.5], and normal [weeks 23.6 – 26]) and composited into 3 effluent samples. The samples are collected in accordance with *Standard Methods for the Examination of Water and Wastewater*, published by the American Public Health Association, unless otherwise specified, and analyzed in accordance with Standard 40. The results of the effluent analysis determine whether the system has passed the Standard 40 requirements and whether it will be classified, based on treatment performance, as a Class I or Class II system. Table 1 lists the sample concentration criteria for Class I and Class II wastewater treatment systems.

3.3 Text Summary: ANSI/NSF Standard 46 - Evaluation of Components and Devices Used in Wastewater Treatment Systems

The purpose of the ANSI/NSF International Standard 46 "is to establish minimum materials, design and construction, and performance requirements for components and devices used in the handling, treating, recycling, reusing, or disposal of wastewater." This standard is used for components and devices not covered by ANSI/NSF Standard 40 that will be used to handle greywater or blackwater. The materials, design and construction, and product literature sections of Standard 46 give general specifics for manufacturers in selecting and designing components. One specific component covered in detail by Standard 46 is the design, construction, and performance of grinder pumps. The standard specifies performance testing and evaluation procedures specifically for grinder pumps. Component testing includes over 6 weeks of operation with 26 different household items being ground by the device (*e.g.*, diapers, nylon hose, toothbrush, wood pencil, metal toy car) and three different levels of operation (low-capacity, mid-capacity, and maximum capacity). The grinder must also be put through shut-off, negative head, basin leakage, and structural integrity tests. Once a grinder pump or other component has passed the criteria specified in Standard 46, it may be marketed for use in wastewater treatment systems.

3.4 Other Relevant State Regulations and Parish Ordinances

Department of Environmental Quality

LDEQ currently maintains a Class I Sanitary General Permit, permit number LAG530000, that applies to all sanitary discharges less than 5,000 gpd, except for those from individual residences. Technically this permit applies to sanitary wastewater discharges and other wastewaters that can be treated biologically. It applies to onsite wastewater treatment systems that handle sewage from two or more homes, and privately-owned community wastewater treatment systems with flows under 5,000 gpd.

Under this permit, discharges less than 2,500 gpd must be monitored once per year, while discharges between 2,500 gpd and 5,000 gpd must be monitored once every six months. Effluent limits are the same for all discharges regulated under this permit: maximum weekly average biochemical oxygen demand (BOD) of 45 mg/L; maximum weekly average TSS of 45 mg/L; maximum weekly average fecal coliform bacteria (FC) concentration of 400 colonies per 100 mL MPN; and pH between 6 and 9. If the discharge utilizes an oxidation pond the maximum weekly average TSS limit is 135 mg/L. If the outfall discharges to an oyster propagation area, as determined by LDEQ, the FC limit is a maximum monthly average of 14 colonies per 100mL MPN and a maximum weekly average of 43 colonies per 100 mL MPN.

Another LDEQ permit applies to sanitary discharges, General Permit LAG550200. It was originally issued by USEPA, on September 1, 1989, as a National Pollution Discharge Environmental Standards (NPDES) permit, and currently exists as a Louisiana Pollution Discharge Environmental Standards (LPDES) permit. General Permit LAG550200, which expired on August 31, 1994, applies to sanitary discharges less than 2,500 gpd, including those from individual residences that existed prior to the permit expiration date. Dischargers are automatically covered under this permit (*i.e.*, dischargers were not required to submit a notice of intent to be covered by this permit), and there is no associated fee collected. The permit requires monitoring twice per year; if at any point the daily maximum limit is exceeded the monitoring frequency increases to once per month until a sample is less than the daily maximum. Effluent limits under this permit are: average BOD of 30 mg/L; daily maximum BOD of 45 mg/L; average TSS of 30 mg/L; daily maximum TSS of 45 mg/L; average FC of 200 colonies per 100 mL MPN; daily maximum FC of 400 colonies per 100 mL MPN; and pH between 6 and 9.

General Permit LAG530000 replaced General Permit LAG550200 for all applicable discharges, excluding those from individual residences. Discharges from individual residences that went online after the LAG550200 expiration date are not currently covered under any LDEQ permit (as is the case with any sanitary discharge, these systems are still permitted by LDHH). LDEQ has plans to create a new general permit applicable to sanitary discharges from individual residences (G. Aydell, pers. comm.).

Department of Natural Resources

The Coastal Management Division of the Louisiana Department of Natural Resources administers the Louisiana Coastal Resource Program. Under this program, a Coastal Use Permit must be obtained for any activity -- including new home and camp construction, or significant renovations of existing homes and camps -- occurring within the Louisiana Coastal Zone. Of the four coastal parishes in the Barataria-Terrebonne estuary, all of Plaquemines and Jefferson Parish, most of Terrebonne Parish, and the southern half of Lafourche Parish is included in the Louisiana Coastal Zone.

It is standard operating procedure that each Coastal Use Permit is routed to a LDHH representative for comments, prior to final approval and issuance (G. DuCote, pers. comm.). For a typical home or camp construction or renovation permit, the LDHH representative normally recommends permit condition number 7 (G. DuCote, pers. comm.), summarized below from the March 3, 1997 list of Coastal Use Permit Standard Permit Conditions:

7. That the applicant shall insure that any habitable structure (i.e., home, camp, trailer, etc.) existing at the site (or subsequently anticipated as a result of these property improvements) has been provided (or shall be appropriately provided, upon such structure siting) with an individual-type domestic waste disposal system (*i.e.*, septic tank, oxidation pond, mechanical plant, etc.) for which local health unit approval shall have been secured, as is required by the State Sanitary Code.

Parishes

The Barataria-Terrebonne estuary contains all or part of the following parishes: Assumption, Ascension, Iberville, Jefferson, Lafourche, Orleans, Plaquemines, Point Coupee, St. Charles, St.

James, St. John the Baptist, St. Mary, St. Martin, Terrebonne, and West Baton Rouge. Four of these parishes -- Jefferson, Lafourche, Plaquemines, and Terrebonne -- are "coastal" in that they border the Gulf of Mexico. The majority of these parishes have an ordinance requiring a LDHH sewerage system permit prior to being provided a critical utility service (M. Vidrine, pers. comm.). In general, ordinances in the larger parishes specify that electricity service be withheld until a LDHH sewerage system permit is obtained, and ordinances in the smaller parishes specify that water service is similarly withheld. Other applicable ordinances in the four "coastal" parishes are detailed below as examples of parish-level onsite wastewater treatment system management.

Plaquemines Parish

Section 13-21 of the Plaquemines Parish Code states "The Sanitary Code, State of Louisiana as it exists on the adoption date of this Code is here adopted as the sanitary code for the parish," with the following definitions:

- The term "Louisiana State Board of Health" shall mean Plaquemines Parish Advisory Board of Health.
- The term "State Health Officer" shall mean Plaquemines Parish Health Department Administrator.
- The term state officers, agents, or employees of the Louisiana State Board of Health shall mean the respective officers, agents, or employees of the Plaquemines Parish Advisory Board or Plaquemines Parish Health Department Administrator.

Penalties for violations are the same as provided by the Sanitary Code, State of Louisiana.

Jefferson Parish

Jefferson Parish has not promulgated any rules, regulations, or ordinances that go above and beyond the regulations in Chapter XIII of the Sanitary Code, State of Louisiana (G. Barilow, pers. comm.). Onsite wastewater treatment systems are permitted for installation according to these regulations.

Lafourche Parish

Lafourche Parish has not promulgated any rules, regulations, or ordinances that go above and beyond the regulations in Chapter XIII of the Sanitary Code, State of Louisiana (Lafourche Parish Health Unit representative, pers. comm.). Onsite wastewater treatment systems are permitted for installation according to these regulations.

Terrebonne Parish

Chapter 23, Sewers and Sewage Disposal, of the Terrebonne Parish Code specifies the following rules applicable to the use of onsite wastewater treatment systems:

- It is the parish government's policy to provide sewerage service wherever feasible for property owners who desire such service.
- It is unlawful to cause the discharge of any waste matter that may be harmful to public health or that may create safety hazards, odors, unsightliness, or a public nuisance.

- It is unlawful to discharge into any natural outlet any sewage, treated or untreated, except where such discharge is from sewage treatment facilities constructed in a manner approved by the appropriate parish government, state and federal agencies.
- Where there is a public sewer line within 300 feet of the property line, the owner shall pay the actual cost of any work performed by the parish government in the course of providing sewerage services to that property, plus administrative cost equal to 10 percent of such construction cost.
- Where a public sanitary sewer is not available, the building sewer shall be connected to a private sewage disposal system complying with provisions of this article and other applicable laws.
- Before constructing a private sewage disposal system, the owner shall obtain a permit signed by the parish government after first obtaining the approval of the Louisiana Department of Health and Hospitals, Office of Public Health.
- The type, capacities, location, and layout of private sewage disposal systems shall comply with all regulations of the Louisiana Department of Health and Hospitals, Office of Public Health.
- Once a public sewer becomes available to a property served by a private sewage disposal systems, a direct connection shall be made to the public sewer, and any septic tanks, cesspools, and similar sewage disposal facilities shall be abandoned and filled with suitable materials.

4.0 Evaluation of Onsite Wastewater Treatment Technologies: Purpose and Methodology

Much of coastal Louisiana is unsuited to the use of conventional septic system drainfields because of high water tables and poorly drained clay soils. As a consequence, the soil cannot consistently provide adequate treatment of wastewater before it comes into contact with groundwater and surface water. Some alternative technologies compensate for this by providing secondary treatment prior to ground disposal, substituting pre-treatment for soil depth (Duncan *et al.* 1994). Other technologies provide an alternative disposal method that yields better treatment and less chance of aquatic contamination. In most cases, the tradeoff for superior performance is higher cost.

This survey explores available onsite wastewater treatment technologies and evaluates specific components and systems for performance, cost, and suitability to the environmental conditions of the Barataria-Terrebonne estuary. Based on current regulations, it then analyzes the potential to utilize alternative technologies in the following three applications common to the Barataria-Terrebonne estuary:

- Single-family, permanent residences
- Camps with continuous electricity and water under pressure
- Camps without continuous electricity (both with and without water under pressure)

Options, as they apply to the Barataria-Terrebonne estuary, for treating wastewater from small clusters of residences and camps, are also discussed. The recommendations made in this document are intended to provide a scientific justification for the selection of technologies used in future demonstration projects by the Barataria-Terrebonne National Estuary Program, in partnership with the LDHH and LDEQ.

Scope of Literature Review

The literature review includes more than 90 written sources. Much of the reviewed material came from (1) proceedings of the Seventh and Eighth Annual Symposia on Individual and Small Community Sewage Systems, (2) the National Small Flows Clearinghouse, and (3) the Gulf of Mexico Program. Additional material was obtained through searches of scientific journal databases, Internet searches, citations in other sources, and communications with researchers, regulators, and manufacturers. This review is not intended to be exhaustive, but to be sufficiently comprehensive to provide a balanced and accurate assessment of the performance and relative merits of the various wastewater treatment technologies. In addition, the broad nature of the literature review addresses average operating performance. The review does not specifically address peak flow performance, although this is a continuing issue within the onsite wastewater treatment field (R. Raider, pers. comm.). Lastly, while the use of oxidation ponds for secondary treatment is allowed in the Sanitary Code, the authors felt that the land requirements and exposed nature of the effluent, and the high water table and continuous threat of severe flooding in coastal Louisiana, did not make them a comparable option for residential use, camp use, or cluster-based treatment systems. Therefore they are not discussed in this document.

Evaluation

The performance evaluation of onsite technologies assesses traditional wastewater treatment concerns -- biochemical oxygen demand and suspended solids -- but gives special attention to removal of enteric pathogens and nitrogen. Nitrogen is usually the limiting nutrient in brackish and marine systems (Loomis 1996), and excess nitrogen in wastewater leads to eutrophication and reduction in oxygen levels. Conventional septic systems are not designed for nitrogen removal; conditions in a drainfield promote nitrification but not denitrification. The technologies that favor nitrogen removal will promote conditions that favor the activity of both nitrifying and denitrifying bacteria, either through a system that is physically complex (or has multiple stages) or has temporal variation in conditions (*i.e.*, alternating aerobic and anaerobic conditions in the same location).

Of even higher priority are enteric microorganisms. These potential pathogens can render shellfish contaminated and inedible, and are a considerable concern in coastal areas. The technologies that best remove enteric microorganisms are those that maintain aerobic conditions, under which enteric organisms tend to be out-competed by other, less pathogenic bacteria and fungi (Loomis 1996). Fecal coliform bacteria are used as an indicator for all enteric microorganisms because they are common and easy to assess, although their concentration is not always a valid indication of the degree of contamination, especially with respect to viruses (Bechdol *et al.* 1994, Carodona 1998, Harris 1995). Viruses have different behavior than bacteria because they are small enough to form colloids in water and tend not to be bound to particulate matter, as are bacteria (Bechdol *et al.* 1994). Additionally, viruses survive longer in salt water and have been detected in marine systems when fecal coliform bacteria are absent. Despite these limitations, fecal coliform bacteria are used as an indicator in this review because they are usually the only enteric organism measured for most studies and provide a consistent means of comparing performance among technologies.

Different researchers use different methods for measuring nutrients and other potential pollutants, so it is not always possible to compare results from different analyses. In this document, pollutant concentrations are compared only to others of the same type (for example, TKN is compared to TKN, but not to TN). The various pollutants include the following:

- Ammonium (NH_4^+).
- Nitrate (NO_3^-). Nitrite (NO_2^-) is usually present in smaller concentrations and is sometimes grouped with nitrate.
- Total nitrogen (TN), a measure of all forms of inorganic and organic nitrogen.

- Total Kjeldahl nitrogen (TKN), a measure of most forms of nitrogen except for nitrate, nitrite, as well as certain other forms that are usually present in relatively small concentrations (can be approximated as TN minus NO_3^-).
- Phosphate (PO_4^+), the most available inorganic form of phosphorus.
- Total phosphorus (TP), a measure of both organic and inorganic phosphorus.
- BOD_5, the biochemical oxygen demand of a sample, measured over five days. In other words, this measures the amount of oxygen consumed by microorganisms as they degrade organic carbon in the sample over a period of five days.
- COD, the chemical oxygen demand of a sample (the amount of oxygen consumed in a chemical digestion of carbon). COD is sometimes used if the sample inhibits bacterial growth or is mildly toxic.
- Total suspended solids (TSS) is the most common measure of sediment and turbidity.
- Fecal coliform bacteria (FC) is discussed above. Units = number of colonies per 100 mL.

Performance standards have been proposed by Hoover *et al.* (1998) for onsite wastewater treatment systems and are presented in Table 2. These provide a good frame of reference for evaluating the performance of the systems reviewed in this document. However, considering the significance of enteric microorganisms in the Barataria-Terrebonne estuary, a standard more stringent than 10,000 colonies FC per 100 mL is required. In the State of Louisiana, 14 colonies FC per 100 mL (MPN or most probable number determination) is the threshold for establishing an "approved" classification for shellfish harvesting waters, thereby allowing open access to shellfish harvesting. In addition, 200 colonies FC per 100 mL (MPN) is the threshold for safe primary recreation (*i.e.*, swimming) in Louisiana coastal waters. These lower concentrations are considered a more relevant target for technologies evaluated in this review.

Table 2. Proposed Onsite Wastewater Treatment Performance Standards (Hoover *et al.* 1998).

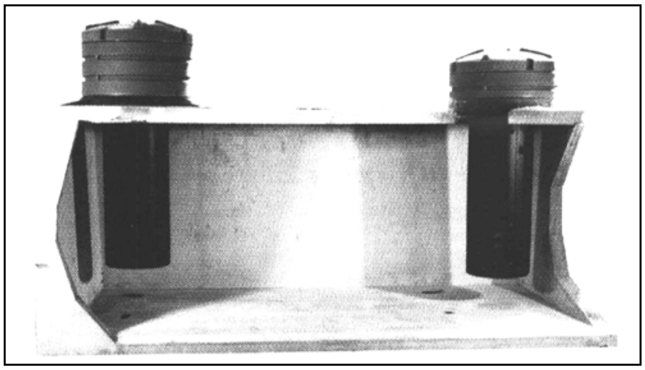
Treatment Level	BOD (mg/L)	TSS (mg/L)	PO4 (mg/L)	NH4 (mg/L)	TN	FC (#/100mL)
Secondary	30	30	15	10	NA	50,000
Tertiary	10	10	15	10	NA	10,000
Tertiary with Nitrogen Reduction	10	10	15	5	50% removal	10,000

5.0 Evaluation of Onsite Wastewater Treatment Technologies

5.1 Septic Tank Modifications

Proper septic tank operation requires regular inspection, maintenance, and removal of accumulated solids. Incorporating well-made, watertight risers -- reinforced polyethylene cylinders and covers at or just below grade -- on a new septic tank installation will allow ready access for the life of the septic tank, for a minimal increase in cost (see Figure 1). Such risers can also be readily retrofitted onto an existing septic tank. In addition, septic tanks can be incorporate trickling filters and effluent filters, described below.

Figure 1. Septic Tank Risers (from Zabel 1999).



Septic Tank with Trickling Filter

Ball (1994) developed a modified septic tank with a scaled-down municipal-type trickling filter, followed by an upflow sand filter. The system was used to treat wastewater from a two-bedroom house with an average actual flow of 115 gpd. Two and one-half years of monitoring showed that the trickling filter system produced a high quality effluent; fully treated effluent from the sand filter exceeded tertiary treatment standards (Table 3). The nitrogen removal capacity of the system is among the highest of any treatment type. Ball claimed that a trickling filter could be added to a conventional septic tank at low cost ($1,500) (Ball 1994), although complete onsite trickling filter systems can run as high as $15,921 to install (NOPD 1998).

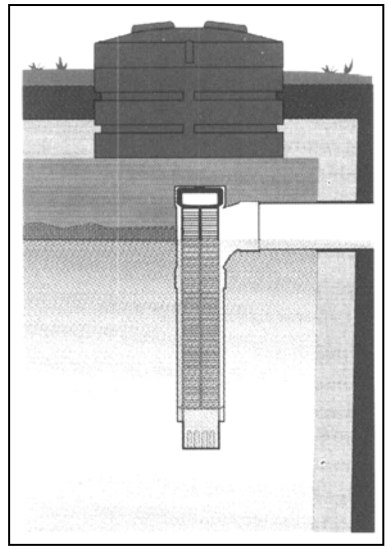
Table 3. Performance of Septic Tank with Trickling Filter and Sand Filter (Ball 1994).

	BOD in mg/L (% removal)	TSS in mg/L (% removal)	TKN in mg/L (% removal)	NH4 in mg/L (% removal)	NO3 in mg/L (% removal)
Conventional septic effluent	125	28	66	54	2
Trickling filter effluent	23 (82%)	10 (64%)	7.7 (88%)	2.4 (96%)	7.1
Sand filter effluent	8 (94%)	1 (96%)	2.9 (95%)	1.2 (98%)	2.5

Septic Tank Effluent Filter

Some states and counties around the United States require that a filter be placed in between the septic tank and drainfield to capture solids flowing to the drainfield and reduce consequent clogging. Effluent filters can be easily fashioned onto a standard 4-inch septic tank outlet T-pipe (see Figure 2). These filters are a low-cost addition to a conventional septic system; a standard residential system filter costs approximately $50, plus the minimal cost of installation (Bill Rawlins, pers. comm.).

Figure 2. Effluent Filter (from Zabel 1999).



Bacteria that readily colonize these filters may remove a component of TSS and BOD in the septic tank effluent. A study by Rohm (1996) demonstrated an average 18.0 and 27.8 percent removal of TSS and an average -26.7 and 51.6 percent removal of BOD by effluent filters at two sites, respectively. A study by Brion (no date) demonstrated removal of BOD through both impingement and biofilm assimilation; the researcher found an average 15.9 and 7.6 percent removal of total BOD at two sites, respectively. Brion found a simultaneous average 27.5 and 15.1 percent removal of TSS at the sites, respectively. Both studies tested both a septic tank operating below capacity as well as an overloaded septic system. An additional benefit of using an effluent filter is that excessive solids in the septic tank can cause the filter to clog, slowing the rate of flow from drains and toilets in the house (Zabel 1999). This initial "backing up" would signal homeowners that the septic tank needs to be pumped out or otherwise serviced. More advanced effluent filters have the capacity to set off an audible or visual alarm in the house as they become clogged. These models remain under $150, plus installation, for a residential application (Zabel 1999).

5.2 Septic Drainfields and Variants

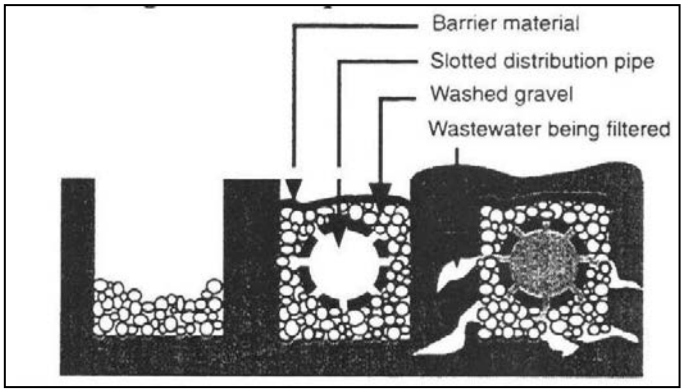
Conventional Absorption Drainfields

A conventional septic drainfield -- the secondary treatment and effluent disposal component of a septic system -- consists of a series of subsurface trenches or beds into which effluent is pumped (or allowed to drain by gravity) via a perforated distribution pipe. These 1- to 3-feet-wide trenches are filled with washed gravel to a depth of 1 to 5 feet, with the tops at least 6 inches beneath the surface of the soil. As illustrated in Figure 3, effluent percolates through the gravel and into the ground via the bottom and sides of the trench (Crites and Tchobanoglous 1998). Most conventional septic systems use gravity distribution, but some use pressure dosing, in which the effluent is pumped into drain fields. Pressure dosing allows for more even distribution of effluent, a shallower distribution network, and a drain field that is at a higher elevation than the septic tank (Crites and Tchobanoglous 1998).

Performance

Under the right conditions conventional septic drainfields can achieve very good performance. A study of an operational septic system in Palm Bay, Florida, determined that TKN was reduced by 59 percent within 40 feet (horizontal distance) from the drainfield, while both nitrate and total phosphorus were reduced 99 percent, based on test-well samples (McNeillie *et al.* 1994). A study in Tampa, Florida, found that, in the unsaturated zone 2 feet below the application of septic tank effluent, BOD was reduced by 98 percent, TKN was reduced by 99 percent, and fecal coliform were completely eliminated. Due to nitrification, nitrate increased to a concentration of 19.9 mg/L (Anderson *et al.* 1994). Note that for both these studies, soils are well-drained fine sand, which has very different properties than the clayey soils that cover much of coastal Louisiana. In fact, when drainfields operate in such clayey soils, considerable effluent evapotranspires through the soil surface (S. Murdoch, pers. comm.).

Figure 3. Conventional Absorption Drainfield (from Hollomon 1997b).



A conventional septic system is not generally designed for nitrogen removal. Although nitrification commonly occurs, conditions are not optimal for denitrification, resulting in relatively high concentrations of nitrate and nitrite when the wastewater joins the groundwater (Loomis 1996). For soils that are continually saturated, however, nitrification may not occur either, resulting in consistently high concentrations of ammonium nitrogen (Carodona 1998).

Limitations

There is substantial evidence that conventional septic systems in coastal areas can and do contaminate estuarine and nearshore marine systems. Researchers in Rhode Island used the U.S. Environmental Protection Agency's (USEPA) VIRALT model to calculate that, along the state's coast, viral transport in groundwater was rapid and viral contamination of shellfish was likely (Bechdol *et al.* 1994). Other studies have also traced the movement of enteric pathogens into groundwater (*e.g.*, Scandura and Sobsey 1997). In addition, soil has a finite capacity to absorb phosphorus, and septic drainfields eventually can become saturated with the nutrient, at which point the excess is exported in dissolved form with groundwater.

The greatest limiting factor with a conventional septic system is the soil in the disposal field. For effective treatment to occur, the drainfield needs to be located upon moderately well drained to well-drained soil that is aerobic to a depth of 2 to 4 feet.

Cost

A conventional septic system is one of the most cost-effective wastewater disposal options available. Septic systems serving an average 3-bedroom home are regularly installed in the Barataria-Terrebonne estuary for $2,600 to $3,600 (septic tank: $500 to $700 and 300 to 400 feet of drainfield line at $7.00 to $8.50 per foot; T. Boudreaux, pers. comm.). Many alternative systems incorporate the main elements of the septic system, such as the septic tank and drainfield, while adding additional components, such as a sand filter, which increases costs. As a consequence, most alternative wastewater treatment systems will be more expensive than conventional septic systems.

Analysis

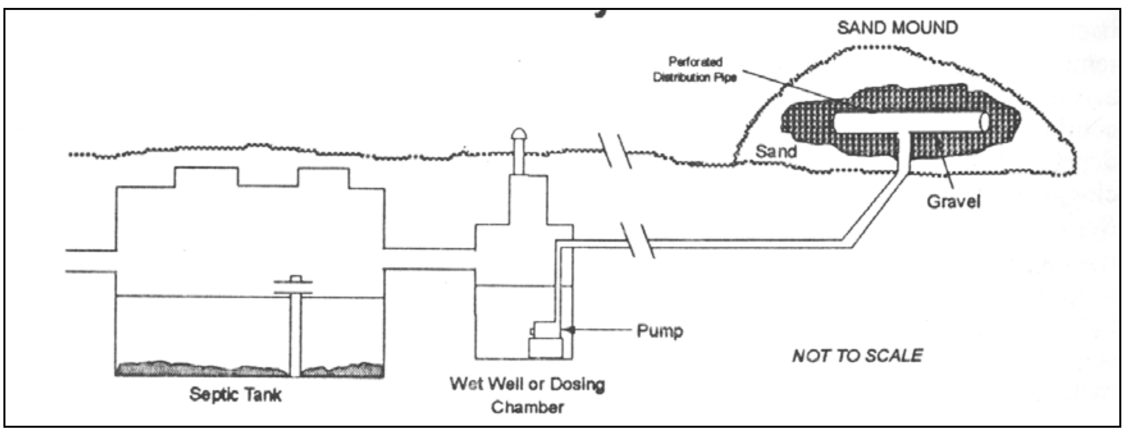
A conventional septic system with a gravity drainfield is an economic and effective choice under the right conditions; however, these conditions do not exist in much of coastal Louisiana.

Drainfield Variants

Mound System

In a mound system, effluent is pumped to an above-ground mound of sand covered with topsoil, from where it percolates into the subsurface soil (see Figure 4). In effect, these are bottomless intermittent sand filters (Crites and Tchobanoglous 1998). They are used where there would otherwise be insufficient depth of aerobic soil for a conventional septic system, whether due to a high water table, confining layers, or other soil conditions. The sand must be 24 inches deep (Crites and Tchobanoglous 1998). Some mound systems, known as evapotranspiration systems, are designed to evapotranspire some or all wastewater. These are most appropriate in arid areas (Crites and Tchobanoglous 1998). Mound systems are 1.5 to 2 times as expensive as conventional septic drainfields (USEPA Region IX 1996)). In Florida they have been found to have a shorter mean lifespan (Sherman 1998).

Figure 4. Mound System (from USEPA Region IX 1996).



At-Grade Systems

At-grade systems are a compromise between mound systems and conventional septic systems. The drainfield is elevated to the level of the soil surface and 12 inches of soil are placed on top (Crites and Tchobanoglous 1998).

Capillary Seepage Trench

A capillary seepage trench is similar to a conventional septic drainfield except that it is designed as a lined trench. Liquid moves laterally through the soil by capillary action, allowing uniform, slow treatment (USEPA Region IX 1996).

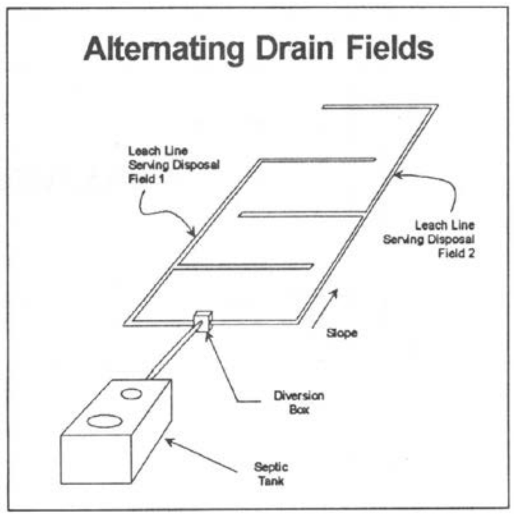
Sand-Lined Trench

The sand-lined trench (SLT) is a septic drainfield variant that is used on soils with a relatively shallow clay layer overlapping a loamy sand or sandy loam layer (Hinson *et al.* 1994). Trenches are dug through the clay and backfilled with loamy sand, and drain tiles are installed along the edges of the field. Distribution lines carry septic tank effluent through the sand-filled ditches. The system allows the effluent to bypass the clay layer and drain through the sandy layer beneath. The SLT concept was tested for a 1-year period at the Pamlico Surface Area of North Carolina. Performance was good, with complete elimination of FC most of the time. During the winter, however, the groundwater level rose high enough so that there was incomplete removal of nitrate and phosphate (Hinson *et al.* 1994). Because it requires the drainage of surface water, SLT cannot be used in locations with a perched water table and saturated soils (because it would constitute wetland drainage). The SLT appears to be a reasonable option in locations where the underlying sand layer is sufficiently thick and where groundwater does not rise within four feet of the top of the layer. Alternatively, a SLT could be an appropriate disposal method for effluent that has been treated to secondary standards.

Alternating Drainfields

The use of two or more full size or smaller drainfields, which are put in and taken out of service on a rotating basis with a diversion box, provides a resting period for the regeneration of natural clogging of subsurface disposal system (see Figure 5). Alternating drainfields can improve treatment in situations with slow soil percolation rates and high effluent loadings (USEPA Region IX 1996). Increased reliability by the use of dual drainfields is emerging again in California where long-term life cycle management is promoted by local authorities (Dix and Nelson 1998). Cost is obviously increased by constructing the additional drainfield line.

Figure 5. Alternating Drainfields (from USEPA Region IX 1996)

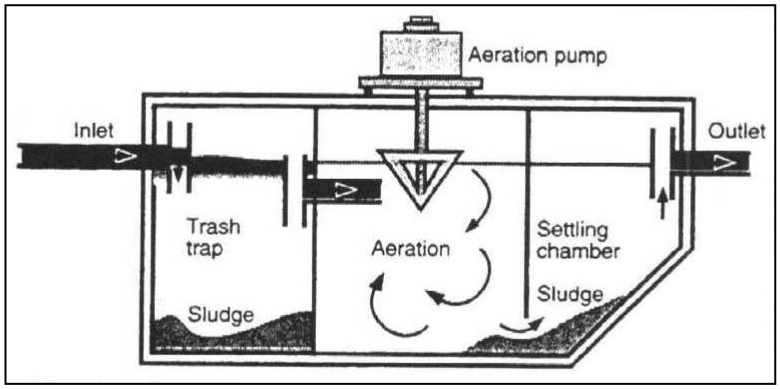


5.3 Aerobic Treatment Plants

Aerobic treatment plants provide both primary and secondary treatment of wastewater in one unit, and, in general, may be used in conjunction with, or in place of, a septic tank. Organic matter is broken down and digested by injecting air into one chamber in the unit with an electric pump or motor (see Figure 6). A number of commercial manufacturers in the United States produce a variety of aerobic treatment plants. In Louisiana, mechanical plants, one type of aerobic treatment plant, are a regularly permitted treatment method when soil conditions or lot size precludes the use of a septic system. Normally mechanical plants discharge directly to a ditch or surface water, although it is estimated that 5 to 10 percent of mechanical plants discharge to an effluent reduction field (M. Vidrine, pers. comm.). The State of Louisiana Sanitary Code does not require disinfection of mechanical plant effluent. While not all mechanical plant models currently installed in Louisiana are ANSI-certified, recent regulatory revisions require this certification for all new models after January 20, 1999, and for all models -- including existing models -- after January 1, 2001.

Performance

Figure 6. Aerobic Treatment Plant (from Hollomon 1997b).



A pilot project in Texas installed onsite wastewater treatment systems using aerobic units and subsurface drip irrigation systems for 81 homes and RV/mobile home parks around a lake (Carlile 1994). The effluent from the aerobic units, prior to disinfection and disposal, was of high quality, with BOD reduced to an average of 8.1 mg/L and TSS to 13 mg/L. A survey of nine aerobic systems in Texas found average effluent BOD of 4.3 mg/L and average TSS of 4.2 mg/L (Carlile 1994). An aerobic unit tested in West Virginia produced effluent with a FC count of 160,000/100 mL (NSFC 1998), and additional treatment was judged to be necessary in areas with limited soil absorption potential. Hoot Aerobic Systems, Inc. manufactures aerobic units that have achieved 97.7 percent reductions in BOD_5 and 98.2 percent reductions in TSS in evaluations by the NSF (Hoot Aerobic Systems, Inc. 1999).

Limitations

Critics of aerobic treatment plants note that they often rely on a small and limited assemblage of microorganisms compared to more "natural" systems such as constructed wetlands, sand filters, and land application. Consequently, these enclosed systems may not function optimally when regular use patterns are disrupted (*e.g.*, during peak flows or extended no-use periods).

Cost

Hoot Aerobic Systems reports that its units sell for approximately $1,900 (Hoot Aerobic Systems representative, pers. comm.). In West Virginia, an aerobic system with polyethylene leaching chambers was installed for $4,021, not including donated staff time (NSFC 1998). Mechanical plants have been regularly installed in Louisiana for $2,000 to $2,500 (T. Boudreaux, pers. comm.). Under certain drainage conditions, mechanical plant permits in Louisiana require the installation of an effluent reduction field, or shortened subsurface absorption drainfield (in most applications approximately 50 feet of drainfield line is required). The cost for an average effluent reduction field is under $700 (T. Boudreaux, pers. comm.).

Analysis

It appears that aerobic treatment plants can discharge high levels of FC, relative to desired levels of treatment, for example 200 or less colonies FC per 100 mL (MPN). Without effluent disinfection or a properly functioning secondary treatment and disposal system, discharges from properly functioning mechanical plants could adversely impact oyster harvesting areas in the southern portion of the Barataria-Terrebonne estuary. Ensuring regular maintenance of a system's mechanical parts is critical.

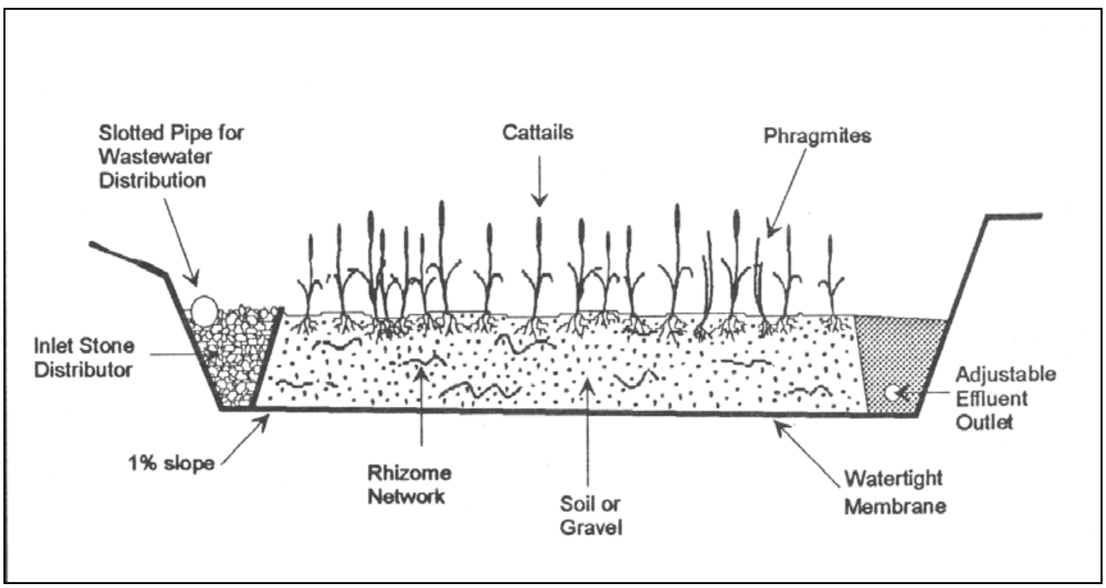
5.4 Constructed Wetland Systems

Free-Water Surface and Subsurface-Flow Constructed Wetland Systems

Constructed wetlands (CW) are a very flexible technology that can be used onsite or in small centralized systems to treat primary or secondary effluent, as well as to further improve effluent from other treatment methods. CWs can be divided into two categories: Free Water Surface (FWS) systems in which the water level is regularly above the soil surface, and Subsurface Flow (SF) systems in which the water level is maintained below the soil surface (USEPA 1996) (see Figure 7). A number of other closely related alternative treatment systems which are considered types of constructed wetlands, are discussed at the end of this section.

Some researchers (Choate *et al.* 1993) have found FWS systems to be more adaptable and cost effective in handling high levels of suspended pollutants. However, other authors have pointed out several advantages of SF systems. Because the water level is below the surface of the soil (or other media), there are few odors, few insect pest problems, and less of a chance for public exposure to pathogens. Such systems may also provide improved performance due to the greater surface area available for treatment (Reed 1993). On the other hand, if the CW is designed for primary treatment then FWS systems may be preferable, because SF systems can be subject to clogging by solids (Leszynka and Dzurik 1994).

Figure 7. Subsurface Flow Constructed Wetland (from USEPA Region IX 1996)



Typically, wastewater is first pre-treated in a septic tank or other primary treatment unit before being pumped to a CW. The CW itself can consist of a single cell, two cells in series, or multiple cells either in series or parallel. At least the first cell must be lined, while succeeding cells may be unlined to permit percolation of treated wastewater into the soil and groundwater (Steiner *et al.* 1993). These "zero-discharge" percolation CW systems are not appropriate for areas where the water table is very high. In these cases disposal should be to surface waters, possibly after additional finishing or disinfection.

Vegetation is an essential characteristic of the CW. The major functions of aquatic and semiaquatic plants are to transfer oxygen to the subsurface and to serve as substrate for microbial growth (Brix 1997). In addition, plants transpire water, reducing the volume of wastewater that must be discharged into a disposal field (Burgan and Sievers 1994). Macrophytes take up nutrients and other contaminants at rates ranging from 30 to 150 kg P/hectare per year and 200 to 250 kg N/hectare per year; in a FWS system, harvesting can remove 8 to 10 percent of N and P. Overall, harvesting plants is not considered a very significant path of contaminant removal and is not necessary for good wetland performance (Brix 1997, EPA 1988).

Because proper aeration of CWs is critical to their performance, several researchers have investigated the ability of different plant species to oxygenate their root zones. One such study by Stengel (1993) compared iris (*Iris pseudacorus*), cattail (*Typha latifolia*) and giant reed (*Phragmites australis*) in both a laboratory setting and in a CW. The three species varied significantly in their ability to pump oxygen into the water. *Typha* increased oxygen levels the most, producing complex oscillations during day and night. *Phragmites* had less of an effect on oxygen levels and produced a diel pattern, with much higher oxygen levels at night than during the day. *Iris* had no effect on oxygen levels (Stengel 1993). However, a study in North Carolina found that a wetland cell planted with *Phragmites australis* outperformed a wetland cell planted with *Typha angustifola*. Despite these findings, a study by Neralla *et al.* (1998) found no effect of plant species on overall wetland performance (although aeration was not specifically addressed). Neralla *et al.* recommend that plants be chosen for their ability to thrive in the local climate. In addition, selected plants should be native to the region whenever possible (Steiner *et al.* 1993).

Design

The design of a CW should be site-specific and based on rational models, such as those that incorporate Darcy's Law and plug-flow principles (Reed 1993). The CW must be designed to maintain the desired water level, which for a SF system is commonly 2 inches below the surface (House 1996). For a SF system, a slight grade is desirable to ensure a hydraulic gradient (Reed 1993), but too much of a grade will lead to ponding, resulting in uneven performance and poor growth of most plants (which will tend to be either too dry or too wet) (House 1996).

Many researchers recommend rock or gravel that is not readily compacted (*e.g.*, Steiner *et al.* 1993). One study in North Carolina determined that a CW with a sand substrate out-performed a CW with gravel substrate in all measured parameters (House 1996). These results are summarized in Table 4.

Some researchers have found that high length-width ratio enhances performance (USEPA 1988). A study by Bounds *et al.* (1998) compared the performance of rock-plant filters of different length-width ratios: 4:1, 10:1 and 30:1 designed to treat wastewater from a typical three-bedroom house in Louisiana. Each had a surface of 25 m^2, a design flow of 1514 L/d, and was preceded by two septic tanks in series. All three designs proved sufficient for reducing BOD_5 to effective levels, but the 30:1 bed demonstrated the best performance. The 30:1 bed was also less anaerobic and had a greater reduction in ammonium and sulfide, although results may have been confounded by the fact that in the second year each of the beds was planted with a different plant species (Bounds *et al.* 1998).

Table 4. Sand vs. Gravel as a Substrate for Constructed Wetlands (House 1996).

Substrate		TSS	TN	NH4	PO4
Sand	Effluent (mg/L)	10.4	24.1	18	3.2
	% Removal	88.6	38.0	54.4	52.9
Gravel	Effluent (mg/L)	46.4	26.7	33.6	5.9
	% Removal	49.5	31.4	14.9	13.2

Effluent = concentration of contaminants in effluent from the treatment system
% Removal = change in contaminant concentration between influent and effluent

Total volume of the CW will depend on the design flow and site-specific characteristics. Amberg (no date) suggests a minimum recommendation of 210 cubic feet, which translates to 3 feet wide by 70 feet long by 1 foot deep for a 400-gpd, narrow rock-plant filter-type CW. The most important factor is that the CW maintain at least a 4.5- to 5-day detention time (Bounds *et al.* 1998). Water conservation measures that minimize flow to the CW also improve performance (Steiner *et al.* 1993).

Performance

TSS removal rates are high for CWs (Reed 1993). BOD removal in wetlands is also high but is limited by BOD production due to the decomposition of plant material within the CW. As a consequence, effluent from CWs will always contain a certain minimal amount of residual BOD (2 to 7 mg/L) (Reed 1993).

According to the USEPA (1988), CWs can achieve nitrogen removal rates of 25 to 85 percent. Some case studies have borne this out while others have found that under many conditions N removal rates are negligible (*e.g.*, Steiner and Combs 1993). In many systems, nitrification is limited by available oxygen (Choate *et al.* 1993, Reed 1993). When oxygen levels are high, when plant roots fully penetrate the substrate, and when there is sufficient residence time, CWs can achieve very high rates of nitrification. In practice, few have managed to meet these requirements. In fact, a number of CWs generate more ammonium than they remove, probably from decomposition of organic nitrogen. This is especially a problem in CWs that are coupled with lagoons where large amounts of algae grow (Reed 1993).

Table 5. Performance of Constructed Wetlands Based on Average Measurements Across the 33 Studies/Sites Reviewed for this Evaluation.

	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	TP (mg/l)	FC (col/100mL)
Effluent	24.38	20.34	18.05	14.90	0.22	2.90	7,412.25
% Removal	65.36	61.30	33.17	8.43	38.61	no data	80.17

Effluent = the concentration of contaminant in effluent from the treatment system.
% Removal = the change in contaminant concentration between system influent and effluent.
Details on each study found in Appendix A, Table APP1.

CWs typically achieve FC removal rates of 90 to 99 percent. In his 1993 review, Reed found that CWs, on the average, achieved 90 percent removal rates, and that disinfection is required for many systems. Metal removal rates can be high for SF systems due to soil adsorption, but are lower for FWS systems (EPA 1988). See Table 5 for a summary of CW performance (also see Appendix A, Table APP1).

Performance of CWs is correlated with residence time, as demonstrated by a study by Huang *et al.* (1994) (see Table 6). The same study showed that recirculation of effluent through the CW does not have a significant impact on effectiveness of pollutant removal. CW performance does not appear to decline over time (Choate *et al.* 1993). On the contrary, several wetland studies have found that performance increases over the first several years, as vegetation becomes fully established (Steiner and Combs 1993, Green and Upton 1993, Bounds *et al.* 1998).

Table 6. Pollutant Removal By Constructed Wetlands as a Function of Detention Time (Huang *et al.* 1994).

Detention time (d)	Effluent Concentration in mg/L (except where noted)			
	BOD5	TKN	PO_4-P	Fecal Coliform (col/100 mL)
2.6	48.6	32.2	2.86	2251
3.92	39.2	27.7	2.50	3941
5.93	30.3	23.3	2.09	4183

Limitations

CWs, like other land-based treatment methods, require a much larger area than conventional wastewater treatment. CWs that discharge to surface waters will use 4 to 10 times the land of a conventional facility, while zero-discharge facilities may need 10 to 100 times the area (USEPA 1988).

Because they are open to the atmosphere, rain events pose a problem for CWs. Researchers have found that a significant rain event can reduce retention times and pollutant removal rates by 50 percent or more. To manage this, CWs should be designed to increase retention time longer following rainfall (Johnson *et al.* no date). Some researchers have noted the importance of sufficient sunlight, noting that six hours a day is necessary for healthy growth of many CW plants (Steiner and Combs 1993).

Open standing water in a CW can emit noxious odors (Steiner and Combs 1993). Subsurface inflow of wastewater can reduce such odors (Johnson *et al.* no date), and odors should not be a concern with SF systems. Mosquitoes can also be a problem for FWS systems. Some researchers have suggested using fish such as *Gambusia* in FWS systems to control mosquitoes (Johnson *et al.* no date).

Costs

The average cost of establishing an onsite CW is $2,600 in late 1980s dollars, based on three reported pilot studies (Stegner and Combs 1993, Johnson *et al.* no date). One of these studies is probably a slight underestimate because the CW was built largely by the homeowner, so construction costs are not fully included. A more recent study in Alabama installed a CW for $6,519, although this was considered rather expensive (Shirk and White 1999).

Constructed wetlands are considered a very economical alternative to conventional treatment. The town of Monterey, Virginia, found that adding additional capacity to its conventional treatment plant would cost $500,000, while a CW -- a lined subsurface rock filter system with bulrushes -- could be built for $166,000. In addition, the CW has very low operation and maintenance costs (GAO 1994).

A study in the early 1990s showed that the average cost for constructing a community SF system was around $87,000 per acre (Reed 1993). An acre is sufficient to treat, perhaps, 0.1 to 0.2 mgd. A FWS system was only about $22,000 per acre, although most FWS systems have much lower hydraulic loading rates, so that the cost of treating a gallon of wastewater is higher ($0.78) for a FWS system than for a SF system ($0.62/gallon) (Reed 1993). This translates to roughly $372 per home for a SF system and $468 for a FWS system, assuming a design flow of 600 gpd per home. Costs will vary greatly depending on the value of land and the availability of suitable materials. For example, for some CWs in Louisiana, gravel had to be transported from Arkansas at considerable expense (Reed 1993).

Analysis

Constructed wetlands are inexpensive and tend to be very effective at removing TSS and BOD. Properly designed and installed CWs may also be effective at removing nitrogen, although this has historically been a problem for many systems due to their inability to maintain aerobic conditions. FC removal can be high but may be insufficient when the CW is the only treatment system.

Combination Systems

Systems that combine different types of wetlands or wetlands with other treatment technologies have been constructed and studied. The different ecological conditions created by combination systems have the potential for more complete treatment of wastewater (House 1996).

In 1992, a two-cell CW with both vertical flow and horizontal flow was established in Gates County, North Carolina, to treat wastewater from an elementary school. Four years of evaluation showed that the system was very effective in nitrogen removal, lowering TN concentration by 95 percent and ammonium by 98.5 percent. BOD was lowered by 97 percent, but TSS was only reduced by an average of 55 percent, possibly due to hardwood mulch added to the wetland cells (House 1996).

A combination sand mound-wetland system, built to treat domestic wastewater from a single-family home, has proven somewhat less effective, although performance was still judged to be good. Eighteen months of data collected from 1990 to 1991 showed that TN was reduced by 75 percent to 11.1 mg/L. Almost all the ammonium was nitrified, but little denitrification occurred, so that nitrogen in the effluent was almost entirely in the form of nitrate. Phosphorus removal was very high (93 percent), with an average effluent concentration of 0.6 mg/L (House 1996).

Complex Systems

A step beyond combination systems are those designs that incorporate three or more natural treatment systems involving a wide range of physical and biological conditions. A typical system of this sort combines aerated ponds with reed beds, constructed wetlands, and meadows to which overland flow is applied. This provides a greater range of biochemical and physical reactions to treat wastewater (Ogden 1993). Rather than relying on one or two species of plants and their associated microorganisms, complex systems employ a wide range of organisms, including bacteria, algae, zooplankton, crustaceans, fish, and higher plants for removal of contaminants. Many of these systems are designed for processing solids along with liquids, eliminating the need for removal of solids and separate disposal or digestion.

Performance of complex systems appears to be quite good, exceeding that of most other systems. Pilot studies have reported fecal coliform bacteria removal rates exceeding 99.999 percent, removal of 96 percent or more of suspended solids and BOD, and removal of high levels of nitrogen and phosphorus (Ogden 1993). Further details on the performance of one system are provided in a brief case study below. In the sources reviewed here, no data were provided for the costs of initial infrastructure investment, although it would appear that they would exceed those for more conventional CWs. Operating and maintenance costs are reported to be very low, however (Guterstam and Todd 1990; Ogden 1993). *Note: the term "complex systems" is not used in the literature; most researchers simply call these "natural systems." The term is used here to distinguish complex systems from other technologies.*

Natural Wetland Systems

The characteristics that make CWs so effective in processing wastewater also exist in natural wetlands. In fact, the dense network of canals and levees in coastal Louisiana have left many wetlands hydrologically isolated and allow a similar level of control as constructed wetlands (Day *et. al.* In review). Natural wetland treatment systems have been shown to remove from wastewater high levels of nutrients, BOD, TSS, heavy metals, trace organic compounds, and pathogens (USEPA 1987). While a special permit can be obtained to utilize natural wetlands for tertiary wastewater treatment, discharging unprocessed or partially processed wastewater into a natural wetland is generally not considered an acceptable practice (USEPA 1988 and USEPA 1987). As of 1987, more than 400 natural wetlands in the southeastern United States had been approved to receive secondary-treated wastewater (USEPA 1987). While natural wetland systems do not appear to be feasible for individual residences or camps, they are discussed below because of their applicability to community wastewater treatment and their particular relevancy to wetland degradation problems in the Barataria-Terrebonne estuary.

The foundation principle in natural wetland wastewater treatment is that the rate of effluent application must be balanced with the rate of decay or immobilization; therefore, the primary management controls in the natural system are loading rates and residence times (Breaux and Day 1994). Within the Barataria-Terrebonne estuary, effluent from a municipal facility in Thibodaux, Louisiana has been treated in natural wetlands since 1992. After several years of operation, N and P concentrations had been reduced 100 percent and 66 percent, respectively, and there were no indications of detrimental impacts (Day *et. al.* In review). Another municipal discharge in coastal Louisiana, from the town of Breaux Bridge, has been discharging to a cypress/tupelo swamp for 40 years with no apparent detrimental impacts, and complete nutrient assimilation (Breaux and Day 1994). A natural wetlands treatment system in Oregon was found to reduce BOD_5 by 67.2 percent and suspended solids by 78.4 percent (Walters 1986a).

The State of Louisiana developed a set of tentative standards for the Thibodaux wastewater treatment site, designed to protect wetlands from any adverse effects of wastewater application (Breaux and Day 1994): (1) no more than 20 percent decrease in naturally-occurring litterfall or stem growth; (2) no significant decrease in the dominance index or stem density of bald cypress; (3) no significant decrease in faunal species diversity and no more than a 20 percent decrease in biomass.

Discussion continues on the ability of natural wetlands to remove pathogens from wastewater, although extended residence times have demonstrated natural die-off (USEPA 1987). Municipal treatment facilities in Louisiana are normally required to disinfect wastewater prior to discharge, as is the case with the Thibodaux and Beaux Bridge effluents, so it can be assumed that pathogens were not of concern at these sites. Given the expense of community-level disinfection, future wetland treatment sites with long residence times and low loading rates should be monitored without disinfection to determine whether adequate pathogen removal can be attained (Breaux and Day 1994).

Increased accretion rates within the receiving wetlands have been found at the Thibodaux and Breaux Bridge sites; additions of wastewater have stimulated biomass production and subsequent soil formation (Breaux and Day 1994). A study by Hesse, Day, and Doyle (1998) clearly demonstrated the sustained long-term enhancement of baldcypress growth at the Breaux Bridge site. These effects are particularly important in coastal Louisiana where large-scale subsidence is a significant contributor to wetlands degradation.

Natural wetland systems appear to be a promising, low-cost alternative for community wastewater disposal in coastal Louisiana. The capitalized cost savings of using natural wetland systems at the Thibodaux and Beaux Bridge sites were estimated at $500,000 and $1.4 million, respectively, over 30 years (Day *et. al.* In review). The natural wetland system in Oregon was substantially less expensive than alternative wastewater treatment options (Walters 1986a).

Four Constructed Wetland Case Studies

Subsurface Flow Systems: TVA Experiences (Steiner and Combs 1993). The Tennessee Valley Authority (TVA) has assisted in the construction of numerous small CWs. In 1988, a-600 gpd SF system was constructed for a four-bedroom house in Signal Mountain, Tennessee, to replace a failing septic drainfield. The 18.6 m^2 two-cell CW accepts wastewater from a septic tank. The first cell is fully lined, while the second cell is lined only on the sides, allowing the treated wastewater to percolate into the soil and eliminating the need for any surface discharge. The performance appears to be fair -- insufficient for surface discharge of the effluent, but more than adequate for disposal through soil percolation. The BOD removal rate was 89 percent, with an effluent concentration of 27 mg/L; FC removal was a relatively low 78 percent, with an average 61,000 colonies/100 mL in the effluent. The cost of the system was only $2,000, although much of the labor was performed by the homeowner.

A 123-m^2 complex system CW was built in 1989 to treat the waste from the Chattanooga Nature Center. Like the Signal Mountain CW, this system consists of a septic tank and two cells, the first lined and the second unlined. The system was built for a design flow of 1,300 gpd -- enough to serve two or three homes -- for a cost of $8,000. Sampling data were only available from Cell 1 effluent, but these indicated a fairly high level of treatment: BOD was reduced to 12 mg/L, TSS to 6 mg/L, and FC to 5,800 colonies per 100 mL.

A small CW was constructed in Washington County, Kentucky, to treat wastewater from a three-bedroom house with an average flow of 360 gpd. Waste was pre-treated with a septic tank before being pumped to two wetland cells, both unlined because an impervious clay soil layer prevents infiltration. The system provided good control of FC, although ammonium reduction appeared to be negligible. In the first few months of operation the CW did not provide good control of suspended solids, which actually increased from Cell 1 to Cell 2. This may have been due to inadequately established vegetation or to sampling after flow surges that occurred when the pump was switched on. BOD concentrations averaged 34 mg/L in the effluent and TSS averaged 26 mg/L, including the period of poor control.

Generally, TVA researchers found that operators of small CWs are pleased with their performance. It appears that most problems were actually due to construction errors.

Subsurface Flow System, Central Missouri (Burgan and Sievers 1994). A SF system was built on private property in central Missouri in 1992 to treat domestic wastewater from two homes. The first cell consisted of a limestone base with bulrush (*Scirpus validus)* and horsetail (*Equisetum hyemale).* The second cell had a coarse sand base that was originally planted with water plantain (*Alisma plantago*), and later planted with arrowhead (*Sagittaria latifolia*) and soft rush (*Juncus effusus*). The wetland was sampled regularly for 16 months and was found to reduce BOD by an average of 87 percent, TSS by 65 percent, ammonium by 42 percent and fecal coliform bacteria by 98 percent. Effluent concentrations of BOD and TSS were 14 mg/L and 16 mg/L, respectively. Due to construction errors (in which the inflow pipe from Cell 1 to Cell 2 was laid in sand, rather than in gravel), ponding occurred in Cell 2, which resulted in algal growth and an increase in suspended solids concentrations. Once the problem was corrected, TSS concentrations declined.

Subsurface Flow System (Reed Bed System): Little Stretton, England (Green and Upton 1993). In 1987, a series of gravel-filled lagoons was established at the outfall of an existing community septic tank that serves all but two houses in a small community of 15 dwellings and two farms. The lagoons were underlain with an impervious liner and planted with pots of *Phragmites* reeds. In the first two years of operation, performance was mediocre, with no removal of ammonium and effluent concentrations of BOD that frequently exceeded 30 mg/L. In 1990 the performance of the system improved, partly due to the diversion of runoff from cattle standing areas away from the reed beds. Periods of poor performance were often associated with higher flows, when the water level was above the surface of the gravel and oxygen levels declined. Cost information was not provided, but similar reed-bed systems in the region were reported to cost between 700 and 1600 pounds per capita (in October 1999 1 pound equaled approximately US$1.65; converts to US$1,100 - $2,700 per capita).

Complex System: Arroyo Hondo, New Mexico (Ogden 1993). A pilot septage treatment system was constructed in Arroyo Hondo, New Mexico, with a series of linked systems that included a screened receiving chamber, an aerated equalization tank, a reed bed, an aerated water hyacinth lagoon, a CW located within a greenhouse, an outdoor constructed wetland, and four irrigated hedgerows. Actual flow into the system averaged 356 gpd. A complex assemblage of plant, arthropod, bacteria, and protozoan species is maintained in the system. Water monitoring results from 1991 showed high levels of treatment (see Table 7), including high rates of removal for nitrogen and phosphorus. TSS was reduced by over 99 percent. The operating costs for the Arroyo Hondo facility were described as "very low"; no cost data were provided for construction.

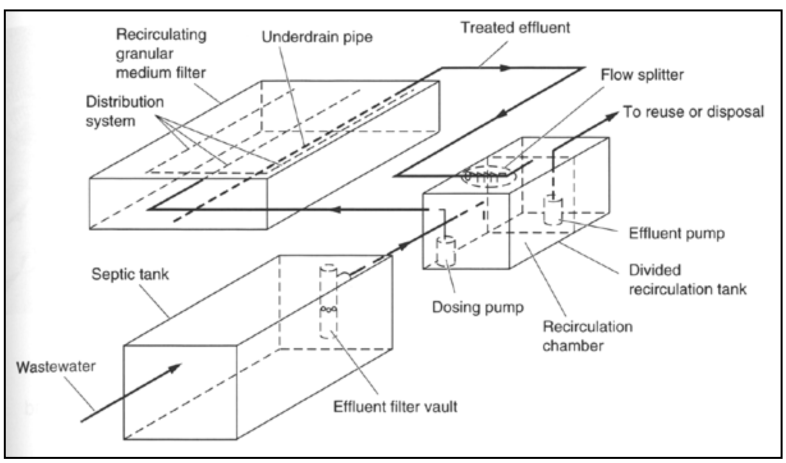
Table 7. Performance of the Arroyo Hondo Complex Natural System (Ogden 1993).

	COD (mg/L)	TN (mg/L)	NH4 (mg/L)	Phosphate
Inflow	25000	677	157	no data
Outflow	769	55	44	no data
% Removal	96.92	91.88	71.97	estimated 50-60%

5.5 Intermittent and Recirculating Sand Filter Systems

Sand filters are not a new technology. They were invented in the 1860s in Britain and installed on a municipal scale in Massachusetts in the 1870s. Despite their successful implementation in a number of communities on various scales, their use gradually waned until the 1970s, when they began to enjoy a resurgence (Crites and Tchobanoglous 1998). Sand filters have again become a widely used and well-proven technology in much of the United States. For example, in Anne Arundel County, Maryland, more than 100 recirculating sand filters were installed between 1987 and 1994.

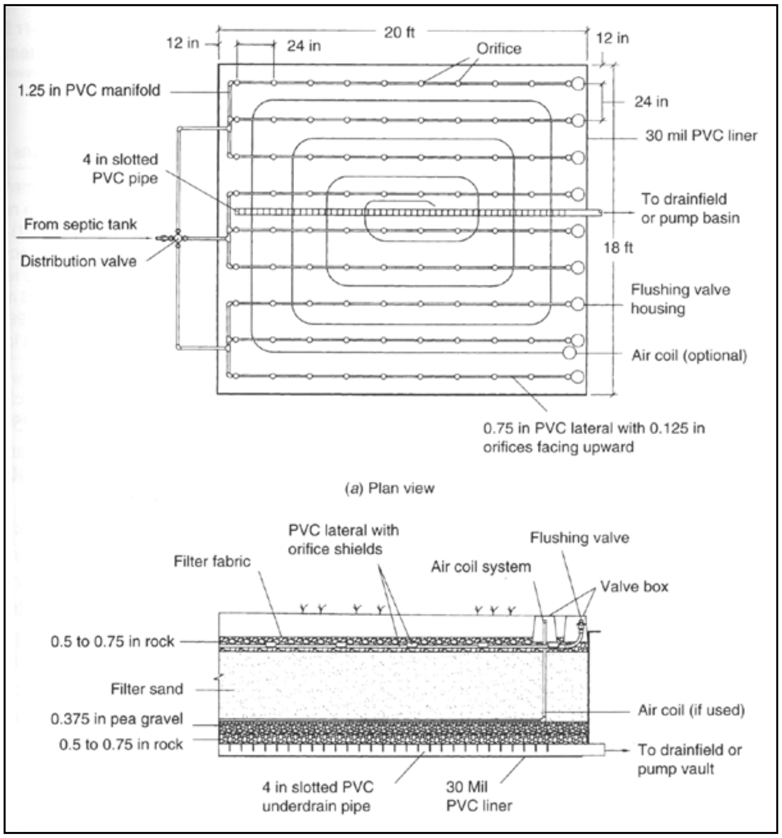
Figure 8a. Recirculating Sand Filter Design (from Crites and Tchobanoglous 1998).



A sand filter consists of a bed of sand or similar medium over a layer of gravel, all within a liner or container. Wastewater is discharged onto the top of the sand, is filtered by microbial action, and is collected by drain pipes embedded in the gravel. There are two major types: an intermittent filter, in which wastewater passes through only once, and a recirculating filter, in which effluent is pumped back through the filter multiple times (see

Figures 8a and 8b). An intermittent filter is better able to maintain aerobic conditions than some recirculating filters (Gidley 1985), but a recirculating filter can obtain higher removal rates of nitrogen. Before it is applied to a sand filter, wastewater should be pre-treated with a septic tank or some other form of primary treatment. Effluent from the sand filter may be disposed of through conventional drainfield disposal; the field may be much smaller than for wastewater that has received only primary treatment (Piluk and Peters 1994).

Figure 8b. Intermittent Sand Filter Design (from Crites and Tchobanoglous 1998).



Design

Although a common recommendation is that the sand filter medium for a single-pass filter should be 0.4 to1.0 mm in diameter (Gidley 1985), some studies have shown benefits from using gravel in the range of 1.0 to 6.0 mm (Venhuizen 1996). Coarser media may be preferential to fine sand because the finer media can more quickly become clogged with oil, grease, and biological material (Liu *et al.* 1999, Miller *et al.* 1994). The sand should be 24 to 42 inches deep; a study by Widrig *et al.* (1996) demonstrated that sand filters 12 to 18 inches deep achieve lower performance than those 24 inches deep (see Table 8). The design area of the filter is based on a number of factors, but a typical recommendation is a square foot for every 3 gpd of effluent; for an average residential home, this translates to a 100-square-foot bed (Venhuizen 1996). However, Piluk and Peters (1994) report success with much smaller sand filters sized at 1 square foot for each 14 gpd of effluent. Regulations in the State of Louisiana Sanitary Code require, at a minimum, a 300-square-foot bed with at least 24-inches of sand.

Table 8. Sand Filter Performance as a Function of Filter Depth (Widrig *et al.* 1996).

Depth of Filter	Concentration, Trial One (mg/L)			Concentration, Trial Two (mg/L)		
	BOD	TSS	NH4	BOD	TSS	NH4
Inflow	115	56	25	161	75	25
1.0 ft	28	16	3.6	40	28	3.0
1.5 ft	18	11	1.8	31	25	0.89
2.0 ft	12	10	0.53	20	16	0.39

This table shows pollutant concentrations in the effluent of sand filters at various depths. There is a consistent trend of increasing performance with increasing depth.

Flow must be evenly distributed over the sand filter. If it is not, ponding will occur and parts of the filter will be short-circuited, shortening the medium's life span. The system must be periodically flushed to prevent clogging of distribution nozzles (Patrakis 1998). A sand filter may be open to the soil on the sides to allow disposal, or it may be entirely enclosed in a container.

Sand filters are well-studied technologies and accepted, standardized designs are now available. Some governments, such as Anne Arundel County, Maryland, will approve the installation of a sand filter that follows a standardized design without requiring that an engineer be retained (Piluk and Peters 1994).

Performance

Under proper conditions, an intermittent sand filter can reduce BOD_5 and TSS to less than 10 mg/L (Gidley 1985). They can reduce FC levels by 99 percent or more. Recirculating sand filters are capable of equivalent or higher levels of BOD_5 and TSS removal, but FC removal may be somewhat limited in some recirculating filters because the effluent is periodically returned to the anaerobic conditions of the septic tank.

The well-aerated conditions inside intermittent sand filters limit their capacity for denitrification. As a consequence, TN removal rates tend to be relatively low. However, a properly designed recirculating sand filter can achieve higher rates of denitrification if the effluent is recirculated back through an anaerobic chamber. Circulation can either be through the second chamber of a two-chamber septic tank, or through a single-chamber septic tank fitted with a screen, or through another anaerobic compartment specifically designed for denitrification. These methods can result in TN removal rates in excess of 60 percent (Venhuizen 1996).

A case study below describes two recirculating sand filters that, built on this principle, achieved TN reductions of 60 and 70 percent. Adding a denitrification chamber can further improve TN removal, but there are practical limits that arise as nitrogen removal increases above 70 percent (Mote and Ruiz 1994). These arise because optimizing for nitrogen removal can compromise the filter's capacity for carbon (BOD) removal. This can be overcome by piping the effluent to another aerobic sand filter but, of course, this adds considerably to total cost. See Tables 9 and 10 for complete performance information on both intermittent and recirculating sand filter systems (also see Appendix A, Tables APP2 and APP3).

Table 9. Performance of Intermittent Sand Filter Systems Based on Average Measurements Across the 7 Studies/Sites Reviewed for this Evaluation.

	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	FC (col/100mL)
Effluent	5.57	10.40	35.13	2.20	20.70	632.83
% Removal	96.23	85.44	32.43	94.52	0.00	99.81

Effluent = the concentration of contaminant in effluent from the treatment system.
% Removal = the change in contaminant concentration between system influent and effluent.
Details on each study found in Appendix A, Table APP2.

Table 10. Performance of Recirculating Sand Filter Systems Based on Average Measurements Across the 11 Studies/Sites Reviewed for this Evaluation.

	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	FC (col/100mL)
Effluent	7.81	8.44	20.71	5.58	10.47	6.06	27,011.63
% Removal	96.17	87.18	56.67	83.83	no data	27.25	99.27

Effluent = the concentration of contaminant in effluent from the treatment system.
% Removal = the change in contaminant concentration between system influent and effluent.
Details on each study found in Appendix A, Table APP3.

Limitations

The top layer of the sand filter occasionally needs to be removed and replaced as sand pores become clogged with biological material. However, even when serious clogging occurs and water ponds on the filter's surface, performance can still be satisfactory (Venhuizen 1996). Resting a sand filter for several months can also restore its hydraulic conductivity (Widrig *et al.* 1996). A sand filter will become saturated with phosphorus over time as binding sites are filled, and eventually phosphorus removal will decline to negligible levels (Loomis 1996). Regular replacement of the top layer will also help maintain binding sites. During cold weather an open sand filter may need to be covered with insulated material (Gidley 1985).

Cost

Sand filter systems range in cost from $5,000 to $10,000 or more for a system serving a single residential home. Recirculating systems generally cost slightly more than intermittent systems because of the additional complexity and materials. A recent study in Delta Port, Alabama, installed off-the-shelf intermittent filter systems in two homes for $8,225 each (Shirk and White 1999). A study on recirculating filters in Anne Arundel, Maryland, installed three systems for costs of $5,850, $7,000 and $10,000, respectively, in 1993 (Bruen and Piluk 1994). An important part of the cost is the price of the sand itself, which can be considerable in areas where there is not a local supply (such as much of Louisiana).

Analysis

Sand filters provide very good removal of TSS and BOD, as well as good removal of ammonium and FC. Used alone, an intermittent sand filter probably will not provide sufficient nitrogen removal for coastal communities. A well-designed recirculating filter may be able to attain the necessary nitrogen removal rates. Alternatively, a sand filter used in combination with another technology, such as a constructed wetland or slow-rate land application system, could provide very high rates of removal, although the cost would increase accordingly. One researcher called sand filters and drip irrigation a "natural marriage" (Venhuizen 1996) because sand filters are so effective at delivering the low-turbidity effluent required for drip irrigation. While this would be prohibitively expensive as an onsite treatment option, it could be reasonable for cluster treatment.

Table 11 compares the performance and cost of onsite constructed wetlands and intermittent sand filters operated at the same time under similar conditions in Alabama. The constructed wetland, while less expensive, performs slightly poorer. The effluent concentrations for ammonium and nitrate illustrate the differences in the aeration: the intermittent sand filter is capable of nitrifying the wastewater but not denitrifying, while the constructed wetland is denitrifying the small amounts of nitrate available, but not removing any ammonium. This again suggests the value of linking sand filters with constructed wetlands to achieve more complete nitrogen removal.

Table 11. Performance and Cost Comparison of Constructed Wetlands and Intermittent Sand Filters.

Parameter	Constructed Wetland	Intermittent Sand Filter
Effluent BOD5 (mg/L)	36	5
Effluent NH4 (mg/L)	24	1
Effluent NO3 (mg/L)	1	16
Effluent Fecal Coliform (col/100mL)	11,220	514
Cost of Installation ($)	6,519	8,225

Source: Data are from a recent pilot project in Alabama (Shirk and White 1999).

Two Sand Filter Case Studies

Intermittent Sand Filter (Gidley 1985). The town of Gardiner, New York, needed to replace the failing septic systems in its 150 homes. In the early 1980s, the town decided to use small-diameter effluent sewers to collect the wastewater from the existing septic tanks and treat it with a centralized intermittent sand filter system. The system had a design flow of 57,000 gpd and used four filters, each with a surface area of 5,800 square feet. The effluent was disinfected with chlorine and then discharged to a river. BOD_5 removal averaged 93 percent and suspended solids removal averaged 89 percent during a 1-year period (1984 to1985). The effluent contained an average of 10.6 mg/L BOD_5 and 9.4 mg/L TSS. System cost was not accurately reported.

Recirculating Sand Filters (Osesek *et al.* 1994). Two recirculating sand filters were constructed at private residences in Wisconsin. Prior to installation of the filters, one home was served only by a conventional drainfield while the second home was served by a mound system. In each case, the sand filters were designed to treat wastewater after it exited the septic tank and before it was discharged to the existing disposal system. Wastewater flowed from the septic tank to the top of the filter, was recirculated through the filter again, was pumped back to the septic tank for denitrification, and then finally was sent to the disposal field. Each of the filters was entirely enclosed within a 2,000-gallon septic tank. Performance proved to be excellent, with an average 96 percent BOD removal, 80 percent NH_4 removal, and 65 percent TN removal.

5.6 Peat Filter Systems

A peat treatment system is much like a sand filter that uses peat as the matrix to support microbial populations. Peat is useful as a filter medium because it has large pore spaces and surface area, resists compaction, and is rapidly colonized by microorganisms (White *et al.* 1995).

A typical peat system, such as those produced by Bord na Mona of Ireland, involves pre-treatment with a septic tank, the effluent of which is transferred to the main processing unit via a pump and a flow-splitting manifold (see Figure 9). The main unit consists of fibrous peat media contained within multiple polyethylene cells 24 inches deep. Total residence time in the main unit is 3 to 4 days. A 500-gpd system requires 320 square feet of space, including a percolation ground disposal area.

Performance

A study by Lens *et al.* (1994) found that peat filters provide excellent removal of BOD, TSS, TN, and FC. Research by Boyle *et al.* (1994) found similar results, including excellent FC removal, but poor nitrogen removal. FC removal may be enhanced by the specific microflora associated with the peat, which includes fungal species with antibacterial properties that affect stressed enteric organisms but not bacterial decomposers (Lens *et al.* 1994, Henry 1996). Phenolic groups in the peat lignin may also contribute to the degradation of enteric bacteria (Lens *et al.* 1994). However, an extensive study of the Puraflo system by the Gulf of Mexico Program determined that, under some circumstances, performance is much lower (Canody 1996). Although system failures are partly at fault for this low performance, climate may also be a factor. A study in Northern Minnesota found that nitrogen removal was substantially lower in the summer than in the winter (McCarthy *et al.* 1998). Table 12 summarizes the peat filter performance information (also see Appendix A, Table APP4).

Figure 9. Two Bord na Mona Puraflo Peat Filters Installed at the Vernon James Center, Plymouth, NC (from http://plymouth.ces.state .nc.us/septic/jmscntr.html).

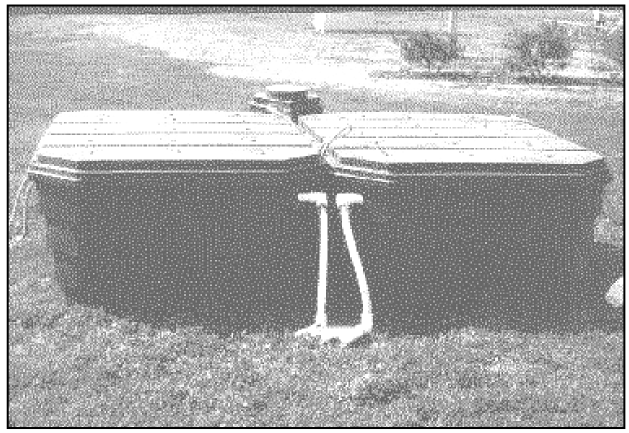


Table 12. Performance of Peat Filter Systems Based on Average Measurements across Five Studies/Sites Reviewed for this Evaluation.

	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	FC (col/100mL)
Effluent	8.04	5.74	40.18	9.53	20.21	7.06	11,543.8*
% Removal	95.13	93.75	26.57	79.57	0.00	11.48	98.52

**If White* et al. *(1995) is excluded (one of five studies reviewed), average fecal coliform bacteria concentration is 13.5 colonies / 100 mL.*

Effluent = the concentration of contaminant in effluent from the treatment system.

% Removal = the change in contaminant concentration between system influent and effluent.

Details on each study found in Appendix A, Table APP4.

Lens *et al.* (1994) evaluated the performance of ground bark and woodchips as filter media by comparison to peat systems. They reported good removal of nitrogen, and fair removal of BOD and TSS for both systems, although FC reductions were only one log unit and COD removal rates were determined to be unacceptably low for the wood chips. They were judged to be generally inferior to peat systems. The authors suggested that bark, in combination with peat, has potential for effective treatment.

Limitations

Oil and grease must be removed before effluent enters the main processing unit, or the system will fail. Nitrification tends to occur near the bottom of the treatment module (Henry 1996). This suggests that nitrate levels may be high in the effluent, because there is no recirculation, unless the system is maintained on the verge of aerobic/anaerobic activity. The acidic conditions that are unfavorable to enteric bacteria may be more favorable to enteric viruses (Loomis 1996).

The peat in a filter will gradually break down over time and require replacement. Peat is formed over a period of hundreds of years by the partial decomposition of plants under acidic, anaerobic conditions. Extensive use of peat as a filter medium might not be a sustainable practice.

Cost

The peat system tested at Weeks Bay (described in a case study below) cost $7,413 for each home system and $1,800 for installation, including engineering, for a total cost of $9,213 per home. A peat filter was installed in Anne Arundel County for a cost of $10,001. Complete Ecoflo® peat systems (including septic tank and installation) have been regularly installed for $5,000 to $8,000 depending on site-specific conditions; this cost includes a seven year maintenance contract for annual inspections (R. Raider, pers. comm.). Operating costs are estimated at less than one dollar per month for an average residential home (Henry 1996).

Analysis

Peat filters are capable of very good removal of BOD, TSS, and FC. Their nitrogen-removal capacity appears to be limited, however. In a comparison between peat filters and sand filters, Boyle *et al.* (1994) found that peat filters were superior in FC removal, inferior in nitrogen removal, and roughly equivalent on other parameters. The problems experienced in the Weeks Bay study do not appear to be typical of peat filters. Peat filters likely represent a good alternative when combined with some type of nitrogen removal technology or in areas where nitrogen removal is not critical. Their cost is roughly comparable to sand filters.

Peat Filter Case Study

Weeks Bay, Alabama (White *et al.* 1995, Canody 1996). As a partially funded activity of the Gulf of Mexico Program, septic drainfields of twenty homes near Weeks Bay were replaced by Puraflo peat systems from Bord na Mona of Ireland. Initial performance was somewhat disappointing, partly because three of the systems suffered from electrical malfunctions that resulted in grease and sludge carryover into the peat media. The peat systems also appeared to require several months to adapt to local environmental conditions, which are hotter and more humid than other locations where the systems have been tested. Average fecal coliform bacteria removal rates were 93 percent, although at the end of the 12-month sampling period, each achieved a 99 percent reduction level. Fecal coliform bacteria concentrations in the effluent averaged 57,665 colonies per 100 mL during the span of the study, but dropped to an average of 4,911 in the final month. During the final two months, BOD reduction was 85 percent, organic nitrogen was reduced by 73 percent, and ammonium nitrogen removal averaged 96 percent.

Samples were taken from the effluent of the treatment modules, prior to soil infiltration, which would result in further treatment.

5.7 Marshland Upwelling and Shallow-Well Injection Systems

Marshland upwelling is an emerging technology that holds promise for removing contaminants in areas where there is little or no soil for effluent disposal (*e.g.*, overwater camps). The technique involves pumping effluent into wells drilled into the marsh soils prevalent in coastal Louisiana. The lower density of the freshwater effluent causes it to rise through the substrate, which provides treatment similar to a media filter. A pilot study was performed at the Louisiana Universities Marine Consortium (LUMCON) satellite camp in Port Fourchon, Louisiana by Rusch *et al.* (1995). Three 15-foot PVC wells were drilled into the semi-fluid clay through hydraulic jetting. Eighteen groups of monitoring wells were installed around them to sample water at depths of 5 feet, 10 feet and 15 feet. Effluent from a mechanical plant (*i.e.*, an aerobic treatment plant) was pumped at an average rate of 500 gpd into one of the wells. The effluent took 5 to 7 days to travel 5 feet vertical and 4 feet horizontal to the closest wells; by the time the effluent rose within 5 feet of the surface, FC levels had been reduced from 1,000 to 10,000 colonies/100 mL to undetectable levels. Tracer viruses were also completely removed. Studies of vegetation found no significant effect of wastewater on production of *Spartina alterniflora*. In addition, this marshland upwelling system is almost maintenance-free (Rusch, pers. comm.).

Shallow-well injection of wastewater into coastal saline water has been widely used in the sand and limestone substrates of the Florida Keys, where there were an estimated 600 to 700 such disposal systems as of the early 1990s. The effluent is treated and chlorinated, and then pumped into a 90-feet-deep well that is grouted with 60 feet of PVC casing. Inspectors are on hand when the well is drilled to ensure that it is installed in an appropriate location and fully grouted (K. Sherman, pers. comm.). In the Florida Keys, phosphorus removal is high due to chemical binding of the phosphorus to the limestone to form apatite (K. Sherman, pers. comm.). The term shallow-well injection is used here to distinguish this practice from deep-well injection, which involves the pumping of contaminated materials into deep, isolated aquifers or caverns.

Limitations

In the Louisiana pilot study of the marshland upwelling system, wastewater was initially injected at a high flow rate of 5.8 gpm for 30-minute increments three times a day. After several months, it appeared that the high flow rate might be leading to preferential flow paths through the substrate, which precluded complete treatment. This was successfully prevented by reducing the rate to approximately 0.5 gpm at 1.5 hour intervals applied eight times a day (Rusch *et al.* 1995).

Because of limestone bedrock, shallow-well injection in the Florida Keys has proven to be a mixed success. Injected wastewater moves rapidly up through pores in the stone. Studies have shown that tracer viruses injected into the wells reach nearby seawater in as little as 20 hours, moving at rates up to 24.2 miles per hour (Paul *et al.* 1997, Paul *et al.* 1995b). Enteric bacteria and viruses have been collected in subsurface aquifers and in nearshore waters off of the Florida

Keys, although this contamination could be due in part to other wastewater treatment methods used on the islands (Paul *et al.* 1995a).

Costs

Marshland upwelling in Louisiana is inexpensive, due to limited material needs and minimal labor involved in installation. Materials for the Port Fourchon project, including appropriate pumps and PVC pipe, cost $500 (K. Rusch, pers. comm.). In the Florida Keys, shallow-well injection cost approximately $12,000 to $15,000, depending on the geology at the site (K. Sherman, pers. comm.).

Analysis

In the conditions in Louisiana, marshland upwelling systems may be an effective and economical method for polishing and disposing of domestic effluent that has already been treated to secondary standards (*e.g.*, discharge from a mechanical plant). The ability of marshland upwelling to treat primary-treated effluent -- from a 500-gallon or less holding tank -- is currently being evaluated at the Port Fourchon site. Initial results for FC removal appear very good, from over 4 million to less than 10 colonies/100 mL (K. Rusch, pers. comm.).

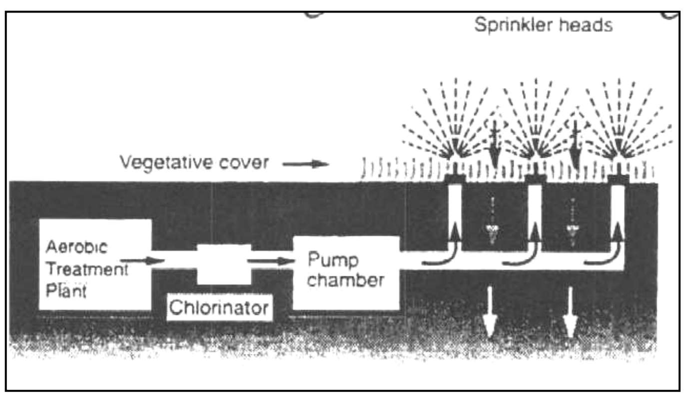
5.8 Land Disposal

Slow-Rate Land Application - Spray and Drip Irrigation

Slow-rate land application (SRLA) is the controlled application of wastewater to vegetated or cropped land. The wastewater is treated as it passes through the soil, and disposal occurs as the liquid evapotranspires or percolates into the soil. Only minimal levels of pre-treatment are required, depending on the location and nature of the site (Walters 1986b). This method can be applied on a community or homeowner level. A complete residential spray system might include the following components:

- Dual-chamber aerobic treatment unit/septic tank
- Dosing tank
- Filtration system (sand filter or a simple screen)
- Disinfection unit
- Pump chamber
- Piping and spray system (Canody 1997; McIntyre *et al.* 1994)

Figure 10. An Example Use of Spray Irrigation (from Hollomon 1997b).



Spray irrigation of effluent should be conducted on soils with slow to moderately rapid permeability (see Figure 10). According to Pennsylvania guidelines, spray irrigation should be limited to slopes of less than 4 percent for cropland, less than 8 percent for grass, and less than 25 percent for woodlands (McIntyre *et al.* 1994). In some cases, effluent is recaptured with wells or drainage ditches and either reused or discharged into surface water (Canody 1997).

Drip irrigation can be used as an alternative to spraying. Such a system releases effluent at a very slow rate through drip tubes placed on the surface or just under the surface of the soil. It can be considered in areas of shallow soils, high water table, or low soil permeability, all of which are otherwise unsuitable for disposal (No author 1997).

Design

The area required for spray irrigation depends on the soil, slope, and discharge rate. For a 2000-gpd home system, spray area can range from 0.25 acre under the best conditions to 4 acres under the worst. In addition, a buffer should be maintained around the spray field so that the field is at least 25 feet from property lines, roads and streams, and 100 feet from occupied dwellings, wells, or bore holes. These buffer requirements tend to restrict the use of spray fields to properties of at least 2 acres in size, or much larger if conditions are not optimal (McIntyre *et al.* 1994).

Proper engineering and design are critical to the success of SRLA, as for other forms of alternative wastewater treatment. In Georgia, where spray and drip irrigation have been applied on a large scale by several counties and municipalities, a number of failures have occurred due to improper engineering and inadequate maintenance. Contamination of both surface and groundwater may have resulted (Howard Marshall, pers. comm.).

Performance

SRLA has the capacity to produce the highest quality effluent of any land treatment method (Walters 1986b). BOD removal rates regularly exceed 98 percent and effluent usually averages less than 2.0 mg/L BOD (Crites and Tchobanoglous 1998). SRLA removes 99 percent or more TSS (Crites and Tchobanoglous 1998), with less than 1.0 mg/L suspended solids in the effluent (Walters 1986b). Under the proper conditions, the effluent will also contain less than 0.5 mg/L ammonium and 3.0 mg/L TN (Walters 1986b), although some SRLA systems produce effluent TN exceeding 10.7 mg/L (Crites and Tchobanoglous 1998). Removal rates for TN vary from 66 to 94 percent. Phosphorus removal usually exceeds 90 percent, and effluent generally contains less than 0.1 mg/L P, and no fecal coliform bacteria (Walters 1986b, Crites and Tchobanoglous 1998). Usually, enteric microorganisms are eliminated prior to SRLA through the use of chlorine or other methods. More performance data on SRLA systems are provided in Table 13 (also see Appendix A, Table APP5).

Table 13. Performance of Slow-Rate Land Application Systems Based on Average Measurements Across 6 Studies/Sites Reviewed for this Evaluation.

	BOD (mg/L)	TN (mg/L)	NO3 (mg/L)	TP (mg/L)
Effluent	1.15	6.79	2.80	0.25
% Removal	0.98	0.73	no data	0.97

Effluent = the concentration of contaminant in effluent from the treatment system.
% Removal = the change in contaminant concentration between system influent and effluent.
Details on each study found in Appendix A, Table APP5.

Limitations

A spray or drip field requires a large amount of land, which can be a limiting factor in the technology's applicability. Poor soil permeability, freezing weather, and saturated soil conditions can preclude the use of spray irrigation (Canody 1997). Drip irrigation may be an option under some of these conditions. Formerly drip tubes were subject to clogging by bacterial growth and infiltration of roots, but these problems have largely been overcome through techniques such as automatic backflushing and the use of periodic doses of chlorine (Crites and Tchobanoglous 1998, Patrakis 1998).

The amount of pre-treatment limits the siting of a sprayfield and, to a lesser extent, a dripfield. For onsite systems and for disposal sites with any type of public access, enteric microorganisms must be eliminated with chlorination or other type of disinfection (Canody 1997). Calculations by the California Department of Health Services determined that, if a golf ball rolled across six feet of grass that had been recently irrigated with undisinfected greywater, on average, the ball would pick up enough viruses to cause a 100 percent chance of infection if the ball was handled and viruses were ingested (CDHS 1990). Chlorination, in turn, can have harmful effects on vegetation (Anderson *et al.* 1981). On the other hand, McIntyre *et al.* (1994) notes that "there have been NO documented cases in which the spray effluent of properly treated wastewater has caused ANY problems."

Onsite sprayfields require significant homeowner operation and maintenance activities that average one hour per week. Among other things, such maintenance includes addition of chlorine tablets to the disinfection unit (McIntyre *et al.* 1994). Rubin *et al.* (1994) note that programmable logic controllers can effectively substitute for much of the maintenance associated with the disposal system.

Costs

For a homeowner system, SRLA is considerably more expensive than conventional septic systems. Initial construction costs range from $10,000 to $15,000, plus $1,500 to $2,500 in engineering expenses (McIntyre *et al.* 1994). Operation and maintenance costs average about $250 per year (Canody 1997). A recent study in coastal Alabama found that construction of a drip-emitter-application system cost $11,736 (Shirk and White 1999). Cluster and community systems are more economical, as evidenced in the case study below (Walters 1986b).

Analysis

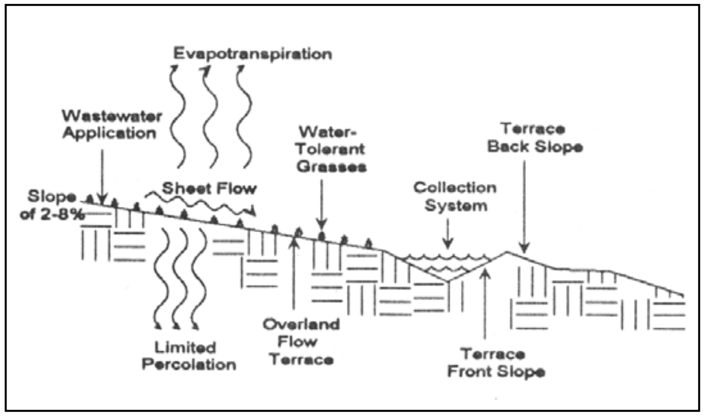
SRLA systems provide very good performance when properly constructed and maintained. They are a good choice for a cluster and centralized system, provided there is sufficient land of the appropriate type. They are an expensive and high-maintenance option for onsite domestic wastewater treatment.

Rapid Infiltration Land Application

With rapid infiltration, a basin is intermittently flooded with wastewater and allowed to dry (USEPA Region IX 1996). The intermittency allows aerobic processes to occur. The technology requires 5 to 8 feet of unsaturated, well-drained soil and site selection is absolutely critical to its success (Crites and Tchobanoglous 1998). Because it is unlikely that there would be suitable locations in the Louisiana coastal region for rapid infiltration to be an effective, environmentally safe technique, it is not discussed further.

Overland Flow

Figure 11. Overland Flow Effluent Treatment and Disposal (from USEPA Region IX 1996).



In an overland flow system, wastewater that has undergone at least primary treatment is applied to the top of a gently sloping vegetated hill (see Figure 11). The effluent is collected at the bottom of the hill, where it is disinfected and discharged. The system requires a 100- to 200-feet slope of 2-8 percent grade with vegetated terraces (USEPA Region IX 1996). Soils should be slowly permeable or have restricting layers at shallow depths. Cover crops should have a long growing season, extensive roots and a tolerance for saturated soil conditions (Walters 1986c). Rational models have been developed to calculate appropriate slope length and loading rates (Crites and Tchobanoglous 1998).

Performance

Under appropriate conditions, overland flow can reduce BOD by 80 to 95 percent (Walters 1986c), with typical effluent concentrations of 5 to 15 mg/L (Crites and Tchobanoglous 1998). Overland flow is effective in removing suspended solids by 80 to 95 percent, with effluent concentrations of 10 to 15 mg/L (Crites and Tchobanoglous 1998), as well as TN by 75 to 90 percent (with effluent concentrations of 7.5 mg/L or less) (Walters 1986c, Crites and Tchobanoglous 1998). Phosphorus removal rates may be limited to 30 to 60 percent by lack of soil-wastewater contact (Walters 1986c, Crites and Tchobanoglous 1998). Under some circumstances, FC removal rates can be high (90 to 99.9 percent) (Walters 1986c), but when secondary effluent is applied, FC counts may not be lowered much beyond their already relatively low levels (compared to primary effluent) (Crites and Tchobanoglous 1998).

Limitations

Overland flow requires a large land area of appropriate conditions. Freezing weather precludes the use of the overland flow method. In cold climates, provision must be made to store wastewater during such periods. The extremely flat topography of coastal Louisiana is not appropriate to overland flow.

Costs

Overland flow land application can be very economical. The town of Kenbridge, Virginia, found that an overland flow system cost $88,000 per year, compared to an aerated lagoon, which would have cost $168,800 per year (GAO 1994).

Three Land Disposal Case Studies

Slow-Rate Land Treatment: Craigsville, Virginia (Walters 1986b). Craigsville, Virginia, a rural town of approximately 150 homes, needed to replace its failing septic systems and pit privies with a more effective treatment system, but lacked the funds for a proposed advanced wastewater treatment facility. When a correctional facility was constructed near the town in the late 1970s, a wastewater treatment facility was designed to handle waste from the town and the new institution. The selected system involved gravity collection to a centralized treatment center, where wastewater passed through Imhoff tanks, aerated lagoons, and finally was sprayed onto fields. The selected treatment system had a design flow of 250,000 gpd and cost $1,330,000. The cost per home averaged approximately $8,900, although, if the share of the prison is included, this per-home cost drops by almost 50 percent. The proposed advanced wastewater treatment facility had a design flow of only 150,000 gpd and cost $1,623,000, nearly twice the cost per gallon. Performance data were not available for the facility, but samples from the river that drains the site showed no influence of the land treatment on water quality.

Slow Rate Land Treatment: North Carolina Piedmont (Rubin *et al.* 1994). Drip disposal systems were installed at two locations in the North Carolina Piedmont where heavy textured, clayey soils dominated. The first system treated up to 240 gpd from a single two-bedroom mobile home with pre-treatment by a septic tank and disk filter. The second system served a three-bedroom home, and included a septic tank and recirculating sand filter, all designed to handle 360 gpd. The first system had a 2,400 square foot drip field, while the second required a 3,600 square foot drip field using loadings of 0.75 to 1.0 gpd per square foot. Monitoring wells demonstrated very good overall contaminant removal, as shown in Table 14.

Table 14. Drip Filter Performance in North Carolina Case Study (Rubin *et al.* 1994).

Season	Remaining TOC (mg/L)		Remaining NO3 (mg/L)		Remaining TN (mg/L)	
	Site 1	*Site 2*	*Site 1*	*Site 2*	*Site 1*	*Site 2*
Summer	16.7	14.2	2.5	3.9	6.3	5.5
Fall	8.8	8.7	3.4	1.7	4.1	4.0
Winter	9.2	9.3	4.8	2.1	6.4	5.1
Spring	8.9	8.8	2.2	1.9	3.6	2.4

Overland Flow: Kenbridge, Virginia (Walters 1986c). Kenbridge, Virginia needed to upgrade an existing community wastewater treatment facility. An aerated lagoon was proposed at an average cost of $168,000 per year. It was soon found, however, that a site adjacent to the treatment facility was well suited to the overland flow method, and this option was pursued for a cost of $88,000 per year. For a design flow of 300,000 gpd, an area of 22.1 acres was required. Effluent from the existing wastewater treatment system was applied by slotted pipes to 15 terraces that ranged in length from 60 to 710 feet. Effluent was tested only for BOD and TSS. The overland flow system was found to be effective in removing BOD, with effluent concentrations averaging 19.4 mg/L, but suspended solids varied and were found to be higher during winter months.

5.9 Sequencing Batch Reactors

A sequencing batch reactor (SBR) uses an activated sludge-type process but differs from conventional treatment plants in that many of the treatment stages occur sequentially in the same chamber, rather than in a series of separate tanks. Because it is designed for batch operation rather than continuous operation, it is well suited for handling intermittent wastes. It is considered to be relatively simple, reliable, and has low sludge production (USEPA 1996). The SBR process includes screening and grit removal, and possibly clarification, before the wastewater is piped to the SBR tank itself. The SBR tank is allowed to fill without pumps to allow anoxic decomposition; then aeration is begun to encourage aerobic digestion of wastewater. After processing, the effluent is decanted for disposal and the waste sludge can be pumped out for digestion and disposal (Norcross, 1992; USEPA 1996).

Performance

The SBR technology can produce a very high quality effluent, with BOD and TSS of less than 10 mg/L and ammonium concentrations under 1 mg/L (Norcross 1992). A small -- 28,000 gpd -- municipal SBR plant in Lake Edgewood, Michigan was reported to have a removal efficiency of 97.9 percent for TSS, 96.1 percent for NH3, and 93.6 percent for P (Norcross 1992). A full-scale pilot study in Korea reported 95 percent removal of BOD (7.3 mg/L in effluent), 70 percent removal of TN (13.6 mg/l in effluent), and 77 percent removal of TP (0.9 mg/L in effluent) (Rim *et al.* 1997). SBRs may produce superior effluent than continuous flow processes in small treatment plants serving less than 10,000 people (Chambers 1993).

Cost

Sequencing batch reactors have somewhat higher per capita costs than package treatment plants but are still moderately priced, with capital costs of approximately $7 per gpd (EPA 1996). A proposed SBR system in Britain serving 600 people was estimated to cost approximately $579 per capita, using 1999 currency conversion rates (Chambers 1993). While it appears that SBR technologies are most widely applied at the community level, a proprietary SBR was demonstrated at a single-family residence through the NODP. The reported cost was $6,900, but did not include the cost of the donated proprietary SBR , other donated materials, and volunteer staff time by two government entities (NODP 1998).

Limitations

Early SBR designs, which date back nearly 80 years to the first activated sludge plants, suffered operational difficulties which led to their abandonment in favor of continuous flow designs. However, these problems have been largely eliminated by modern control processes (Chambers 1993), leading to the present revival of SBRs.

Analysis

SBRs are a promising centralized treatment option for all types of wastewater, and appear to be especially appropriate for intermittent wastewater flows. They should be considered for the centralized treatment of wastewater from clusters of residences or camps.

5.10 Patented Systems

Patented systems use proprietary methods, technologies, or designs to process wastewater. Several of these technologies provide alternatives to conventional drainfields. Several others are enclosed systems where effluent is passed through a matrix of natural or artificial material that supports a biofilm of microorganisms, which break down the wastewater components. Jowett and McMaster (1995) claim that these systems can maintain higher loading rates, than conventional drainfields and sand filters, without clogging. Critics of these aerobic biofilter systems note that many types contain a very small and limited assemblage of microorganisms compared to more "natural" systems such as constructed wetlands, sand filters, and land application. As a consequence, these enclosed systems may not be as resilient when regular use patterns are disrupted (Venhuizen 1996). While no performance information could be obtained on such systems, proprietary upflow anaerobic biofilters are also available.

Waterloo Biofilter

The Waterloo Biofilter was designed at the University of Waterloo and is manufactured by a spin-off company, Waterloo Biofilter Systems, Inc. of Ontario. It is a single-pass (intermittent) aerobic biofilter designed to treat septic tank effluent and replace the septic drainfield. Versions have been developed for individual homes and for community systems. It is similar in concept to an intermittent sand filter, although it uses a plastic foam medium instead of sand, which allows for improved aeration and ten times the design flow per unit area (Jowett 1995).

The Waterloo Biofilter has been extensively tested under a variety of conditions. Average results of these tests show that the technology can reduce BOD by 90 percent, TSS by 83 percent, TN by 36 percent, ammonium by 89 percent, and FC by 99 percent (with 50 percent or more recirculation back to the septic tank). Table 15 shows the average effluent concentrations and pollutant reductions for five residential performance tests of the Waterloo Biofilter. Nitrogen removal performance can be enhanced by recirculating effluent through the septic tank or by passing the nitrate-rich effluent through a box of organic matter, which can remove nearly all nitrate (Jowett 1995).

Table 15. Average Performance of Waterloo Biofilter in 5 Tests (adapted from Jowett 1995).

	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	FC (col/100mL)
Effluent	14.02	12.34	28.00	1.80	no data
% Reduction	90.60	83.00	35.67	88.67	99.00

Effluent = the concentration of contaminant in effluent from the treatment system.
% Removal = the change in contaminant concentration between system influent and effluent.

Several Waterloo Biofilter systems were installed in 1996 in coastal Rhode Island at an average cost of $12,820 each (Loomis and Dow 1998). Recently the Waterloo Biofilter technology was purchased by Zabel Environmental Technology, modified to fit within a 38-inch-tall cylindrical plastic canister, and renamed the Aerocell. The redesign of this technology makes it less expensive to ship (the multiple basins required for a typical installation can be shipped by the United Parcel Service). While the dollar value could not be confirmed with the company, indications are that Zabel has reduced the cost of this technology (L. Garner, pers. comm.).

Bioren Living Filter

Form Cell Research, Inc., has developed the Bioren Living Filter, a membrane reactor designed to replace conventional home and commercial septic systems. The reactor consists of a large surface-area fiber membrane that serves as a substrate for microorganisms. According to the manufacturer, the system has several major advantages: (1) it occupies a much smaller area of land than a conventional septic drainfield; (2) it can be used in areas of very high soil permeability and/or high water tables; and (3) it attains its long-term acceptance rate within two weeks, which is much quicker than conventional methods, making it very appropriate for seasonal use. The manufacturer did not provide performance data, but claimed that the system was very effective in removing BOD, phosphorus, nitrate, viruses, and pathogenic bacteria. However, it appears that the system is intended to maintain anaerobic conditions, which could limit nitrification and result in high levels of ammonium in the effluent (Form Cell Research 1999).

Hydroxyl Modular System

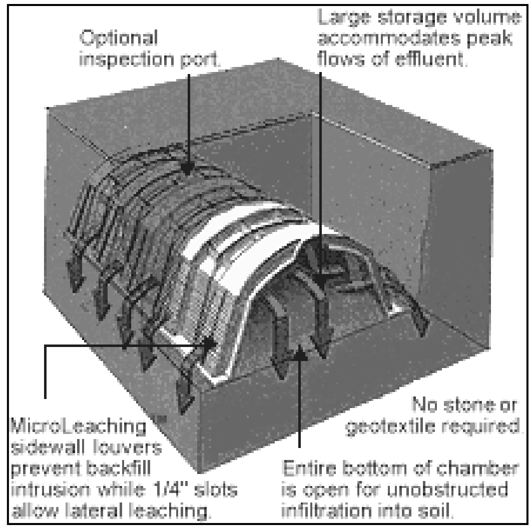
Hydroxyl produces modular package plants for flows as small as 13,000 gpd, which can serve approximately 37 homes. The system consists of a separation tank that uses "electrostatically-charged air bubbles to float particulate matter to the surface." Screened effluent is sent to an aerobic chamber and then through a foam biofilter. Effluent from the biofilter is disinfected using ozone and hydroxyl free radicals to oxidize microorganisms. The manufacturer claims that the effluent has BOD_5 and TSS of less than 10 mg/L, and a fecal coliform bacteria count of less than 2.2 per 100 mL. Because the treated wastewater is of "rainwater quality," only a very small disposal field is necessary, resulting in considerable savings if the effluent is to be disposed of in soil (Hydroxyl Systems 1999).

MicroSepTec System

MicroSepTec Company's eponymous wastewater treatment system is self-contained, highly technological, and designed to serve a single home. Wastewater first enters a clarification chamber (*i.e.*, septic tank), where solids settle out; the wastewater then flows into an aerated biofilm reactor chamber, where BOD_5 is reduced. The wastewater flows into a third chamber, which is also aerated and designed to promote nitrification, before passing into a clarifying chamber and being recirculated back through the first chamber to allow denitrification to occur. Clarified effluent eventually leaves the system by passing through a disinfection unit to kill fecal coliform bacteria and to a subsurface discharge mechanism. Solids that accumulate in the first chamber are periodically emptied into a "Thermal Processor," which uses microwave dehydration followed by high-temperature electrical incineration to vaporize the solids. The exhaust is treated by a catalytic converter and vented, while the ash is flushed out with the wastewater. The manufacturer claims that effluent will contain less than 10 mg/L CBOD, TSS and TN, and fecal coliform bacteria counts of less than 2.2 colonies per 100 mL (MicroSepTec 1999).

Chamber Drainfields

Figure 12. Infiltrator Chamber Design (from Infiltrator Systems, Inc.).

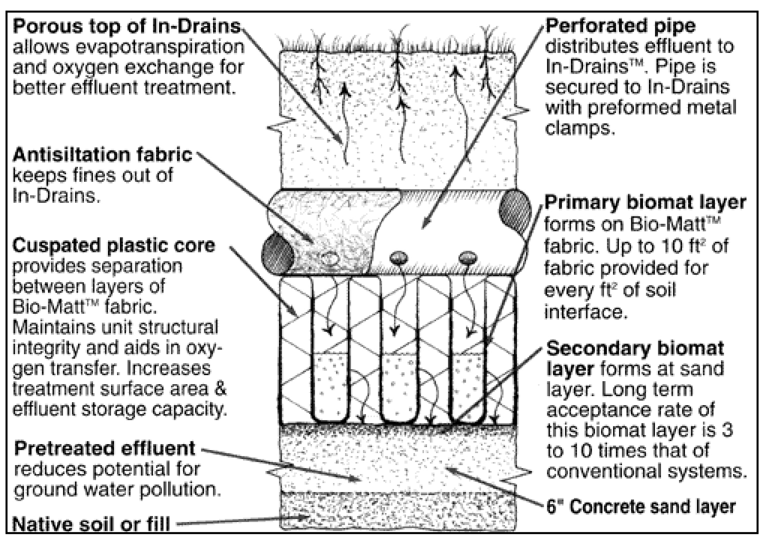


Infiltrator Systems, Inc. has patented the Infiltrator® chamber, a direct replacement for conventional stone-and-pipe drainfields. The chamber is suitable for trench, bed, mound, serial-distributed, pressure-dosed, and other septic design applications. The chambers rest directly on the trench bottom and have a louvered sidewall, facilitating increased soil contact (see Figure 12). The technology provides almost twice the infiltrate capacity of a conventional stone-and-pipe system -- 4 gallons per foot versus 2.6 gallons per foot (S. Murdoch, pers. comm.). The manufacturer claims that many states have approved it with a reduction in drainfield size of up to 50 percent. Infilitrator's Equilizer 24 model is approved for use in Louisiana. Iron-impregnated sand media laid beneath the Infiltrator chamber is a new effluent disposal process being tested in Michigan through the National Onsite Demonstration Project (Dix and Nelson 1998). The cost, installed, for 50 feet of chamber drainfield following a mechanical plant -- a typical installation in Louisiana -- ranges from $1,500 to $1,800 (S. Murdoch, pers. comm.).

In-Drain System

Eljen Corp. has patented a non-aggregate drainfield system that incorporates a Bio-Matt™ fabric technology to pre-treat septic tank effluent prior to entering the native soil (see Figure 13). The company claims that their In-Drain™ System maintains greater long-term leaching capacity and requires a much smaller area, when compared to conventional stone-and-pipe drainfields. In addition, the company's website claims that its Bio-Matt offers a comparable environment to soil for biomat growth and presents no masking effect on infiltration capacity. Average cost (including installation; without septic tank) for a typical 3-bedroom home in $7,500 (E. Ingram, pers. comm.).

Figure 13. In-Drain System (from Eljen Corp.)



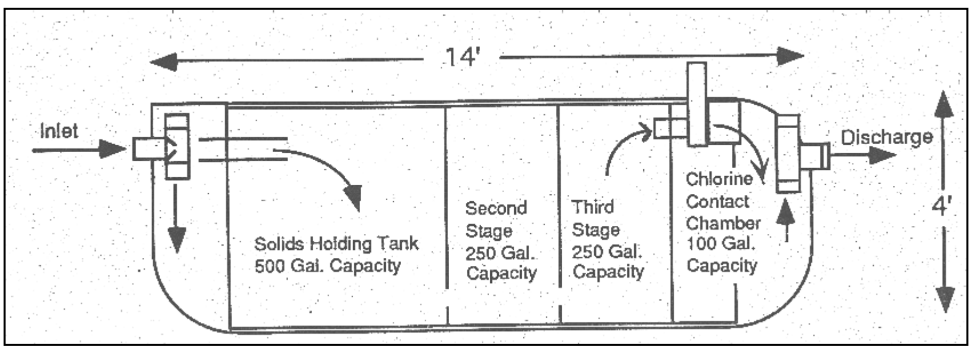
No-Mound System

The Oak Hill Company has patented the "No-Mound" system, which is a conventional septic drainfield enclosed on the sides and top by a PVC liner. Air is pumped into the top of the field to generate a pressure head sufficient to force the water table 4.6 feet below the cap. This allows sufficient depth of unsaturated soil without the construction of a mound in areas with a high water table (Jesperson 1999). More information is available at *www.nomound.com*.

5.11 Limited-Use Systems

Structures occupied three days per week or less and located in a marsh/swamp area or over water -- namely fishing and hunting camps in areas without soils suitable for traditional onsite treatment -- can utilize limited-use wastewater treatment systems. Conventional limited-use systems (often referred to as a "camp unit") have a four-compartment treatment unit and discharge directly to the receiving water (see Figure 14). Disinfection is provided by chlorine contact in the fourth chamber of the unit (Tetra Tech, no date). Because the user must manually add chlorine tablets, regulations require that the units be equipped with an automatic cutoff to prevent flow from the third chamber if the chlorine supply is exhausted. A representative at Advanced Fiberglass, Inc. indicated that the chlorine tablet supply would have to be replaced every six to twelve months, with regular weekend camp use.

Figure 14. A Conventional Limited-Use System (from Tetra Tech no date).



In August 1999, a new type of limited-use system -- the HBO250 -- manufactured by Houseboat Outlet, was approved for general use by the LDHH. The HBO250 uses an AC- or DC-powered blower (the blower can be powered by batteries where camps do not have access to continuous electricity) for additional secondary treatment within the main treatment chamber. The polyethylene enclosure measures 5’9” by 2’10” wide by 3’6” high. Maximum capacity is 250 gallons, with a design-flow of 125 gpd with a retention time of 48 hours (W. Rebouche, pers. comm.). The chlorine tablet supply needs to be replaced every one to two months, with regular weekend camp use. Note that the HBO250 does not have an automatic cutoff mechanism when the chlorine supply is exhausted.

Performance

No performance data are available on either approved limited-use system (M. Vidrine, pers. comm.). Assumably effluent from the conventional limited-use system is high in BOD, ammonium, TN, and phosphorus, but low in FC if chlorine tablets are added regularly to the contact chamber. The HBO250 might further reduce BOD and TSS through aeration of the wastewater.

Limitations

Because they guarantee only primary treatment, limited-use systems have relatively low effluent quality. They rely on regular owner maintenance to ensure disinfection, since chlorine tablets must be added manually. An AC or DC power supply must be available for operation of an HBO250. The issue has been raised about the effect of chlorine residues in the discharges from limited-use systems.

Costs

The cost for a conventional-1,000 gallon limited-use system ranges from $1,400 to $1,600 (per a representative at Advanced Fiberglass, Inc.). The cost for the HBO250 is approximately $1200 (W. Rebouche, pers. comm.). For either unit, replacement of chlorine tablets costs approximately $10.

Analysis

Currently-approved limited-use systems provide inexpensive basic treatment. They should be considered the treatment system of last resort when all other alternatives are prohibitively expensive. Studies of conventional limited-use system effluent and evaluations of the new HB250 are needed.

5.12 Composting and Incinerating Toilets

The purpose of composting toilets is to provide complete treatment of the blackwater waste stream by replacing the conventional flush toilet with a waterless system that composts biosolids through aerobic bacterial action (see Figure 15). The principal process variation in composting toilets is continuous or batch composting. Virtually all composting toilets require daily or near-daily maintenance by the owner, involving manually rotating a processing drum with a crank and adding peat moss, woodchips, or other composting material. One model by Biolet (Biolet 1999) performs automatic mixing. If properly operated and maintained, composting toilets should be odorless and should break down waste to 10 to 30 percent of its original volume (USEPA 1999c). The resulting composted "humus," legally must be either buried or removed by a licensed hauler in accordance with regulations (USEPA 1999c).

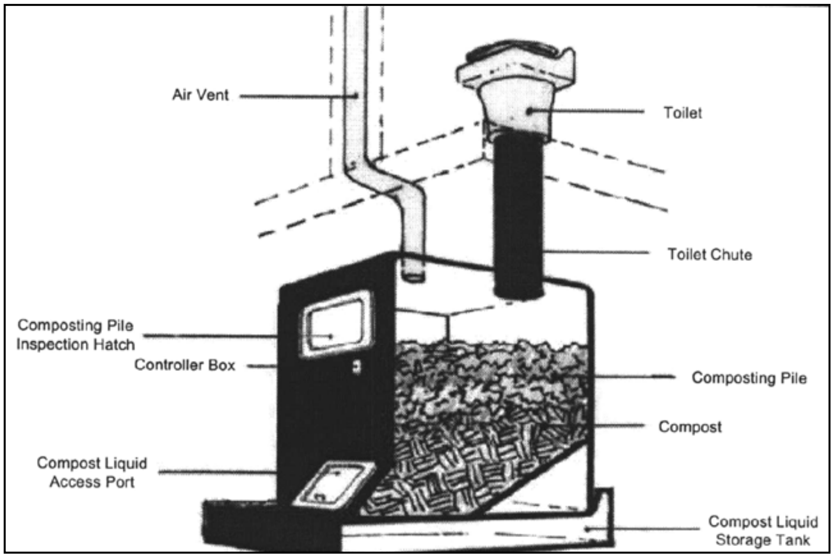
Performance and Cost

Performance data on composting toilets are sparse in the scientific literature. One study by Guttormsen (1978) found that composting toilets completely eliminate enteric pathogens in waste after a four-week residence time. Approval reviews by the NSF similarly have found that composting toilets reduce FC counts to near-negligible levels (Biolet 1999, Sun Mar 1999, Riggle 1990). There are several manufacturers of composting toilets in the United States; details of selected models have been summarized from information on the manufacturers’ websites.

Biolet composting toilets range in price from $999 to $1,999. The product line includes non-electric, electric, and automatic electric models. Biolet claims that at least one of its models (the *XL* model) has been reviewed by the NSF, which determined that the system's final compost had a FC count of 3 colonies per 100 mL (Biolet 1999).

Clivus Multrum** manufactures composting toilets for domestic and institutional use (*e.g.*, in remote locations in national parks). These include electric, non-electric, and very low-flow water models. Clivus Multrum produced the first composting toilet to be certified by the NSF, in 1982, which found that compost produced by the toilet had a FC count of 32 colonies per 100 mL (Riggle 1990). The company also manufactures greywater systems to complement its toilets.

Figure 15. Composting Toilet (from USEPA 1999c).



Envirolet composting toilets (manufactured by Sancor) cost between $949 and $1,649, and include non-electric, AC electric, and battery-powered versions (Sancor 1999). Sancor also offers versions that use very small amounts of water to flush.

Sun Mar, like the other manufacturers, offers electric and non-electric models. Biolet reports that Sun Mar toilets tested by the NSF produce compost with a FC count of 27 per 100 mL. Although higher than Biolet's product, this is still a very low count (Sun Mar 1999).

Advanced Compost Systems offers several waterless, residential composting toilet models. One of these units has been successfully used at the Alabama Onsite Wastewater Training Center (L. Garner, pers. comm.).

Limitations

Consumer acceptance is a significant problem with composting toilets, which differ significantly from conventional water-flush toilets (Kouric 1990). In the Florida Keys, composting toilets were regarded unfavorably by residents, who referred to them as "indoor outhouses" (K. Sherman, pers. comm.). Models that flush with very small amounts of water may be more acceptable than the no-water models (Kourik 1990).

Analysis

Composting toilets have the capacity to completely compost sewage biosolids, thus eliminating them from the wastewater treatment process. Composting toilets conserve water. The negative public perception of these systems and maintenance requirements would be a major implementation barrier, especially for residential uses. However, these systems might be well suited to camps. Improper maintenance could lead to health hazards and odor problems.

Incinerating toilets, another variation of waterless toilets, are self-contained units consisting of a holding tank and an electric or gas heating system that incinerates the waste products in the holding tank. Incineration products are water and a fine, non-hazardous ash that can be disposed of without infection hazard; in fact, the sterile ash can be thrown in the trash (USEPA 1999d). A typical four-person incinerating toilet, plus installation, is estimated to cost $4,000; energy costs to operate an incinerating toilet can be as high as $1,500 annually (USEPA 1999d). Maintenance costs include heating coil and blower fan replacement. While there is complete neutralization of the blackwater waste stream with incinerating toilets, there are significant energy requirements for their use and such systems suffer from the same negative public perception and maintenance requirements as composting toilets. While incinerating toilets can operate remotely, these systems might be well suited to camps with continuous electricity.

5.13 Disinfection Techniques

There are many infectious agents associated with domestic wastewater, including bacteria, protozoa, helminths, and viruses (Crites and Tchobanoglous 1998). Disinfection inactivates or eliminates pathogenic organisms in wastewater, thereby mitigating health hazards associated with wastewater discharge. Four common disinfection techniques are briefly described.

Ultraviolet Irradiation

Ultraviolet (UV) irradiation disinfection is provided by passing wastewater under a mercury arc lamp which emits light within the ultraviolet wavelength range. When UV radiation penetrates the cell wall, it disrupts an organism's genetic material and retards the ability to reproduce (USEPA 1999b). Exposure to the UV radiation can also directly kill microorganisms. It is essential that wastewater is free of particulate matter, as turbidity and suspended solids can render UV disinfection ineffective, by reducing or preventing an organism's exposure to the UV radiation.

Studies performed by Hoover *et al.* (1977) and at the University of Wisconsin (1977) revealed that FC, total coliform, fecal streptococci, total bacteria, *Pseudomonas aeruginosa*, and poliovirus I populations in UV-irradiated effluents, from both sand filter systems and aerobic unit plants, were reduced by at least 97 percent in all cases (NAPHCC 1992).

UV disinfection does not appear to be as inexpensive as chlorination. A household-scale UV disinfection system from one manufacturer costs about $900, with substantial quantity discounts available (P. Neofotistos, pers. comm.). The one major maintenance cost with UV disinfection is lamp bulb replacement; lamps are usually replaced after 12,000 hours of use (USEPA 1999b). Bulb replacement and other important maintenance activities, such as periodically cleaning the bulb, require less time and attention than required for maintenance of a chlorination system. Additionally, a UV system eliminates the formation of harmful chemical compounds associated with chlorine use.

Ozone

Ozone, a high reactive form of oxygen, is produced when oxygen molecules are dissociated by an energy source into oxygen atoms, which combine to form an unstable gas (USEPA 1999a). Ozone's powerful oxidation properties make it suitable for wastewater disinfection; it has the ability to destroy algae, bacteria, and viruses, and to oxidize most organic and inorganic contaminants (NAPHCC 1992). Ozone is more effective than chlorine in destroying bacteria and viruses (USEPA 1999a). When used in combination with ultraviolet light, ozone, which forms hydroxyl radicals, has an even greater disinfection capability. Ozone is toxic to humans at high concentrations, but a well-designed ozone disinfection system would not operate at concentrations that are harmful to humans. The cost of ozone treatment can be relatively high in initial capital and electricity, and has intensive operating and maintenance responsibilities. It appears that ozone would not be appropriate for effluent disinfection from individual residences or camps.

Chlorine

Chlorine tablets are commonly used to disinfect discharges from onsite wastewater treatment systems. Normally, the chlorine tablets dissolve when they come in contact with the wastewater in a separate compartment of the onsite system. The wastewater must remain in contact with chlorine for an appropriate amount of time for bacterial reductions to occur. Chlorine has demonstrated the ability to reduce populations of fecal coliform, total coliform, fecal streptococci, and *Pseudomonas aeruginosa*, but some parasitic species have shown resistance to low doses of chlorine. One major drawback with chlorine disinfection is that the chlorine residual, even at low concentrations, is toxic to aquatic organisms (USEPA 1999e). While chlorination is currently more cost effective than UV or ozone disinfection, a dechlorination requirement can raise the cost of chlorine disinfection and make it comparable to UV disinfection (USEPA 1999b).

Iodine

Iodine crystal units operate just as chlorine contact chambers, but the limited solubility of iodine normally requires a dosing pump to ensure proper contact with the wastewater. A study by Budde *et al.* (1977) reported greater than 98 percent reductions in coliform bacteria when using 5 mg/L or more iodine.

5.14 Ongoing Onsite Demonstrations in the Gulf of Mexico Region

The evaluation of the Port Fourchon marshland upwelling system continues. Rusch *et al*. (1995) presented results of this system as a FC polishing mechanism for effluent from a mechanical plant. It proved to be very successful in this application. Since January 1999, a new study has begun, using this same marshland upwelling system to treat primary-treated effluent (Rusch, pers. comm.). Wastewater from the camp at the study site is routed to a holding tank, where most solids are retained, and then directly to the upwelling system. Current project funding is being used to evaluate FC removal, and initial results are very positive for both FC and BOD removal. LUMCON has submitted a proposal to LDEQ to fully evaluate BOD removal and at-depth organic loading rates, beginning in the summer of 2000. Nutrient removal rates need to be evaluated.

The Alabama Onsite Wastewater Training Center, on the University of West Alabama campus in Livingston, Alabama, has numerous ongoing demonstrations in climactic and soil conditions similar to those in areas of coastal Louisiana (L. Garner, pers. comm.). They include the following:

- Bord na Mona Puraflo peat biofilter
- Nayadic aerobic system with Geoflow drip emitters
- A constructed wetland system (designed by Dr. Kevin White of University of South Alabama)
- Orenco sand filter
- A control fill system

All ongoing demonstrations utilize risers and effluent filters. The Center has near-term plans to install an Ecoflow peat biofilter, an Aerocell aerobic foam biofilter, a Delta aerobic system, and a Southern aerobic system.

The Center is unique in that two units of each system are in operation, one underground with a wastewater influent and one aboveground with a freshwater influent. The freshwater demonstration allows training class attendees to observe the operation of the system and it facilitates trouble-shooting if there is a malfunction or problem with a system.

The Florida Keys Demonstration Project is evaluating 10 alternative onsite technologies utilizing wastewater from a prison facility on Big Pine Key. The project goal is to meet wastewater treatment levels for N and P of 3 mg/L and 1 mg/L, respectively. More information can be found by at *http://www.epa.gov/owm/smallc.htm*.

Results from several of the 36 alternative onsite wastewater treatment systems that have been demonstrated under Phase I of the National Onsite Demonstration Project (NODP), such as those described from Anne Arundel County, Maryland, are included in this survey. See Appendix B for an overview of the NODP. Sites have been selected for additional demonstrations under Phase II of the NODP. While none of these sites are in Louisiana or in the Gulf of Mexico region, planned projects at Green Hill Pond, Rhode Island, might demonstrate systems applicable to coastal Louisiana. A description of the Green Hill Pond project follows.

> "The Green Hill Pond is an approximately 400-acre, poorly flushed coastal lagoon along the southern Rhode Island coastline that has experienced pronounced water quality degradation in recent years from nonpoint-source pollution inputs. The Green Hill Pond watershed is approximately six square miles in area with about 2,200 housing units. Since 1993, Green Hill Pond has been permanently closed to shellfishing due to elevated bacterial levels. The main cause of pollution is marginally functioning and failed septic systems, which have contributed to shellfish closures due to high fecal coliform counts and eutrophication from excess inputs of nitrogen. The objective of this project is to retrofit up to five failed conventional septic systems in the Green Hill Pond Watershed with alternative and innovative onsite systems." (*from NODP website*, www.estd.wvu.edu/nsfc/NSFC_NODP.html*, accessed in October 1999*)

6.0 Other Critical Considerations

In investigating the issue of utilizing alternative onsite wastewater treatment technologies in coastal Louisiana, it became evident that four management considerations needed to be explored simultaneously: (1) the necessity for proper onsite system maintenance; (2) options for combining wastewater treatment and disposal operations for small clusters of residences or camps; (3) options for greywater reuse/treatment; and (4) the benefits of water conservation.

6.1 Proper Onsite System Maintenance

Most people do not regularly think about sewage treatment or their onsite wastewater treatment systems, hence the idiom "flush and forget." The Gulf States Onsite Wastewater System Conference (1994) made a number of recommendations regarding the management of onsite systems to ensure proper system maintenance and proper wastewater treatment. These recommendations include the following:

- Require regular life-span inspection, maintenance, and monitoring of onsite wastewater systems
- Require water-saving fixtures in all new homes using onsite wastewater systems
- Mandate homeowner/homebuyer education programs
- Establish performance standards for onsite systems
- Mandate repairs and permits for existing systems

Proper, consistent operation of onsite wastewater treatment systems -- be they conventional or alternative technologies -- may well depend upon adoption of these recommendations, and consistent enforcement once they are established. The allocation of resources for consistent enforcement of onsite system maintenance requirements is an obvious, but sometimes disregarded, need.

The Coastal Research and Extension Center at Mississippi State University and the Gulf of Mexico Program have collaborated to develop *A Framework for Wastewater Legislation: Developed as a Model for Use in the Gulf Coast States* (Hollomon 1997a). The document contends that, when the concepts and criteria within the framework are codified and adopted, they will result in a unified and consistent approach to the regulation and enforcement of nonpoint source contaminants originating from failing onsite wastewater treatment systems. The document lists the following criteria as necessary for wastewater legislation to be comprehensive enough to assure protection against pollution from failing systems:

1. Promulgate rules and regulations governing the design, construction, installation, operation, and maintenance of onsite wastewater systems.

2. Provide provisions for alternative techniques and technologies for onsite wastewater systems.
3. Require a permit process with approval authority to construct, install, alter, or repair onsite wastewater systems. Incorporate renewal requirements into the permitting process.
4. Require installation of water conservation devices in all new structures using onsite wastewater systems.
5. Require connection to centralized treatment facility, if available.
6. Require limitations on electrical and water services, pending system approval.
7. Promote education and outreach programs.
8. Require mandatory homeowner and homebuyer education concerning onsite wastewater systems.
9. Provide administrative and criminal enforcement capabilities.
10. Provide state training, registration, and certification for installers of onsite wastewater systems.
11. Provide state training, registration, and certification for persons that remove and dispose of sludge.
12. Provide state training and certification for site evaluators.
13. Provide authority to regulating agency to suspend or revoke certifications.
14. Allow local authorities to enact more restrictive ordinances.
15. Establish performance standards of effluent quality from onsite wastewater systems.
16. Provide an authority to grant variances.
17. Define the types of wastes allowed to be treated and disposed using onsite wastewater systems.
18. Require existing systems, within regions that may impact shellfish areas, to obtain a permit if not already granted. All other existing systems require a permit upon transfer of title.
19. Provide mechanism for applicant to appeal an undesirable decision.

A Framework for Wastewater Legislation: Developed as a Model for Use in the Gulf Coast States is available from the Gulf of Mexico Program, Bldg. 1103, Room 202, Stennis Space Center, MS 39529, Phone: 228-688-3726.

6.2 Combining Wastewater Treatment Operations for Small Clusters of Residences and Camps

The potential exists to combine the wastewater treatment operations for clusters of residences and camps, possibly increasing management, monitoring, and maintenance efficiencies. A potential barrier to acceptance of many alternative onsite technologies is the personal involvement of the homeowner, who frequently would rather let someone else manage the problem. Regulatory personnel in California have found that homeowners generally do not perform necessary preventative maintenance for alternative systems on their own (Cagle and Johnson 1994). One analyst put it this way:

> "What is so appealing about central sewerage is not the technologies used or the costs; rather, it is the public management that removes responsibility for system performance from the individual user. If onsite and cluster systems are to be an accepted alternative, they must be managed in such a way as to be as invisible to the user as central sewerage" (Otis 1998).

Decentralized Wastewater Management

A more comprehensive exploration of decentralized wastewater management issues, including funding options, case studies, voluntary management standards, model ordinances, and the USEPA Response to Congress can be found at the "Decentralized Wastewater Management" website at http://www.epa.gov/owm/smallc.htm.

The term "decentralized" is loosely used to refer to wastewater treatment and/or disposal and reuse options that occur at or near the source of wastewater generation (Nelson 1997) (*i.e.*, most types of wastewater treatment other than traditional centralized systems fed by a network of large gravity sewers). Under the decentralized umbrella are several categories of wastewater treatment systems. These include:

- Onsite systems, wherein wastewater treatment and disposal occurs on the property at which it was generated.
- Cluster systems, wherein wastewater is collected from a small number of homes and treated nearby. Alternative collection systems are employed to transport wastewater.
- Small centralized systems, which might serve a village or large residential community, but which usually employ some type of alternative collection system.

For each of these categories, the system may be managed by a contract similar to one required for any utility serving a residence or commercial development. In fact, some managers and researchers contend that proper, consistent functioning of onsite, decentralized, and small centralized wastewater treatment systems requires centralized management (Otis 1998, Cagle and Johnson 1994). With management, the same systems can be operated more intensively -- or put another way, the same home may be served by a smaller, less-expensive system (Crites and Tchobanoglous 1998).

Since 1994, the Ad Hoc Task Force for Decentralized Wastewater Management has been studying a "decentralized wastewater treatment districts," approach, which would supplement centralized collection with appropriate "centralized management of decentralized treatment" (Nelson 1997). One motivating factor for decentralized wastewater management is that 25 percent of American homes currently use onsite wastewater treatment systems, and current projections indicate that 37 percent of new homes will use onsite systems (Nelson 1997). One promising development is the management of decentralized systems by electric utilities and rural electric cooperatives. Control systems, standard for electric utilities, are just emerging in the wastewater field. Under this type of management, developers could build knowing that wastewater management service will be provided, just as if they were connecting to a regional municipal system (Dix and Nelson 1998). Such arrangements could meet the strong preference for community-level systems, over individual sewerage systems, in the State of Louisiana Sanitary Code (Louisiana, State of 1999).

Private companies and public entities are realizing that wastewater is, in fact, a resource, one that can be used for irrigation, and the replenishment of groundwater and streams. As an example, hybrid community treatment/reuse systems could be implemented where solids are retained in septic tanks at each lot, while the community's combined treated wastewater is used to irrigate nearby parks and golf courses.

Advanced System Management

Most advanced decentralized wastewater treatment systems will require professional management, monitoring, and maintenance. The development of remote sensing and monitoring is currently being explored by a number of companies, and includes the possibility of using Supervisory Control and Data Acquisition (SCADA) systems for onsite treatment scenarios (Dix and Nelson 1998). Currently, advanced onsite systems use a "control box" that turn electric pumps on and off, monitor septic tank levels, and sound an alarm inside the house when an unusual condition occurs (*e.g.*, unusual pressure changes in dosed drainfield systems). When an alarm sounds, the homeowner must call in a report. Remote sensing can eliminate this homeowner responsibility by sending a signal directly to a central monitoring office. In more complex systems the communication can be interactive, for example, drainfield-line-dosing pump frequencies can be altered from a central office. The Joe Wheeler Electric Membership Co-op, in Trinity, Alabama, plans to develop a SCADA-based decentralized system for a new 50-home community near Hartsells, Alabama (Zabel 1999). This project has spurred considerable interest from other developers in the area.

Potential Cost Efficiencies of Decentralized Wastewater Management

In general, conventional onsite systems are the least expensive option. Soil conditions and lot size chiefly limit their use, although some of the alternative onsite options discussed in this survey can be situated on relatively small lots. In rural areas, cluster systems and small centralized systems served with alternative collection technologies are usually slightly more expensive, but still far cheaper than traditional centralized systems fed by large gravity sewers. The reason is simple: the collection system represents from 70 to 90 percent of the central wastewater treatment system’s capital costs, and alternative collection systems are usually far cheaper than gravity sewers. Traditional centralized systems and large gravity sewers are only favored economically when housing density exceeds 100 homes per mile of sewer (GAO 1994) and, even at those densities, traditional collection and treatment may be more expensive due to topographic conditions. In addition, traditional centralized systems have far higher operation and maintenance costs than decentralized systems, although for extensive systems economies of scale make these more reasonable.

In a 1996 Report to Congress, USEPA analyzed the costs of providing different types of wastewater treatment to two hypothetical communities. The first community was a small rural community with large lots. The second community was a suburban development on the fringe of an urban area with an existing centralized treatment plant and a network of gravity sewers.

USEPA modeled the costs of connecting each of these communities with traditional centralized systems, cluster systems with alternative collection, and onsite systems. The results are summarized in Table 16.

For the rural community in this example, onsite treatment and cluster treatment are both reasonable options; centralized treatment could not be considered. For the urban fringe community, onsite treatment is clearly the cheapest option. If lots are sufficiently large and environmental conditions are appropriate, onsite treatment would be a viable option, even though a centralized treatment facility is located nearby. If effective onsite treatment is not possible, either cluster or centralized treatment would be a reasonable choice, *if* the existing sewer lines run close to the community. If the closest interceptor line is several miles away, however, the cost of laying the new line could quickly become prohibitively expensive (USEPA 1996).

Table 16. Cost of Different Wastewater Treatment Systems for Two Hypothetical Communities (adapted from USEPA 1996).

Treatment Option	Capital Cost per Home	Annual O&M Cost per Home	Total Annual Cost per Home
RURAL COMMUNITY			
Centralized	$27,781	$298	$2,537
Cluster	$4,430	$54	$411
Onsite	$3,777	$99	$403
URBAN FRINGE COMMUNITY			
Centralized (1 mile from existing sewer)	$7,523	$189	$794
Centralized (5 miles from existing sewer)	$12,140	$216	$1,195
Cluster	$8,541	$41	$729
Onsite	$4,779	$134	$519

Louisiana's Experience with Decentralized Wastewater Management

The State of Louisiana currently has had one experience with decentralized wastewater management and alternative collection systems. In the 1980s, a sewer district in Calcasieu Parish decided to use a pressure sewer collection system in order to get a USEPA grant with a larger federal cost share. The engineer that planned the project of approximately 700 onsite pressure sewer pumps did not adequately investigate a power source for the pumps. The local utility company indicated, after the 700 pumps were installed, that approximately 200 residences in the community needed to have new circuit/breaker boxes installed before being used as the sewer pump's power source. Calcasieu Parish requires a building permit for any significant rewiring on a residential property and issuance of a building permit requires that all wiring in the residence be brought up to code (note that this strict requirement does not apply in all Louisiana parishes). The cost of rewiring some of these 200 homes was prohibitive. In the end, approximately 540 of the residences in the district were hooked up to the central sewer system via their pressure system pumps. Another 160 remain on septic tank systems with an unused pressure system pump on their property. As a result of this experience, the LDEQ Municipal Facilities Division prefers that communities use conventional gravity sewer collection systems whenever feasible and cost effective.

An Overview of Alternative Collection Systems

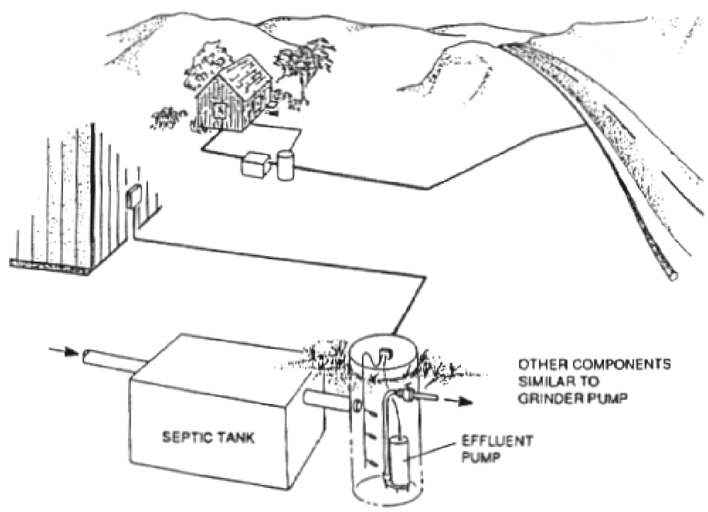
For decades, sewer collection systems have transported wastewater from densely populated areas to wastewater treatment facilities. Conventional gravity systems are designed with large-diameter concrete pipes that are laid in the ground at a slope great enough to carry sewage solids and liquids without any mechanical help. Gravity systems have been used effectively in most areas of the United States, but there are cases where the lack of topographic relief and/or soil composition will not allow the placement of conventional gravity systems.

Alternative sewer collection systems, such as pressure sewers, vacuum sewers, and small-diameter gravity sewers, can be used effectively in areas with the following conditions: rocky terrain; high groundwater table; unstable soils; variable or flat topography; sparse settlements; urban development in rural areas; restricted construction conditions. All three alternative systems use lightweight plastic pipe (*e.g.*, PVC) buried at shallow depths and pressure and vacuum systems use some form of mechanical system to transport wastewater through the pipe.

Pressure Sewer Collection Systems

In a pressure sewer collection system, wastewater is transported in small diameter PVC pipes, or mains, laid in shallow trenches following the contour of the land. The main is buried to a minimum depth of 75 cm (30 inches) or below the frost line. The diameter of the main is dependent on the number of homes being serviced, for example, 2-inch for 6 homes; 3-inch for 60 homes; 4-inch for 120 homes; 6-inch for 240 homes; 8-inch for 560 homes. Pressure systems normally serve 50 to 200 residences, but some have been designed to serve more than 10,000 residences.

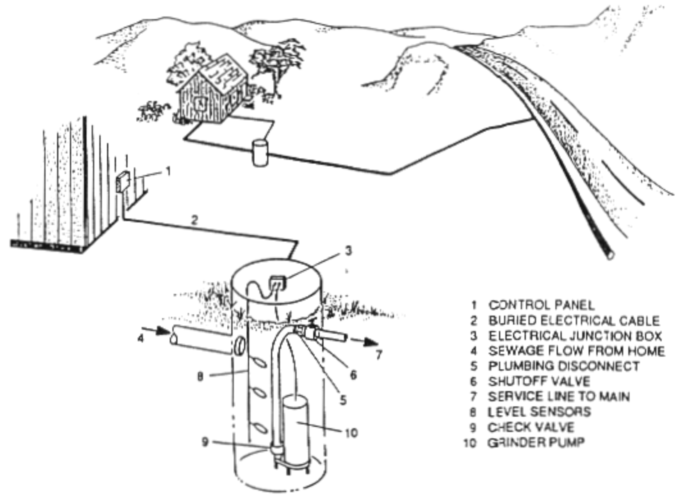
Figure 16. Septic Tank Effluent Pump (STEP) System (from USEPA 1991).



Each residence served by the pressure system has a holding tank/pump combination, which is used to periodically move wastewater from the holding tank to the main. No special plumbing is normally required inside the residence. Two types of pumps are used: a 1 (or less) horsepower Septic Tank Effluent Pump (STEP) or a 2-horsepower grinder pump. A STEP pump is used in conjunction with a septic tank to transport only the wastewater from the tank to the main (see Figure 16). The septic tank is used to collect all of the solids and scum, which must be periodically removed from the tank, and produces a partially clarified liquid wastewater. If the STEP malfunctions, a high-water sensor activates either a light outside the home or an audible alarm, or both.

A grinder pump works like a kitchen garbage disposal to grind wastes into a slurry before transporting them to the main (see Figure 17). Because the grinder pump holding tank (the wet well) does not provide much room for extra wastewater if the system were to malfunction and, because there is no septic tank, it is important that same-day emergency service is available for grinder pump connections. Both STEPs and grinder pumps are very reliable, but preventative maintenance must include annual inspections for the pumps, septic tanks, and overall system. When designing a pressure system, it is important to factor in an adequate power source at each residence for STEP and grinder pump operation.

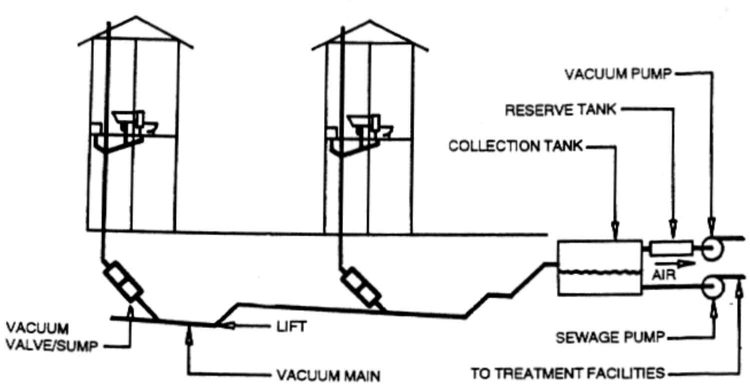
Figure 17. Grinder Pump System (from USEPA 1991).



Vacuum Sewer Collection Systems

Vacuum sewer collection systems use the same principles as a freshwater distribution system, only the flow is reversed to carry solids and wastewater away from each residence to a central location. Vacuum sewers rely on the suction of a vacuum, created by a central pumping station and maintained in small-diameter PVC mains laid with the contour of the land, to draw and transport wastewater through the collection system. Because of their limited ability to transport wastewater uphill, vacuum systems are well suited to areas with flat terrain. Some communities have installed vacuum-assisted gravity sewers to cut down on the cost of a full vacuum collection sewer system.

Figure 18. A Typical Vacuum Sewer Collection System (from USEPA 1991).



Vacuum systems normally serve a minimum of 75 to 100 residences per vacuum station, but some have been designed to serve less than 50 residences and more than 2,000 residences per station. Vacuum systems use various size mains, depending on the number of residence and businesses served, for example, 4-inch for 70 homes; 6-inch for 260 homes; 8-inch for 570 homes; 10-inch for 1,050 homes. The power of the vacuum pump depends on the size of the main.

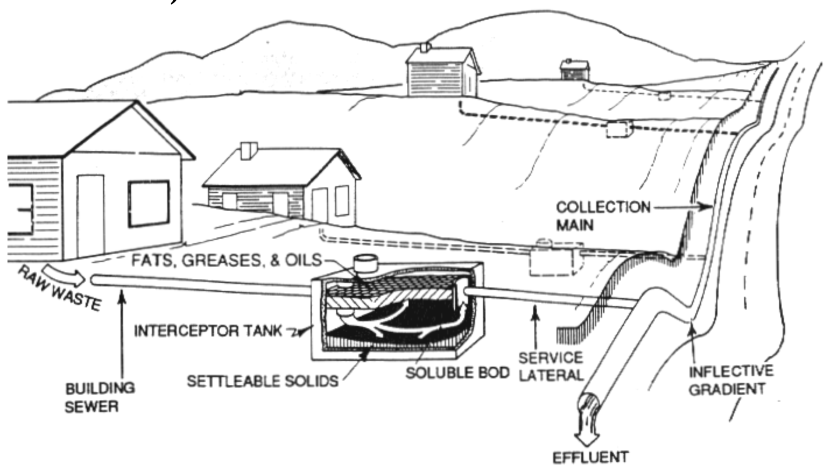
Most of the vacuum system designs used in the United States do not require vacuum toilets or any special plumbing inside the residence. Wastewater flows by gravity to a holding tank or valve pit that serves one residence or a small group of residences. When the tank or valve pit reaches a predetermined “full” level, a pneumatic valve opens, allowing the wastewater plug to enter the main. The initial force of the vacuum taking up the wastewater from the tank or valve pit is usually enough to break up any solids in the wastewater. The valve remains open for a few seconds to also allow an air plug to enter the main. The alternate plugs of wastewater and air travel through the mains to the central pumping station and empty into a collection tank (see Figure 18). Wastewater in the collection tank is then transported to the treatment facility using separate pumps.

Vacuum systems need a central source of power to run the vacuum pumps and valves, a two-story building for each vacuum station, and vent systems at each residence to allow air into the collection lines. Division valves that connect different parts of the sewer lines need to be checked at least twice a year, and the pneumatic vacuum valves at each residence should be checked annually. Depending on the system's size, communities may need to employ full- or part-time operation and maintenance staff. The vacuum and sewage pumps at the central station need to be checked and gauge readings need to be taken daily. Vacuum systems also require a working emergency generator at the central station.

Small-Diameter Gravity Sewers

Like conventional sewers, small-diameter gravity sewers (SDGS) use gravity, rather then pumps or pressure, as the primary force to transport wastewater. A SDGS can serve any number of residences and, in fact, the name may be misleading because, in some cases the PVC main collection pipe can get quite large. Each residence has a watertight interceptor tank (similar to a septic tank) that collects solids and scum and allows only wastewater to flow into a lateral pipe that connects to the SDGS main. The removal of all solids is important because the wastewater in a SDGS is transported at a slower rate than in a mechanized system, and solids can inhibit the gravity-forced flow rate. Although the interceptor tanks are normally located on private property, they are usually owned and maintained by the utility district to ensure regular pumping. Air vents are required in the plumbing system at each residence.

Figure 19. Schematic of a Small-Diameter Gravity System (from USEPA 1991).



Mains for the SDGS, which are buried to a minimum depth of 75 cm (30 inches), can be placed at variable or inflective gradients, but the overall uniform gradient must be sufficient to maintain a 45-cm-per-second (1.5 feet per second) flow velocity (see Figure 19). While, in most cases, gravity serves to transport wastewater from the interceptor tank to the main and from the main to the treatment facility, STEP pumps or mainline lift pumps can be used for one residence, a cluster of residences, or a large drainage basin.

In some instances, SDGSs have been installed to correct problems with failing septic tank systems in densely developed urban fringe areas. When designed for this purpose, existing septic tanks need to be replaced with new watertight interceptor tanks. Also, designers must be cognizant of the ultimate growth in population when sizing these systems because the size of mains is dictated by hydraulics rather than the system's solids carrying capabilities. SDGSs are well suited for low-density residential and commercial developments because the routine maintenance cost is relatively low. SDGSs are not recommended for high-density developments because the cost of installing and maintaining inceptor tanks can be high. SDGSs are also known as Australian sewers, variable-grade or minimum-grade effluent sewers, small-bore sewers, small diameter effluent drains, and common-effluent sewers.

Limitations

The major drawback to alternative sewer collection systems concerns operation and maintenance costs and requirements. Alternative systems have components that gravity collection sewers do not have, such as septic tanks that need to be inspected and pumped and mechanical parts that use electricity and need to be serviced and replaced. These components may cost more to operate, and require more frequent and regular maintenance than gravity sewers.

Farrell and Darrah (1994) claim that grinder pump systems offer several advantages over STEP systems (it should be noted that the authors are employees of a major manufacturer of grinder pumps). The waste and gases from anaerobic processes in a septic tank can be corrosive to the pump in a STEP system. Odor problems may also result, and hydrogen sulfide and methane produced in the septic tank can be hazards to those performing maintenance. Further, effluent pumps can clog if solids do happen to pass through the septic tank.

Costs

In most cases alternative collection systems can be more cost effective than traditional gravity collection systems but, as with any new technology, the system must be designed by a qualified person and maintained properly. In areas where there is rocky terrain or a high groundwater table, the use of alternative systems can reduce the cost of installation by 30 to 65 percent. A recent study, entitled *Economic Comparison of Gravity, Pressure, and Vacuum Sewer Systems for Wastewater Collection*, attempted to determine the "most economical application range" for each wastewater collection system (Public Works Research Institute, Ministry of Construction, Japan, no date). The following was the result of their cost comparison based on simplified calculations:

- Gravity systems are the most economical when the average distance between dwellings is shorter.
- Pressure systems are the most economical when the average distance between dwellings is longer and the total number of catchment dwellings is fewer.
- Vacuum systems are the most economical when the average distance between dwelling is longer and the total number of catchment dwellings is larger.
- Pressure systems and vacuum systems are the most economical when the number of dwellings per unit is larger and soil conditions are bad.

A STEP system and community sand filter serving 90 homes in Alicia, Arkansas, was constructed in 1982-1983 for a total cost of $321,790, or $3,317 per home (Foster and Stalcup

1986). A STEP system in Cuyler, New York, was installed for a cost of $4,153 per home (Fuess *et al.* 1994).

A grinder pump collection system was installed in Augusta, Maine, for a total cost of $3,100 per connection (Gidley 1987). Power costs for a grinder pump are $10 to 20 per year (1984 dollars). Operation and maintenance costs tend to be slightly higher than for STEP sewer systems (Gidley 1987). In a survey of grinder pump systems installed by Environment One, annual operation and maintenance costs ranged from $13.24 to $53 per pump unit (Farrell and Darrah 1994).

The town of Cedar Rocks, West Virginia, constructed a vacuum sewer collection system for $1.23 million in 1978, substantially less than the low bid of $2.15 million for a gravity collection system (GAO 1994).

Three Decentralized Wastewater Management Case Studies

Grinder Pump/Pressure Sewer: Augusta, Maine (Gidley 1987). A redesign of the municipal gravity sewer system left about 20 homes at an elevation lower than the nearest interceptor. To collect wastewater from these homes, a grinder pump pressure sewer system was installed in 1981. Special allowances had to be made for homes that were only seasonally occupied to ensure that wastewater would not stagnate in the pump well while the occupants were away. Some seasonally occupied homes shared a pump with perennially occupied homes, so there would be at least some year-round flow. Homes that had their own grinder pump had the system flushed with fresh water after the occupants left. These safe guards appeared to be adequate to prevent problems. The grinder pump system cost approximately $3,100 per house, although the exact cost was not known because the contract also included a section of interceptor main and force main. Operation and maintenance costs averaged $106 per year.

STEP: Cuyler, New York (Fuess *et al.* 1994). The town of Cuyler, New York, decided to replace its failing septic systems with a centralized community system using alternating drainfields. However, with a population of only 130, conventional gravity sewer would have cost more than $14,000 per home (in 1978 dollars), which was not economically feasible for residents. As an alternative the community chose to install a pressure sewer, which cost only $4,153 per home. Total annualized costs per home were $210, which included operation and maintenance, repair, and annualized costs of initial construction.

Combination Home/Community System: Dewees Island (Eddy 1996). Dewees Island is a 1,200 acre barrier island off the coast of South Carolina that is being developed to a maximum of 150 residences. To minimize the water pollution resulting from development, the developer has installed a system that combines onsite and community treatment. Effluent from each house passes through a 1,000-gallon septic tank and two 1,000-gallon anaerobic rock filters before being pumped into a pressure sewage system, which carries it to a community mound. The mound system is 10 feet high and covers 70,000 square feet. Total cost was approximately $475,000 for the collection and mound system. Homeowners pay a $5,000 fee for the residential portion, and a monthly fee of $20 plus $2 per 1,000 gallons of water used.

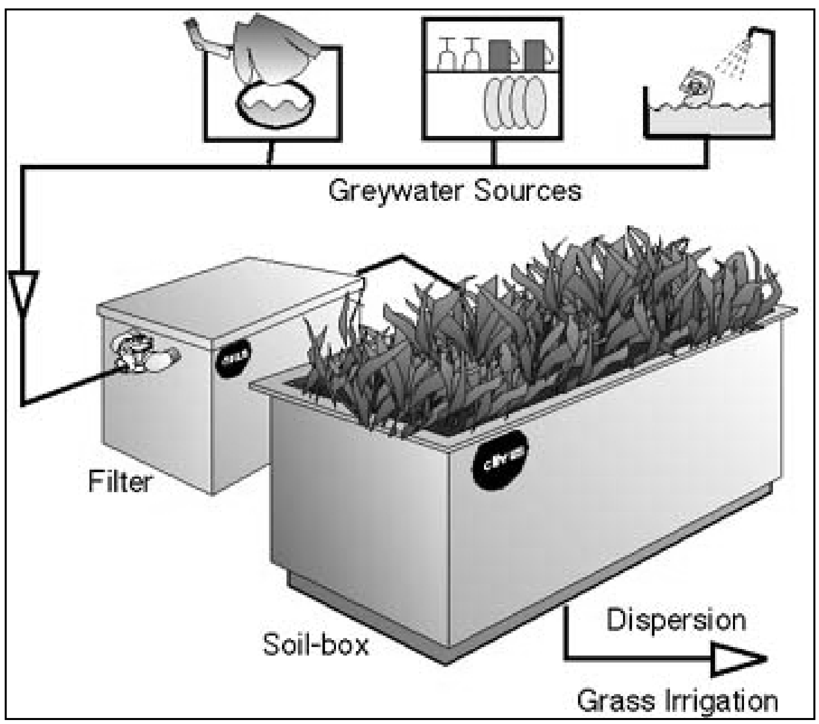
6.3 Greywater Reuse/Treatment and Water Conservation

There are two types of graywater systems: those in which the graywater is recycled for use in toilets and irrigation, and those in which graywater is disposed of separately from blackwater (toilet water) without reuse. A graywater reuse system is essentially a water conservation technique. Separate graywater and blackwater handling may be appropriate when a composting toilet or some other method of handling solids is in place. Because greywater decomposes more rapidly than mixed wastewater, a smaller, shallower disposal field may be used (Clivus Multrum 1999).

A graywater reuse system can reduce domestic water consumption by 27 to 77 percent, according to various studies; the high end of the range is from laboratory simulations (Anderson *et al.* 1981, NAPHCC 1992). A review of graywater systems found a great deal of variability in cost, from $500 to $5000, depending on the complexity and degree of automation (NAPHCC 1992).

Although much less harmful than blackwater or mixed wastewater, graywater can contain high levels of contaminants. BOD values typically range from 51 to 80 percent of those for combined sewage, phosphorus values range from 58 to 86 percent of those for combined wastewater (possibly less now that many detergents are low in P) while nitrogen values are only 1 to 33 percent of those for combined sewage (NAPHCC 1992). FC counts can exceed 10 million colonies per 100 mL (Anderson *et al.* 1981). Consequently, graywater must be disinfected before it is reused domestically or used for irrigation, and undisinfected graywater should never come into human contact (CDHS 1990). Refer to the above discussion under SRLA for more information on this subject.

Figure 20. The Clivus Multrum Graywater System (from Clivus Multrum 1999).



The Clivus Multrum company offers graywater treatment and disposal systems to compliment its composting toilets. With these systems, graywater is used to irrigate either indoor or outdoor enclosed planter beds (see Figure 20). The effluent is then collected via drainage pipes and discharged to a small drainfield. At this point the graywater should not be septic and will not form a clogging mat in the drainfield (Clivus Multrum 1999).

Case Study: Graywater Reuse System (Anderson *et al.* 1981).

For a study by the University of Wisconsin, Aquasaver brand graywater reuse systems were installed in two occupied residences. The systems consisted of graywater treatment through sedimentation in a storage tank, pressure cartridge filtration, and chlorine disinfection. The system cost $3,250 to install (1980 dollars). Water savings were 20.6 percent and 22.3 percent, respectively, for the homes, which were somewhat lower than previous studies because the homes were already outfitted with some water conservation devices. The reviewers found that the pressure cartridge treatment provided little additional benefit, and could be eliminated from the system to reduce costs. The cost of a graywater system is also partially offset by savings in septic tank pumpout costs and septic tank drainfield construction costs. However, the researchers found that the costs of the graywater system may not be warranted by the water savings, when compared to other water conservation devices.

Water Conservation

Water conservation can enhance performance and decrease costs of many wastewater treatment methods. As an example, devices such as low-flow toilets and faucets can reduce average water use from 70 gpd per person to 50 gpd per person (Crites and Tchobanoglous 1998). Wastewater authorities and water quality agencies should seriously consider the benefits of promoting the development and everyday use of water conservation devices and practices.

7.0 Discussion of Alternatives Appropriate to the Barataria-Terrebonne Estuary and Survey Recommendations

The preceding sections of this document have analyzed the performance, limitations, costs, and other management considerations in utilizing alternative onsite wastewater treatment systems in the Barataria-Terrebonne estuary. Based on this analysis, a discussion is developed on appropriate alternative technologies in the following three applications: 1) single-family, permanent residences; 2) camps with continuous electricity and water under pressure; and 3) camps without continuous electricity (both with and without water under pressure). Options, as they apply to the Barataria-Terrebonne estuary, for treating wastewater from small clusters of residences and camps, are also discussed.

This survey's recommendations are intended to provide a scientific justification for the selection of technologies used in future demonstration projects by the Barataria-Terrebonne National Estuary Program, in partnership with the Louisiana Department of Health and Hospitals and the Louisiana Department of Environmental Quality. As a reference for the following recommendations, Table 17 provides cost comparisons, and Table 18 and Figure 21 provide performance comparisons of selected onsite technologies evaluated in this survey.

In general, this survey recognizes the absolute importance of the proper design, installation, and maintenance of onsite wastewater treatment systems. Without adequate attention to these matters, any technology -- conventional or alternative -- can readily fail. Proper system design should incorporate site conditions (climatic, topographic, and soils), the type of use, nature and strength of the waste, and hydraulic loading. While good design information is abundant, any regulating entity should only consider systems designed by trained professionals and with current ANSI-certification. Testing the system in various local conditions, before approval for widespread use, would be the ideal.

The State of Louisiana has, or will soon have, some excellent management mechanisms in place. New Sanitary Code regulations will require that all mechanical plants used in Louisiana meet ANSI/NSF-40 1996 beginning January 1, 2001. The Sanitary Code has provisions for the licensing of manufacturers and installers of onsite systems. The regulations, many new or revised as of January 20, 1999, require training courses for installers, liability insurance requirements for installers and manufacturers, and annual inspection of mechanical plant installers by system manufacturers. Sewage haulers are currently required to obtain an annual license. New requirements for initial and extended service contracts for mechanical plants should provide a significantly higher level of treatment performance by these systems in the future. Ideally, some form of extended service contract would be required for all onsite wastewater treatment systems, at both residences and camps.

Table 17. Cost Comparison for Selected Onsite / Cluster Wastewater Treatment Technologies.

Treatment Type	Average Cost / Home*	Cost Range*	Notes
Septic System (in coastal Louisiana)	$3,100	$2,600 - 3,600	Septic tank and gravity drainfield
Mechanical Plant (in coastal Louisiana)	$2,250	$2,000 - 2,500	Add $700 for effluent reduction field
Constructed Wetland	$3,580	$2,000 - 6,500	--
Sand Filter	$9,741	$5,850 - 15,308	Includes disposal
Septic Tank w/ Trickling Filter / Sand Filter	$13,545	$10,982 - 15,927	Includes disposal
Peat Filter	$7,500	$5,000 - 10,001	Includes disposal
Slow Rate Land Application	$15,243	$11,112 - 22,880	Includes full pre-treatment
Waterloo Biofilter	$14,369	$12,600 - 18,500	Includes disposal
Community Constructed Wetland	$420	$372 - 468	Collection costs are $3,000 to $4,000
Community Slow Rate Land Application	$4,900	(only 1 value)	Includes collection costs

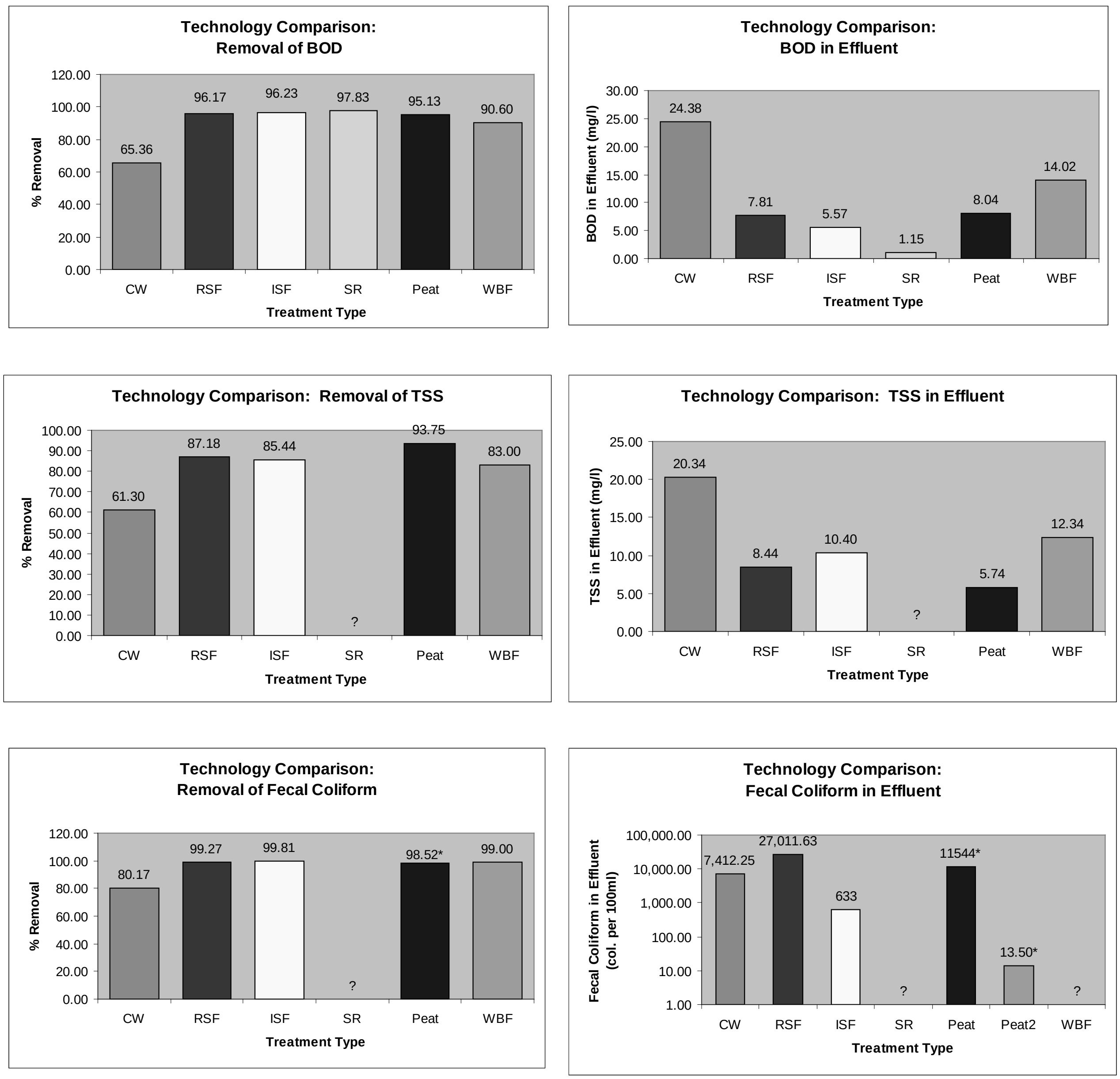
Sources: These data are summarized from the many studies previously cited in Section 6.0 of this survey.
*Values approximate cost for installation, septic tank (for pre-treatment), the listed treatment type, and disposal.

Table 18. Performance Comparison of Selected Onsite Wastewater Treatment Technologies.

		BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	FC (col/100mL)
Constructed Wetlands[a]	Eff.	24.38	20.34	18.05	14.90	0.22	2.90	7,412
	% R	65.36	61.30	33.17	8.43	38.61	no data	80.17
Intermittent Sand Filter[b]	Eff.	5.57	10.40	35.13	2.20	20.70	no data	633
	% R	96.23	85.44	32.43	94.52	0.00	no data	99.81
Recirculating Sand Filter[c]	Eff.	7.81	8.44	20.71	5.58	10.47	6.06	27,012
	% R	96.17	87.18	56.67	83.83	no data	27.25	99.27
Peat Filter[d]	Eff.	8.04	5.74	40.18	9.53	20.21	7.06	11,544*
	% R	95.13	93.75	26.57	79.57	0.00	11.48	98.52
Slow Rate Land Application[e]	Eff.	1.15	no data	6.79	no data	2.80	0.25	no data
	% R	97.83	no data	72.50	no data	no data	96.71	no data
Waterloo Biofilter[f]	Eff.	14.02	12.34	28.00	1.80	no data	no data	no data
	% R	90.60	83.00	35.67	88.67	no data	no data	99.00

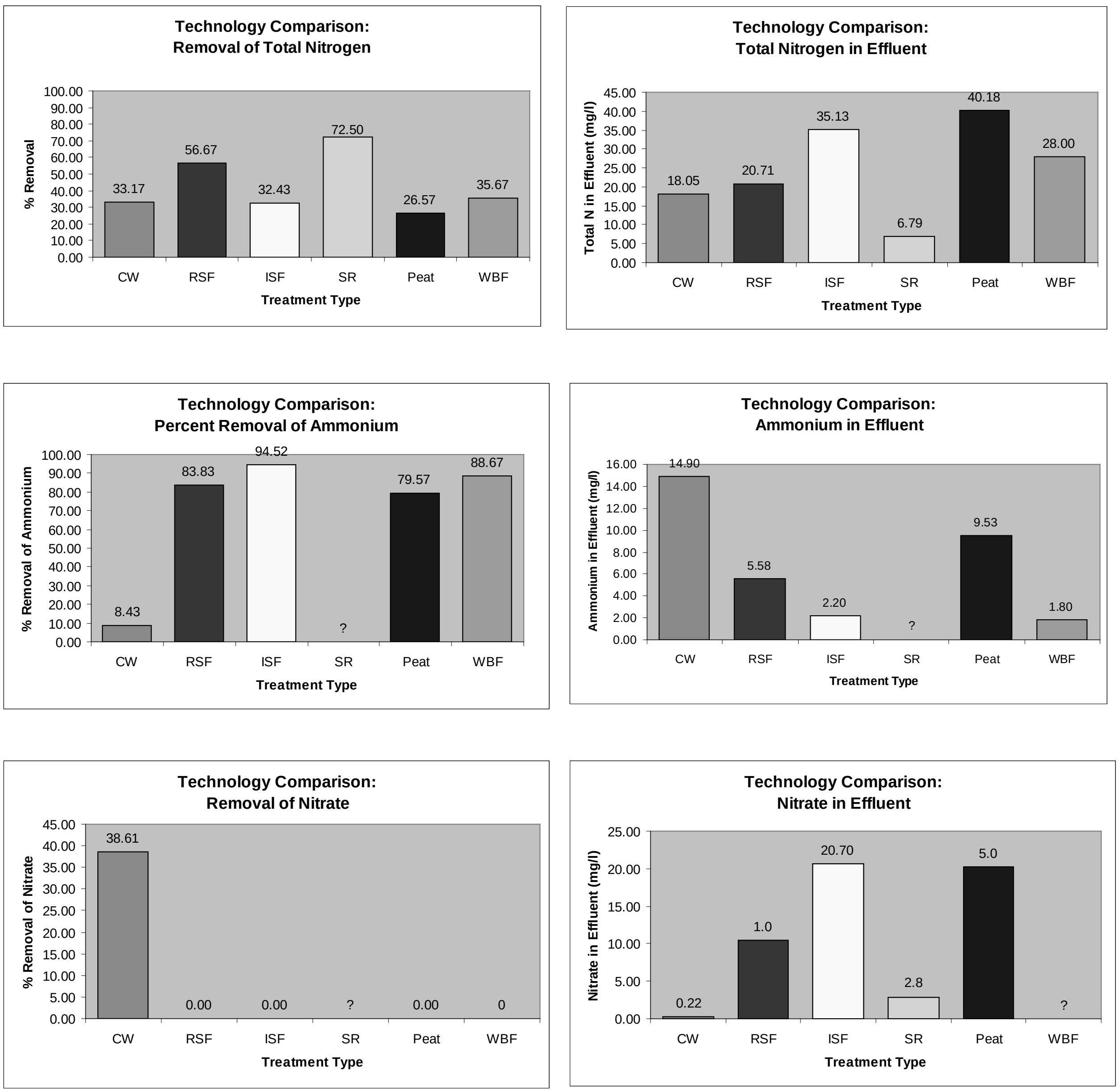
**If data from White* et al. *(1995) are excluded (1 of 5 studies reviewed), average fecal coliform bacteria count is 13.5/100 mL.*
Eff. = the concentration of contaminant in effluent from the treatment system.
% R = the change in contaminant concentration between system influent and effluent.
Sources: a = 33 CW studies/sites were reviewed; see Appendix A, Table APP1 for details on each study.
b = 7 ISF studies/sites were reviewed; see Appendix A, Table APP2 for details on each study.
c = 11 RSF studies/sites were reviewed; see Appendix A, Table APP3 for details on each study.
d = 5 peat filter studies/sites were reviewed; see Appendix A, Table APP4 for details on each study.
e = 6 SRLA studies/sites were reviewed; see Appendix A, Table APP5 for details on each study.
f = from Jowett 1995.

Figure 21. Performance Comparison of Selected Onsite Wastewater Treatment Technologies.



* *Within the* Technology Comparison: Fecal Coliform in Effluent *table, Peat includes data from all five peat filter studies*, *and Peat 2 excludes data from one of these five studies*, *White et al. (1995).*

Figure 21 (continued). Performance Comparison of Selected Onsite Wastewater Treatment Technologies.



Source: Table 18.
CW = Includes data from 33 **Constructed Wetland** studies; see Appendix A, Table APP1 for details on each study.
ISF = Includes data from 7 **Intermittent Sand Filter** studies; see Appendix A, Table APP2 for details on each study.
RSF = Includes data from 11 **Recirculating Sand Filter** studies; see Appendix A, Table APP3 for details on each study.
SR = Includes data from 6 **Slow Rate Land Application** studies; see Appendix A, Table APP5 for details on each study.
Peat = Includes data from 5 **Peat Filter** studies; see Appendix A, Table APP4 for details on each study.
WBF = Includes data from Jowett 1995 on the **Waterloo Biofilter**.

7.1 Treating Wastewater from Single-Family, Permanent Residences

Discussion

Within the Barataria-Terrebonne estuary, some type of onsite wastewater treatment will be the lowest cost option for single-family permanent residences that are distributed at low densities. The BTNEP Management Conference cited onsite wastewater treatment systems as probable causes of estuarine eutrophication and pathogen contamination, two of the seven priority problems identified in the Barataria-Terrebonne estuary (BTNEP 1996a). Mitigating pathogen contamination of oyster harvesting waters in the southern portion of the Barataria-Terrebonne estuary is a particularly important economic and public health concern, and has been the subject of much work by BTNEP. As such, it is assumed that an adequate onsite wastewater treatment system must provide satisfactory BOD and TSS removal (*e.g.*, 30 mg/L or less), good ammonium removal (*e.g.*, 10 mg/L or less), very good FC removal (*e.g.*, 99.5 percent or more), and at least some nitrogen removal. This discussion assumes that the land available for onsite treatment is characterized by poorly drained clay soils and a consistently high water table.

Most would agree that cost will be the primary limiting factor in implementing any wastewater treatment alternatives. At current economies of scale, almost all of the alternative wastewater treatment systems reviewed in this document cost substantially more than currently-approved septic systems and mechanical plants. Residents in the Barataria-Terrebonne estuary are quite conscious of the cost saving -- on average, less than $500 -- of installing a mechanical plant with an effluent-reduction field, rather than a conventional septic system (T. Boudreaux, pers. comm.). But given the fact that the suite of currently-approved onsite systems might not be appropriate for conditions prevalent in coastal Louisiana, the bottom line is that proper wastewater treatment will only be attained by spending additional money on more appropriate treatment technologies. Overcoming the general public's opposition to paying for a service that has long appeared "free" (or that has been subsidized) is a universal barrier to improving wastewater treatment, and this barrier must be overcome within the Barataria-Terrebonne estuary.

CWs are the lowest-cost alternative onsite wastewater treatment technology, often adding less than $500 to the average cost of a conventional septic system. When used independently, though, their limited ability to remove FC and ammonium make them an unrealistic solution for areas that directly impact oyster-harvesting waters or recreational waters. If the effluent was collected from the CW cell (lined because of the high water table) and disinfected prior to disposal, treatment could be sufficient for more general use. The disinfection step, however, will raise the cost of this alternative by several hundred dollars, add maintenance responsibilities, and ammonium concentrations in the discharge will remain relatively high. While the climate in southern Louisiana is conducive to maintaining thriving plant communities in a CW, maintenance requirements might make these systems less desirable for individual residences. In fact, local officials note that some rock-plant filters -- one type of CW -- have failed in Louisiana because of lack of maintenance (T. Boudreaux, pers. comm.).

Of the technologies surveyed in this document, ISF systems appear to offer the most consistently high FC removal rates. Unfortunately, nitrogen removal is limited, and acquiring appropriate sand and gravel will add to the cost of the system because these materials are not readily available in coastal Louisiana. Adding a trickling filter to the septic tank in an ISF system would provide the capability to remove considerable nitrogen. RSFs of the proper design could achieve higher rates of nitrogen removal, although their ability to remove FC appears to be lower than ISFs. If a disinfection mechanism is added, at a cost of several hundred dollars and additional maintenance requirements, RSF systems might serve as a good alternative. Cost would probably be a near-term implementation barrier as both types of sand-filter systems are, on average, around $10,000 for an individual residence application. Addition of a trickling filter to an ISF would increase the cost by at least $1,500. Sand filter cost could be reduced by reassessing the required minimum area and bed depth in the Sanitary Code, based on studies reviewed in this document.

Peat filter systems have also been found to provide high FC removal rates, although one study demonstrated that the Gulf coast climate might cause these systems to have an unusually long acclimation period (White *et al.* 1995). This inconsistency should be further researched through another study in the Gulf coast area, or better yet, in coastal Louisiana. As with ISFs, nitrogen removal is limited with a peat filter system. The cost of peat filter systems seems to be decreasing, based on contacts made during this survey; the average cost for complete system installation at an individual residence is currently in the range of $5,000 to $8,000.

SRLA, through either spray or drip irrigation, could offer the best overall treatment performance, but the need for a large tract of land, great expense (average of $15,000 including full pre-treatment), and high maintenance requirements make it impractical for single-family residential use. In fact, local officials claim that spray irrigation has never been used in the Barataria-Terrebonne estuary because of the great land requirements (T. Boudreaux, pers. comm.). The high cost of this system is unfortunate because drip irrigation seems to be a secondary treatment and disposal system appropriate for conditions prevalent in coastal Louisiana -- flat topography, high water table, and soils with limited permeability. Because uplands in the Barataria-Terrebonne estuary are extremely limited, adequate space for single-home drip irrigation could only be secured on large lots. Higher-cost systems can also reduce the intensive maintenance requirements of drip irrigation.

Mechanical plants, a type of aerobic treatment plant, are widely used in the Barataria-Terrebonne estuary. Competition to provide the least expensive system has led to a number of models, installed for under $2,500. Ensuring regular maintenance of an aerobic treatment system's mechanical parts is crucial. The mechanical failure of blowers and consequent system failure is well documented in coastal Louisiana. Most management problems recognized by local officials should be addressed by recent revisions to the Sanitary Code. These revisions will ensure ANSI-certification of all mechanical plant models used in Louisiana by January 1, 2001, inspections every six-months for the first two years after installation, and annual inspections for the life of the system.

The ability of aerobic treatment plants to handle peak flows is still questionable; extremely high flows can flush a portion of the system's microbial assemblage (R. Raider, pers. comm.).

Likewise, the more limited microbial assemblage in aerobic treatment plants can perish under extended no-use conditions. Effluent reduction requirements for mechanical plants were proposed, but not included, in the January 20, 1999 revisions of the Sanitary Code. Discussions continue at LDHH to codify this requirement, and as of the writing of this document, effluent reduction requirements might be in place by July 1, 2000. The continued permitting of effluent-reduction fields (and other effluent-reduction systems) with mechanical plant installations, based on site inspections by public health officials, could help address some of the peak flow problems.

It appears that aerobic treatment plants can discharge high concentrations of FC, relative to desired levels of treatment, for example 200 or less colonies FC per 100 mL (MPN). While concentrations of FC in mechanical plant effluent should be scientifically characterized, this discussion assumes mechanical plant effluent normally has relatively high levels of FC. Without effluent disinfection or a secondary treatment and disposal system, discharges from properly-functioning mechanical plants have the potential to cause two major health hazards in the Barataria-Terrebonne estuary region. First, direct mechanical plant discharges to roadside ditches, common in the Barataria-Terrebonne estuary, offers opportunities for human exposure to sewage pathogens. Second, drainage pumps or direct rain runoff could carry sewage pathogens to oyster-harvesting waters in the southern portion of the Barataria-Terrebonne estuary. Ideally, an appropriate secondary treatment and disposal technology, or effluent reduction system, would be required on all new mechanical plant installations.

A disinfection requirement, in existing situations where the effluent is direct-discharged to a ditch or surface water, should be considered. Inexpensive chlorine disinfection has been widely used on limited-use systems, although it is dependent on the user replacing chlorine tablets. The use of UV disinfection might be more appropriate for residential mechanical plants. A household UV-disinfection system from one manufacturer costs about $900, with substantial quantity discounts available (P. Neofotistos, pers. comm.); cost to provide UV disinfection might be as low as $500. Operational costs would include periodic bulb replacement and electricity costs.

Many of the proprietary aerobic biofilter systems reviewed in this document might provide better treatment performance in situations where mechanical plants are currently approved. The artificial media contained within these systems provide considerably more surface area for microbiological contact with the wastewater. As with the aerobic treatment plants, a disinfection requirement or a properly functioning secondary treatment and disposal system might be desirable for FC elimination. At current economies of scale, the cost of these systems is considerably higher than the least-expensive mechanical plants used in Louisiana, but costs for mechanical plants will rise once the ANSI-certification requirement is implemented on January 1, 2001. At the same time, indications are that the costs of some of the aerobic biofilter systems reviewed in this document are currently decreasing; costs of the Waterloo Biofilter (currently manufactured as the Aerocell Advanced Modular Treatment System by Zabel, Inc.) are lower than costs reflected in Table 17 (J. Christensen, pers. comm.).

The proprietary drainfield technologies described in this document -- chamber drainfields and non-aggregate mat systems -- might provide improved secondary treatment and disposal, relative to conventional stone-and-pipe drainfields, in soils with limited permeability (L. Garner, pers. comm.). Both of these drainfield technologies can be utilized in mound systems for sites with a high water table. The manufacturers of these systems claim that less area is needed for equivalent treatment, so they would be appropriate for smaller lots. The cost of both drainfield technologies is greater than conventional stone-and-pipe systems, but less than drip-irrigation systems.

Most alternative technologies described in this document require wastewater pre-treatment with a septic tank. Proper septic tank operation requires regular inspection, maintenance, and removal of accumulated solids. Incorporating well-made, watertight risers on a new septic tank installation will allow ready access for the life of the septic tank. Prefabricated polyethylene risers can be installed on a new septic tank, or retrofitted onto an existing tank, for less than $200 in materials cost (Zabel 1999).

Because of their low cost (about $50 plus installation and maintenance), effluent filters appear to be a highly desirable addition to both new and existing septic tanks. While they have been shown to reduce clogging of conventional drainfield lines and provide a modest level of additional pre-treatment, the most important feature of effluent filters is to slow the rate of flow from drains and toilets in the house when there are excessive solids in the septic tank. This slow draining would signal to homeowners that the septic tank requires pumping or other maintenance service. More advanced effluent filters have the capacity to set off an audible or visual alarm in the house as they become clogged. These models remain under $150, plus installation and maintenance, for a residential application (Zabel 1999). Effluent filters would apply to many conventional and alternative on-site technologies because most require wastewater pre-treatment with a septic tank.

Composting toilets (and incinerating toilets) have the capacity to render sewage biosolids innocuous, and to eliminate them from the wastewater treatment process. Greywater systems could then be used to treat other household wastewater, although greywater can contain high levels of FC. Conventional systems could also be used to treat the greywater; because greywater decomposes more rapidly than mixed wastewater, a smaller shallower disposal field could be used. Utilizing a composting toilet / greywater treatment system combination does not appear to reduce onsite wastewater treatment costs, but there is the benefit of reusing the greywater for certain applications. Possibly the most important issue, the negative public perception of composting toilets and frequent maintenance requirements would likely be a major implementation barrier to any widespread residential use. In addition, the Sanitary Code states that composting toilets should preferentially be used where water under pressure is not available (State of Louisiana 1999).

Various combinations of the technologies described above can greatly enhance wastewater treatment, but also at increased cost. One of the NODP demonstrations provides a good example. At a site with an elevated water table of 12 to 24 inches, with saturated sands, and an organic soil layer, wastewater is processed with a septic tank, an ISF, and a chamber drainfield constructed within a sand mound. Initial sampling has shown complete nitrification of the effluent (NOPD 1998). This system, while very effective, cost more than $10,000 to install. Another NODP demonstration system used a septic tank, recirculating sand filter, and drip irrigation system at a single-family site with groundwater at 18 inches. The system achieved excellent BOD, TN, and FC removal rates at a cost of $11,100 installed (NODP 1998). Likewise, data in this report indicate that a septic tank with a trickling filter, an ISF, and an effluent-reduction field could provide excellent BOD, TSS, ammonium, nitrogen, and FC removal. Because such combinations are likely to cost more than $10,000, widespread implementation in coastal Louisiana, at least at the current time, is unlikely. Nevertheless, technology combinations are available to attain a high level of effective onsite wastewater treatment and such combinations could be required for environmentally sensitive areas.

Summary and Recommended Actions: Permanent, Single-Family Residences

Given the overall trend of homeowners neglecting to adequately maintain their onsite systems, it might be argued that procedures that guarantee satisfactory operation and maintenance are more necessary than "high tech" or improved treatment systems. Recent Sanitary Code revisions, requiring ANSI-certification of systems and long-term maintenance contracts, should significantly improve the operation of mechanical plants in Louisiana. This issue remaining, technologies capable of providing effective and consistent onsite wastewater treatment, in conditions prevalent in the Barataria-Terrebonne estuary, are available. Such technologies cost considerably more (often twice as much) than presently approved conventional septic systems and mechanical plants, at current economies of scale.

The recommended actions are divided into three sections: (1) installation of new systems at new or existing residences, (2) improvements to existing septic systems, and (3) improvements to existing mechanical plants. The recommendations are not intended to be comprehensive but, rather, priorities that are related to the use of appropriate onsite wastewater treatment technologies (and some management techniques) in conditions prevalent in the Barataria-Terrebonne estuary.

<u>New Systems at New or Existing Residences</u>

- Require effluent filters on all new septic tank installations, preferably filters with alarms that signal clogging. Clogged effluent filters can facilitate regular maintenance or indicate improper septic system use or function.
- Require ready-access risers on all new septic tank installations.
- Facilitate an evaluation of the benefits -- effluent reduction and additional secondary treatment -- of effluent reduction fields, installed after mechanical plants, in various soil conditions prevalent in the southern portion of the Barataria-Terrebonne estuary. If performance data supports such an action, adopt, into the Sanitary Code, effluent-reduction requirements for all new mechanical plant installations. In the interim, where appropriate, continue permitting effluent-reduction fields with new mechanical plant installations. Consider the use of proprietary chamber and non-aggregate-mat drainfield technologies for effluent reduction. If effluent reduction is not appropriate and there will be a direct discharge from the mechanical plant to surface waters or an open ditch, consider requiring some form of effluent disinfection (*e.g.*, UV or, if UV is not feasible, chlorine contact).
- Test the performance of peat-filter systems in residential demonstrations, with the intent of approving these systems for general use in Louisiana. Peat-filter systems have demonstrated

very good FC removal and the recent decrease in their cost might make these systems more attractive to homeowners.

- Require long-term maintenance contracts with licensed private companies, similar to the new program for mechanical plants effective January 1, 2001, for all onsite wastewater treatment systems. LDHH should review maintenance reports and conduct random inspections of contract-maintained systems, as resources allow.
- Require ANSI-certification of all new or modified onsite wastewater treatment systems, similar to the new program for mechanical plants effective January 1, 2001.
- Facilitate performance testing of proprietary chamber and non-aggregate mat drainfield technologies in residential demonstrations, and compare results to conventional stone-and-pipe drainfield performance. Consider the use of these technologies for septic system drainfields and effluent reduction on mechanical plant installations.
- Facilitate performance testing of selected proprietary aerobic biofilters in residential demonstrations, and compare results to common mechanical plant performance.

Existing Septic Systems

- Require installation of effluent filters on existing septic tanks, preferably filters with alarms that signal clogging, at some maintenance or management event (*e.g.,* pumpout, inspection, transfer of property). Clogged effluent filters can facilitate regular maintenance or indicate improper septic system use or function.
- Distribute (or continue distributing) educational materials about the need for regular removal of solids from septic tanks, and indications of a failing drainfield.
- Conduct septic system inspections as resources allow (assumably through LDHH).

Existing Mechanical Plants

- Implement the long-term maintenance contract requirement for new and grandfathered mechanical plants, scheduled to begin January 1, 2001.
- Implement the ANSI-certification requirement for mechanical plants (all new models beginning in January 20, 1999, and all existing and new models by January 1, 2001).
- Facilitate performance testing of residential mechanical plants operating with a direct discharge to ditches or surface waters.
- Where appropriate, require effluent-reduction fields at mechanical plants cited for failure. Where appropriate, require effluent-reduction fields at existing mechanical plants at property transfers. Consider the use of the proprietary chamber and non-aggregate-mat drainfield technologies for effluent reduction.
- Test the performance of UV disinfection on individual mechanical plant discharges. Based on the results, consider requiring UV disinfection for existing mechanical plants without effluent-reduction systems, or where there is otherwise a direct discharge from the mechanical plant.

Treating Wastewater from Small Clusters of Permanent Residences

In rural communities throughout the Barataria-Terrebonne estuary, the opportunity exists to combine the wastewater treatment operations for clusters of residences. Most importantly, decentralized management of these cluster systems would eliminate the need for homeowner involvement in system operation and maintenance (note that homeowner maintenance responsibilities are indeed greater for many alternative technologies reviewed in this report). Increased treatment, management, monitoring, and maintenance efficiencies appear to make decentralized management of cluster systems cost-competitive with both traditional centralized collection/treatment and individual onsite wastewater treatment (for example a resident might pay, on average, from $4,000 to $5,000 for cluster-based treatment; see Tables 16 and 17). In addition, some form of decentralized wastewater treatment would allow a community to preserve its rural character, frequently lost when central sewer systems are installed and high-density or industrial development follows.

A well-planned and well-engineered demonstration of clustered residential wastewater treatment, an alternative collection system, and decentralized wastewater management, is greatly needed in Louisiana. The one experience that Louisiana has had with alternative treatment concepts was a complete failure and, justifiably, that experience has soured many state and local officials. Officials might be more inclined to undertake a new demonstration project if it included significant economic incentives, access to technical leadership or expertise, and/or reputable private-sector partners.

While not the intended focus, several technologies reviewed in this survey appear to lend themselves to cluster- or community-level wastewater treatment. A discussion of these technologies follows below.

In most cases, a reliable, economical choice of alternative collection systems will be a STEP system, where wastewater is clarified by septic tanks at each home site. For actual implementation of a STEP collection system, though, each existing septic tank would have to be inspected, and replaced if found to be defective or inadequate. In addition, regular removal of solids from the septic tanks would continue to be a maintenance and enforcement issue. A grinder-pump system might make sense if there is an existing centralized wastewater treatment plant with capacity to accept more conventional sewage. In the absence of such an existing plant, a grinder-pump system would require more expensive treatment to handle the added solids. For both STEP and grinder pump systems, an adequate power source would have to be available at each building. A vacuum-sewer collection system could also be a feasible option, although there appear to be more concerns related to reliability with these systems than with the STEP systems. A SDGS would not be effective in low-gradient coastal Louisiana.

From the information reviewed in this survey, very effective cluster-level treatment of wastewater can be attained through sand filtration, followed by drip irrigation. The limiting factor for such a system would be the availability of sufficient land, an implementation obstacle in the southern portion of the Barataria-Terrebonne estuary. Availability of sufficient land would also limit the use of free-water-surface constructed wetlands. A sand-filter system, followed by a subsurface-flow constructed wetland, appears to be an effective and cost-competitive technology for cluster-level treatment. Where constructed wetlands were not appropriate or desired, sand filtration, followed by some type of disinfection, would be similarly effective.

As recommended in BTNEP's Comprehensive Conservation and Management Plan, the use of natural wetlands for secondary or tertiary treatment of wastewater, especially where land area is limited, should be investigated for clusters of residences (BTNEP 1996b). While there appear to be significant regulatory and process hurdles to using them for secondary treatment, natural wetlands are currently being used to successfully treat and dispose of secondary-treated wastewater from municipal facilities in Thibodaux, within the Barataria-Terrebonne estuary, and in Breaux Bridge (Breaux and Day 1994), also in coastal Louisiana. In addition to a high level of effluent treatment, Breaux and Day (1994) and Day *et. al.* (In review) have suggested several significant ancillary benefits of natural wetland systems, based on studies at numerous sites in coastal Louisiana: (1) increased accretion rates to balance subsidence, (2) increased productivity of vegetation and maintenance of wetland function, and (3) financial savings of capital not invested in conventional treatment systems.

7.2 Treating Wastewater from Camps

Discussion

One issue with camps in the Barataria-Terrebonne estuary is that many have no treatment system and are discharging sewage directly into the marsh (BTNEP 1996b). Limited resources might best be used to ensure that all camps have some form of approved treatment. To facilitate such an action, the LDHH Oyster Water Monitoring Program is currently geo-locating (using a Geographic Positioning System) all camps in the Barataria-Terrebonne estuary; over 2,000 have been geo-located to date, and this effort will continue (K. Hemphill, pers. comm.). In addition, camp owners have requested access to an uncomplicated explanation -- in the form of a brochure -- of appropriate wastewater treatment options based on the camp usage patterns (V. Dufforc, pers. comm.). With these points made, a discussion of alternative technologies appropriate for camps follows.

The following discussion assumes that camps have continuous electricity and water under pressure, are located over marsh or open water (or directly adjacent to marsh or open water), and are used on an intermittent basis. The treatment of wastewater from camps presents a unique set of challenges. First, because the periodically or continuously flooded marsh soils cannot be relied upon to perform any secondary treatment, limited-use systems are normally completely self-contained (*i.e.*, they provide both primary and secondary treatment) and discharge directly to surface waters. No scientific evaluations of the performance of camp systems were identified for this survey. Therefore, there is no evidence that these systems are regularly failing or, alternatively, meeting performance standards.

Second, camps, by definition, are limited-use structures. Intermittently occupied residences – such as camps not used for a month or more -- are problematic because many onsite treatment methods require lengthy startup times before healthy microbial populations are established. Treatment performance may be quite low during this startup period. It appears that relatively few studies have specifically addressed this issue and most technologies are not designed for good performance under such intermittent-use conditions.

Form Cell Research claims that its patented Bioren Living Filter can attain peak performance in two weeks, making it more appropriate for seasonal use than some other technologies (Form Cell Research 1999). Biofilters, in general, will not maintain peak efficiency if overused after a prolonged dormant period, such as at a weekend or summer retreat (Jowett and McMaster 1995). Yukelsen (1998) conducted research on an aerobic trickling filter, combined with a high-rate sedimentation unit that was intended for use in seasonally occupied hotels and resorts. Results were variable from this one type of aerobic trickling filter (similar systems that were not reviewed in this survey include the Aquaerobic and the Chromaglass). BOD removal rates ranged from 63.5 to 86.9 percent and TSS removal was between 19.7 and 87.4 percent.

Sequencing batch reactors (SBRs) appear to effectively treat intermittent wastes because they store wastewater and process it in batches. SBR systems, functioning at the community level, were reviewed in this document and demonstrated good removal of BOD, TSS, ammonium nitrogen, nitrate, and phosphorus.

Sand filters and peat filters appear to take a longer time to reach their peak performance level. Whether they can maintain good performance with intermittent use is unclear, although a recirculating sand filter is more robust to fluctuating flows because recirculation can sustain the microbial population, even if no new wastewater is added to the system. Once established, constructed wetlands may prove to be good at handling intermittent flows, but engineering an individual CW that is fully separated from the surrounding wetlands would likely be a difficult and expensive proposition.

Composting toilet and incinerating toilet systems appear to be ideal for intermittent camp use. Incinerating toilets would be more appropriate for camps over marsh or open water, as compost from composting toilets is normally buried or hauled away. Both systems have the capacity to eliminate the major FC load (*i.e.*, the blackwater waste) from the wastewater treatment process, and, therefore, from the direct surface water discharge from most limited-use systems. Where a composting or incinerating toilet is used, conventional limited-use systems could then be used to treat other wastewater from the camp, although greywater can contain high levels of FC. Utilizing a composting toilet or incinerator toilet and a limited-use system for greywater treatment would obviously increase the total wastewater treatment cost. It is possible that the negative public perception of composting toilets and frequent maintenance requirements would likely be less of an implementation barrier at camps, when compared to residential use. It should be noted that the Sanitary Code states that composting toilets should preferentially be used where water under pressure is not available (State of Louisiana 1999).

Ideal camp effluent treatment would be sufficient to bring BOD and nitrogen concentrations down to low levels (*e.g.*, less than 45 mg/L, the current mechanical plant standard for BOD), and virtually eliminate enteric microorganisms, prior to direct discharge to the marsh. Currently approved limited-use systems can readily fail in two ways. Because limited-use systems discharge directly to surface waters, overloading a conventional limited-use system would result in poorly treated or untreated wastewater being discharged to the marsh. At the same time, the maintenance requirement to add chlorine in the last chamber of the unit must be met for any meaningful FC reduction. Conceptually, the discharge cutoff mechanism should activate if the chlorine supply if not adequate in a conventional limited-use system. Intentional disruption of the chlorine contact mechanism is another problem; a regional colloquialism explains that a tin of tobacco snuff is the same size and weight of a chlorine tablet.

The recently approved HBO250, another limited-use system, utilizes aerobic treatment followed by a chlorine-contact chamber. While no scientific evaluations of the performance were identified for this survey, it is possible that the HBO250 could attain a higher level of treatment -- at least for TSS and BOD -- than the conventional limited-use system. Similarly, an aerated foam biofilter, or other patented aerobic biofilter system, may attain higher levels of treatment, albeit at a higher cost. With any of these systems, there is still an issue of adequate maintenance of mechanical parts. Another issue is the risk of high FC concentrations in the surface-water discharges of biofilter systems. In contrast to the conventional limited-use system, the HBO250 does not have an automatic cutoff mechanism when the chlorine supply is exhausted, and this could compromise FC removal. Targeted education and outreach might help to ensure proper chlorine tablet replacement in camp systems. Some systems in use in the State of Texas have a visual alarm that lights when chlorine tablets have fully dissolved.

Two additional problems associated with chlorine tablet use are availability and proper tablet type. There are few retail outlets in the Barataria-Terrebonne estuary for chlorine tablets for wastewater treatment. Often, camp owners must purchase tablets from the retailer that sold them their treatment unit. Anecdotal evidence suggests that many people purchase and use chlorine tablets for swimming pools, rather than those for septic use; swimming pool tablets are composed of sodium hypochlorite, while septic grade tablets are composed of calcium hypochlorite. Note that only calcium hypochlorite tablets are approved for use by USEPA in wastewater treatment systems.

The major barrier to improving wastewater treatment at camps is cost. Currently, camps meeting the limited-use requirement in the Sanitary Code must install a system that is often less than $1,600. As was the case in evaluating alternative technologies for permanent residences, overcoming the general public's opposition to paying for improved wastewater treatment technologies is the major implementation obstacle. Because many camps are often second homes, significant cost increases for wastewater treatment might be even less acceptable.

Considering this cost constraint, valid or not, addressing the priority concern of pathogen contamination in the southern portion of the Barataria-Terrebonne estuary might be a cost-conscience strategy for improving wastewater treatment in limited-use systems. The rationale is that, with respect to pathogen contamination of oyster-growing waters, it seems intuitive that a failing limited-use system in the marsh poses a greater risk than a failing septic system within a leveed drainage district. Several technologies reviewed in this document, all relatively inexpensive, could provide either alternative disinfection or some form of secondary treatment and disposal. As a proactive public health mechanism, limited-use systems in or directly impacting oyster-growing waters should have the capacity for complete and consistent disinfection. One potential problem with conventional limited-use systems, and now also with the HBO250, is that the owner must manually add chlorine tablets or the effluent will receive minimal or no disinfection prior to discharge.

An alternative would be to use UV disinfection, assuming the suspended solids load in limited-use system effluent will allow proper UV light contact with waterborne pathogens. A household UV disinfection system from one manufacturer costs about $900, with substantial quantity discounts available (P. Neofotistos, pers. comm.), potentially bringing the cost as low as $500. While such a system will require occasional cleaning and bulb replacement, and will draw electricity, maintenance would be less than for a chlorination chamber system. Additionally, a UV system would eliminate the discharge of harmful chemical compounds associated with chlorine use.

A promising alternative for disinfection in higher-salinity areas (greater than 10 ppt) is marshland upwelling. In the demonstration at Port Fourchon by Rusch *et al*. (1995), wastewater was first treated by a mechanical plant, but not disinfected (through chlorine contact, for example). FC removal was excellent -- less than 10 colonies/100 mL in the effluent -- and consistent (Rusch, pers. comm.).

Even more promising is an ongoing study, by this same investigator, to evaluate the ability of marshland upwelling to treat primary-treated effluent from a holding tank. Initial results look very good for FC and BOD removal (K. Rusch, pers. comm.). The cost of a 500-gallon holding tank and marshland upwelling system (including installation) would be cost competitive with a conventional limited-use system (in the neighborhood of $1,500) and, overall, would require less maintenance (K. Rusch, pers. comm.). The cost of electricity for this treatment method should be determined. Marshland upwelling also addresses the concern of intermittent use of camp systems because an upwelling system should provide good performance under intermittent use conditions. Another interesting question is if this treatment technique would work in areas with salinities less than 10 ppt.

Summary and Recommended Actions: Camps

The following recommendations are not intended to be comprehensive but, rather, priorities that are related to the use of appropriate onsite wastewater treatment technologies (and some management techniques) in conditions prevalent in the Barataria-Terrebonne estuary.

- With the intention of further evaluating the ability of a marshland upwelling system to treat and dispose of primary-treated wastewater, begin a new demonstration in the Barataria-Terrebonne estuary (specifically in an area that directly impacts oyster growing waters and an overall salinity greater than 10 ppt). An alternative is to continue evaluation of the Port Fourchon system, for parameters such as nutrient removal. If this technology continues to perform well, consider requiring marshland upwelling for camps at appropriate sites (at a minimum those in, or that directly affect, oyster-growing waters). Develop techniques and assessment criteria to rapidly evaluate if a camp site has appropriate soil and salinity conditions for marshland upwelling systems.
- Evaluate the performance of proprietary effluent filters on conventional limited-use systems.

- To help ensure consistent chlorine disinfection in conventional limited-use systems and HBO250s, design and implement a targeted public information campaign to (1) inform owners about potential adverse impacts of untreated discharges from camps and (2) encourage proper chlorine tablet replacement. If resources are available, distribute free chlorine tablets at selected retail stores (those that sell bait, tackle, ice, hunting supplies, etc.) with "catchy" public outreach signs. In addition, design and print a public brochure to explain appropriate wastewater treatment options for various camp usage patterns.
- Particularly in the absence of any demonstrations of marshland upwelling, test the performance of UV disinfection on limited-use systems. Based on the results, consider requiring UV disinfection for limited-use systems, aerobic treatment plants, and aerobic biofilters used at camps in, or that directly affect, oyster-growing waters. Adding UV disinfection to limited-use systems might provide excellent disinfection without great expense.
- Facilitate performance testing of conventional limited-use system and the HBO250, under a variety of use loads, with and without consistent disinfection.
- Require long-term maintenance contracts with licensed private companies, similar to the new program for mechanical plants beginning January 1, 2001, for all limited-use systems. LDHH should review maintenance reports and conduct random inspections of contract-maintained systems, as resources allow.
- Assess public perception associated with utilizing composting and incinerating toilets at camps.

Treating Wastewater from Small Clusters of Camps

As with permanent residences, the opportunity exists to combine the wastewater treatment operations for camps clustered along a bayou or concentrated in a particular area of marsh. Centralized treatment would allow more flexibility in treatment options. As an example, it might be possible to locate the treatment facility on adjacent uplands. Another possibility is to use a STEP or vacuum-sewer collection system that accepts effluent from existing conventional limited-use systems, eliminating the need for treating solids at the centralized location. The major advantages include eliminating camp-owner maintenance requirements, improving overall treatment of wastewater generated at the camps, and ensuring proper disinfection.

It is probable that current versions of most alternative collection-system components would not be appropriate for immediate use at camps. It is likely that only a well-planned and well-engineered demonstration project would serve as a rationale to re-engineer some of these components, for example STEPs, for over-water use, as opposed to their typical subsurface use.

Where sewage solids were transported from camps for centralized treatment (for example, by re-tooled grinder pumps), sequencing batch reactors might be an appropriate cluster treatment technology. SBRs appear to effectively treat intermittent wastes because they store the wastewater and process it in batches. The community-level SBR systems reviewed in this document demonstrated good removal of BOD, TSS, ammonium nitrogen, nitrate, and phosphorus. Disinfection of the clarified effluent, however, would likely be necessary.

If solids were retained in the onsite limited-use system and the wastewater treatment process was located on land, the discussions in Section 7.1 concerning systems appropriate for clustered treatment operations, would apply. These systems could include a sand-filter system followed by drip irrigation, a sand-filter system followed by a subsurface-flow constructed wetland, or sand filtration followed by some type of disinfection. Treatment and disposal of wastewater in natural wetlands, discussed above for clusters of permanent residences, might be most appropriate for clusters of camps.

Due to increased construction logistics, the cost of decentralized wastewater management for clusters of camps will probably be greater than for cluster of residences. In general, then, the cost of decentralized wastewater management at clusters of camps will be considerably greater than the cost of currently approved limited-use systems. For example, a camp owner might pay an average of $1,600 (plus installation) for a conventional limited-use system and, using Table 17 as a reference, and $4,000 or more for cluster-based treatment. Another potential scenario, but similarly expensive, would be to utilize composting toilets to treat biosolids at each camp, and then centrally treat and re-use greywater.

There appears to be one exception to this general discussion, applicable to camps in higher-salinity waters (greater than 10 ppt). Marshland upwelling systems for small clusters of camps, while untested at this time, has the potential to provide excellent treatment at a cost comparable or below the sum of the cost of several conventional limited-use system. For a small cluster of camps -- 10 or fewer for this discussion -- on one side of a bayou, gravity could be used to route wastewater to a central holding/settling tank. One large pump would deliver clarified effluent to several upwelling wells. Because of the need only for one holding tank and one pump, costs should be competitive with individual conventional limited-use system. Again, an interesting question is if this treatment technique would work in areas with salinities less than 10 ppt.

7.3 Treating Wastewater from Camps without Continuous Electricity

Discussion

The discussion that follows assumes that camps may or may not have access to water under pressure, that they are located over marsh or open water, and that they are used intermittently. For camps without electricity, alternative wastewater treatment options are limited. As previously discussed for camps in general, limited resources might best be used for ensuring that all camps without electricity have some form of approved wastewater treatment system.

Acknowledging that the contribution of limited-use systems to pathogen contamination in the Barataria-Terrebonne estuary has not been scientifically evaluated, it appears that the best treatment system for camps without electricity are the currently-approved conventional limited-use system and HBO250. The manufacturer of the HBO250, which provides aerobic treatment followed by a chlorine-contact chamber, contends that the system can operate on DC battery power (presumably recharged by a generator or solar panel). While no scientific evaluations of the performance were identified for this survey, it is possible that the HBO250 could attain a higher level of treatment -- at least for TSS and BOD -- than the conventional limited-use system.

There is the risk of high FC concentrations in the surface-water discharges from both the conventional limited-use system and the HB0250. The maintenance requirement to add the chlorine tablets, of the proper type, in the last chamber of the unit must be met to achieve meaningful FC reduction. Conceptually, the discharge cutoff mechanism on the conventional limited-use system should activate if the chlorine supply is not adequate. The fact that the HBO250 does not have an automatic cutoff mechanism, as in the conventional limited-use system, could compromise FC removal. Targeted education and outreach might help to ensure proper chlorine tablet replacement in camp systems.

Several companies manufacture proprietary composting toilets that are self-contained and that operate without electricity. These systems have demonstrated excellent treatment of biosolids; however, all require considerable attention by the user to ensure proper operation. It is uncertain whether people would accept the operational burden of composting toilets, but acceptance seems much more likely at rustic camps than at permanent residences. Greywater treatment would still be required. A conventional limited-use system might serve this function well, although proper disinfection remains a moderate concern. Nevertheless, the combined use of a composting toilet with greywater disinfection could be a good option for camp owners that do not have access to electricity.

Another alternative to existing limited-use systems is a holding tank. While holding tanks have low initial capital cost, operational costs are high because they must be pumped out regularly and the wastewater must be transported to a treatment facility. However, holding tanks eliminate all the problems associated with effluent discharges to the marsh. When the tank needs to be pumped, the owner will be compelled to give it attention because his plumbing will begin to back up. Unfortunately, experiences in other states suggest that some camp owners will illegally dispose of their wastewater, rather than pay for their holding tank to be pumped (K. Sherman, pers. comm.). In addition, holding tanks would require ready access by truck or boat (*i.e.*, for the "honey wagon").

Summary and Recommended Actions: Camps without Electricity

The following recommendation are not intended to be comprehensive but, rather, priorities that are related to the use of appropriate onsite wastewater treatment technologies (and some management techniques) in conditions prevalent in the Barataria-Terrebonne estuary.

- To help ensure consistent chlorine disinfection in conventional limited-use systems and HBO250s, design and implement a targeted public information campaign to (1) inform owners about potential adverse impacts of untreated discharges from camps and (2) encourage proper chlorine tablet replacement. If resources are available, distribute free chlorine tablets at selected retail stores (those that sell bait, tackle, ice, hunting supplies, etc.) with "catchy" public outreach signs. In addition, design and print a public brochure to explain appropriate wastewater treatment options for various camp usage patterns.
- Evaluate the performance of proprietary effluent filters on conventional limited-use systems.

- Assess public perception associated with utilizing composting toilets at rustic camps. If appropriate, evaluate the potential for using proprietary composting toilets for the treatment of biosolids and currently-approved limited-use systems for greywater treatment.
- Facilitate performance testing of conventional limited-use systems, under a variety of use loads, with and without consistent disinfection.
- Require long-term maintenance contracts with licensed private companies, similar to the new program for mechanical plants effective January 1, 2001, for all limited-use systems. LDHH should review maintenance reports and conduct random inspections of contract-maintained systems, as resources allow.
- Evaluate the potential for using holding tanks in areas readily accessible by truck or boat.

7.4 Key Opportunities for Demonstration Projects within the Barataria-Terrebonne Estuary

Based on the performance and cost data analyzed in this survey, and on input from state and local experts, there are a number of key opportunities for demonstration projects within the Barataria-Terrebonne estuary. Proposed projects fall into two categories. The first is evaluating the performance of several currently-implemented onsite technologies, to obtain baseline performance data. This first category of projects is strongly supported by LDHH, with the idea that effective demonstrations of alternative onsite technologies should be compared and contrasted to the performance of currently-implemented systems, to quantify the benefits of these new technologies. Key demonstration projects include:

- Evaluate the performance of effluent reduction fields, installed after mechanical plants, in different soil types prevalent in the Barataria-Terrebonne estuary to determine (1) the volume of effluent reduced and (2) the level of additional secondary treatment attained.
- Evaluate the performance of conventional limited-use systems (or "camp unit"), with and without consistent chlorine disinfection.
- Evaluate the performance of the HBO250 limited-use system, with and without consistent chlorine disinfection.
- Evaluate the performance of conventional limited-use systems in treating greywater.

The second category of demonstration project includes alternative technology demonstrations and demonstrating alternative wastewater management techniques within the Barataria-Terrebonne estuary. The rationale in implementing some or all of these projects is to demonstrate their value to the officials, politicians, and citizens that are collectively responsible for deciding what technologies and management techniques are appropriate within their jurisdictions. Because funding for such demonstrations is limited, the BTNEP Management Conference should work closely with LDHH in selecting demonstration projects with a high potential feasibility and in planning implementation of such projects.

Key Individual Onsite Wastewater-Treatment Demonstration Opportunities

- With the intention of validating the ability of a marshland upwelling system to treat and dispose of primary-treated wastewater (*i.e.*, from a holding tank), begin a new camp demonstration in an area that directly impacts oyster growing waters in the Barataria-Terrebonne estuary. Determine an exact cost of installing the system. If this technology appears to provide effective and consistent treatment, develop techniques and assessment criteria to rapidly evaluate if a camp location meets the appropriate soil and salinity conditions for marshland upwelling. An alternative to beginning a new demonstration project is to continue evaluation of the Port Fourchon system, for unexplored parameters such as nutrient removal.
- Demonstrate the performance and management benefits of effluent filters, preferably filters with alarms that signal clogging, on septic tanks. Studies reviewed in this survey indicate a modest level of improved treatment with the use of effluent filters, and clogged filters can facilitate regular maintenance or indicate improper septic system use or function. Evaluate the cost of different effluent filter options. Consider testing effluent filters under a variety of septic tank loading conditions. Consider entering a partnership with owners/suppliers of proprietary technologies for a local demonstration project. There is a precedent for companies to donate materials for demonstrations of their technologies.
- Demonstrate the performance of effluent filters on conventional limited-use systems.
- To help ensure consistent chlorine disinfection in conventional limited-use systems and HBO250s, design and implement a targeted public information campaign to (1) inform owners about potential adverse impacts of untreated discharges from camps and (2) encourage proper chlorine tablet replacement. If resources are available, distribute free chlorine tablets at selected retail stores (those that sell bait, tackle, ice, hunting supplies, etc.) with "catchy" public outreach signs. In addition, design and print a public brochure to explain appropriate wastewater treatment options for various camp usage patterns.
- Test the performance and evaluate the cost of UV disinfection on one or several individual mechanical plant discharges in residential demonstrations. Adding UV disinfection to mechanical plants installed without effluent reduction systems might provide excellent disinfection without great expense (possibly as low as $500).
- Test the performance of proprietary chamber and/or non-aggregate-mat drainfield technologies in a residential demonstration, and compare results to conventional stone-and-pipe drainfield performance. Evaluate and compare costs of these drainfield technologies. Consider entering a partnership with owners/suppliers of these proprietary technologies for a local demonstration project.
- Test the performance and evaluate the cost of a proprietary peat-filter system in a residential demonstration. Peat-filter systems have demonstrated good reduction in FC and the recent decrease in cost might make them more attractive to residents. Consider entering a partnership with owners/suppliers of these proprietary technologies for a local demonstration project.
- Test the performance and evaluate the cost of a proprietary aerobic biofilter in a residential demonstration, and compare results to common mechanical plant performance. Consider

entering a partnership with owners/suppliers of these proprietary technologies for a local demonstration project.

- In the absence of a marshland upwelling demonstration, test the performance of UV disinfection, on one or more limited-use systems, at camps with continuous electricity. Select the UV disinfection demonstration project -- at a conventional limited-use system or a HBO250 unit -- taking into account the suspended solids loading. Adding UV disinfection to limited-use systems might provide excellent disinfection without great expense (possibly as low as $500).

Key Cluster-Based Wastewater Treatment Demonstration Opportunities

The foremost need in Louisiana is a well-planned and well-engineered demonstration of clustered residential wastewater treatment, an alternative collection system, and decentralized wastewater management. The one experience that Louisiana has had with these concepts was a complete failure and, justifiably, has soured many state and local officials. Officials might be more inclined to undertake a new demonstration project if it included significant economic incentives, access to technical leadership or expertise, and/or reputable private-sector partners.

Because there are such varied collection and treatment options at the cluster- and community-level, technologies should be selected on a site-specific basis. Therefore, the first challenge is to identify a small cluster of residents in the Barataria-Terrebonne estuary that is interested in participating in a decentralized wastewater management demonstration. The second challenge is to identify a private or public management district partner to perform the decentralized management responsibilities (see Section 6.2 for more detail). One wastewater treatment and disposal method might be particularly appropriate for small clusters of residences, especially in upland-limited areas common to the Barataria-Terrebonne estuary -- the use of natural wetlands for secondary or tertiary treatment. While there appear to be significant regulatory hurdles to using them for secondary treatment, natural wetlands are currently accepting secondary-treated wastewater from a public facility in Thibodaux, within the Barataria-Terrebonne estuary, and a number of other sites in coastal Louisiana (Day *et. al.* In review).

A similar decentralized wastewater management demonstration could be implemented for a small cluster of camps. A timely opportunity might exist in this region because a representative of an organized camp community -- the Bayou Segnette Voters and Boaters Association -- has already approached BTNEP about participating in a demonstration project for an alternative technology wastewater treatment or management approach (K. St. Pé, pers. comm.). For a small cluster of camps in higher-salinity waters (greater than 10 ppt), a marshland upwelling system demonstration seems very promising. Such a system has the potential to provide excellent treatment at a cost comparable or below the sum of the cost of several conventional limited-use systems. For a small cluster of camps on one side of a bayou, gravity could be used to route wastewater to a central holding/settling tank. A system could be readily designed for one large pump to deliver clarified effluent to several upwelling wells in a small field (K. Rusch, pers. comm.).

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Appendix A

Performance Data by Literature Source (Tables APP1 to APP5)

Onsite Wastewater Treatment Survey
Barataria-Terrebonne National Estuary Program
November 1999

Table APP1. Performance of Constructed Wetlands.

Effluent = the concentration of contaminant in effluent from the treatment system.
% Removal = the change in contaminant concentration between system influent and effluent.

Study		BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	FC (col/100ml)
Steiner and Combs 1993	Effluent	27.00	13.00	26.00			3.30	61,000.00
(Signal Mountaint)	% Removal	89.00	78.00	59.00			64.52	78.00
Steiner and Combs 1993	Effluent	12.00	6.00		20.00			5,800.00
(Chattanooga)	% Removal	73.00	95.00		44.00			99.00
Steiner and Combs 1993	Effluent	36.00	47.00					43.00
(Washington Co)	% Removal	83.00	25.00		0.00			97.00
Green and Upton 1993	Effluent	29.00	19.00		10.00			
	% Removal	80.27	85.61		0.00			
Green and Upton 1993	Effluent	33.00	24.00		13.80			
	% Removal	70.54	71.76		-13.11			
Green and Upton 1993	Effluent	34.00	43.00		11.30			
	% Removal	79.01	66.14		24.16			
Green and Upton 1993	Effluent	3.90	28.00		12.10			
	% Removal	96.52	69.89		51.21			
Green and Upton 1993	Effluent	3.90	28.00					
	% Removal	93.28	46.15					
Guterstam and Todd 1990	% Removal	0.99	0.98	0.85-0.98		0.43-0.95		1.00
Guterstam and Todd 1990	% Removal	0.96	0.97	0.85		0.62		1.00

Table APP1 (continued). Performance of Constructed Wetlands.

Study		BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	FC (col/100ml)
Johnson et al.	% Removal	0.94	0.98	0.77	0.60			0.97
Reed 1993	Effluent	1.00	3.00	9.00	2.00			10.00
(Bear Cr., AL)	% Removal	92.31	95.00	81.25	80.00			99.99
Reed 1993	Effluent	6.00	4.00		2.80			
(Benton, LA)	% Removal	66.67	92.98		-366.67			
Reed 1993	Effluent	8.00	17.00		5.10			
(Carville, LA)	% Removal	60.00	81.72		-6.25			
							TP	
Reed 1993	Effluent	10.00	7.00		2.10		4.00	
(Mandeville, LA)	% Removal	75.61	88.14		-50.00			
Reed 1993	Effluent	9.00	4.00		7.40		3.40	
(Benton, KY)	% Removal	65.38	92.86		-45.10			
Reed 1993	Effluent	9.00	17.00	12.50	9.90		2.20	
(Hardin, KY)	% Removal	82.35	85.59	41.04	1.98			
Reed 1993	Effluent	4.10	9.40	10.00	8.30		2.40	
(Hardin, KY)	% Removal	91.96	92.03	52.83	17.82			
Reed 1993	Effluent	14.00	23.00		2.90		2.40	700.00
(North Utica)	% Removal	63.16	55.77		56.72			69.67
Reed 1993	Effluent	11.00	11.00		3.10		2.60	
(South Utica)	% Removal	64.52	65.63		44.64			
Shirk and White 1999	Effluent	34.00	24.00		26.00	0.80		12,872.00
	% Removal	67.62	72.73		35.00			98.86

Table APP1 (continued). Performance of Constructed Wetlands.

Study		BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	FC (col/100ml)
Shirk and White 1999	Effluent	37.00	43.00		22.00	0.20		9,573.00
	% Removal	80.53	65.04		8.33	0.00		88.58
House 1996	Effluent		10.40	24.10	18.00			
	% Reduction		88.67	38.05	54.43			
House 1996	Effluent		46.40	26.70	33.60			
	% Reduction		49.46	31.36	14.94			
Huang et al 1994	Effluent	47.10			25.70	0.14		1,666.00
Cattail 1	% reduction	56.87			24.41	50.00		99.74
Huang et al 1994	Effluent	37.80			20.30	0.14		5,110.00
Cattail 2	% reduction	65.38			40.29	50.00		99.20
Huang et al 1994	Effluent	35.70			20.20	0.13		3,112.00
Cattail 3	% reduction	67.31			40.59	53.57		99.51
Huang et al 1994	Effluent	28.10			15.00	0.14		1,704.00
Cattail 4	% reduction	74.27			55.88	50.00		99.73
Huang et al 1994	Effluent	50.00			25.20	0.13		2,221.00
Woolgrass 1	% reduction	54.21			25.88	53.57		99.65
Huang et al 1994	Effluent	42.50			21.50	0.12		3,706.00
Woolgrass 2	% reduction	61.08			36.76	57.14		99.42
Huang et al 1994	Effluent	40.90			20.60	0.14		2,193.00
Woolgrass 3	% reduction	62.55			39.41	50.00		99.65
Huang et al 1994	Effluent	32.60			15.70	0.13		5,686.00
Woolgrass 4	% reduction	70.15			53.82	53.57		99.10

Table APP1 (continued). Performance of Constructed Wetlands.

Study		BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	FC (col/100ml)
Duncan et al. 1994	Effluent	46.00			27.70	0.30		3,200.00
	% reduction	60.34		0.34	27.11	6.25		91.06
Average of All Studies	**Effluent**	**24.38**	**20.34**	**18.05**	**14.90**	**0.22**	**2.90**	**7,412.25**
	% reduction	**65.36**	**61.30**	**33.17**	**8.43**	**38.61**		**80.17**

Table APP2. Performance of Intermittent Sand Filter Systems.

Effluent = the concentration of contaminant in effluent from the treatment system.
% Removal = the change in contaminant concentration between system influent and effluent.

Study		BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	FC (col/100ml)
Gidley 1985	Effluent	10.60	9.40				
	% Removal	93.16	89.20				
Crites and	Effluent		3.20		30.00	407.00	
Tchobanoglous 1998	% Removal	98.53		48.28			99.84
Crites and	Effluent		9.00			650.00	
Tchobanoglous 1998	% Removal	92.68					99.89
Crites and	Effluent		4.00		38.00	1,600.00	
Tchobanoglous 1998	% Removal	96.85		9.52			99.27
Shirk and White 1999	Effluent	3.00	10.00		1.00	16.00	752.00
	% Removal	98.15	83.87		96.88	0.00	99.99
Shirk and White 1999	Effluent	7.00	6.00		1.00	15.00	277.00
	% Removal	95.60	90.91		96.30		99.97
Cagle and	Effluent	2.17	16.20	37.40	4.60	31.10	111.00
Johnson 1994	% Removal	98.65	77.78	39.48	90.38		99.90
Average of All Studies	Effluent	**5.57**	**10.40**	**35.13**	**2.20**	**20.70**	**632.83**
	% Removal	**96.23**	**85.44**	**32.43**	**94.52**	**0.00**	**99.81**

Table APP3. Performance of Recirculating Sand Filter Systems.

Effluent = the concentration of contaminant in effluent from the treatment system.
% Removal = the change in contaminant concentration between system influent and effluent.

Study		BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	FC (col/100ml)
Crites and	Effluent	6.00	6.00	32.00				
Tchobanoglous 1998	% Removal	95.74	81.25	44.83				
Osesek et al. 1994	Effluent	5.70		23.40	7.00			
	% Removal	97.90		69.40	88.80			
Osesek et a. 1994	Effluent	6.80		7.80	6.30			
	% Removal	94.60		72.80	71.50			
Bruen and Piluk 1994	Effluent	18.40	13.00	28.90		16.70	4.10	5,500.00
	% Removal	94.00	83.00	31.00			41.43	98.74
Bruen and Piluk 1994	Effluent	13.00	9.00	15.70		11.54	3.10	41,000.00
	% Removal	94.00	93.00	66.00			39.00	98.47
Bruen and Piluk 1994	Effluent	6.00	6.00	21.00		2.10	12.10	21,500.00
	% Removal	95.56	95.74	30.46		42.15	12.95	99.16
Piluk and Peters 1994	Effluent	4.00	8.00	22.00				34,000.00
	% Removal	98.14	88.89	59.26				99.13
Piluk and Peters 1994	Effluent	2.00	5.00	17.00				240.00
	% Removal	98.39	91.07	62.22				99.86
Piluk and Peters 1994	Effluent	8.00	10.00	21.00				95,000.00
	% Removal	97.81	89.69	70.42				99.05
Boyle et al. 1994	Effluent	9.00	11.00	19.00	3.00	12.00	6.00	813.00
	% Removal	95.34	78.00	59.57	91.67		14.29	99.99

Table APP3. Performance of Recirculating Sand Filter Systems.

Study		BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	FC (col/100ml)
Boyle et al. 1994	Effluent	7.00	8.00	20.00	6.00	10.00	5.00	18,040.00
	% Removal	96.37	84.00	57.45	83.33		28.57	99.80
Average of All Studies	**Effluent**	**7.81**	**8.44**	**20.71**	**5.58**	**10.47**	**6.06**	**27,011.63**
	% Removal	**96.17**	**87.18**	**56.67**	**83.83**		**27.25**	**99.27**

Table APP4. Performance of Peat Systems.

Effluent = the concentration of contaminant in effluent from the treatment system.
% Removal = the change in contaminant concentration between system influent and effluent.

Study		BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	FC (col/100ml)
White et al. 1995	Effluent	17.60			1.90	24.60		57,665.00
	% Removal	86.60			96.30	0.00		92.60
Lens et al. 1994	Effluent	2.00	16.00	37.00	1.00	9.00		9.00
	% removal	98.81	90.91	38.33	92.86	0.00		99.99
Boyle et al. 1994	Effluent	2.00	2.00	50.00	12.00	34.00	7.00	39.00
	% removal	98.96	96.00	-6.38	66.67	0.00	0.00	100.00
Boyle et al. 1994	Effluent	3.00	2.00	35.00	6.00	25.00	7.00	0.00
	% removal	98.45	96.00	25.53	83.33	0.00	0.00	100.00
McCarthy et al. 1998	Effluent	15.60	2.97	38.73	26.77	8.47	7.17	6.00
	% removal	92.81	92.09	48.79	58.67	0.00	34.45	100.00
Average of All Studies	**Effluent**	**8.04**	**5.74**	**40.18**	**9.53**	**20.21**	**7.06**	**11543.8***
	% removal	**95.13**	**93.75**	**26.57**	**79.57**	**0.00**	**11.48**	**98.52**

**If White et al (1995) is excluded , average fecal coliform level is 13.5.*

Table APP5. Performance of Slow Rate Land Application Systems.

Effluent = the concentration of contaminant in effluent from the treatment system.
% Removal = the change in contaminant concentration between system influent and effluent.

Study		BOD (mg/L)	TN (mg/L)	NO3 (mg/L)	TP (mg/L)
Crites and Tchobanoglous 1998	Effluent	1.00	3.90		0.05
	% Removal	0.98	0.67		0.99
Crites and Tchobanoglous 1998	Effluent	1.00	10.70		0.39
	% Removal	0.98	0.84		0.95
Crites and Tchobanoglous 1998	Effluent	1.40	9.50		0.30
	% Removal	0.99	0.66		0.96
Crites and Tchobanoglous 1998	Effluent	1.20	7.30		
	% Removal	0.97	0.73		
Rubin et al. 1994	Effluent		5.10	3.20	
Rubin et al. 1994	Effluent		4.25	2.40	
Average of All Studies	**Effluent**	**1.15**	**6.79**	**2.80**	**0.25**
	% Removal	**0.98**	**0.73**		**0.97**

Appendix B
An Overview of the National Onsite Demonstration Project

Onsite Wastewater Treatment Survey
Barataria-Terrebonne National Estuary Program
November 1999

An Overview of the National Onsite Demonstration Project

The following information was adapted from the National Onsite Demonstration Project (NODP) website (http://www.estd.wvu.edu/nsfc/NSFC_NODP.html) and the NODP Summary Report: Phase I *(NODP 1998).*

Established in 1993, the National Onsite Demonstration Project (NODP) was developed to help encourage the use of alternative, decentralized wastewater treatment technologies to protect public health and the environment in small and rural communities. There are four phases of NODP:

Phase I

As part of Phase I of the NODP, seed money for the design, installation, and monitoring of alternative wastewater systems was provided to six communities representing diverse geographic regions. Each community has both unique and common wastewater-related problems. The six Phase I demonstration sites, the environmental concerns that were addressed, and the systems demonstrated include:

North Gloucester, Massachusetts, which has coastal pollution and whose site restrictions include a high groundwater table and shallow, glacial soils.

- Septic Tank with Synthetic Foam Biofilter and Gravity Trench ($17,980)
- Septic Tank with Recirculating Trickling Filter with Pressure-Dosed, Sand-Lined Trench ($15,297)
- Septic Tank with Intermittent Sand Filter and Pressure-Dosed, Shallow Trench ($15,308)
- Septic Tank with Recirculating Trickling Filter with a Shallow, Gravelless Trench ($7,169)

Benzie County, Michigan, which has restrictions due to numerous lakes, small lots, sandy soils, and seasonal fluctuations in population.

- Septic Tank with Iron Oxide Phosphorus Removal Barrier Trench ($8,746)
- Septic Tank with Recirculating Sand Filter and Phosphate Removal Chamber with Low Pressure Shallow Trench ($14,934)
- Septic Tank with Recirculating Trickling Filter, Phosphorus Removal Trench, and Shallow Trench ($10,982)
- Septic Tank with Plastic Foam Biofilter and Low Pressure Contour Trench ($9,566)
- Septic Tank with Intermittent Sand Filter and Shallow Disposal Trench ($10,444)
- Septic Tank with Upflow Biofilters ($9,801)
- Septic Tank with Single-Pass Sand Filter and Chamber System on Sand Fill ($9,801)

Waquoit Bay, Massachusetts, an area with coastal pollution and highly permeable soils.

- Septic Tank and Proprietary Organic Denitrification Barrier Beneath Leaching Chamber Trenches ($10,500)
- Septic Tank with Proprietary Sequencing Batch Reactor ($6,900)
- Septic Tank with Proprietary Biofilter ($18,500)
- Septic Tank with Shallow Trench Soil Absorption System ($19,875)

Monongalia County, West Virginia, with difficult terrain and shallow, impermeable soils.

- Septic Tank with Recirculating Sand Filter/Gravelless Trench and Sand-Lined Trench ($14,994)
- Septic Tank with Constructed Wetlands and Gravelless Trench ($15,901)
- Home Aeration Unit/Contour Chamber Trench ($4,021)
- Septic Tank with Disk Filter and Drip Irrigation System ($22,880)

- Septic Tank and Contour Systems ($4,953)
- Septic Tank with Low-Pressure Dosing Pipe System ($10,570)

Paradise, California, where stringent state standards for groundwater protection require removing nitrates and pathogens through soil absorption.

- Recirculating Gravel Filter
- Septic Tank with Pump Chamber
- Septic Tank with Recirculating Gravel Filter and Drip/Spray Irrigation

Anne Arundel County, Maryland, which needs to control and prevent pollution of the Chesapeake Bay.

- Septic Tank with Recirculating Expanded Shale Filter and Gravelless Trench ($1,490+)
- Septic Tank with Recirculating Advanced Pretreatment Filter and Gravelless Trench ($8,945)
- Septic Tank with Peat Filter ($10,001)
- Septic Tank with Shallow Trench ($4,200+)
- Septic Tank with Recirculating Sand Filter and Drip Irrigation System ($11,112)
- Septic Tank with Expanded Shale Filter ($625+)
- Septic Tank with Proprietary Aerobic Treatment Unit and Soil Expansion Treatment ($4,200+)
- Septic Tank with Proprietary Aerobic Treatment Unit and Soil Expansion Treatment ($3,000+)
- Septic Tank with Expanded Shale Filter ($1,490+)
- Septic Tank with Expanded Slate Filter ($1,490+)
- Septic Tank with Proprietary Single-home Aerobic Treatment Unit ($10,400)
- Septic Tank with Synthetic Foam Biofilter ($8,600)

Phase I of the NODP has been completed and a final report, available through the National Small Flows Clearinghouse, describes each system, the installation experiences, monitoring results, and lessons learned.

Phase II

Phase II of the NODP is the result of several states' requests for demonstration projects, following the first phase of the project referenced above. Sites for Phase II were selected based on community interest and a number of other criteria, such as ecologically/geologically sensitive areas and areas where no wastewater treatment facilities exist.

Rockbridge, Missouri

The Rockbridge site was chosen because it is situated in a major geological area of karst terrain that includes fractured limestone bedrock, sinkhole plains, and caves with underground drainage systems. The residential sites (five) chosen lie within a major sinkhole plain with most of the underground drainage going to Devils Icebox Cave, which runs through the park. In addition, the soils of the area are high in clay content, with moderate to high shrink-swell potential and low permeability. The objective of this project is to demonstrate innovative/alternative onsite wastewater technologies that protect ecological and water quality in an environmentally sensitive karst terrain.

Centerville, Pennsylvania

The Centersville project is located in southern Bedford County, Cumberland Valley Township, which comprises the entire watershed of Evitts Creek that drains into Koon and Gordon Lakes. These lakes provide water for more than 50,000 customers in parts of Pennsylvania, Maryland, and West Virginia, and are owned by the City of Cumberland, Maryland. There are about 45 residences in the Village of

Centerville, where most onsite systems failed or were inadequate, malfunctioning, or discharging directly into a ditch or stream. A permanently closed school has a treatment plant that will be used/retrofitted to serve the cluster of homes. The objective of this project is to identify the number of malfunctioning or direct-discharge systems and connect them to a system that will serve the majority of the homes (cluster), thus protecting public health and water quality.

Green Hill Pond, Rhode Island

The Green Hill Pond is about 400 acres of poorly flushed coastal lagoon along the southern Rhode Island coastline, which has experienced pronounced water quality degradation from nonpoint-source pollution inputs. The Green Hill Pond watershed is approximately 6 square miles in area with about 2,200 housing units. Since 1993, Green Hill Pond has been permanently closed to shellfishing due to elevated bacterial levels. The main cause of pollution is marginally functioning and failed septic systems, which have contributed to shellfish closures due to high fecal coliform counts and eutrophication from excess inputs of nitrogen. The objective of this project is to retrofit up to five failed conventional septic systems in the Green Hill Pond Watershed with alternative and innovative onsite systems.

Warren, Jericho, Addison, and Windham Vermont

According to the document "An Overview of Problems and Recommendations for Action," the Vermont Agency of Natural Resources states that Vermont's sewage disposal regulations are a conglomeration of rules that fail to provide adequate protection of public health. The major problems include a significant number of systems that are failing, great variation in the oversight of construction, and encouragement of poor land use. In addition, permits for innovative systems are hard to obtain. There are five different participants in this project: Vermont State Housing Authority, Addison County Demonstration Project, Town of Jericho, Town of Warren, and the Windham Regional Commission.

Burnett, Washington

The Town of Burnett is located on South Prairie Creek, which is one of the largest salmon producers in the Puyallup River Basin, in Washington. As with many coal mining towns, when the coal was gone so were most of its workers. What was left behind were the coal mines, shafts, tunnels, cave-ins, old sewer lines that usually discharged directly to the nearest stream, water systems of all types, and a town that was not planned but placed over the top of the mines. Burnett is riddled with old coal tunnels that are macro-arteries to groundwater contamination from onsite systems. Many of the homes dispose septic tank effluent into mine shafts, groundwater, and creeks, doing nothing to ensure proper treatment before disposal. The objective of this project is to identify, correct, and reduce the conditions that cause improper functioning of onsite wastewater systems, eliminating the risk to public health, and protecting the various water sources and the environment.

Monongalia County, West Virginia

Monongalia County, located in North-Central West Virginia, has suffered unplanned growth and exceeded infrastructure improvements. The lack of public sewers has caused residents to use onsite wastewater systems in urban as well as rural areas. Wastewater disposal problems have hampered development and have caused unnecessary health hazards. The county comprises a wide variety of topography and soil and site conditions that impact onsite wastewater systems. The belief exists that extending public sewer lines is the only acceptable method of wastewater disposal. This uninformed viewpoint undermines the use of cost-effective and safe onsite wastewater systems. Lack of understanding by the public, elected officials, and the government, as well as legal constraints, have impeded the use of such systems. The outcome of this proposal offers an alternative to public sewers through the effective use of onsite wastewater systems and management; provides an extensive education and training program about onsite systems; and the information, motivation, and support necessary to establish a management district.

Installation of onsite systems was scheduled to be completed by the end of spring/summer 1999; monitoring began and will continue for the duration of the project. In addition, NODP Phase II projects will involve septic system operation and maintenance training, and the creation of management districts.

Also, as part of NODP Phase II, the NSFC is currently developing a Demonstration Projects Database that will house a wide range of information on domestic wastewater demonstration projects across the United States. The NSFC will be collecting information on demonstration projects that meet the following criteria:

- Design flow does not exceed 1 mgd
- Onsite system serves 10,000 people or less

Information in this database will include (but not be limited to): project objective(s); contacts; funding source(s); site location(s) and conditions; demonstrated technologies; and monitoring/management program(s).

Phase III

Phase III of the NODP is a two-year program that builds upon the onsite demonstration work of Phases I and II, concentrating particularly on flood-ravaged areas. Earlier phases of the NODP have focused primarily on technology demonstrations. Phase III of the project will focus on developing a state's capacity to promote proven onsite treatment methods and management approaches, including technology, training, technical assistance, decentralized management systems, and financing of onsite systems. These demonstrations will promote changes in states' management approaches, resulting in wider acceptance of onsite systems as permanent wastewater solutions. Phase III offers unique community assistance opportunities to provide wastewater treatment where there previously was none, or to reconstruct, repair, or upgrade technologies and/or systems.

The states that have been selected for Phase III demonstration projects are West Virginia, Oregon, New York, Alaska, and Vermont. The general criteria used to select the states were high occurrence of flooding since 1996, difficulty of terrain and/or soils, and a rural nature. States' proposals for specific sites and project activities have been reviewed.

Phase IV

The emphasis of Phase IV will be to promote and develop management strategies for onsite wastewater treatment in our nation's small communities. NODP Phase IV will assist local officials in implementing management districts around the country by identifying successful management models and providing information to educate local officials about these models. A three-year project, Phase IV began in fall 1998. This project is designed to research, develop, and disseminate information and resources, such as educational materials for the development of management programs.