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Decentralized Systems

FINAL REPORT

Performance & Cost of Decentralized Unit Processes

DEC2R08

PERFORMANCE & COST OF DECENTRALIZED UNIT PROCESSES

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The "Wastewater Planning Model" must be accessed and downloaded from the WERF Decentralized Cost website.

Performance & Cost of
Decentralized Unit Processes

1.0 INTRODUCTION

Small community leaders and planners have a critical need for information and tools to help make good decisions concerning local wastewater management.

Community leaders and planners can use the resources in this document to help evaluate the performance, cost, and other factors of various technologies and decide which are the most appropriate for their particular needs.

This document is a compendium of products developed from a Water Environment Research Foundation (WERF) project titled "Performance & Cost of Decentralized Unit Processes". The products consist of three components: a primer on wastewater basics; a series of fact sheets on decentralized wastewater collection, treatment and dispersal; and a decentralized wastewater cost estimation tool and accompanying user's guide.

Section 2.0, Wastewater Basics for Small Community Leaders and Planners, is the best place for readers to get started. This section provides an overview of and context for the fact sheets and cost tool that were developed as part of this project.

In Section 3.0, a series of nineteen fact sheets give basic information on the full range of currently available collection, treatment and dispersal technologies for wastewater management and how they may be used individually or in combination.

Collection Fact Sheets	Treatment Fact Sheets	Dispersal Fact Sheets
C1: Gravity Sewer Systems	T1: Liquid-Solid Separation	D1: Gravity Distribution
C2: Pressure Sewer Systems	T2: Suspended Growth Aerobic Treatment	D2: Low Pressure Distribution
C3: Effluent Sewer Systems	T3: Fixed Growth Aerobic Treatment	D3: Drip Distribution
C4: Vacuum sewer Systems	T4: Constructed Wetland Systems	D4: Spray Distribution
	T5: Lagoons	D5: Evapotranspiration System
	T6: Nutrient Reduction	D6: Surface Water Discharge
	T7: Disinfection	D7: Wastewater Reuse
	T8: Residuals Management	

Section 4.0, Wastewater Planning Model User's Guide, is a user's guide which accompanies the cost spreadsheet tool. The tool can be downloaded from the WERF website at www.werf.org/decentralizedcost. The spreadsheet tool provides planning level cost estimations of different decentralized wastewater management scenarios commonly used in small communities. Initial capital costs as well as long-term maintenance and energy costs are included. Users can take advantage of the default unit cost values provided based on national data or use better, local information when available.

The information in this document is not intended to serve as a design manual, but rather to provide small community decision-makers the information necessary to work with engineers, soils professionals, construction managers and financial personnel to get the best wastewater solution for their community.

2.0 WASTEWATER BASICS FOR SMALL COMMUNITY LEADERS AND PLANNERS

Wastewater Basics

Performance & Cost of Decentralized Unit Processes

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DECENTRALIZED WASTEWATER SYSTEMS

WASTEWATER BASICS FOR SMALL COMMUNITY LEADERS AND PLANNERS

Project Background

The materials presented here were developed in response to a Request for Proposals (RFP) to address the topic of ***Decentralized System Selection: Unit Processes, Costs, and Non-monetary Factors.*** The RFP was issued by the Water Environment Research Foundation (WERF), a nonprofit organization that operates with funding from subscribers and the federal government. This project was supported by funding from the US Environmental Protection Agency (US EPA) and administered by WERF as part of the National Decentralized Water Resources Capacity Development Project (NDWRCDP).

The 19 Fact Sheets and electronic cost estimation tool included in this package were developed by members of the Consortium of Institutes for Decentralized Wastewater Treatment (CIDWT). The CIDWT is a group of Educational Institutions cooperating on decentralized wastewater training and research efforts. CIDWT members participating in the development process include:

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Supplemental Fact Sheets

Additional Fact Sheets that discuss specific Dispersal, Collection and Treatment Technologies are included with these materials. Each Fact Sheet provides a more detailed description of the technology, including use, installation, general maintenance needs and how it might fit into the community vision. Also included is a general estimate of the costs associated with installation and long-term operation and maintenance. The costs provided in the documents are for comparison purposes only. The actual cost for system components will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

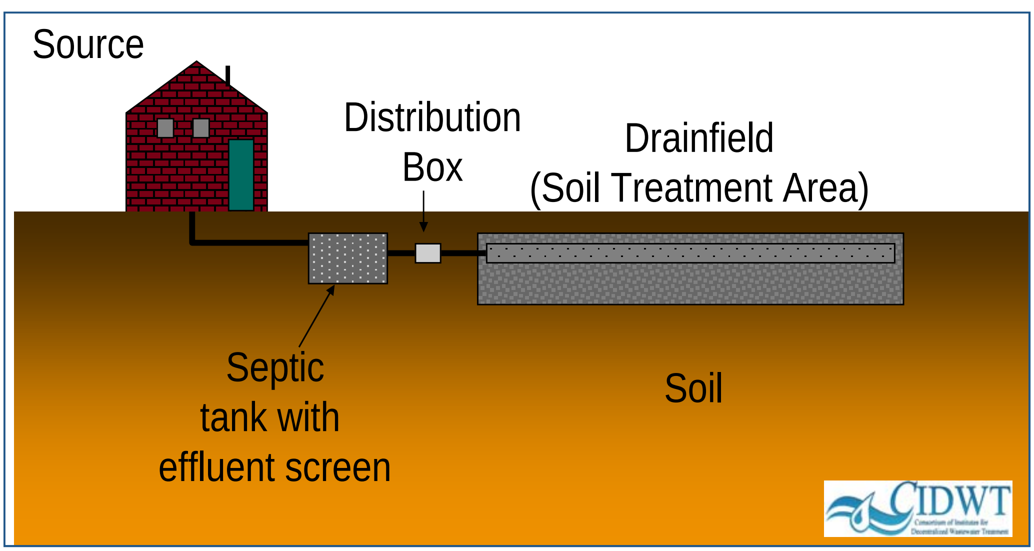
Category	Fact Sheet	Technology
Dispersal	D1	Gravity Distribution
	D2	Low Pressure Distribution (LPD)
	D3	Drip Distribution
	D4	Spray Distribution
	D5	Evapotranspiration
	D6	Surface Water Discharge
	D7	Wastewater Reuse
Treatment	T1	Liquid-solid Separation
	T2	Suspended Growth Aerobic Treatment
	T3	Fixed Growth Aerobic Treatment
	T4	Constructed Wetland Systems
	T5	Lagoons
	T6	Nutrient Reduction
	T7	Disinfection
	T8	Residuals Management
Collection	C1	Gravity Sewer Systems
	C2	Pressure Sewer Systems
	C3	Effluent Sewer Systems
	C4	Vacuum Sewer Systems

Introduction

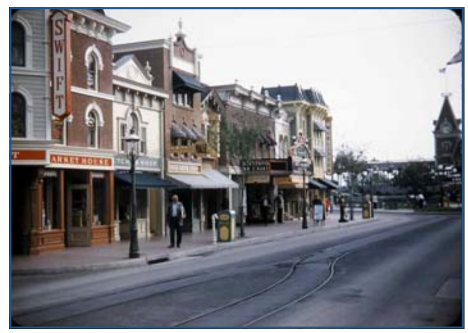
The purpose of this guide is to provide small community leaders and planners with the basic information needed to make good decisions concerning local wastewater management. Whether the plan is to establish a new infrastructure or retrofit an existing situation, decentralized wastewater treatment technologies offer multiple solutions for collection, treatment and dispersal. Included with this guide are fact sheets that discuss various wastewater collection, treatment and dispersal technologies, and spreadsheets that help to estimate localized costs. The Fact Sheets provide basic information on the full range of technologies currently available for wastewater management and how they may be used individually or in combination. Community leaders and planners can use these documents to evaluate the various technologies and decide which are the most appropriate for their particular needs.

In these materials, a small community is defined as 200 connections or approximately 50,000 gallons of wastewater per day. This document is not a design manual. Rather, it is intended to provide decision-makers with the information necessary to work with engineers, soils professionals, construction managers and financial personnel to get the best wastewater solution for their community.

In many small communities, each home and business has an individual onsite septic system consisting of a septic tank and a soil treatment area or drainfield. When properly sited, designed, installed, and



maintained individual septic systems are very effective at renovating domestic wastewater and protecting public health. Each septic system has land dedicated to the treatment and dispersal of wastewater. As communities grow (both in population and commerce), land often becomes too valuable to be dedicated to wastewater. When land near the wastewater source is no longer available, engineered wastewater management systems may need to be considered. Another common reason to upgrade local wastewater infrastructure is that approximately 50% of the individual onsite wastewater systems in the United States were built before most jurisdictions adopted modern standards for acceptable installation. This is not to say that 50% of the individual onsite wastewater systems are malfunctioning, but many older communities have a higher percentage of malfunctioning septic systems. Older systems were often intended for temporary use (until a centralized sewer connection was available) or were not constructed to handle the increased volume and/or strength of wastewater generated today. Older individual systems are often located on small lots. There may not be sufficient suitable soil available to increase the capacity of the existing system or to install an upgraded system. This can result in wastewater on the surface, which is a public health hazard. If a significant number of individual onsite wastewater systems are malfunctioning, a community-scale wastewater solution may be warranted. Decentralized technologies offer a range of options for consideration. They also provide the flexibility of combining individual, residential/commercial clusters and community-scale options to tailor a solution that fits the particular need.



Designing, constructing and maintaining a community-scale wastewater management system is an expensive undertaking. Before design work can begin, local leaders and planners must establish a vision for the future of the community. This vision must include estimations for expanding or shifting population as well as commercial and industrial development. Community wastewater management must anticipate future needs to ensure that growth is not hampered. This guide is based upon the assumption that the community has already either established a vision for its future or is in the process of doing so. With a vision, the community can design and construct the wastewater infrastructure that protects water quality while encouraging growth, increasing community pride, and fostering economic development in a sustainable manner. Communication tools for bringing ideas to the community, building partnerships with stakeholders, and strategies for success are available on the Livable Communities website administered by WERF at www.werf.org/livablecommunities/tool_comm.htm.

1. Wastewater Management

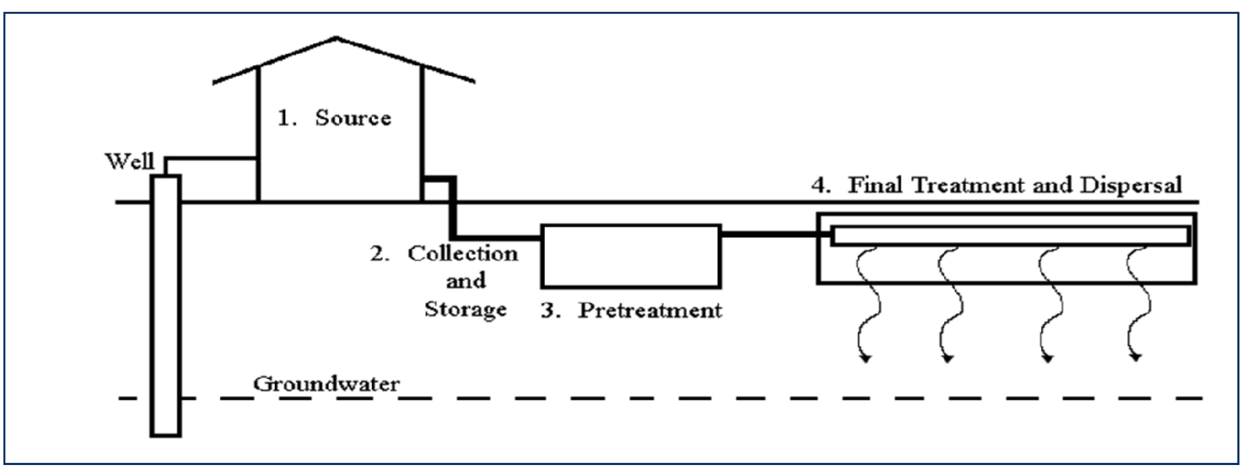
The Big Picture

The primary goal of all wastewater management systems is to remove waste products from water and to safely return the water back into the environment. Every day, society generates a significant volume of wastewater because we depend on water to transport wastes away from our bodies, our clothes, and our homes. Once water comes in contact with waste products, the water becomes wastewater, despite the fact that it is still 99.9% water! The natural environment has a tremendous potential to renovate wastewater back into water. However, society generates wastewater in amounts that typically exceed nature's capacity for renovation. Thus, we manage wastewater by optimizing and supplementing the natural processes that remove wastes from water.

Wastewater management involves:

- Collection and transport of wastewater from the source to a treatment process,
- Removal of all or most of the waste products that are suspended and/or dissolved in the water,
- Returning the water back to the environment, and
- Management of these processes to ensure that a wastewater system is fully functional.

All wastewater systems include a collection component, a treatment component, a dispersal component, and a management component. Individual septic systems have traditionally collected wastewater from the home or business, removed (treated) waste products using a septic tank and soil absorption field, and returned (dispersed) the treated water to the groundwater. Local officials manage individual systems by



overseeing the installation of septic tanks and soil absorption fields. This style of management tends to be more *prescriptive* – there are specific rules that must be followed based upon predictions of wastewater volume and strength. The system owner is typically responsible for operation and maintenance. This includes removal of accumulated solids from the septic tank as needed. It also includes NOT flushing "system killers," or materials that hinder the wastewater treatment process. Prescriptive management is often insufficient, particularly because system owners are either not aware, do not follow the rules and/or enforcement is inconsistent.

At the other end of the spectrum, large population centers tend to have a community-wide collection system that conveys wastewater to a centralized treatment facility where the waste products are removed from the water. Once treated, the water is then returned back to the environment via a surface water discharge. Management is provided in accordance with regulations that limit the mass of waste constituents that can be discharged. Larger wastewater systems are thus subject to *performance* requirements in the form of specific measurable and enforceable pollutant effluent limits. System management is provided by a public or private utility that ensure that the system is financially secure and environmentally sound.

Recently, individual and residential/cluster systems in some areas are becoming subject to performance requirements similar to those used for larger systems because of the increased use of components that can provide secondary treatment on a smaller scale. But this approach is not yet universal. Certainly, when systems must meet performance requirements, an increased level of management is essential to ensure that systems are in compliance.

Quick Definitions

Prescriptive requirements: Minimum specific physical standards or specifications for design, siting, and construction of system components.

Performance-based requirements: Minimum performance criteria established by the regulatory or proprietary authority to ensure compliance with the public health and environmental goals of the state or community.

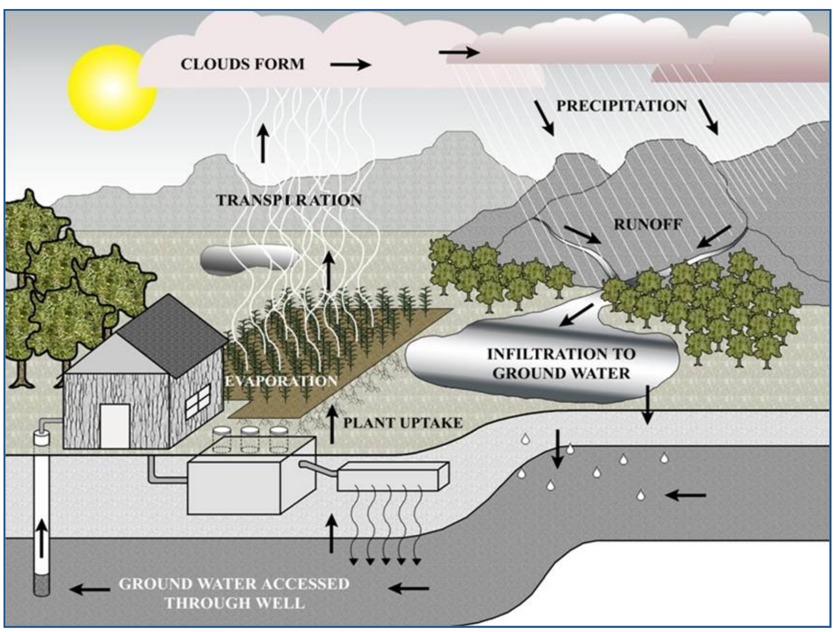
Centralized and Decentralized Management Philosophies

It is easy to describe a centralized approach to wastewater management – all the community's wastewater drains to a common collection network and is transferred to a centralized treatment and disposal facility. It is more difficult to describe a decentralized approach. In order to 'decentralize' wastewater management, the wastewater treatment infrastructure is distributed across a community. This may be accomplished by building individual onsite systems, having small residential clusters of homes on common systems, and/or by some combination of both to serve multiple wastewater management zones. Decentralized wastewater management is often a recognition that, for some communities, the installation and maintenance of a purely centralized infrastructure is too expensive and unnecessary. It also validates the concept that a creative mix of available technologies can establish, preserve and/or enhance community identity and charm.

Wastewater as a Resource

Water is essential to all life. Making sure that citizens have clean water is a basic responsibility of government. Domestic wastewater is 99.9% water – it is the remaining 0.1% that causes problems. Tremendous effort goes into removing the waste constituents from water so that it can be returned to the environment. This water has value and should be used for productive purposes. Unfortunately, many planners, regulators, and engineers still think in terms of wastewater "disposal." This is a short-sighted mentality. Water is never disposed of, it is only recycled. Treated wastewater 'disposed of' in a river becomes the next community's source of raw water destined for conveyance to a water treatment plant to become potable water. Wastewater that is dispersed to the soil eventually rejoins groundwater that is often used as a potable water source.

When planning for a new wastewater management infrastructure, a community should consider installing components for the reuse of treated wastewater on the local level. Reuse is the planned direct use of reclaimed wastewater. Using a combination of conventional and advanced treatment processes that return wastewater to a very high quality, reclaimed wastewater can be made available for beneficial applications. Irrigation of golf courses, grassed traffic medians, and urban landscaping can be accomplished using



Wastewater is never 'disposed of'.

We simply recycle it.

reclaimed water. Toilet flushing is another potential use. A reclaimed water distribution system can be installed at the same time as a wastewater collection system and reduce the initial cost of the infrastructure. It must, however, be understood that wastewater reuse must be done with appropriate management controls in place to protect public health.

2. Wastewater Characterization

What's in Wastewater?

It is important to understand what is in wastewater so that treatment systems have the appropriate processes needed to reduce or remove the particular constituents of concern. The constituents described below will be present in all wastewater in varying amounts.

<u>Solids</u>

Water is heavy, with a typical density of just over eight pounds per gallon. This density allows easy transport of many materials in moving water. Fecal matter and toilet paper are two obvious types of wastewater solids. Other solids are also present and can originate from the laundry (lint, detergent powders and soil), the bathroom (soil, soap, toothpaste, and personal hygiene products), and the kitchen (food scraps, fats, oils, and greases). Solids and 'non-aqueous' liquids that have a density different from water will either settle (sedimentation) or rise to the surface (floatation). Solids removal is typically the first treatment process and liquid-solid separation is often called preliminary or primary treatment. Once preliminary or primary treatment is achieved, some amount of solids will still be present. These must be reduced through additional treatment processes.

Quick Definitions

Primary Treatment: Physical treatment processes involving removal of particles, typically by settling and flotation.

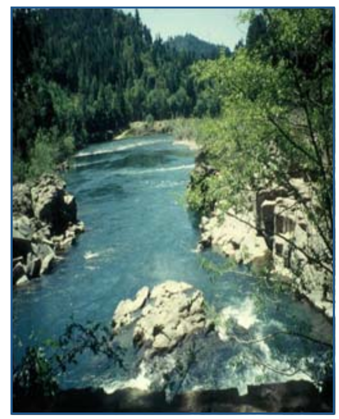
<u>Fats, Oils and Grease (FOGs)</u>

Non-aqueous liquids include Fats (animal source), Oils (vegetable source), and Grease (petroleum source) which are collectively known as FOGs. These constituents are very difficult to treat because they degrade very slowly. Some will congeal during primary treatment and be removed with other solids. Because these FOGs can congeal in the collection system, most community wastewater systems will require food preparation businesses to install grease interceptors on site. This management practice lessens the demand for collection system maintenance.

Organic Compounds

Many of the waste products in wastewater are organic in nature. Fecal matter, food scraps, fats, oils, cotton fibers, and paper products are major sources of organic compounds. However, medications and personal care products are also included in this category. Many organic compounds are in a solid form and are removed during liquid-solid separation. Organic compounds that are too small to be captured as solids or are dissolved in the wastewater can be removed using biological treatment provided by naturally-occurring microorganisms. Microorganisms use many dissolved organic compounds as a food source, and thus remove these compounds from the wastewater.

Nutrients



Nitrogen and phosphorus are essential nutrients for all plants and animals. These nutrients are excreted as part of human bodily wastes. As excreted, much of the nitrogen and phosphorus is bound in an organic form. As these organic compounds are broken down through microbial activity, nitrogen and phosphorus are converted into inorganic forms. Dispersing a high concentration of these nutrients to the environment may adversely affect human health and water quality. Treatment systems can include processes specifically designed to reduce nutrients to protect water quality.

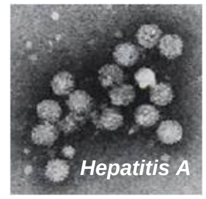
Odors and Vectors

Before humans understood the health implications of not managing our bodily wastes, we understood the negative implications of the smell. Odors come from volatile compounds released as microorganisms break down organic materials. The compounds that cause odors are ammonia, hydrogen sulfide, and other sulfur compounds. Aside from the aesthetic implications, odors also attract vectors (insects and vermin) which can spread diseases. Properly managed and operated wastewater systems have little or no associated odors.

Pathogens

E. Coli 157

Pathogens are disease-causing organisms. Pathogens can be single-cell microorganisms such as bacteria and viruses, or more complicated parasites such as protozoa and helminths (worms). Disease-causing organisms tend to be shed with the bowel movements of infected persons. The primary public health concern in wastewater management is to substantially reduce the risk of transferring pathogens into the environment and minimize negative impacts on public health. Some pathogens are removed during liquid-solid separation and other treatment processes. Others die off naturally in the soil or are preyed upon by other microbes. Under certain circumstances, additional unit processes (disinfection) must be added to inactivate them or prevent their reproduction.



Sources of Wastewater within the Community

Different sources within the community are expected to generate a certain volume of wastewater. Likewise, the constituents in wastewater from similar sources will generally be uniform. By identifying and/or projecting the sources of wastewater expected to be connected to the system, leaders and planners can select the appropriate wastewater management technologies. While it is sometimes difficult to predict the quantity and quality of wastewater from various sources, two broad categories include Domestic and Non-domestic sources.

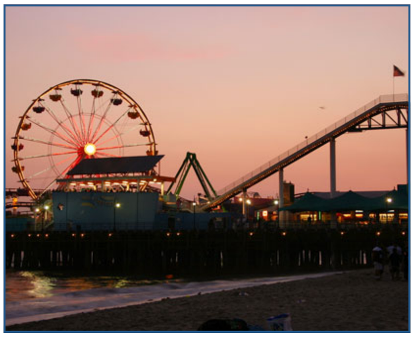
Domestic Wastewater

The primary focus of this guide is domestic wastewater – water used to transport human bodily wastes (feces and urine), water used for personal hygiene, laundry water, and water used for cooking and cleaning. Homes, apartments and other residential units are the primary sources of domestic wastewater in a small community.

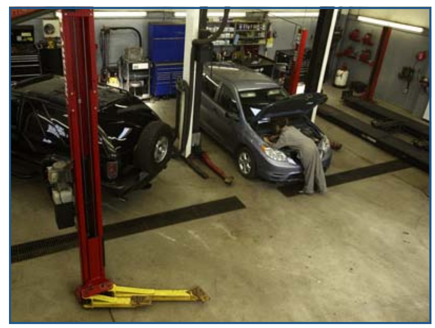
Non-Domestic Wastewater

Small community wastewater management systems must be capable of handing wastewater from other sources aside of residential units since these will also be part of the flow. Some sources may generate wastewater that is similar in composition to domestic wastewater, while others may have one or more constituents present in levels that exceed typical domestic ranges. The labels *institutional, commercial, recreational* or *industrial* often reflect the nature of the source (public or private) instead of specific wastewater characteristics, but it is helpful to group the sources to ensure that all are considered. Many sources may actually be included in more than one category.

Institutional sources would typically include schools, day care centers, churches, hospitals, clinics, rest homes and prison facilities.



Commercial sources include businesses. Food service facilities such as restaurants, cafeterias, bars and cocktail lounges fall into this category. Hotels, motels, boarding houses and similar entities are also included and these establishments often also include a food-service component. Office buildings, shopping centers, grocery stores, self-service laundries, theatres, as well as beauty and barber shops can also be included. ***Recreational*** sources may be public or private entities and include tent or RV campgrounds, picnic and amusement parks as well as highway rest areas. ***Industrial sources*** may produce process wastewater with constituents that are more difficult to treat than others. This category not only includes some manufacturing facilities, but also service facilities such as automobile repair shops, car wash facilities, dry cleaning establishments and funeral homes.



High-strength Wastewater

Any of the sources mentioned above might generate wastewater that requires more treatment as a result of high levels of one or more constituents. This is often expected of some commercial or industrial sources. For example, food and beverage production facilities use water to flush pipes and tanks, clean and separate raw foodstuffs, as well as to sanitize food preparation and packaging areas. These facilities thus generate wastewater with high levels of food ingredients (both solids and organic matter) that may need additional treatment. Recreational sources such as campgrounds with pump-out facilities generate wastewater with high amounts of chemicals from RV holding tanks. Institutional sources like schools and day care centers may generate wastewater with high nitrogen while those associated with health care may generate wastewater with high levels of pharmaceuticals. Commercial food-service establishments often generate wastewater with high levels of FOGs that are difficult to degrade. Even wastewater from residential sources may be considered high strength under some circumstances. Homeowners that engage in hobbies such as brewing beer produce effluent that requires a higher level of treatment. If a family member must use antibiotics or cancer treatment drugs for an extended period of time this can also result in high-strength wastewater. The point is that the community wastewater management system must be designed and constructed with consideration of both wastewater *volume* and wastewater *strength*.

3. Processes for Wastewater Management

Overview of Processes

As stated previously, wastewater management involves four activities:

- Collection and transport of wastewater from the source to a treatment process,
- Removal of all or most of the waste products that are suspended and/or dissolved in the water,
- Returning the water back to the environment, and
- Management of these processes to ensure that a wastewater system is fully functional.

The limitations of the receiving environment often determine which processes are needed for wastewater treatment. Most single-family wastewater systems use the soil as a means of both treatment and dispersal after liquid-solid separation has occurred in a septic tank. A site with deep, well-drained soil can provide all the treatment necessary (including disinfection of pathogens) prior to dispersal of effluent. But if soils are shallow or poorly-drained, additional processes are needed to remove constituents before dispersal occurs. Ultimately, some sites are simply unsuitable for dispersal due to economic and/or engineering constraints. If a receiving stream already has too much nitrogen, then the treatment components must remove most of the nitrogen compounds before effluent can be discharged. Thus, when planning a new wastewater management system or modifying an existing one, the natural resources available for dispersal must be the first consideration since they often determine what treatment is required. Both the dispersal and treatment components may drive the choice of a collection option. This section provides broad overviews of topics that are described in more detail in the Fact Sheets that accompany this guide (see page 3). Technologies appropriate for dispersal are discussed first, then those for treatment, followed by those for collection. The concluding section discusses the critical topic of management to ensure that the wastewater system remains fully functional. It is important that decision-makers understand that many of the technologies described under a particular category here may be used for multiple purposes. The flexibility offered by the decentralized approach allows consideration of a mix of technologies.

Choosing among the available decentralized options is sometimes driven by the volume of wastewater that will be generated. Table 1 includes a listing of Dispersal, Treatment and Collection technologies with an indication of the range of daily flows for which they are most appropriate. If a community is faced with a particular issue such as nutrient sensitive waters or shallow soils, it is helpful to consider the particular technologies that can address the problem. Table 2 can be used to guide this part of the process.

Tables 1 and 2 on the succeeding pages should be used only as a general guide to evaluate options relative to wastewater volume, population density, land use and other issues. Communities should carefully investigate wastewater management options through consultation with qualified industry professionals.

Table 1. Applicability of Unit Process by Daily Wastewater Volume

Process Category	Daily Wastewater Volume in gallons per day (gpd)				
	Single Family	Community			
	150 to 1000 gpd	1,000 to 5,000 gpd	5,000 to 10,000 gpd	10,000 to 50,000 gpd	50,000 gpd and greater
Soil Subsurface Dispersal					
Gravity Trenches	*****	*****	*****	****	***
Low Pressure Distribution	*****	*****	*****	****	***
Drip Distribution	*****	*****	*****	*****	*****
Soil Surface Dispersal					
Spray Distribution	*	***	****	****	*****
Evapotranspiration Systems	***	***	***	**	**
Water Surface Discharge					
Surface Water Discharge	n/a	*	**	***	****
Wastewater Reuse					
Irrigation Reuse	**	**	***	****	*****
Urban Reuse	**	**	***	***	***
Industrial Reuse	n/a	n/a	n/a	**	***
Environmental/Recreational Reuse	n/a	n/a	n/a	n/a	**
Primary Treatment					
Septic Tanks (Precast)	*****	*****	***	*	*
Primary Tanks (Built in place)	*	**	*****	*****	*****

*****	Good application of technology
****	Application may have some limitations due to siting
***	Limited application either due to economic or siting constraints
**	Very limited application due to economic or siting constraints
*	Generally not a recommended use of the technology
n/a	Technology has no or very little applicability to the situation

Table 1. Applicability of Unit Process by Daily Wastewater Volume (cont.)

Process Category	Daily Wastewater Volume in gallons per day (gpd)				
	Single Family	Community			
	150 to 1000 gpd	1,000 to 5,000 gpd	5,000 to 10,000 gpd	10,000 to 50,000 gpd	50,000 gpd and greater
Secondary Treatment					
Suspended Growth Aerobic Treatment (Built in place)	*	*	**	*****	*****
Suspended Growth Aerobic Treatment (Modular)	*****	*****	*****	****	****
Single-Pass Fixed Growth Aerobic Treatment	*****	*****	****	***	***
Recirculating Fixed Growth Aerobic Treatment	*****	*****	*****	*****	*****
Constructed Wetland Systems	*	**	***	***	***
Lagoons	*	**	***	****	*****
Tertiary Treatment					
Nutrient Reduction	*	**	***	****	*****
Chlorine Disinfection	**	**	***	***	***
Ultraviolet Light Disinfection	*****	*****	*****	*****	*****
Residuals Management					
Co-treatment at WWTP	*****	*****	*****	*****	*****
Local Land Application	*****	*****	*****	*****	*****
Solids Stabilization/ Liquid Dispersal	*****	*****	*****	*****	*****
Collection Systems					
Gravity Sewers	n/a	***	****	*****	*****
Low Pressure Sewers	n/a	*****	*****	*****	*****
Effluent sewers (STEP/STEG)	n/a	*****	*****	*****	*****
Vacuum System	n/a	n/a	n/a	**	*****

*****	Good application of technology
****	Application may have some limitations due to siting
***	Limited application either due to economic or siting constraints
**	Very limited application due to economic or siting constraints
*	Generally not a recommended use of the technology
n/a	Technology has no or very little applicability to the situation

Table 2. Applicability of Wastewater Technology by Issue

Issue	Collection	Treatment*	Dispersal/Disposal*
Low population density	Pressurized collection system (C3)		
Less than 24 inches (depth) of suitable soils		Oxygen demand removal (T2, T3, T4, T5), nutrient reduction (T6), disinfection (T7)	Pressurized soil-based distribution (D2, D3, D4) or surface water discharge (D6)
Small land parcels	Install Collection system (C1, C2, C3, C4)	Provide treatment as appropriate for selected dispersal	Clustered dispersal areas (D2, D3, D4, D5)
Rugged, rocky terrain	Pressurized collection system (C2, C3, C4)		Pressurized soil-based distribution (D2, D3) or surface water discharge (D6)
Steep terrain	Pressurized collection system (C2, C3)		
Arctic Conditions	All components must be below the frost depth and/or must completely drain between usages		
Arid Conditions		Consider processes that take advantage of evapotranspiration (D5, T5), consider reuse possibilities (D7)	
Nutrients		For nitrogen, consider treatment processes that recirculate (T2, T3). For phosphorus, consider chemical precipitation.	Pressurized soil-based distribution (D2, D3, D4)
Pathogens		Oxygen demand removal (T2, T3, T4) and disinfection (T7)	Pressurized soil-based distribution (D2, D3, D4)

*Note that regardless of issues, all systems will include Liquid-solid Separation (T1) and Residuals Management (T8).

FACT SHEETS

Dispersal
D1 Gravity Distribution
D2 LP Distribution
D3 Drip Distribution
D4 Spray Distribution
D5 Evapotranspiration
D6 Surface Water Discharge
D7 Wastewater Reuse

Treatment
T1 Liquid Solid Separation
T2 Suspended Growth Aerobic Treatment
T3 Fixed Growth Aerobic Treatment
T4 Constructed Wetland Systems
T5 Lagoons
T6 Nutrient Reduction
T7 Disinfection
T8 Residuals Management

Collection
C1 Gravity Sewer Systems
C2 Pressure Sewer Systems
C3 Effluent Sewer Systems
C4 Vacuum Sewer Systems

Dispersal: Returning Treated Water to the Environment

In the United States more than 70% of treated wastewater is discharged to surface water. Securing the permits to discharge effluent is a rigorous process and the wastewater must be renovated to a very high degree. In contrast, soil-based dispersal accomplishes additional treatment (prior to returning effluent to the environment) through infiltration to groundwater and by evaporation to the atmosphere and transpiration through plants. Detailed Fact Sheets are referenced for each of the dispersal options discussed below.

Soil-Based Dispersal

Although this section addresses *dispersal* options, the soil also has a large capacity for wastewater *treatment* because of its physical, chemical, and biological properties. The potential to provide both dispersal and a certain amount of treatment means that less pre-treatment may be required prior to soil-based dispersal. This will depend upon the particular characteristics of the available soil. A professional with soils training and expertise must evaluate soil properties as well as site characteristics. From this evaluation, an effluent loading rate is determined, which is used to calculate the area required to safely disperse the anticipated volume of effluent. However, adjustment of the loading rate may be required on the basis of wastewater characteristics. If effluent has a high organic strength, aerobic degradation of organic compounds will require additional infiltrative surface area.

Soils have potential for BOTH treatment AND dispersal of effluent.

Most individual wastewater systems use a series of trenches to apply septic tank effluent to the subsurface soil. Trenches are shallow excavations placed on contour across the landscape. They are up to three feet wide and are partially backfilled with an inert media that provides void space. The void space provides short-term storage during high-flow events when more effluent is applied than can be immediately absorbed by the soil. The remainder of the backfill is the native soil that was originally removed. Effluent can be applied to trenches using either Gravity or Low-pressure distribution. See **Fact Sheets D1** and **D2** for detailed discussions of these technologies and possible variations.

For more information, see:
D1: Gravity Distribution
D2: Low-pressure Distribution

Irrigation technologies may be used to apply effluent to the soil. These include Drip dispersal and Spray irrigation. The primary goal of these technologies is for the effluent to infiltrate into the soil, evaporate or be taken up by vegetation on the site. Effluent is applied either on or just beneath the soil surface where oxygen levels and biological activity are optimum for treatment. **Fact Sheets D3** and **D4** provide additional details.

For more information, see:
D3: Drip Distribution
D4: Spray Distribution

Any soil-based dispersal system that has the capacity to serve 20 or more persons per day (either residential or non-residential) or receives any amount of industrial or commercial wastes is considered a Class V Injection Well. Such systems must meet the requirements of the U.S. EPA Underground Injection Control (UIC) program, which is a component of the Safe Drinking Water Act (SDWA). The core mission of the SDWA is the non-endangerment of underground sources of drinking water. Non-endangerment means that system operators prevent fluids containing contaminants to move into underground sources of drinking water where their presence may violate primary drinking water regulations or adversely affect public health (40 CFR, vol. 64, section 234, Dec. 7, 1999). Gravity, low-pressure, drip and spray systems that accommodate flows in excess of the threshold limit for a given regulatory jurisdiction will be designated as a Class V Injection Well and be subjected to pertinent regulatory oversight.

What's it mean???
Acronyms

EPA UIC: *EPA Underground Injection Control Program*

SDWA: *Safe Drinking Water Act*

CFR: *Code of Federal Register*

NPDES: *National Pollutant Discharge Elimination System*

In Evapotranspiration (ET) systems (details in **Factsheet D5**), primary-treated effluent evaporates from on or near the soil surface and/or is transpired through the vegetation growing on the site. In each case, water vaporizes to the atmosphere. ET systems can be viable alternative for effluent dispersal in arid climates that have significantly more annual evapotranspiration than precipitation.

For more information, see:
D5: Evapotranspiration Systems

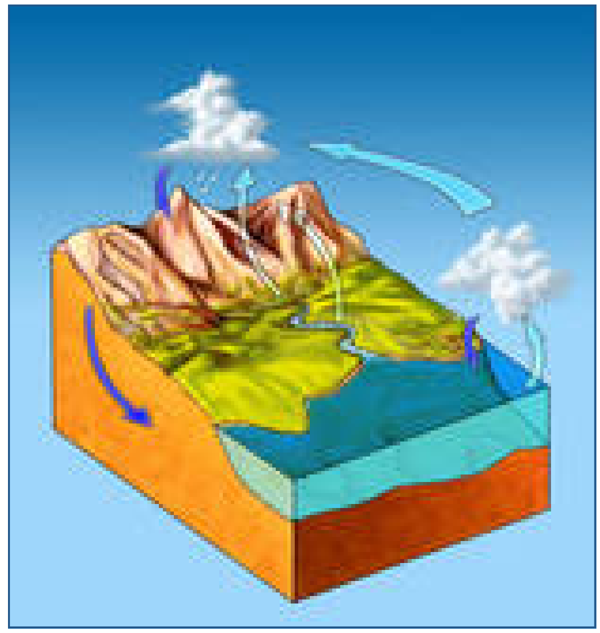
Surface Water Discharge

As previously mentioned, many larger communities depend on surface water to receive treated effluent. A National Pollutant Discharge Elimination System (NPDES) permit is required for surface water discharges which are often referred to as point source discharges. Because of their direct affect on the receiving stream, these discharges are highly regulated. Prior to permit issuance, investigations are performed to determine the relative ability of the receiving water body to assimilate waste constituents present in effluent. System performance is then regulated through specific permit limits on what is discharged. See **Fact Sheet D6** for further information.

For more information, see:
D6: Surface Water Discharge

Reuse and Reclamation

Obviously, we continuously reuse water; this is the basis of the hydrologic cycle. However, we can shorten the cycle size by reusing treated water rather than pulling more water out of the cycle. Reuse is a means of dispersing high-quality effluent back into the environment while simultaneously doing something productive with the water. Treating wastewater to the appropriate level for the particular reuse is of obvious importance. Irrigation is the most common method of reuse, and refers to a system specifically designed for reuse of treated wastewater for a 'value-added' purpose such as growing grasses, crops and/or trees. The second common use of reclaimed water is industrial reuse for cooling system make-up water, boiler-feed water, process water, and general wash down.



Reuse is the basis of the hydrologic cycle.

Wastewater reuse for other purposes has increased in the relatively recent past. Urban reuse systems provide reclaimed water for a wide variety of non-potable purposes including irrigation for ornamental landscapes, use in decorative water features, dust control, concrete production for construction projects, fire protection through reclaimed water fire hydrants, as well as toilet and urinal flushing in commercial and industrial buildings. In environmental reuse, reclaimed water is used to create manmade wetlands, enhance natural wetlands and sustain or augment stream flows. Recreational reuse allows reclaimed water to be used in impoundments for fishing, boating and (in some cases), body-contact water recreational activities. **Fact Sheet D7** describes methods use for Reuse and Reclamation of wastewater.

For more information, see:

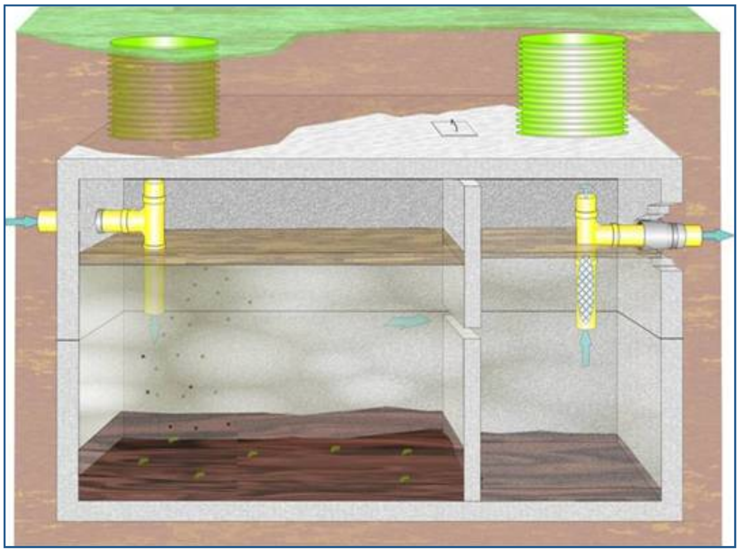
D7: Wastewater Reuse

Treatment: Removing Waste Constituents from Wastewater

Water scientists and regulators like to ask the rhetorical question: "At what point in the treatment process does wastewater become water?" After all, wastewater is 99.9% water and 0.1% waste products. The practical answer is that wastewater becomes water when the treated effluent does not negatively affect the quality of the receiving environment. Using this philosophy, treatment components are selected on the basis of producing effluent that can meet the appropriate standard for the selected dispersal option. Detailed Fact Sheets are referenced for the eight treatment processes discussed below.

Liquid-Solid Separation (Preliminary & Primary Treatment)

Separating the solids fraction out of wastewater is the first level of treatment. Solids consist of fecal matter, residual foodstuff, fats, oils, grease, and a large variety of garbage. Solids removal is often divided into two categories – preliminary and primary treatment. Preliminary treatment separates out the coarse solids and is generally associated with collection systems that transport both solids and liquids to a central location. Wastewater flows through screens or grates where larger materials are physically separated out of the stream. Primary treatment allows for separation based on particle density. This can be accomplished in septic tanks or larger, built-in-place primary tanks. Solids and 'non-aqueous' liquids that have a density different from water will either settle (sedimentation) or rise to the surface (floatation). Non-aqueous liquids include fats (animal source), oils (vegetable source), and greases (petroleum source) which are collectively known as FOGs. Once preliminary or primary treatment is achieved, some amount of solids will remain suspended in the effluent. These are known as Total Suspended Solids or TSS. Along with Biochemical Oxygen Demand (BOD), TSS is commonly used to express the strength of wastewater. These solids must be reduced through additional treatment processes. **Fact Sheet T1** provides information on options for liquid-solid separation.



Septic tanks are an effective method of removing solids from wastewater.

For more information, see:

T1: Liquid-Solid Separation

Oxygen Demand Removal (Secondary Treatment)

After liquid-solid separation, dissolved and suspended organic matter is still present in effluent. If this organic matter is not removed before the effluent is dispersed, microorganisms in the receiving environment will begin to process it. As they consume the organic matter, they also consume oxygen or create an *oxygen demand.* The resulting low oxygen or *hypoxic* conditions negatively affect the receiving environment. In many cases hypoxic waters do not have enough oxygen to support fish and other aquatic animals. In situations where hypoxic conditions develop abruptly, massive fish kills can occur. In other situations where it happens gradually, fish populations will shift. Game fish, such as trout, may need as much as 4 milligrams per Liter (mg/L) of dissolved oxygen to thrive. Less desirable species of fish, such as carp, may thrive on oxygen levels of less than 2 mg/L.

The function of secondary treatment systems is to create an *aerobic* environment to provide oxygen for naturally-occurring microorganisms present in the wastewater so that they will consume the organic matter before it is dispersed into the environment. Biochemical oxygen demand (BOD) is a measure of how much oxygen microorganisms use up as they consume organic matter. BOD is thus another common indicator (along with TSS) of how strong wastewater is and how much treatment it needs. There are several different treatment components that can provide the necessary aerobic conditions for BOD removal. The basic difference among these components is how the dissolved oxygen is provided. If mechanical methods are used to transfer oxygen, high rates of BOD removal can be achieved. Examples of high-rate systems are suspended growth and fixed growth aerobic treatment systems (**Fact Sheets T2** and **T3**, respectively). In suspended growth systems microorganism and wastewater are continuously mixed in a well-aerated tank. Aeration is often provided mechanically by compressors or blowers that introduce air into the water. In fixed growth systems, wastewater is applied to a fixed surface (typically using a pump) and microorganisms become established and break down the constituents. This action provides tremendous surface area for oxygen transfer. There are many variations of suspended and fixed growth systems, most of which are proprietary. The main objective with all these options is to provide the proper (aerobic) environment for beneficial microorganisms to become established so that they can process the carbon in organic matter. In contrast to these high-rate systems, simple, passive, natural systems such

Quick Definitions

Secondary Treatment:
Biological and chemical treatment processes designed to remove organic matter; a typical standard for secondary effluent is BOD and TSS less than or equal to 20 mg/L each on a 30-day average basis.

Biochemical Oxygen Demand (BOD):
Amount of oxygen required by bacteria while stabilizing, digesting, or treating wastewater under aerobic conditions; an indirect measure of the amount of organic matter in wastewater; a measure of the relative strength of wastewater expressed in mg/L.

Total Suspended Solids (TSS):
Measure of all suspended solids in a liquid, typically expressed in mg/L.

For more information, see:
T2: Suspended Growth Aerobic Treatment
T3: Fixed Growth Aerobic Treatment

as constructed wetlands (**Fact Sheet T4**) and lagoons (**Fact Sheet T5**) remove BOD at a slow rate. Oxygen moves into the water at the interface between the water and the atmosphere.

For more information, see:
T4: Constructed Wetland Systems
T5: Lagoons

Additional oxygen demand is exerted by other constituents in wastewater. The breakdown of discarded proteins releases nitrogen, phosphorus, and other compounds. As nitrogen is released, it is converted to the ammonium form (NH_4^+). Like organic matter, ammonium nitrogen creates a demand for oxygen as microorganisms convert ammonium to nitrate nitrogen (NO_3^-). The aerobic (oxygen-rich) conditions provided in secondary treatment components facilitate this conversion.

Nutrient Reduction (Tertiary Treatment)

The breakdown of organic compounds releases nitrogen and phosphorus. These two compounds are considered nutrients (fertilizers). When excessive amounts of nutrients are discharged into a surface water body, excessive growth of algae and other photosynthetic organisms can occur and degrade water quality. Further, the nitrate (NO_3^-) form of nitrogen is considered a human toxin if excessive levels are present in drinking water supplies.

Quick Definitions

Tertiary Treatment:
Advanced treatment of wastewater for enhanced organic matter removal, pathogen reduction, and nutrient removal; typical standards for tertiary effluent vary according to regulatory requirements.

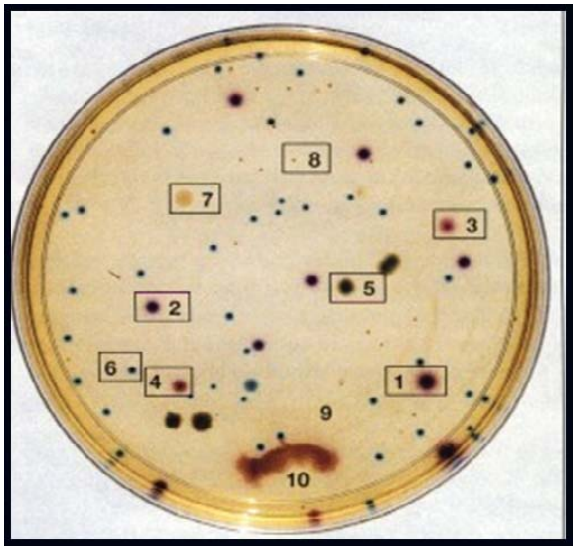
Both nitrogen and phosphorus are essential elements for microorganisms. During treatment, some nitrogen and phosphorus is incorporated into new cells. When these cells are removed with other solids some nitrogen and phosphorus is also removed. If additional nitrogen reduction is required, other processes can be incorporated into treatment systems. Additional phosphorus can be removed through chemical precipitation using metals (such as aluminum or iron) which react with soluble phosphate to create an insoluble form that can be removed as part of the sludge. Many soils have the capacity to sequester (tie-up) phosphorous. The relative capacity for this is dependent upon the soil mineralogy. Processes for Nutrient Reduction are discussed in **Fact Sheet T6.**

For more information, see:
T6: Nutrient Reduction

Pathogen Reduction (Tertiary Treatment)

Large populations of (non-pathogenic) coliform bacteria live in the human intestinal tract, a portion of which are regularly discharged from the body during a bowel movement. Since it is impractical (if not impossible) to measure for the presence of all disease-causing organisms, water samples are often tested for fecal coliform bacteria to determine whether water has been contaminated with sewage. If coliform bacteria are detected in a water sample, it is an indication that pathogens (from sewage) are likely to be present.

Disinfection (discussed in detail in **Fact Sheet T7**) reduces the number of pathogenic organisms such that the probability of disease transmission is very low. If low numbers of indicator coliform bacteria are found after disinfection, the water is assumed to be safe. *Note that disinfection does not mean that water is sterile.* It simply means that the number of pathogens are below a certain level and considered safe. Disinfection is generally the last treatment process before effluent dispersal. Chlorine and ultraviolet light are two common agents used for disinfection. Chlorine is very strong oxidizer and breaks down the cellular structure of microorganisms. Ultraviolet light is used to irradiate microorganisms and damage the DNA and RNA such that they are unable to reproduce.



Disinfection does not mean that water is sterile, but numbers of pathogens are significantly reduced. Plate counts (Above) are performed to determine the amount of indicator bacteria in a sample.

For more information, see: T7: Disinfection

Residual organic compounds and solids can interfere with the disinfection process. Since chlorine will also oxidize residual organic compounds, these compounds must be reduced to a reasonably low level through prior treatment so that the chlorine can act primarily upon the pathogens. Likewise, in order for UV disinfection to be effective, the influent must have low turbidity (be relatively clear) to allow the transmission of UV rays into the water. Chlorine and UV Disinfection are thus only effective if effluent has received both primary and secondary treatment.

Effluent must be relatively clear in order for disinfection methods to be effective.

Residuals Management

Solids removed from wastewater must still be managed. This includes solids retained in septic tanks through settling (sludge) and floatation (scum) as well as the bacterial cells and waste products that accumulate during clarification in suspended growth unit processes. When solids are periodically removed from these components, they are known as *residuals*. Residuals are frequently placed in approved landfills or on permitted land application sites. Alternately, they may be subject to co-treatment at municipal wastewater treatment plants or treated at a plant dedicated to their stabilization. **Fact Sheet T8** describes various options for residuals management.

For more information, see: T8: Residuals Management

Collection: Moving it All to One Place

Designing and installing a wastewater collection system is the most expensive component of developing a community wastewater infrastructure. Unless treatment and dispersal components are located at every site, each wastewater-generating structure must be connected to a common collection system so that wastewater can be transferred to a location where treatment can be accomplished. The process of installing a collection system results in considerable disruption as right-of-ways and easements become construction zones. It is a logistical challenge to plan the construction in such a manner that minimizes the impact to the citizens and to private property. The community must be aware of the cost and disruption in light of their resources and vision.

Sewers can be designed to convey all the wastewater (both solid and liquid) or they may convey only the liquid portion (effluent). They may be designed to operate by gravity, pressure or vacuum. Each option has its advantages relative to installation cost, long-term operation and maintenance as well as the space that each occupies. Some methods can be used in combination. The following is a general description of broad categories of Collection options. Detailed Fact Sheets are referenced for each of the four options discussed below.

Gravity Sewer Systems

Gravity sewers (**Fact Sheet C1**) can be used when the treatment facility is at an overall lower elevation than most of the homes and businesses being serviced by the system. Each building sewer is connected to the main sewer. Some sections of the main system may require lift stations to collect and pump wastewater over a hill. Manholes are necessary for system maintenance, and are typically placed every 300 feet and at each change of direction. If a building sewer is at an elevation that does not allow gravity flow to the

Gravity sewers require large diameter pipe.

sewer main, it can be connected to a basin fitted with a grinder pump. The pump is fitted with blades that grind the solids as wastewater is sent to the gravity main. Overall, gravity sewers use large diameter pipes and can require relatively deep excavations to maintain the required slope.

For more information, see:
C1: Gravity Sewer Systems

Pressure Sewer Systems

With Pressure sewer systems (**Fact Sheet C2**), each residence or business is connected to a basin fitted with either a grinder pump or a sewage pump that moves the wastewater into the main sewer. Grinder pumps are fitted with blades that grind the solids, while sewage pumps are capable of pumping solids up to 3 inches in diameter. In either case, the mainline is pressurized as each pump activates. Pressure sewers have smaller diameter pipe than gravity sewers. Because the pipes can be located at a shallow elevation, they can be installed in areas with irregular terrain, rocky conditions, or high groundwater where gravity sewers might not be practical. The pumps and controls used at each connection must be maintained.

For more information, see:
C2: Pressure Sewer Systems

Effluent Sewer Systems

Primary treatment (liquid-solid separation) may be integrated into a collection system by installing a septic tank fitted with an effluent screen at each site. The tank receives the wastewater and retains solids The effluent is then conveyed by either gravity or pressure to the main transmission line. These configurations are known as effluent sewers and are described in **Fact Sheet C3.** There are two basic types of effluent sewers: Septic Tank Effluent Pump (STEP) and Septic Tank Effluent Gravity (STEG). In STEP systems, an effluent pump installed in the outlet of the septic tank sends the effluent to the main sewer line. In STEG systems, effluent flows by gravity from the septic tank to a gravity mainline. STEG systems are very similar to conventional gravity sewer systems except that the system hydraulics do not have to account for solids in the wastewater. This allows use of

Effluent sewer systems include a septic tank with an effluent screen at each site.

smaller diameter pipes and shallower installation. However, maintenance is still needed. The pumps and controls used with STEP systems must be maintained. Because effluent sewers depend on primary tanks and screening on each lot, the accumulated solids must be periodically removed from septic tanks and effluent screens must be maintained. This means that each source must be inspected on a regular basis.

For more information, see:
C3: Effluent Sewer Systems

Vacuum Sewers

In a vacuum sewer system (**Fact Sheet C4**), pumps located at a central vacuum station are used to create negative pressure in sewer lines. A basin or pit fitted with a vacuum valve collects wastewater from one to several wastewater sources. After a predetermined volume of wastewater enters the pit, the vacuum valve opens. The pressure difference between the valve pit and the main vacuum line pulls the wastewater through the service line and into the main vacuum line. Like pressure and effluent sewers, vacuum sewers use small diameter piping installed at a shallow elevation. The vacuum pumps and vacuum valves require regular inspection and maintenance.

For more information, see:
C4: Vacuum Sewer Systems

Management Programs: Creating a Sustainable Infrastructure

Things to Consider

Every community must include a management component as it considers wastewater infrastructure options. Regardless of the dispersal, treatment and collection system components chosen, a management program should be designed in accordance with the community's resources and implemented with consideration of the vision of its future. However, a management program must include the entire range of activities associated with decentralized systems including proper design, siting, and installation in addition to effective and ongoing operation and maintenance. All of these elements must be implemented with conscious consideration of risk to public health and the environment and the complexity of the technologies used. Increased risk and complexity necessitate higher level of diligence. However, ***all systems require some level of management***. The community should begin by assessing the existing regulatory framework since it will influence the approach to management. Next, it must consider the skills required to provide the appropriate level of management needed for the components selected. The basic O&M requirements for each unit process are discussed in the Supplemental Fact Sheets in this series. Finally, the community must also evaluate the financial environment to determine whether it should take on all aspects of management or offer opportunities to private sector entities. Fiscal sustainability must be the foundation for whatever approach is used.

The U.S. EPA's *Voluntary National Guidelines for Management of Onsite and Clustered Wastewater Treatment Systems* describes a range of management options. Detailed, practical information on implementation of various approaches can be found in a series of Fact Sheets on **Establishing Successful Responsible Management Entities (RME)** published by the Water Environment Research Foundation (WERF) and available on line at http://www.werf.org/rme. The following discussion provides basic information on the types of management programs communities might consider and a brief discussion of the costs associated with each. Leaders and Planners must remember that Management includes all aspects from source through collection and treatment to dispersal.

Levels of Management

The Bare Minimum: Owner Education and Practitioner Training

Typically, all systems are subject to some level of public health regulatory oversight. Often, prescriptive codes dictate the size and nature of individual systems and the required maintenance. Codes may even require certification of professionals to ensure proper and timely site and soil evaluation, design, installation and maintenance. In low-risk contexts (simple technology and few serious consequences from malfunction), the system owner may be capable of providing the long-term maintenance. Historically, this has not been the case as system owners tend to adopt an 'out-of-sight/out-of-mind' mentality or are unaware of their role. Educating the public on the proper use (and avoiding misuse) of systems with relatively simple technologies can be accomplished through public service announcements, factsheets on system care, public workshops and regular notices to perform maintenance at appropriate intervals. This level of management requires trained professionals to disseminate information to the public, answer questions and provide guidance. It also requires that skilled private sector professionals be available to provide inspection and maintenance services on this level, including tank pumpers with appropriate training in residuals management. Communities may employ public resource officers to provide guidance, track systems and notify system owners. Public education and professional training can effectively be accomplished through local Cooperative Extension personnel associated with Land Grant Universities. Local, state and national wastewater professional associations may be a

Links to Training and Education Resources:

www.onsiteconsortium.org

www.epa.gov

www.nawt.org

www.neha.org

www.nowra.org

resource as well. A wide range of materials for outreach education and training for both citizens and service providers is available. In addition to the U.S. EPA, the Consortium of Institutes for Decentralized Wastewater Treatment (CIDWT) offers links to educational brochures for the public and website links to training resources and opportunities (www.onsiteconsortium.org). The National Environmental Health Association (NEHA - www.neha.org) and the National Onsite Wastewater Recycling Association (NOWRA - www.nowra.org) are professional organizations with additional resources. Costs to the community associated with management on this level are relatively low, consisting of system tracking and information dissemination unless the latter is left to others. Service providers would compete in the private sector to offer necessary maintenance at appropriate prices, offering an economic opportunity.

Maintenance Contracts

The public health regulatory authority may require that system owners secure maintenance contracts for systems with greater complexity. This would include collection, advanced treatment and dispersal options. The nature and frequency of maintenance activities may be codified and certification or licensure of a service provider may be required. In this case, the costs to the community include supporting the activities of public health officials to track contract execution and required certifications. If failure to contract has an associated penalty, enforcement costs must be included as well. Another economic opportunity is created as certified service professionals compete in the private sector. Costs to system owners include maintenance contracts, removal of solids from collection and treatment components, and the cost of replacement parts as they are needed. This management approach might be enhanced by the addition of an operating permit requirement discussed in the next paragraph.

Requiring maintenance contracts between system owners and service providers is another management option.

Operating Permits

When performance-based codes are implemented to encourage or facilitate use of more advanced collection, treatment and dispersal technologies, the local regulatory authority may issue operating permits for systems. Permit renewal is based upon meeting conditions for proper maintenance at the designated frequency and achieving reasonable system performance. Certified or licensed service providers may be part of the equation and act as a Responsible Management Entity or RME. The permitting authority monitors system performance, and carries out enforcement in cases of non-compliance. They may even act as the service provider. If the permitting authority services systems, additional costs might include travel, time spent on the site, lab analysis of collected samples and overhead associated with employees. The community must bear the cost of logistical and administrative support for the permitting authority. These costs might be offset by renewal fees for operating permits. Costs to the system owners would typically include permits, maintenance contracts, solids removal and disposal as well as the cost of replacement parts as they are needed.

RME Operation and Maintenance

Where public health and environmental risk increase, a community might consider requiring system management on behalf of the property owners. A qualified organization with certified or licensed personnel maintain all collection, treatment and dispersal components in exchange for a fee paid by the owners. This is known as "contract operation" since the RME makes sure that the system is in compliance, but does not own the infrastructure.

RME Ownership

Alternately, the RME might actually own the entire infrastructure in addition to providing maintenance to ensure compliance. The RME might be one of several types of organizations depending upon their structure, the services they provide and their legal status. Options include: a government-owned public utility; a privately owned, publicly regulated utility; a limited liability, for profit entity, or; a private not-for-profit organization such as a cooperative.

Applicability of Management Approaches

An existing community might conclude that the status of their existing infrastructure dictates the implementation of a program of maintenance contracts or operating permits. Development of new systems lends itself well to using management via RME operation and maintenance or even RME ownership because oversight can be provided at the very beginning. The ability to combine management of individual systems with residential/ commercial clusters should be considered by using a combination of the management options. Regardless of the management option chosen, public education, practitioner certification, system tracking and appropriate handling of residuals (by either the public or private sector) are an essential part of **ALL** management programs.

Educating the public and training service providers are essential components of ALL management programs.

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3.0 FACTS SHEETS

3.1 COLLECTION SERIES

Fact Sheet C1

Performance & Cost of
Decentralized Unit Processes

Water Environment Research Foundation
Collaboration. Innovation. Results.

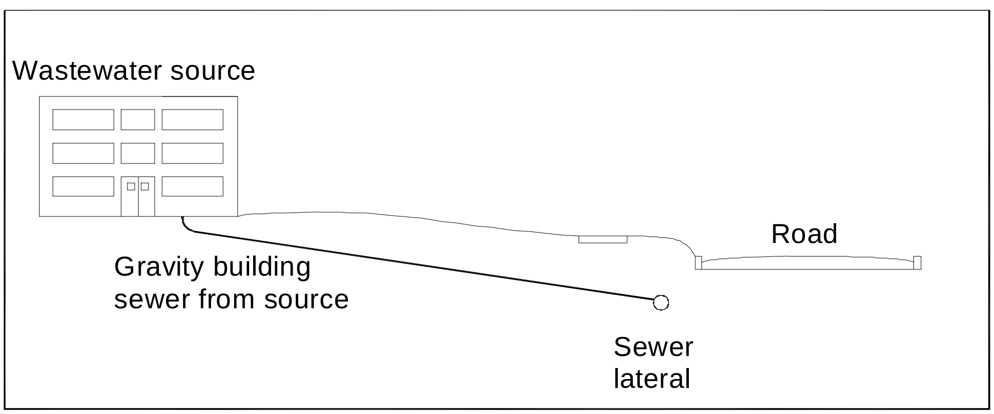
DECENTRALIZED WASTEWATER SYSTEMS

COLLECTION SERIES

GRAVITY SEWER SYSTEMS

What is a Gravity Sewer System?

A gravity sewer system is used to collect wastewater from multiple sources and convey the wastewater by gravity to a central location. Wastewater from each source is conveyed through a building sewer to a collection line. Collection (sewer) lines are typically eight-inch or larger diameter pipe. Pipe diameters increase with increasing volume of water being transported. Pipes are installed with sufficient slope to keep the suspended solids moving through the system. If gravity flow is not possible throughout the system, lift stations (pumps) are employed. Lift stations are installed at lower elevations of the network in order to pump the sewage up to another gravity line, to convey wastewater over hills, and/or up to a treatment facility. Manholes are installed at regular intervals to provide maintenance access to collection lines.



Properly designed and constructed gravity sewers are a viable collection option for urban areas, but can be expensive for small communities. In its purest form (i.e., uniform slope from service connections to treatment components) gravity is an inexpensive means to convey water. However, the topography is rarely conducive to purely gravity flow, and lift stations must often be included. The cost of gravity sewers may be prohibitive unless there is sufficient population density to justify the installation.

Selecting any wastewater collection option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

Compatibility with the Community Vision

Installation costs for gravity sewers are significant. The community must have a good vision of its future to ensure that the sewer is properly sized. If the capacity for long-term use is built into the design, the system can accommodate the anticipated growth for the next 50 or more years. Realistically, over-building the sewer means that the current users will bear the cost of that future use.

Once installed, the components of a gravity sewer are minimally visible. Manhole lids and lift stations will be evident at the surface but are not obtrusive. Odors may be associated with access points and odor control may be necessary. The potential loss of trees or other local charm during installation must be considered because of the need for broad and deep cuts during excavation. For this reason, it is a common practice to install sewers under paved roads resulting in severe and lengthy community disruption.

When considering options for a Management Program, the community must decide whether on-lot costs for installation, maintenance and repair will be borne directly by the landowner or spread across the community.

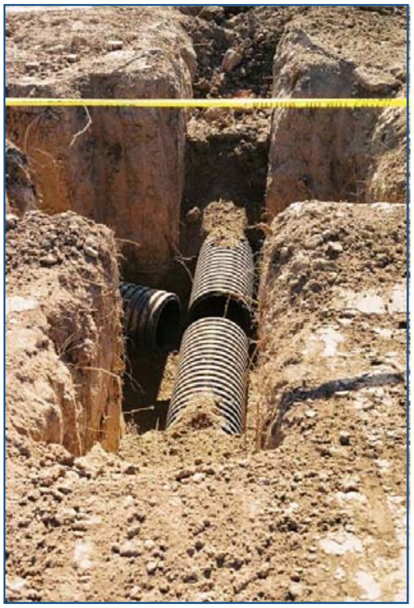
Land Area Requirements

The land area required for a gravity sewer system is a function of the area required for installation of piping. Horizontal Directional Drilling (HDD) boring can minimize the need for large, deep trenches that disrupt existing utilities, landscaping, roads and driveways. Additional land will be required for each lift station. Lift stations can be fairly compact, but sufficient space is needed to install a wet-well, pumps and controls, and the electric service. Manholes do not require additional land, but they must be accessible.

Note that additional land area will be required for the treatment and dispersal components selected by the community.

Construction and Installation of Gravity Sewer Systems

Gravity sewers must be installed so that the pipeline has a sufficient slope to prevent suspended solids from settling. If the community has relatively flat topography, the sewers will get progressively deeper (and more expensive) along their length. In rolling terrain, the sewer lines are installed to move wastewater from the



top of hills to the valley bottom. If the slope is sufficient to transport sewage, then the pipeline need not get deeper with length.

Installation of pipe, manholes, lift stations, building connections, junction chambers or boxes and terminal cleanouts requires large amounts of excavation. This results in disruption of utilities, temporary road closures and detours. Overall, there is a significant amount of disturbance over a long duration associated with the installation of traditional gravity sewer. However, once installed, most gravity components are either below ground or flush with finish grade.

Most jurisdictions set the minimum sewer pipe diameter at eight inches. As more wastewater is collected and carried by a given pipeline, the pipe diameter must increase. Although larger pipes require wider excavations, pipe depth is the primary driver for excavation costs. The pipes are sized to carry the peak flow rate that would be expected from a given service area. The peak flow rate is often calculated as four times the daily flow rate plus an estimation of the amount of groundwater infiltration that will occur.

Licensing requirements for personnel who install gravity sewer systems varies with jurisdictions, but typically they must be licensed as a public utility contractor by the state or region in which they work.

Operation and Maintenance

Effective operation of a conventional gravity sewer begins with proper design and construction. Regular inspection of system components is critical. Leaky pipe connections are a potential source of groundwater and stormwater infiltration. This extra water must be treated. Infiltration must be controlled, or the capacity of the treatment system will be exceeded during wet weather conditions. Modern construction materials have reduced the infiltration issue. However, tree roots, shifting soils, and poor pipe connections (especially to manholes) are still major problems and gravity sewers commonly are designed to carry up to 40% clear water.

Regular service is important for all systems to ensure best long term performance to protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of any pretreatment components used prior to dispersal.

Proper maintenance includes periodic line repairs and inspection, cleaning out blockages, and repairing areas where significant infiltration is occurring. On an approximate 10-year rotation, each sewer line should be inspected via a down-the-hole closed-circuit camera so that areas needing repair can be identified. Service providers must have the knowledge and skills related to sewer cleaning technologies and the associated safety precautions. Operators must have proper training and may be subject to certification requirements depending upon jurisdiction.

Costs for Gravity Sewer Systems

Installation costs include five major factors: Pipe diameter, excavation depth, total length, restoration, and labor. Larger flows require larger diameter pipe which is more expensive. Deeper, excavation may be required to provide sufficient slope or overcome soil and site issues. The extent of site disturbance and nature of the restoration required affect costs. Roads, sidewalks, and yards will be highly disturbed during installation. Existing utilities may have to be moved or worked around. Horizontal Directional Drilling (HDD) can be used in some cases to minimize time and money during actual installation because utility replacement, road closings, detours and expensive dewatering and restoration costs associated with trenching are substantially reduced. While each of these factors is system-specific, the purchase and installation of gravity sewer components could easily range from $100 to $200 and more per foot of main line service.

Larger flows require larger diameter pipe for gravity sewer systems. Deeper (and more expensive) excavation is also needed but the cost may be offset by the fact that pumps and lift stations are only required in areas with inadequate slope for gravity flow.

Gravity sewers in cluster or small community systems do not include septic tanks for primary treatment on each lot. Thus, the central treatment facility must provide primary treatment (liquid-solid separation).

If gravity flow can be maintained throughout the system, there is no electrical requirement. If lift stations are needed, energy costs vary according to the number, specifications and size of the pumps used. The required number of lift stations is dependent on the topography of the community. Engineers will evaluate the location and strive to use gravity flow to collect wastewater and direct it to points of lower elevation. At these low points in the system, lift

For other Collection system options, see:

Factsheet C2: Pressure sewers

Factsheet C3: Effluent sewers

Factsheet C4: Vacuum sewers

stations followed by short pressure mains can be installed to move the wastewater back to a higher elevation. The energy cost will depend on the daily wastewater volume and the distance (both horizontally and vertically) that wastewater has to be transferred.

Tables 1-3 are cost estimations for the materials, installation, and maintenance of conventional gravity sewer. These costs assume an estimated average distance between wastewater sources of 200 feet, relatively flat topography, 20% overhead and profit to the contractor, and no sales tax on materials. Engineering fees and other professional services are not included in the costs. Communities may choose to have lot owners pay for materials and installation of on-lot components. Tables 1 and 2 assume that the lot-owner will build and maintain the system components that are installed on-lot and that the utility will build and maintain the collection network. Table 3 assumes that a utility will build the collection network and the on-lot components; however, the lot-owner would still be responsible for the building sewer maintenance. For the purpose of estimating costs, Tables 2 and 3 provide three example gravity sewer systems developed and priced for flows ranging from 5,000 to 50,000 gpd. The costs given in this document are for comparison purposes only. The actual cost for a system will vary tremendously depending on site conditions and local economics. The costs for the systems below include piping, manholes, installation, and maintenance. These examples do not include a lift station.

Table 1. Estimated cost to the lot owner if utility does not cover the materials and installation of on-lot components.

On-Lot Cost	Cost Issues	Costs
Materials and Installation	Install building sewer and connect to sewer main	$1,800 - $2,700
Annual electricity	No energy unless source needs lift pump to sewer main	-0-
Annual O&M	Annualized cost to clean building sewer	$16 - $24 per yr

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

Table 2. Estimated cost of materials and installation to build the collection network not including the on-lot components.

Network Cost	Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$210,000 - $315,000	$419,000 - $629,000	$2,182,000 - $3,273,000
Annual O&M	$6,400 - $9,600	$12,800 - $19,200	$65,000 - $97,000
Annual electricity	Lift stations are the primary energy demand for gravity collection systems		

Table 3. Estimated cost of materials and installation for utility to install both the collection network and on-lot components

	Wastewater Volume (gpd)		
Network and On-Lot Cost	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$234,000 - $352,000	$469,000 - $703,000	$2,429,000 - $3,644,000
Annual O&M	$6,400 - $9,600	$12,800 - $19,200	$65,000 - $97,000
Total Cost per lot	$11,700 - $17,600	$11,700 - $17,600	$12,000 - $18,000
60 year life cycle cost – present value (2009 dollars)	$435,000 - $653,000	$871,000 - $1,306,000	$4,472,000 - $6,708,000

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Fact Sheet C2

Performance & Cost of
Decentralized Unit Processes

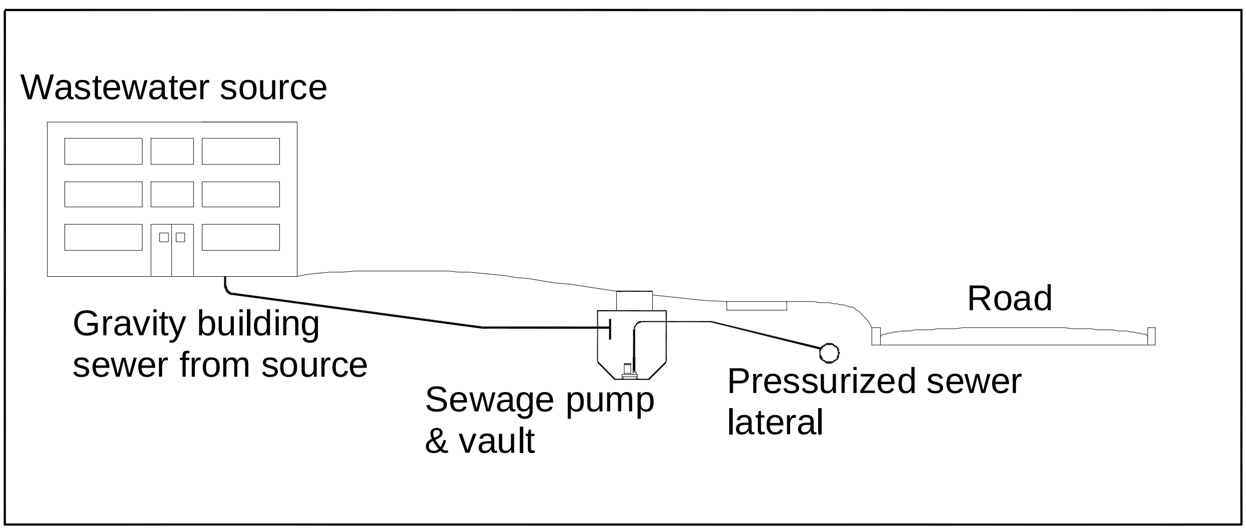
DECENTRALIZED WASTEWATER SYSTEMS

COLLECTION SERIES

PRESSURE SEWER SYSTEMS

Pressure Sewers and Their Use

Pressure sewers are a means of collecting wastewater from multiple sources and delivering the wastewater to an existing collection sewer, and/or to a local or regional treatment facility. Pressurized sewers are not dependent on gravity to move wastewater; and thus there is less concern about the local topography. A typical arrangement is for each connection (or small cluster of connections) to have a basin that receives wastewater. When the basin fills to a set point, a pump within the basin injects wastewater into the sewer. This transfer of wastewater pressurizes the sewer. As various pumps along the length of the sewer inject sewage into the line, the wastewater is progressively moved to the treatment facility.

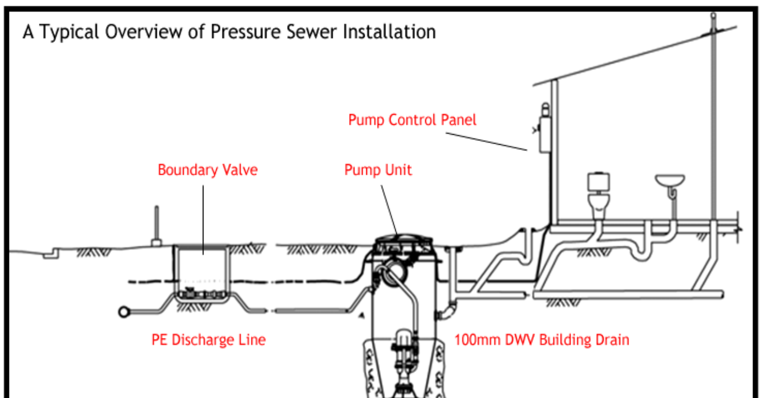


The principle advantage of pressure sewers is the ability to sewer areas with undulating terrain, rocky soil conditions and high groundwater tables. Because lines are pressurized, sewer pipe installation can follow the surface topography and remain at a relatively constant depth below the soil surface. As compared to gravity sewers, pressure sewers have smaller diameter pipes. Shallower placement, lack of manholes or lift stations and longer sections of smaller diameter piping equates to a less expensive and less obtrusive installation. This is especially true for road crossings. Horizontal directional drilling (HDD) allows small diameter systems to be installed without disrupting traffic, opening trenches across paved roadways, or moving existing utilities. The piping can also be located along the shoulder instead of the middle of the paved surface.

A community has four basic options when choosing a means of collecting wastewater. This factsheet will focus on solids-handling pumps as a means of taking all the wastewater from a source. The other options are gravity, effluent and vacuum sewers. These three options are discussed in other Fact Sheets in this series. Often, collection technologies can be combined within the same network to provide the best solution for a small community. The most common hybrid includes solids -handling pumps in combination with gravity sewers.

For more information, see:
Factsheet C1: Gravity sewers
Factsheet C3: Effluent sewers
Factsheet C4: Vacuum sewers

The typical installation includes a pump basin at each home or business. This basin provides some wastewater storage. When a designated volume of wastewater has been produced, the pump engages and transfers the sewage into the sewer line. A pump basin for an individual residence typically has a capacity to store about 30 to 70 gallons between pumping events. Each pump basin contains floats or pressure sensors that detect the water depth in the basin. When the predetermined depth is achieved, the pump activates and continues to remove wastewater until a low-water level is reached. Backflow into the pump basin is prevented by a check valve that is integral to the pump. Most pumps operate on 240VAC, which is easily available from the home or business that is being serviced by the pressure sewer system



Source: pressuresewerservices.com

As a comparison, conventional gravity sewers use a few (but large) lift stations to offset excessive excavations that are often required to achieve minimum slope or to move sewage over hills. Pressure sewers have small pump stations at each connection. There are advantages and disadvantages to each method. For a small community, the primary advantage of pressure sewers is the reduced cost of sewer pipe installation. Small communities have smaller population densities; and therefore, there are fewer people per square mile of service to bear the cost of the system.

Compatibility with Community Vision

Selecting any wastewater collection option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

Pressure sewer systems are expandable. A community may desire to only provide sewer to the existing population. As new neighborhoods are established, it might be reasonable to connect them to the collection system on an as-needed basis if there is sufficient available capacity. A better solution might be to create a new cluster or neighborhood system to service them. In contrast, conventional gravity sewage collection systems are generally built to accommodate maximum growth that may or may not occur and are difficult to finance through the current users.

A management issue that was addressed early in the history of pressure sewers was that of pump ownership. Some communities chose to put the burden of ownership on the property owners and homeowner associations with disastrous results. Today, pressure sewer systems are wholly maintained by a local utility (either private or public). In most cases, the connection fee includes the cost (including installation) of all the on-lot components. The operation and maintenance costs are amortized into the monthly sewer bill. This level of utility ownership helps to ensure consistent and sustainable performance.

Land Area Requirements for Pressure Sewers

The on-lot land area required for a pressure sewer system is a function of the area required for installation of the pump basin and the piping that connects it to the sewer main. A single-family home will typically have a basin with 30 to 70 gallon capacity installed below ground with a tank lid 18 to 30 inches in diameter that allows access to the pump and controls. Institutional, commercial or industrial facilities (schools, restaurants, supermarkets, apartment complexes factories, etc.) will have larger basins and may require multiple pumps.

Note that additional land area will be required for the treatment and dispersal components selected by the community.

Construction and Installation of Pressure Sewers

Pressure sewer systems can typically be installed with trenchers and small excavators. Trenches for small diameter pipes can often be dug and restored in the same day. The collection network is comprised of mostly two-inch to six-inch diameter plastic pipe. Occasional clean-outs, air release valves at high points, isolation valves, and other components must also be installed within the network. Large, deep trenches are rarely needed with pressure sewers. The shallower trench width and depth results in minimum surface disturbance, and quicker restoration. Directional boring can reduce highway closures and other urban disruptions and save both time and money. The small diameter piping is flexible and can be routed around obstacles. Pressure sewer mains can often be located on the shoulder of the road.

A licensed electrician must run a circuit from the owner's electrical breaker box out to a sub-breaker box on the exterior of the house or business located near the pump. Once the pump basin has been set, the electrician connects the pump and controls to the owner's electric service.

Licensing requirements for personnel who install pressure sewer systems vary, but they must typically be licensed as a public utility contractor by the state or region in which they work.

Operation and Maintenance for Pressure Sewers

Solids-handling pumps are used under harsh conditions. Corrosive gases and moisture in pump basins will eventually penetrate seals and bushings, resulting in pump failure. These small pumps are designed to be rebuilt, which is more economical than replacing the pump. They are rugged devices, but they are only intended to move the food wastes, fecal solids and the associated paper products, not plastic or metallic objects. When considering the nature of their management program, the community must decide who is financially responsible for pump repair and replacement costs.

Regular service is important for all system components to ensure best long term performance to protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of components used.

Pressurized sewer systems transmit the entire wastewater flow, thus providing the possibility of oils and fats congealing in the pipe network. System cleaning is not normally required for properly designed systems, but if cleanouts are installed in the network, cleaning procedures are facilitated. It is rare that mainline clearing is required. On-lot service line cleaning can be minimized by requiring all commercial food preparation businesses to install grease interceptors before the grinder pump to remove excessive fats, oils and grease (FOGs).

Because the system is pressurized, it is inherently watertight and groundwater infiltration should not be a problem. However, the pump basins must be periodically inspected to ensure that surface water and groundwater are not entering the system through the building sewer. Illegal connections from downspouts, foundation drains and similar sources must be identified and excluded. Avoiding excessive water inflow prevents overloading the pump and wastewater treatment facility.

Costs for Pressure Sewers

The cost of a pressure sewer system can be divided into two major components: The on-lot cost and the collection network cost. On-lot costs include the pump, basin, controls, building sewer, lateral piping, electrical service, and installation. The collection network includes all the piping in the utility easements that directs the sewage to the treatment facility. A small community may consider several means of funding a pressure sewer system. One means is to secure sufficient funding to install the collection network and install the on-lot components. Federal funding and low interest loans are sometimes available to fund these projects. A second means is for the utility to build the collection network and charge each connection for the on-lot cost. Depending on the style of pump and basin selected by the managing utility, on-lot costs are estimated to be $4,800 to $7,200 for an existing single-family home. Typical solids-handling pumps will use less than 1kW-hr of power per day and the electrical cost would be about 50 dollars per year depending upon local electrical rates.

Using many low power-consuming pumps reduces installation cost as compared to a conventional gravity system that may require one or more large-capacity lift stations. Further, it allows more flexibility in choosing locations for and routes to treatment facilities. Larger capacity pumps require three-phase electricity, and this may not be available in remote areas within small communities.

Tables 1-3 are cost estimations for the materials, installation, and maintenance of pressure sewers. These costs assume an estimated average distance between wastewater sources of 200 feet, relatively flat topography, 20% overhead and profit to the contractor, and no sales tax on materials. Engineering fees and other professional services are not included in the costs. Communities may choose to have the lot owners pay for the materials and installation of the on-lot components. Tables 1 and 2 assume that the lot-owner will pay for the system components that are installed on-lot and that the utility will build and maintain the collection network. Table 3 assumes that a utility will build and maintain the collection network and the on-lot components. Tables 2-3 also provide cost estimates for the collection network for three different sizes of communities.

Table 1. Estimated cost to the lot owner if utility does not cover the materials and installation of on-lot components.

On-Lot Cost	Cost Issues	Costs
Materials and Installation	Pump, pump basin, pump controls, excavation, and connection to network	$4,800 - $7,200
Annual electrical	Estimated at 1 kW-hr per day (paid by the lot owner)	$44 - $66 per yr
Annual O&M	Annualized major pump overhaul every 10 years	$120 - $240 per yr

Table 2. Estimated cost of materials and installation to build the collection network not including the on-lot components.

Network Cost	Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$33,000 – $49,000	$65,000 - $98,000	$344,000 - $516,000
Annual O&M	$6,400 - $9,600	$13,000 - $19,000	$56,000 - $84,000
Annual electricity	No network energy cost unless lift stations are needed		

Table 3. Estimated cost of materials and installation for utility to install both the collection network and on-lot components

Network and On-Lot Cost	Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$132,000 - $199,000	$265,000 – $397,000	$1,341,000 - $2,012,000
Annual O&M	$11,000 - $16,000	$21,000 - $32,000	$106,000 - $159,000
60 year life cycle cost present value (2009 dollars)	$243,000 - $365,000	$811,000 - $1,216,000	$4,707,000 - $6,106,000

References

1. Crites, R. and G. Tchobangolous. 1998. Small and Decentralized Wastewater Management Systems. WCB/McGraw Hill Company, Boston, MA.

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3. U.S. EPA. 1991. Alternative Wastewater Collection Systems. Office of Water, Technology Transfer Manual, EPA/625/1-91/024, Washington, DC.

4. Water Environment Federation. 2008. Alternative Sewer Systems, Manual of Practice FD-12, Second Edition. WEFPress, Alexandria, Virginia.

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Fact Sheet C3

Performance & Cost of
Decentralized Unit Processes

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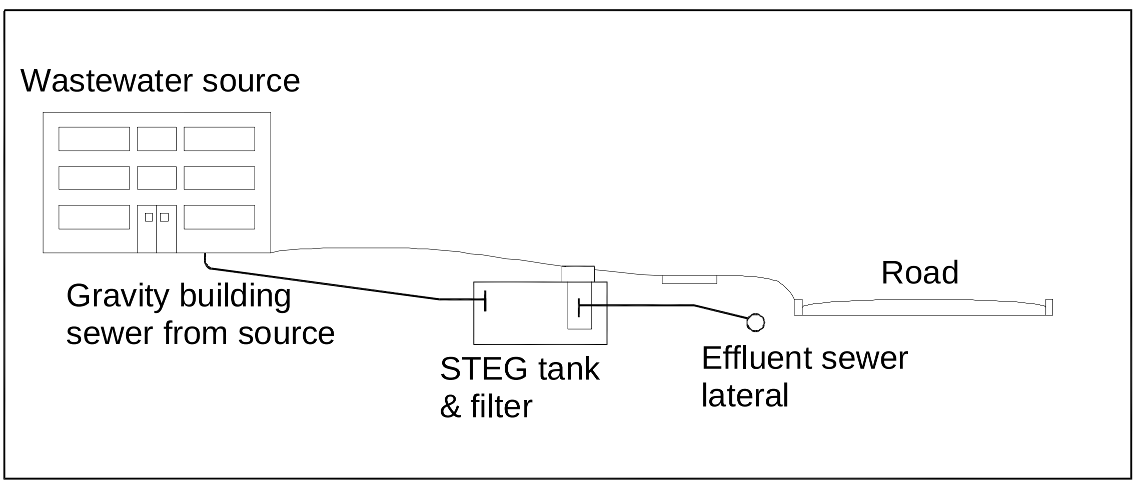
DECENTRALIZED WASTEWATER SYSTEMS

COLLECTION SERIES

EFFLUENT SEWER SYSTEMS

Effluent Sewer Systems and Their Use

The term effluent is commonly defined as *liquid flowing out of a com ponent or device after undergoing treatment.* An effluent sewer carries wastewater that has undergone liquid/solid separation or primary treatment. Septic Tank Effluent Pump and Septic Tank Effluent Gravity sewers (commonly referred to as STEP or STEG) use on-lot septic tanks to provide liquid/solid separation. Raw sewage flows from the house or business to a watertight underground tank (septic tank). The clarified effluent then moves into the collection system using either a pump (STEP) or gravity (STEG). As a collection system, effluent sewers are used to convey effluent from multiple sources to a central location where it can be treated. STEP and STEG configurations can be combined within a given system.



In a STEG system, each source or group of sources has a watertight septic tank with an effluent screen and an access riser. Effluent flows out of the tank and into a collection sewer by gravity. The collection sewer is typically plastic pipe about 4 to 8 inches in diameter. The piping from the tank to the collection line includes an accessible cleanout.

In a STEP system, an effluent pump is installed within a pump vault in the outlet end of a septic tank.

In a STEP system each wastewater source or group of sources is again fitted with a watertight septic tank. However, in this case, an effluent pump (typically capable of pumping 3 or more gallons per minute) is installed in the outlet end of the septic tank or in a separate pump tank or vault. The pump injects the clarified effluent into a pressure sewer system. As each STEP pump in the collection systems operates, effluent is progressively moved toward the wastewater treatment facility.

STEG systems operate totally via gravity owing to a higher elevation relative to the treatment facility. STEP systems operate via pressure owing to a lower elevation or complex topography relative to the treatment facility. Thus, a typical effluent sewer is a mixture of STEP and STEG depending upon the location of the service lines.

Properly designed and constructed STEP/STEG systems are a viable wastewater collection option for individual residences, cluster developments as well as small communities. All styles of collection systems require significant excavation since a pipe network must be installed to connect all the wastewater sources within the designated service area. With STEP/STEG systems, the width and depth of the required excavation for piping is greatly reduced relative to conventional gravity sewers. Because a STEP system is pressurized it does not depend on a slope to move effluent. If topography allows gravity flow, then pumps are not needed at each location. While STEG systems flow by gravity, because solids have been removed in the septic tank, the pipe slope requirements are reduced or eliminated. When compared to conventional gravity sewers, STEP/STEG systems have lower installation expense and result in less community disruption.

Solids remain in the on-lot tank in STEP/STEG systems, resulting in the collection of a lower-strength effluent. Costs of downstream treatment components may thus be reduced. A STEP/STEG community must have a plan for the pumping and management of the residuals held in the tanks. See the Fact Sheet on Liquid-solid Separation for information on expected reduction of organic strength and solids that can be expected from septic tanks. Information on septage handling can be found in the Fact Sheet on Residuals Management.

For more information, see:

Factsheet T1: Liquid-Solid Separation

Factsheet T8: Residuals Management

Compatibility with the Community Vision

Once installed, the components of a STEP/STEG system are minimally visible. Cleanouts are installed within the collection network, but are not obtrusive. Odors may be associated with access points (primarily air-relief valves at high points in the system) and odor control may be necessary. Odor control is usually achieved by venting to soil beds which can be blended into local landscapes. The potential loss of trees or similar obstacles during installation is reduced because STEP/STEG systems can be built with flexible plastic pipe that can be routed around obstacles.

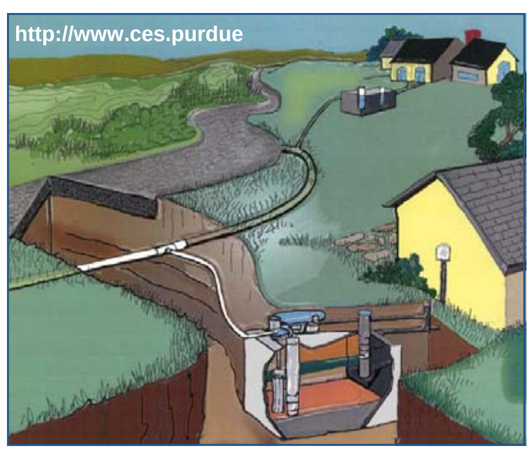
Selecting any wastewater collection option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

As with any collection system, the use of STEP/STEG can result in (or facilitate) increased population density, but these options have far less capacity to drive community growth than central sewers. Because effluent is collected and conveyed to a central location for treatment, the need for on-lot dispersal systems is eliminated. If a STEP/STEG system is being installed in community that already has septic tanks and drainfields, it is strongly recommended to abandon those components and install a new building sewer, a new tank and on-lot piping from the source to the collector in the street. STEP/STEG tanks and building sewers must be watertight so that stormwater and groundwater does not enter the system.

When considering options for a Management Program, the community must decide whether individual on-lot costs for installation, maintenance and repair will be borne directly by the landowner or amortized into the monthly sewer bill.

Land Area Requirements for STEP/STEG Systems

The land area required for a STEP/STEG system is a function of the area required for installation of the septic tank and piping. Tanks for single-family residences have a typical capacity of 1,000 to 1,500 gallons and occupy an area of about 4 feet by 8 feet. Tanks for multiple connections or commercial facilities may require larger capacity (depending upon daily wastewater volume) and thus occupy more space. The area disturbed during excavation will be larger than the dimensions of the tank.



Note that additional land area will be required for the treatment and dispersal components selected by the community.

Construction and Installation

STEP/STEG systems are built in two stages: (1) the collection network and (2) the on-lot components that provide the liquid/solid separation. The major on-lot component is the watertight tank. When possible, tanks are placed such that wastewater can flow from the source by gravity. Tanks are bedded with crushed gravel to provide level and stable support. For STEP tanks, an effluent pump is placed in a screened pump vault installed in the discharge end of the tank. A control panel is installed on the side of a building that is in close proximity to the tank. If included, cleanouts and air release devices (and associated access enclosures) are installed in the outlet piping. STEG tanks also have an effluent screen that prevents excess solids from leaving the tank. Both types of tanks must have access risers that come to the soil surface. The risers should have tamper-resistance fasteners to prevent unauthorized entry into the tanks.

Like all other alternative collection systems STEP collection network require minimum excavation. The required depth of the pipeline is minimal and can generally follow the terrain. The collection network is installed either through trenching or Horizontal Directional Drilling (HDD). HDD reduces or eliminates the need for large, deep trenches that disrupt existing utilities, landscaping, roads and driveways. STEG systems must maintain an overall slope toward a lift station or treatment facility. However, since there are no heavy sewage solids to be transported, slope can be significantly reduced or eliminated. In all cases, slope and sewage velocity requirements are less than a conventional gravity sewer. Many small communities have both STEP and STEG within the same cluster of sources.

Licensing requirements for personnel who install STEP/STEG systems varies, but they must typically be licensed by the state or region in which they work.

Maintenance Requirements

Effective operation of a STEP/STEG system begins with proper design and construction, but regular inspection of system components is critical. Leaky tanks or pipe connections are a potential source of groundwater infiltration that can overload the system's capacity. Tank residuals must be pumped out on a requisite basis (ideally, when solids are 25 to 33% of the liquid depth of the tank) and effluent screens (in STEG tanks) must be inspected annually and cleaned as needed. Service providers must be properly trained and have knowledge and skills related to effluent screens, electrical connections and controls and other sewer appurtenance technologies. They must know and observe the associated safety precautions. Operators must have proper training and may be subject to certification requirements depending upon jurisdiction.

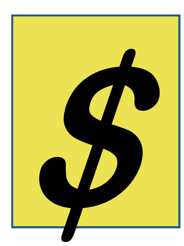
Regular service is important for all systems to ensure best long term performance protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of any pretreatment components used prior to dispersal.

If pumps in STEP configurations are installed with quick-disconnect fittings, maintenance is facilitated and replacement costs are reduced. System components should be standardized as much as possible to facilitate easy maintenance. Some wastewater sources may need more powerful pumps if they are located at lower elevations or at distant sites. When these special pumps fail, they must be replaced with pumps of similar capacity.

Typically, preventive maintenance visits are required for the on-lot components as well as the communal collection components. Historically, STEP unit service callouts are overwhelmingly related to electrical/control issues. With STEG systems, effluent screens should be checked annually and cleaned as needed.

Costs for STEP/STEG Systems

The cost of a STEP/STEG system can be divided into two major components: The on-lot cost and the collection network cost. On-lot installation costs include the pump, tank, controls, building sewer, and electrical service. A STEG system would not have the pump, controls and electric service costs. The initial on-lot costs are usually paid by the lot owner. The installer must follow the guidelines established by the utility for the selection and placement of components. Depending on the style of pump and tank selected by the utility, and the STEP pressure requirements needed to inject sewage into the network, the on-lot costs are estimated to be \$3,500 to \$5,000 for a single-family home. The electrical cost would be about 30 dollars per year.



The cost of the collection network is variable and will be driven by the primary nature of the system. For a STEP system, it will likely consist of mostly two to four-inch diameter plastic pipe. If the system is primarily a STEG, the pipe sizes are more likely to be four to six-inch plastic pipe. Included within the network are occasional clean-outs, air release valves at high points, isolation valves that allow the operator to shut down sections of the system, and other components. Installation costs must account for rocky soils, wet soils, utility easements, site restoration, and labor.

Tables 1-3 are cost estimations for the materials, installation, and maintenance of STEP/STEG effluent sewers. These costs assume an estimated average distance between wastewater sources of 200 feet, relatively flat topography, 20% overhead and profit to the contractor, and no sales tax on materials. Engineering fees and other professional services are not included in the costs. Communities may choose to have the lot owners pay for the materials and installation of the on-lot components. Tables 1 and 2 assume that the lot-owner will pay for the system components that are installed on-lot and that the utility will build and maintain the collection network. For this example, Table 1 assumes that all connections are STEP. A STEG would not include the cost of the pump. Table 3 assumes that a utility will build and maintain the collection network and the on-lot components.

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

Table 1. Estimated cost to the lot owner for if utility does not cover the materials and installation of on-lot STEP components.

On-Lot Cost	Cost Issues	Costs
Materials and Installation	Pump, septic tank, controls, excavation, and connection to network	\$3,000 - \$5,000
Energy	Estimated at one-half kW-hr per day	\$24 - \$36 per yr
O&M	Annualized pump replacement and septage removal every 10 years	\$56 - \$84 per yr

Table 2. Estimated cost of materials and installation to build the STEP collection network, not including the on-lot components.

Network Cost	Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	\$32,000 - \$48,000	\$65,000 - \$97,000	\$340,000 - \$510,000
O&M	\$6,000 - \$9,000	\$12,000 - \$18,000	\$61,000 - \$91,000
Energy	No network electric cost unless lift stations are needed		

Table 3. Estimated cost of materials and installation for utility to install both the STEP collection network and on-lot components

Network and On-Lot Cost	Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	\$88,000 - \$133,000	\$177,000 - \$265,000	\$901,000 - \$1,352,000
O&M	\$6,000 - \$9,000	\$12,000 - \$18,000	\$60,000 - \$90,000
60 year life cycle cost – present value (2009 dollars)	\$243,000 - \$365,000	\$487,000 - \$730,000	\$2,452,000 - \$3,678,000

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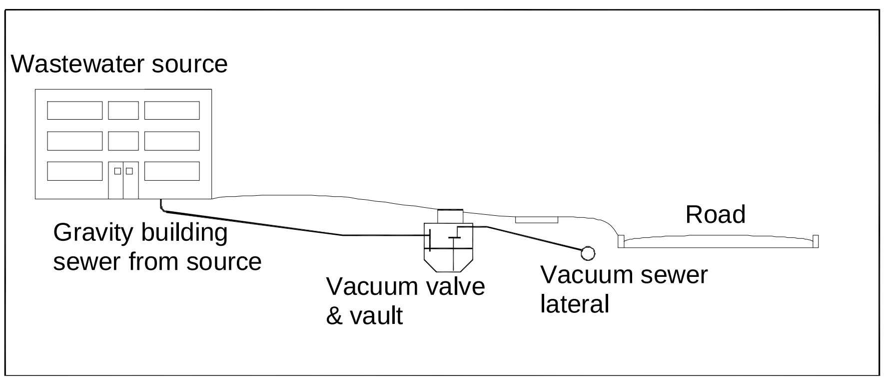
Performance & Cost of
Decentralized Unit Processes

COLLECTION SERIES

VACUUM SEWER SYSTEMS

What is a Vacuum Sewer System?

A vacuum sewer system is used to collect wastewater from multiple sources and convey it to a central location where it can be treated. As the name suggests, a vacuum (negative pressure) is drawn on the collection system. When a service line is opened to atmospheric pressure, wastewater and air are pulled into the system. The wastewater that enters with the air forms a “plug” in the line, and air pressure pushes the wastes toward the vacuum station. This differential pressure comes from a central vacuum station. Vacuum sewers can take advantage of available slope in the terrain, but are most economical in flat terrain. Vacuum sewers have a limited capacity to pull water uphill. The maximum expected lift is between 30 and 40 feet. Vacuum sewers are designed to be watertight since any air leakage into the system reduces the available vacuum.



Vacuum sewers do not require a septic tank at each wastewater source. All of the domestic wastewater and waste constituents are collected and transported by this collection method. Sewage from one or more homes or businesses flows by gravity into a small valve pit. A service line connects the valve pit to the main vacuum line. Each valve pit is fitted with a pneumatic pressure-controlled vacuum valve. This valve automatically opens after a predetermined volume of sewage has entered the sump. The difference in pressure between the valve pit (at atmospheric pressure) and the main vacuum line (under negative pressure) pulls wastewater and air through the service line. The amount of air that enters with the sewage is controlled by the length of time that the valve remains open. When the vacuum valves closes, atmospheric pressure is restored inside the valve pit. The sewage travels in the vacuum main as far as its initial energy allows, eventually coming to rest. As other valve pits in the network open, more sewage and air enters the system. Each input of energy moves the sewage toward the central vacuum station. The violent action in the pipe tends to break up the larger suspended solids during transport.

Like gravity sewers, vacuum sewers are installed on a slope toward the vacuum station. Periodic upturns or 'lifts' are installed in the vacuum line to return it to a shallower elevation. Overall, the lines are installed in a saw-tooth or vertical zigzag configuration so that the vacuum created at the central station is maintained throughout the network.

Pipes for vacuum sewers are installed in a saw-tooth or zigzag configuration to maintain a vacuum throughout the system.

Vacuum stations may include two or more vacuum pumps and a large vacuum tank. The pumps run on 3 to 5 minute cycles or long enough to create adequate vacuum in the system. The tank at the vacuum station holds the vacuum on the collection network and prevents the vacuum pumps from having to operate continuously. As valve pits are activated, there is a loss in the vacuum (negative pressure) in the system. When the negative pressure reaches a threshold level, the vacuum pumps re-engage to pull more vacuum. When sewage reaches the vacuum station, it flows into a collection tank. Sewage pumps are then used to convey the collected sewage through a force main to the treatment component. As with vacuum pumps, multiple sewage pumps are used to provide a backup in case of pump failure.

How is a vacuum sewer system used?

Because of the cost of a vacuum station, vacuum sewers are most appropriate for communities with 200 or more connections. However, in some circumstances, as few as 75 to 100 connections can be feasible. A typical vacuum station can pull from a 15,000-foot radius and serve about 1,200 connections. The general conditions conducive to the use of vacuum sewers include: unstable soil; flat terrain; rolling land with many small elevation changes; high water table; rocky conditions; new and denser urban development in rural areas; and sensitive ecosystems. Established communities that have historical neighborhoods with narrow streets and limited access can also effectively utilize vacuum sewers because the small diameter pipe and shallow excavation takes less area to install.

It is generally not advisable to use this technology in areas with low population and low population densities. Because the movement of wastewater depends upon the differential pressure created when valves open, long pipe runs with few connections can result in poor performance. The same problem is seen when connections are installed but are not yet in use. As a solution for this, temporary valve pits installed at strategic locations can be fitted with timer-controlled valves that allow air to enter even though wastewater is not being generated by the source.

Compatibility with Community Vision

Vacuum sewers are scalable. The system can be zoned (divided into sections) to accommodate the rate of build-out as well as to facilitate maintenance. Access locations to valve boxes and cleanouts (if required) will be evident at the soil surface but are not obtrusive. Higher population densities are well-accommodated with this option. If maintaining local charm while improving infrastructure is a priority, communities can preserve assets such as historical areas or heritage trees.

Vacuum stations are centrally located within their service area. Usually only a single vacuum pump station is required rather than multiple lift stations found in conventional gravity and pressure networks. This frees up land, reduces energy costs and reduces some operational costs. No manholes are necessary and odors and risks associated with hydrogen sulfide gas are significantly reduced because the system is sealed and detention times are short. Vacuum stations are quite large and expensive compared to effluent or pressure sewer system components, but can be designed to blend into the landscape.

Selecting any wastewater collection system option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

A particular problem with vacuum sewers is the noise and odor created by the central vacuum station. As air is drawn through the system, sewer gases are extracted. A good solution to this problem is to pass the exhaust air through a bio-filter, which can absorb much of the gas and reduce odors.

Land Area Requirements for Vacuum Sewers

The land area required for a vacuum sewer system is a function of the area required for installation of the valve pit, the vacuum network and the central vacuum station. Valve pits for single-family residences typically have a 10-gallon capacity and occupy a relatively small area. Tanks for multiple connections or commercial facilities may require larger area (depending upon daily wastewater volume) and thus occupy more space. The area disturbed during excavation of the valve pit will be larger than the dimensions of the valve pit and piping. Horizontal directional drilling (HDD) helps to eliminate the need for large, deep trenches that disrupt existing utilities, landscaping, roads and driveways with installation of conventional sewers. Vacuum collector system pipes are typically only four inches in diameter and thus a trencher or small excavator is often used for excavation.

Note that additional land area will be required for the treatment and dispersal components selected by the community.

Construction and Installation

A valve pit is located at each wastewater source or cluster of sources. Valve pits are typically prefabricated and ready to install. They must be properly oriented and set at the correct elevation to allow for gravity flow from the source. Anti-flotation measures are required in areas with high water tables. An air intake must be installed on the building sewer downstream of the plumbing house trap to ensure adequate venting for the valves. On-lot excavation is typically accomplished using a backhoe. The service line from the valve pit to the vacuum main can also be installed with a backhoe, but this often results in over-excavation. Using a chain trencher instead will result in less property disruption and require less site restoration. Proper bedding and backfilling techniques must be used to avoid settling over time. Service lines that connect valve pits to vacuum mains must be separated from potable water lines to avoid cross-contamination. Vacuum mains must also be separated from other utilities.

A valve pit is installed at each wastewater source.

Piping for most vacuum sewer mains is O-ring gasketed PVC pipe, so solvent welding is not required. It is normally buried about 36 inches deep, but depths of 4 to 5 feet are not uncommon in colder climates. The small diameter piping used for vacuum sewers is flexible and can be routed horizontally around obstacles. Vacuum sewer mains can often be located outside of and adjacent to the edge of pavement. Division valves must be installed at branch/main intersections, both sides of a bridge and road crossings, both sides of areas of unstable soils, and at periodic intervals on long routs. Some local codes still require cleanouts at specified intervals.

Vacuum testing of both valve pits and mains is performed over the course of the installation and upon completion of the entire system. Overall, there is a significant amount of disturbance associated with the installation, but not nearly as much as with deeper conventional gravity sewers. Once installed, most components are either below ground or flush with finish grade. Licensing requirements for personnel who install vacuum sewer systems vary, but they must typically be licensed as a public utility contractor by the state or region in which they work.

Maintenance Requirements

Effective operation of a vacuum sewer system begins with proper design and construction, but regular inspection of system components by staff or remote monitoring is critical. Vacuum stations can be remotely monitored via telemetry or visited daily to record pump running hours and lubricant levels. A variety of tasks must be performed on a regular weekly, monthly or semi-annual basis. These tasks include changing oil and oil filters on vacuum pumps; removing and cleaning inlet filters on vacuum pumps; testing all alarm systems; checking/adjusting motor couplings, and; checking operation of vacuum station shut-off and isolation valves. The operator must conduct external leak tests on all vacuum valves and check/adjust valve timing. Preventive maintenance includes annual visual inspections of valve pits and valves, as well as rebuilding controllers every 3 to 6 years and rebuilding valves every 8 to 12 years.

Regular service is important for all systems to ensure best long term performance to protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of any pretreatment components used prior to dispersal.

As with all mechanical devices, vacuum valves will fail with some frequency. When a valve sticks open the whole system has reduced vacuum. Locating the stuck valve may be time consuming and require two persons. When a valve fails to open, wastewater will backup in the valve pit (and potentially into the source). These failures are easier to locate but can result in an on-lot backup or the discharge of sewage.

Good recordkeeping of system performance and costs is critical. The advent of web-based telemetry has greatly improved the operator's ability to monitor system status. Vacuum sewer system operators must be capable, dependable and knowledgeable. About 2.5 to 3 hours per year per service connection is a good estimate for time commitment. Training and certification is advisable and will typically be required by the local jurisdiction.

Costs for Vacuum Sewers

Long term costs include vacuum station utilities, clerical costs, transportation, supplies/spare parts as well as miscellaneous expenses such as insurance and accounting. Additional costs will be incurred for equipment reconditioning and replacement by trained service providers. Vacuum station equipment has a life expectancy between 15 and 25 years, but there are annual costs associated with reconditioning that offset replacement. Vacuum valves must typically be rebuilt every 8 to 12 years and their controllers require rebuilding every 4 to 6 years.

The vacuum pumps and sewage pumps are the only elements of the vacuum sewer system that require electricity. It is reported that monthly power costs range from $1.66 to $3.34 per month per connection. Larger stations typically have lower power consumption per connection. Each vacuum station must have a standby electric generator to keep the system operating during electric power failures. Part of the energy cost must include the fuel needed to operate this backup power source.

Because 150 to 200 connections are needed before the cost of the vacuum station can be justified, this fact sheet will only investigate the cost of a 200-home community. The vacuum station given in this example is capable of handling more connections and so costs would come down if the full capacity of the station is used. Thus, at full capacity, the cost per connection would decrease. The costs given in this document are for comparison purposes only. The actual cost for a system will vary significantly depending on site conditions and local economics. The costs for the systems below include valve pits and controller valves at all connections, system piping, vacuum pumps, sewage pumps and all additional appurtenances. The extent of site disturbance and nature of the restoration required will also affect costs.

To justify the cost of a vacuum system, 150 to 200 connections are needed.

Table 1 provides cost estimation for the materials, installation, and maintenance of a vacuum sewer system. These costs assume that the wastewater sources average about 200 feet apart, the topography is relatively flat, the contractor would charge 20% for overhead and profit, and there are no sales tax on materials. Engineering fees and other professional services are not included in the costs. With a vacuum sewer system, it is assumed that one vacuum pit will serve at least two sources. Thus, for a 200-connection community, there are only 100 vacuum pits. This example assumes that the utility will install and maintain the vacuum pits. Each lot owner must still to pay for installation of a building sewer to the nearest vacuum pit.

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

Table 1. Estimated cost of materials and installation to build the vacuum collection network, including the on-lot components.

Cost Factor	Building Sewer to Vacuum Pit	Collection Network Cost including 100 Vacuum Pits
Materials and Installation	$1,800 - $2,700	$1,869,000 - $2,804,000
Annual electricity	-0-	$9,500 - $14,000
Annual O&M	$16 - $24 per yr	$82,000 - $123,000
60 year life cycle cost – present value (2009 dollars)		$4,775,000 - $7,162,000

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3.2 TREATMENT SERIES

Fact Sheet T1

Performance & Cost of
Decentralized Unit Processes

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DECENTRALIZED WASTEWATER SYSTEMS

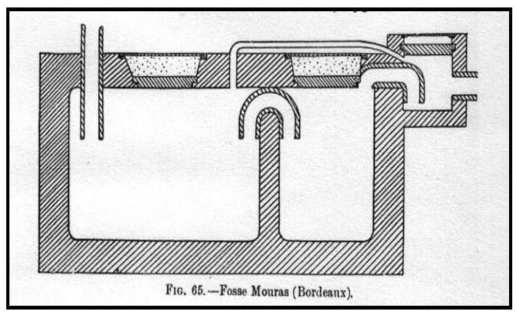
TREATMENT SERIES

LIQUID-SOLID SEPARATION

What is Liquid-Solid Separation?

Liquid-solid separation is typically the first unit process used in a wastewater system. As the name suggests, the primary purpose is to separate liquid wastewater from non-liquid waste constituents. In individual onsite systems, liquid-solid separation is provided by a septic tank. Because of greater flows and the multitude of inappropriate materials that get flushed down the drain, municipal systems have not just one but a series of processes that separate liquid wastewater from non-liquid waste products. Many wastewater professionals refer to liquid-solid separation as primary treatment.

This factsheet focuses on liquid-solid separation technologies that are appropriate for residential and small community wastewater management systems. For all intents and purposes, liquid-solid separation occurs in a tank that is configured and sized to accept the wastewater flow and retain it for a sufficient amount of time for the process to occur. In this Fact sheet, tanks used for liquid-solid separation will be termed *primary tan ks* when serving a community and *septic tanks* when they serve an individual residence or other building. A special tank known as an Imhoff tank may also be used. Although it is designed differently from the septic tanks and primary tanks discussed here, its function is the same.



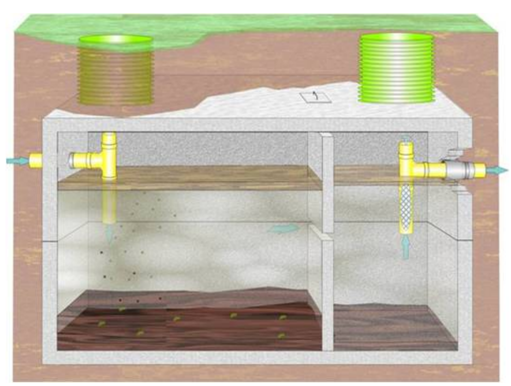


Illustration of similarities between one of the first 'septic tanks' (Mouras' 1883 version, top) and a modern version (bottom). The importance of liquid-solid separation has been recognized for centuries.

Liquid-solid separation is an essential treatment component whether the wastewater management system is serving one home or a whole city. In rural housing, satisfactory liquid-solid separation occurs in a septic tank. There are several options for clustered housing developments and small communities. One option may be to include a septic tank at each house and transfer only effluent to a common treatment location. This arrangement is known as an effluent sewer system. Alternately, the raw wastewater (solids included) may be collected and conveyed to a common primary tank for liquid-solid separation via traditional gravity sewers, low pressure sewers, or vacuum sewers. These four **Collection** system options are described in other Fact sheets included in this series.

For more information on Collection Systems*, see:*
Fact Sheet C1: Gravity Sewer Systems
Fact Sheet C2: Pressure Sewer Systems
Fact Sheet C3: Effluent Sewer Systems
Fact Sheet C4: Vacuum Sewer Systems

Sedimentation and flotation are the primary processes that occur during liquid-solid separation. Once raw wastewater enters a primary or septic tank, non-liquid waste constituents will settle or rise depending on their density. The floating layer in a septic tank is called the *scum* layer and the settled solids form the *sludge* layer. A clarified effluent zone develops between the two layers of solids. The tank outlet is designed to draw effluent from the clarified zone. This separation technology can reduce the solids content by 60 to 80%. Because much of the material captured in the tank is organic, approximately 50% of the organic load is removed by during liquid-solid separation. Effluent from primary tanks and septic tanks typically contains 140 to 220 mg/L BOD_5, 45 to 70 mg/L TSS, and 10-30 mg/L FOG. The performance of primary treatment components influences the nature (and performance) of subsequent components used in a treatment system.

Septic tanks used today typically include an effluent screen installed in the outlet end of the tank. The screen is designed to capture solids that may still be suspended in the effluent as it exits the tank. There are many different proprietary screens available in the market today and most are designed to capture solids in the range of 1/32 to 1/16 inch in diameter. Tanks fitted with effluent screens must have an access at or near the finished grade to allow a service provider to remove and clean the screen on a regular basis.

Effluent screens must be accessible for maintenance.

The tank must be large enough to retain the wastewater in a relatively quiet state to allow settling and flotation to occur. This concept is known as *detention time* and is an important design consideration. Excessive flow creates turbulence that can disrupt the settling process. Thus, tank volume, size, shape, and inlet baffle configuration are each designed to minimize turbulence and prevent the migration of solids to subsequent components. Accumulated solids are stored until they are periodically removed by pumping the tank. Septic tanks and primary tanks are pumped when solids occupy approximately 40% of the tank's volume or on a regular schedule. The removed materials are know as *residuals*. See the Fact Sheet on **Residuals Management** for further information on the management of this material.

For more information, see:
Fact Sheet D7:
Residuals Management

LIQUID-SOLID SEPARATION

Compatibility with the Community Vision

All systems will have some form of liquid-solid separation as a treatment component. However, the location where liquid-solid separation is accomplished can vary. Use of septic tanks in conjunction with individual, cluster development or community systems is a viable option and septic tanks can be effectively used with all types of collection systems.

If an existing community is faced with a significant number of soil-based dispersal system failures, a potential solution for these problem areas is to collect their wastewater and combine the individual dispersal components into a cluster or community system. It may be easier and less costly to convey wastewater that has already undergone liquid-solid separation. Infrastructure and access for maintenance and management of residuals (solids retained in the septic tanks) must always be part of the consideration.

Selection of any wastewater dispersal option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

Land Area Requirements

Tanks are typically sized to accommodate at least twice the expected daily volume of wastewater or two days of detention time. A one-thousand gallon tank typically measures about 4 feet wide by 8 feet long. Larger volumes obviously require larger tanks and occupy more space.

Construction and Installation

Primary tanks and septic tanks are installed below ground. They may be fitted with access risers that extend to finished grade. Prefabricated tanks are available and may be constructed of concrete, fiberglass or plastic. Larger tanks may be built in place using reinforced concrete. Independent of the material of construction, tanks must meet appropriate strength requirements to withstand the exterior soil pressures and interior liquid pressures. It is important that they are constructed of high quality materials so that they remain structurally sound and watertight.

Tanks may require risers to ensure access at finished grade.

Excavations for modular tanks must be performed in accordance with applicable safety regulations. Workers must not enter excavations that may be subject to cave-in unless appropriate stabilization measures are taken. Proper bedding and backfilling procedures must be used to ensure a level and stable installation. In areas where shallow groundwater is present, tanks must be installed to prevent flotation. All tanks must have flexible, watertight seals at all locations where pipes enter and exit and a cast-in-place or mechanically-attached access riser to grade with a tight fitting lid.

Installation of tanks requires reasonable site access for heavy equipment.

Operation and Maintenance

Stored solids (septage or residuals) must be removed on a regular basis. The removal (pumping) frequency is determined by the level of use by the source. Service providers must have knowledge and skills needed to measure depth of sludge and scum to determine when tanks need pumping. A properly operated and installed primary tank or septic tank should have no chemical requirements (i.e., additives).

Service providers regularly measure depth of sludge and scum to determine when tanks need pumping.

The size and depth of the tank are a significant safety concern for the service provider. Gases, such as hydrogen sulfide, methane, and carbon dioxide, result from anaerobic (without oxygen) digestion that occurs in the tank. These gases create a hazardous and corrosive environment. Tanks are considered confined space and must never be entered without the proper training and equipment.

Costs for Liquid-Solid Separation

$

Primary tanks and septic tanks do not require power – gravity is the primary source of energy. The exceptions are when a tank level alarm is included and/or when a pump is installed within the tank to convey the effluent to the next component.

Costs for septic tanks depend upon a variety of factors including subsurface site conditions, location of and access to the site, and the type of tank. Deeper installations require stronger construction and will be more expensive, as will tanks installed where vehicular traffic is expected.

Table 1 is a cost estimation for the materials, installation, and maintenance of a residential septic tank. These costs assume relatively flat topography, 20% overhead and profit to the contractor, no sales taxes on materials. The size of the tank is based on two days of detention. Engineering fees and other professional services are not included in the costs. Maintenance costs were based on a part time service provider and the cost of septage removal. Septage removal was estimated at $360 per 1,000 gallons.

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

Table 1. Estimated cost to install and maintain a septic tank at a single-family residence.

Materials and installation	1,000 gallon tank, delivery, and connections	$2,800 – $4,200
Annual electricity ($0.15 per kW-hr)	Assumes no pump	-0-
Annual O&M	Septage removal every 7 yrs and service provider cost	$70 - $110
60-yr life cycle cost present value (2009 dollars)	Based on maintenance – assumes tank will last 60 years	$5,400 - $8,000

Table 2 estimates the cost of a primary treatment system for three sizes of communities – 5,000, 10,000 and 50,000 gpd. For this example, it was assumed that the tank is being used to provide liquid/solid separation. The tank volume is based on two times the daily flow. These costs assume relatively flat topography, 20% overhead and profit to the contractor, no sales taxes on materials. Engineering and other fees are not included in the costs. The maintenance cost is based on a part-time service provider, a 5-year septage removal cycle, and an assumption that the tank will last for 60 years.

Table 2. Estimated cost for a community-scale tank for liquid/solid separation.

Cost Factor	Daily Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$31,200 - $47,000	$62,000 - $94,000	$312,000 - $468,000
Annual Electricity ($0.15 per kW-hr)	-0-	-0-	-0-
Annual O&M	$1,000 - $1,500	$2,000 - $3,000	$10,000 - $15,000
60 year life cycle cost present value (2009 dollars)	$66,000 - $98,000	$313,000 - $197,000	$656,000 - $984,000

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Fact Sheet T2

Performance & Cost of
Decentralized Unit Processes

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DECENTRALIZED WASTEWATER SYSTEMS

TREATMENT SERIES

SUSPENDED GROWTH AEROBIC TREATMENT

What is Suspended Growth Aerobic Treatment?

Suspended growth aerobic treatment is a process used to provide secondary and (in some cases) tertiary treatment of effluent. After primary treatment via liquid-solid separation, dissolved and some suspended organic matter is still present in effluent. If this organic matter is not removed before the effluent is dispersed, microorganisms in the receiving environment will begin to process it. As they consume the organic matter, they also consume oxygen or create an *oxygen dem and.* The resulting low oxygen or *hypoxic* conditions negatively affect the receiving environment. The goal of all aerobic treatment systems is to provide oxygen to naturally-occurring organisms present in the wastewater so that they will consume the organic matter before it is dispersed into the environment. Biochemical oxygen demand (BOD) is a measure of how much oxygen microorganisms consume as they oxidize organic matter. BOD is thus a commonly used expression of wastewater strength.

Additional oxygen demand is exerted by other constituents in wastewater. As organic nitrogen (N) is broken down in primary treatment processes, it is converted to the ammonium (NH_4^+) form. Like the organic matter, this ammonia nitrogen creates a demand for oxygen as microorganisms convert the ammonium form to nitrate (NO_3^-) through an oxidative process called *nitrification*. Suspended growth aerobic treatment systems make the conversion easier by providing the necessary oxygen.

Thus, aerobic treatment systems reduce oxygen demand in effluent by providing naturally-occurring microorganisms with sufficient dissolved oxygen to consume organic matter and convert ammonium nitrogen to the nitrate form. In their most basic form, aerobic treatment systems are divided into two categories:

Quick Definitions

Secondary treatment:
Biological and chemical treatment processes designed to remove organic matter; a typical standard for secondary effluent is BOD and TSS less than or equal to 20 mg/L each on a 30-day average basis.

Tertiary Treatment:
Advanced treatment of wastewater for enhanced organic matter removal, pathogen reduction, and nutrient removal; typical standards for tertiary effluent vary according to regulatory requirements.

Biochemical Oxygen Demand (BOD):
Amount of oxygen required by bacteria while stabilizing, digesting, or treating wastewater under aerobic conditions; an indirect measure of the amount of organic constituents of wastewater; a measure of the relative strength of wastewater expressed in mg/L.

suspended growth and *fixed growth*. Fixed growth systems encourage the microorganisms to grow on a fixed surface to which wastewater is applied and are discussed in **Fact Sheet T3** in this series. This Fact sheet focuses on suspended growth systems which continuously mix the microorganisms and wastewater in a well-aerated tank.

For more information, see:
Fact Sheet T3: Fixed Growth Aerobic Treatment Systems

A typical suspended growth aerobic treatment system includes *aeration basins* filled with effluent into which air is injected. Air injection mixes the contents of the tank and causes oxygen to become dissolved in the effluent. The mixing action brings the suspended microorganisms into contact with the organic matter (food) and dissolved oxygen (fuel). Because there is plenty of food and dissolved oxygen, the microorganisms thrive and become concentrated within the basin. The microbes oxidize the organic matter into carbon dioxide, new microbes and insoluble matter (*residuals*). The mixing of effluent, organic matter and air in the same basin is known as the *activated sludge process* and the concentrated mass of microorganisms is called *biomass.* Microbes complete their life cycle while suspended in the effluent.

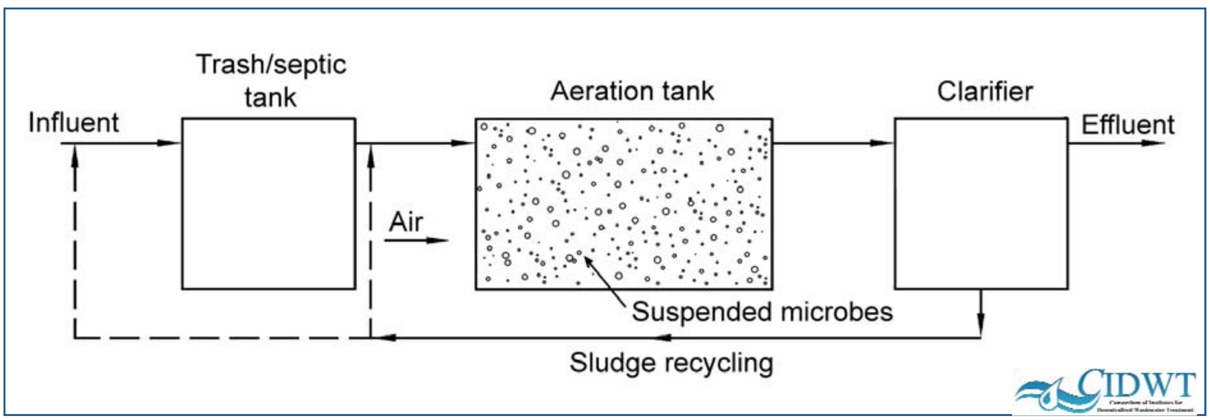


Illustration of basic steps in suspended growth aerobic treatment. Many different configurations are possible.

After the activated sludge process occurs in the aeration basin, the effluent moves into a settling basin or *clarifier*. This is a quiescent (quiet) environment that allows the concentrated biomass to settle out of the effluent. The clarified effluent then proceeds to the next phase of treatment or dispersal. As biomass accumulates, it is periodically removed (either automatically or manually). The removed biomass becomes a residual that can be taken to a landfill, applied on farmland or subjected to further treatment. A Fact sheet on **Residuals Management** is included in this series.

For more information, see:
Fact Sheet D7: Residuals Management

Types of Suspended Growth Aerobic Treatment Systems

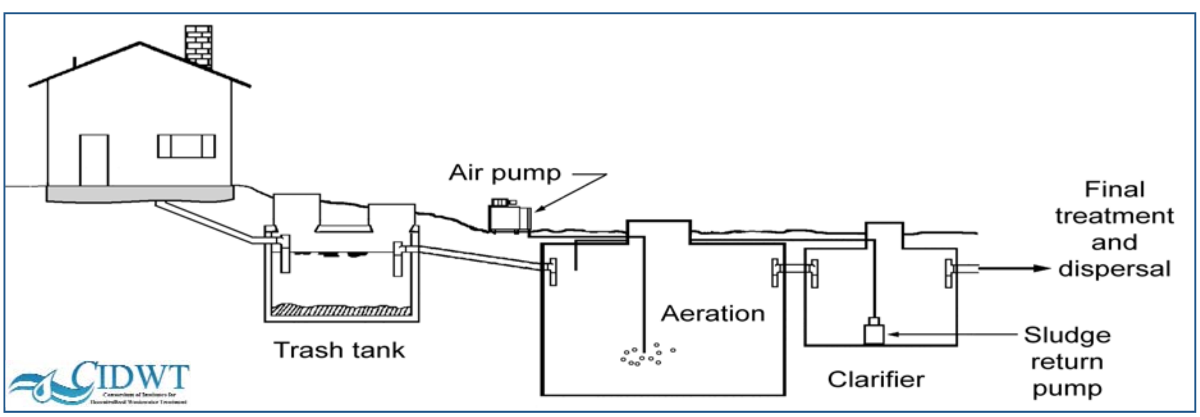
Most suspended growth aerobic treatment systems that are appropriate for small communities or individual homes operate in the *extended aeration* mode. Extended aeration is accomplished by keeping the wastewater in the basin for a long time while providing plenty of air but a limited amount of food (organic matter) to the organisms. If sufficient dissolved oxygen is supplied and minimal food is available, the microbes will readily consume organic carbon - including each other. The goal is to balance the mass of new cells with the mass of degraded cells. A certain amount of biomass will always accumulate and must be removed through a process called *wasting.* The removed biomass becomes the residuals mentioned previously. The advantages of extended aeration include excellent organic carbon removal and excellent conversion of ammonium-nitrogen to the nitrate form (nitrification). The primary disadvantage is the higher electrical consumption needed for aeration.

Suspended growth aerobic treatment can be accomplished in a variety of ways. The primary difference among the optional configurations is how effluent flows through the component and how the biomass is managed. Each option may incorporate additional design modifications to achieve nitrogen and phosphorus reduction. Nitrogen and phosphorus removal is known as **Nutrient Reduction** and is discussed in another Fact Sheet in this series. Four basic configurations for suspended growth aerobic treatment systems are described below.

For more information, see:
Fact Sheet T6: Nutrient Reduction

Complete-mix Suspended Growth

Typically, a complete-mix suspended growth aerobic treatment system is composed of a main treatment basin (aeration chamber) where bacteria, organic matter, and effluent are mixed by the turbulence created by air injection. A second chamber (clarifier) provides quiescent conditions to allow biomass to settle. The two chambers may be separate tanks as shown in the figure or they may be combined in one tank.



Typical complete-mix suspended growth configuration using separate tanks for the aeration chamber and the clarifier.

Sequencing Batch Reactors (SBR)

A sequencing batch reactor (SBR) provides treatment using one chamber. As the name suggests, processes occur in a particular order to provide aeration and biomass separation. These include filling the chamber, aerating the effluent, allowing the biomass to settle, pulling out the clarified effluent (decanting), and then removing a portion of the biomass. This is a *batch* operation, which means that storage must be provided for effluent that arrives while sequential operations are in progress. The SBR process provides some flow equalization and adjusts the quantity and strength of wastewater inflow.

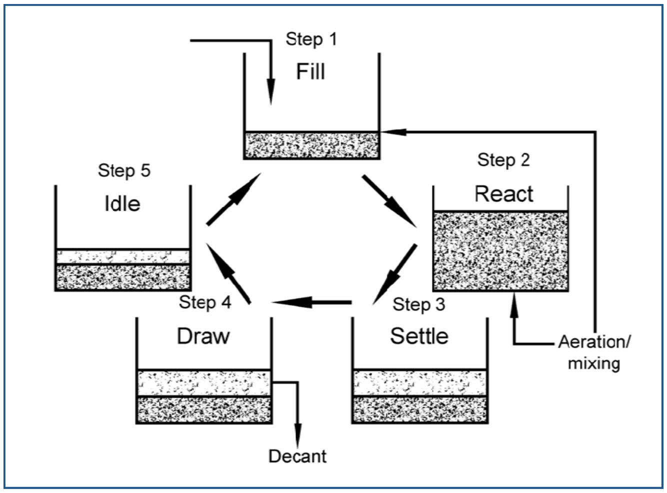


Illustration of batch operations in a sequencing batch reactor (SBR). The steps occur sequentially in a single tank.

Membrane Bioreactors (MBR)

Membrane Bioreactors include activated sludge components but use membrane filtration units to separate biomass from effluent. First developed in the 1960s, MBRs have undergone significant modifications since the late 1990s that have resulted in a more robust and practical membrane filtration unit. Unlike the suspended growth configurations previously mentioned, MBRs do not depend on gravity (settling) to separate the biomass and effluent. With membrane filtration, time and space required for biomass separation is significantly reduced. MBR systems can thus treat a greater volume of water and occupy less space than conventional suspended growth systems. However, the increased treatment capacity is accompanied by increased electrical cost because greater aeration capacity and pressurization is needed to operate a MBR at its full potential. To accomplish nitrogen and phosphorus removal, additional unit processes must be added to the MBR.

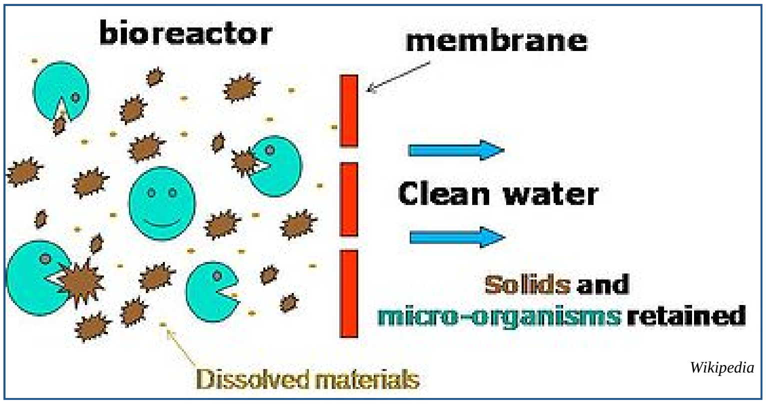
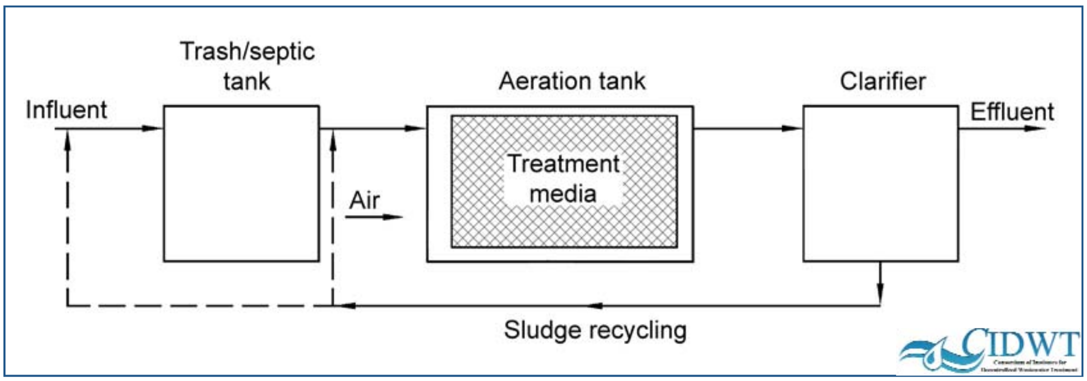


Illustration of processes used in a membrane bioreactor (MBR)

Integrated Fixed-Film/Activated Sludge (IFAS)

As mentioned at the beginning of this factsheet, there are two major categories of aerobic treatment: suspended growth and fixed growth. Fixed growth configurations are commonly referred to as "fixed-film" or "attached growth" because a biological film consisting of continuous colonies of bacteria forms on the surface of the media. When fixed film and suspended growth configurations are combined in the same aeration chamber, the configuration is referred to as an integrated fixed-film/activated sludge (IFAS) system. In these systems, excessive growth falls off or "sloughs" and settles on the bottom of the chamber. These solids will accumulate and must be removed as part of periodic maintenance procedures.



In an integrated fixed-film/activated sludge configuration, treatment media is submerged in the aeration tank. This provides a surface where bacteria can attach and grow.

How is Suspended Growth Aerobic Treatment used?

The primary function of aerobic treatment is to remove oxygen demand by oxidizing organic matter, ammonia nitrogen and other compounds present in wastewater. Depending on permit restrictions, wastewater that is treated to a high degree using aerobic treatment methods may be dispersed or discharged into "high-risk" environments. The *risk* as used here is based upon the sensitivity of the receiving environment and how much additional treatment can be expected in that environment. A community may have the option to use subsurface soil dispersal, but the soil may be shallow with limited treatment capability. By applying aerobically treated effluent, the soil can more readily finish the treatment cycle and safely disperse the water back into the hydrologic cycle. Likewise, when effluent is discharged to surface waters, the oxygen demand can result in environmental degradation as previously described.

Suspended growth systems can be successfully used for very small wastewater flows if appropriate management is provided. Small flows (i.e., individual residences) tend to have significant variation in terms of both water volume and organic loading. Heavy laundry days tend to produce a large volume of water that is low in organic strength. This loading does not provide food for the organisms, which leads to reduction in the biomass population. When a significant organic load is received, the population will recover. However, a portion of the applied wastewater may pass through the system without being fully treated.

Suspended growth aerobic treatment systems can be scaled to provide service for small flows from single-family homes all the way up to the largest municipalities. Most communities that have wastewater flows greater than 500,000 gallons per day employ some variation of suspended growth aerobic treatment as a means of removing oxygen demand. A large volume of wastewater can be treated on a relatively small parcel of land using this high-rate process.

Compatibility with the Community Vision

The community must determine whether individual treatment components will be installed at each connection or if the wastewater will be collected and conveyed to one or more large treatment components. This decision will influence later management and maintenance issues.

Suspended growth aerobic treatment components can be integrated into individual sites with creative landscaping. A properly operated system should have no associated odors. Compressors and/or blowers will create a certain amount of noise, so their location will be important. Residential systems are relatively compact and are usually installed below-grade with only the access lids visible at the surface. Large-scale systems are often installed completely above-grade and are thus highly visible. Landscaping can effectively disguise these below-grade treatment facilities; however, vegetation should not be planted so close to the facility that it might interfere with operation.

Selection of any wastewater dispersal option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

Nitrogen-sensitive areas can benefit from use of these systems provided that the appropriate processes are included in the components. See the **Nutrient Reduction** Fact Sheet for additional information.

For more information, see:
Fact Sheet T6: Nutrient Reduction

Land Area Requirements

A typical design parameter is that the aeration chamber volume should be equivalent to one day's wastewater volume. In addition to the aeration chamber, space is needed for the settling chamber, aeration devices and electrical controls. Components serving residences are typically about the same size as a septic tank. A 50,000 gpd system could occupy 200 to 300 square feet.

Suspended Growth Aerobic Treatment

Construction and Installation

Suspended growth aerobic treatment systems are available as proprietary modular units, or they can be built in place. For individual and small community applications, most suspended growth aerobic treatment systems are pre-engineered and pre-packaged. An individual or community can purchase a treatment system and it can be delivered by truck.

Many jurisdictions require that residential aerobic unit be certified by the National Sanitation Foundation/ American National Standards Institute (NSF/ANSI). NSF/ ANSI Standard 40: Residential Wastewater Treatment Systems is a testing protocol used to evaluate the performance of 400 to 1,500 gallon per day aerobic treatment systems. Larger aerobic treatment systems are often designed on the basis of the *Recommended Standards for Wastewater Facilities* often referred to as the "10-State Standards." This document provides the designer with prescriptive guidelines for sizing of various system components.

Installation will cause significant but temporary site disturbance. Soil must be excavated for below-grade systems and the spoil material must be removed or applied somewhere on the site. The source must be connected to the treatment system via the building sewer or a collection system. The treatment component must then be connected to the next component in the treatment train (for example, disinfection or dispersal components). The electrical components must be connected. Personnel who install this technology be subject to licensure or certification requirements in a given state or region. Certainly, they must be familiar with the specific requirements for the particular application which may necessitate training provided through manufacturers of proprietary components if they are used.

Suspended growth systems may be modular such as the units shown above and below.

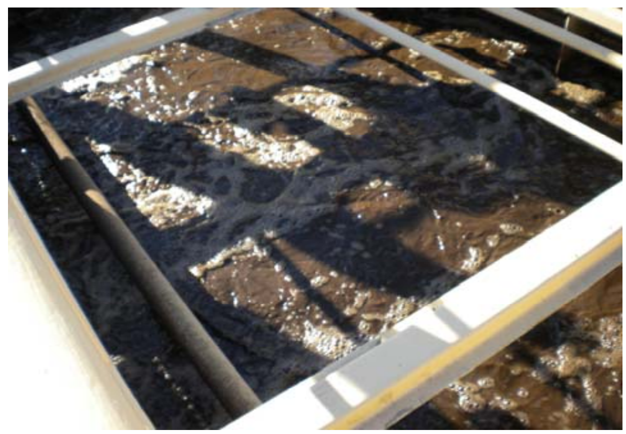
Alternately, components for suspended growth treatment can be installed inside tanks like those shown below.

Operation and Maintenance

The maintenance provider must have a high level of understanding of the processes and equipment. With proper design and a rigorous maintenance program, suspended growth aerobic treatment systems will likely perform well and treat effluent for a long time. The frequency of visits by a maintenance provider varies according to the volume of wastewater treated and the risk to the receiving environment. Residential systems typically require semi-annual or quarterly visits, including solids removal as needed. Cluster-development and community systems require much more frequent visits. Many modern control panels can provide cellular-based telemetry, which allows maintenance providers to remotely view system status. However, this does not eliminate the need for hands-on O&M at a reasonable frequency. Suspended growth systems may require more O&M than fixed growth units.

A service provider performs a general assessment of the unit. This includes checking that the air supply is operable and providing air to the unit through a visual inspection of hoses, clamps, and bubbling action during the visit. A dissolved oxygen meter or kit is used to ensure that conditions are aerobic. During maintenance, an examination is performed to determine if the settled biomass needs to be removed. Biomass is typically removed when the settling chamber is more than one-third full. This must be strictly observed to avoid excessive accumulation of residuals that could carry over to the next component. Filter cleaning and debris removal are also performed during a maintenance visit. State or regional training and certification will likely be required for personnel who operate and maintain these components.

Regular service is important for all systems to ensure best long term performance and protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of the components used.



Bubbling action in an aeration chamber (above) and a pressure gauge used to check air delivery (below)

Energy Requirements

Aeration is accomplished in suspended growth aerobic treatment systems by pumping air through the wastewater. Thus, suspended growth aerobic treatment systems require power to provide wastewater aeration. Blowers, compressors, or aerators may be used to transfer oxygen into wastewater and mix the biomass. Power requirements depend on the daily wastewater volume, the mass of BOD to be removed, the mass of ammonia to be converted into nitrate, and the configuration of the aeration system. If the aeration devices are greater than 7 to 10 horsepower, three-phase electricity may be required to operate the system.

Providing air for suspended growth aerobic treatment processes requires electrical power. Compressors like those shown at left are one method used for aeration.

Table 1 provides rough estimates of aeration power requirements. Assumptions are that that residential strength wastewater is receiving aerobic treatment and that liquid-solid separation is provided prior to aerobic treatment.

Table 1. Mass of oxygen that must be transferred into the effluent per day.

Wastewater flow (gpd)	[1]lbs/day of BOD_5	[2]lbs/day of TKN-N	[3]Required lbs O_2/day
450	0.76	0.11	1.4
5,000	6.3	1.3	15
10,000	13	2.5	30
50,000	63	13	150

[1]Assumes influent with 150 mg/L BOD_5 and 30 mg/L TKN-N

[2]Total Kjeldahl Nitrogen: the combination of ammonia nitrogen (NH_3) and organic nitrogen in a sample

[3]Assumes 1.5 pounds of O_2 required per pound of BOD plus 4.6 pounds O_2 required per pound of TKN-N

The oxygen content of air is only 21% and it takes a large volume of air to provide a pound of oxygen. Thus, aeration devices must move large quantities of air through water in order to transfer the required mass of oxygen into the wastewater. Using the wastewater volumes given in Table 1, Table 2 provides broad estimates of the volume of air that must be pumped through the water and the amount of power required to move it. The values given in Tables 1 and 2 are for educational purposes only. They are based on reasonable assumptions; however, they are not intended to represent the power requirements of a specific system at a specific location.

Table 2. Air flow and power required to meet aeration requirements in Table 1.

Wastewater Volume (gpd)	[1]Rate of Air Flow (SCFM)	[2]Aeration Power (hp)	[3]Monthly Power Consumption (kW-hr)
450	1.9	0.25	40
5,000	21	1	420
10,000	42	1.75	830
50,000	207	8	4200

[1]Standard cubic feet per minute

[2]Horsepower rounded up to the next standard motor size

[3]Assumes continuous operation

Costs for Suspended Growth Aerobic Treatment Systems

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Costs for a suspended growth aerobic treatment system depends upon factors including wastewater volume and quality, site conditions, location of and access to the site and availability of electrical power. Management costs must always be considered. A qualified service provider is required that understands the activated sludge process. Tables 3 and 4 assume a pre-engineered, pre-packaged treatment unit that is delivered to the site and installed does not include the cost of primary treatment or dispersal components.

Table 3 is a cost estimation for the materials, installation, and maintenance of a residential suspended-growth aerobic treatment system. These costs assume that the contractor would charge 20% for overhead and profit, and there are no sales taxes on materials. Engineering fees and other professional services are not included in the costs. Maintenance costs were based on a part time service provider, five year blower life, and the cost of septage removal. Also included is the annualized cost to replace the treatment system in 30 years.

Table 3. Estimated cost to install and maintain a suspended-growth aerobic treatment system at a single-family residence.

Materials and installation	Manufactured system, delivery, and installation	$8,000 - $12,000
Annual Electrical ($0.15 per kW-hr)	Assumes blower runs constantly	$80 - $120
Annual O&M (2 to 4 visits per year)	Annualized service provider, five year blower life, septage removal as needed, & 30-yr system replacement	$450 - $670
60-yr life cycle cost (present value - 2009 dollars)	Assumes 3% inflation, 5% discount rate, no salvage or depreciation	$27,000 - $40,000

Table 4 estimates the cost of a suspended growth (extended aeration) treatment system for three sizes of communities – 5,000, 10,000 and 50,000 gpd. For this example, it was assumed that the installation contractor would charge 20% for overhead and profit. Engineering and other fees are not included in the costs. The maintenance cost is based on a part-time service provider, a five-year blower life, biomass wastage, and that the system will last for 30 years.

Table 4. Estimated cost to install and maintain a community-scale suspended growth aerobic treatment system.

Cost Factors	**Daily Wastewater Volume (gpd)**		
	5,000 gpd or 20 homes	**10,000 gpd or 40 homes**	**50,000 gpd or 200 homes**
Materials and Installation	$100,000 - $150,000	$148,000 – $223,000	$410,000 - $616,000
Annual Electrical ($0.15 per kW-hr)	$900 - $1,400	$1,800 - $2,700	$9,000 - $14,000
Annual O&M	$5,300 - $8,000	$9,000 - $13,000	$34,000 - $51,000
60 year life cycle cost (present value - 2009 dollars)	$320,000 - $480,000	$527,000 - $791,000	$1,915,000 - $2,873,000

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

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Fact Sheet T3

Performance & Cost of
Decentralized Unit Processes

Water Environment Research Foundation
Collaboration. Innovation. Results.

DECENTRALIZED WASTEWATER SYSTEMS

TREATMENT SERIES

FIXED GROWTH AEROBIC TREATMENT

What is Fixed Growth Aerobic Treatment?

After primary treatment via liquid-solid separation, dissolved and suspended organic matter is still present in effluent. If this organic matter is not removed before the effluent is dispersed, microorganisms in the receiving environment will begin to process it. As they consume the organic matter, they also consume oxygen or create an *oxygen demand.* The resulting low oxygen or *hypoxic* conditions negatively affect the receiving environment. The goal of aerobic treatment systems is to provide oxygen to naturally-occurring organisms present in the wastewater so that they will consume the organic matter before it is dispersed into the environment. Biochemical oxygen demand (BOD) is a measure of how much oxygen organisms consume as they oxidize organic matter. BOD is a thus a commonly used expression of wastewater strength.

> **Quick Definitions**
>
> **Biochemical Oxygen Demand (BOD):** The amount of oxygen that microorganisms consume as they break down organic matter. Commonly used to express the strength of wastewater.

Additional oxygen demand is exerted by other constituents in wastewater. As organic nitrogen (N) is broken down in primary treatment processes, it is converted to the ammonium (NH_4^+) form. Like the organic matter, this ammonium nitrogen creates a demand for oxygen as microorganisms convert the ammonium form to nitrate (NO_3^-) through an oxidative process called *nitrification*. Fixed growth aerobic treatment systems make the conversion easier by providing the necessary oxygen.

Aerobic treatment systems reduce oxygen demand in effluent by providing naturally-occurring microorganisms with sufficient dissolved oxygen to consume organic matter and convert ammonia nitrogen to the nitrate form. Some components include additional unit processes where conditions are favorable for reduction of total nitrogen through denitrification. In their most basic form, aerobic treatment systems are divided into two categories: suspended growth and fixed growth. Suspended growth aerobic treatment systems continuously mix the microorganism and wastewater in a well-aerated tank and are discussed in another Fact sheet in this series. This Fact sheet

For more information, see:
Fact Sheet T2: Suspended Growth Aerobic Treatment Systems

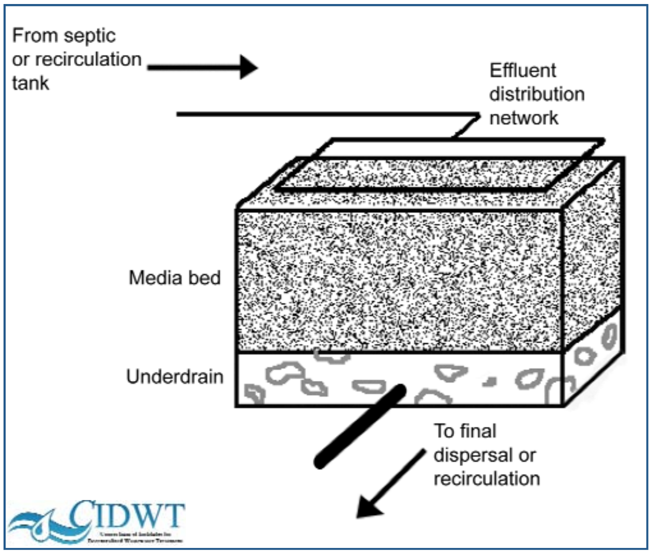
focuses on fixed growth aerobic treatment systems in which the microorganisms to grow on fixed surfaces to which wastewater is applied.

Fixed growth (also known as attached growth) aerobic systems can be further divided according to their configuration. Some fixed growth systems are designed primarily to oxidize organic matter and nitrogen and are known as *trickling filters*. Others are designed to not only oxidize organic matter and nitrogen, but to also physically filter out wastewater constituents. These are known as *media filters*.

Media Filters

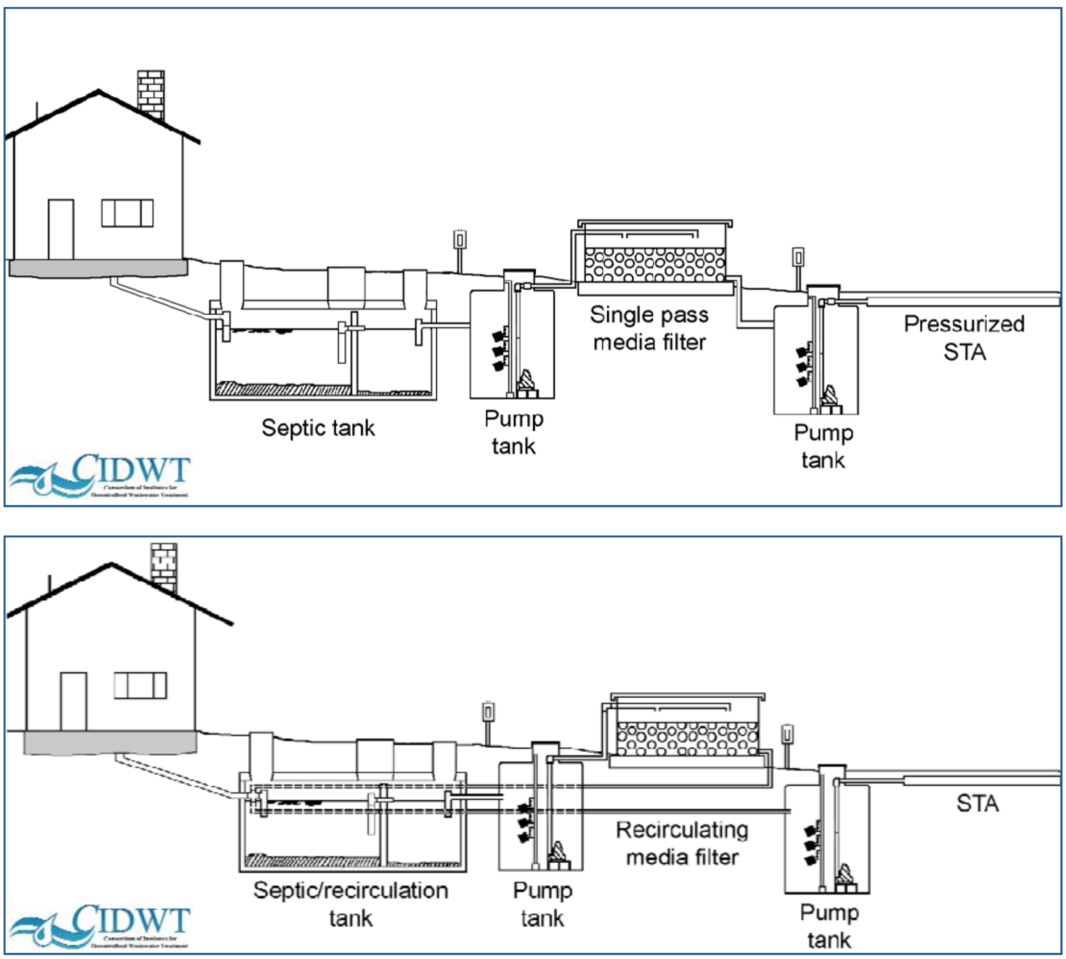
A media filter provides an environment with many attachment sites that allow microorganisms to grow and thrive. The porosity of the media promotes easy movement of effluent and air. As effluent flows past the attached microorganisms, they come into contact with the wastewater constituents. Because of the aerobic conditions resulting from 'dosing and resting' the porous media, conditions are favorable (aerobic) for the microbes to consume the dissolved organic matter in the effluent and convert ammonia nitrogen to the nitrate form through oxidation.

A media filter consists of a watertight container, an underdrain, filter media, a distribution network, and a control system. On a frequent basis (1 to 20 times per day), a small volume of wastewater is distributed across the top of the media. The liquid flows down through the media, collects in the underdrain, and either flows to the next treatment component or is recirculated for additional treatment. In some cases, the media filter is placed directly over the dispersal area and effluent is allowed to weep out of holes in the bottom of the unit. This configuration is only used where soil conditions are appropriate for this application (i.e., well drained soils with sufficient depth to provide final treatment and disperse the liquid). In most applications the media in the filter is about 24 inches deep but can be as deep as 48 inches. Media filters can be constructed at the site or purchased as prefabricated units.



Historically, the media consisted of a coarse sand over a base layer of gravel. In many situations these materials are inexpensive and locally available. When using a mineral aggregate as the media, the aggregate must have a relatively uniform particle size in order to maximize porosity. If small particles or "fines" are included, these particles will occupy the space between larger particles and reduce the overall porosity of the media. Various manufacturers have developed porous, light-weight synthetic media that provide many attachment sites. Examples of synthetic media include foam cubes, textile sheets, and plastic spheres. Other materials that are used for media include sphagnum peat, crushed glass, shredded tire chips, bottom ash and crushed masonry rubble.

Media filters can be designed to operate in single-pass mode or recirculating mode. In single-pass media filters (SPMF) effluent trickles through the media one time before being transferred to the next treatment component. SPMFs provide excellent BOD and suspended solids removal as well as nitrogen oxidation. As the name suggests, recirculating media filters (RMF) re-circulate the effluent through the media and recirculating tank several times before it is conveyed to the next treatment component. RMFs generally utilize coarser media that allow for relatively high loading rates (3 to 8 gallons per square foot per day). A SPMF typically uses finer media and is loaded at a lower rate (1 to 2 gallons per day per square foot). This means that a SPMF will have a larger footprint than a RMF. A RMF will include additional piping and tanks for effluent recirculation.



Basic configuration of single pass (above) and recirculating (below) media filters used for single-family residences. The technology can be configured many different ways and be designed to treat much higher flows than shown here.

The primary advantages of RMF include more complete BOD reduction, additional nitrification, and the potential for some degree of denitrification. After the wastewater passes through the media the flow is split. About 20 to 25% of the effluent flows to the next treatment component or to a dispersal component. The rest of the flow is directed to a recirculation tank and blended with wastewater that has received only primary treatment (liquid-solid separation). The nitrate-rich effluent from the media filter is thus subjected to an environment favorable for denitrification (low oxygen conditions with an available organic carbon source). The nitrate is converted to nitrogen gas and released to the atmosphere. Removing nitrogen is important in environmentally sensitive areas or where nitrates may enter drinking water supplies and affect the health of young children and some adults. Many different recirculation regimes are possible depending upon the wastewater characteristics and treatment goals.

A comparison of overall performance is shown in Table 1. Note that these figures will vary according to the level of hydraulic and organic loading.

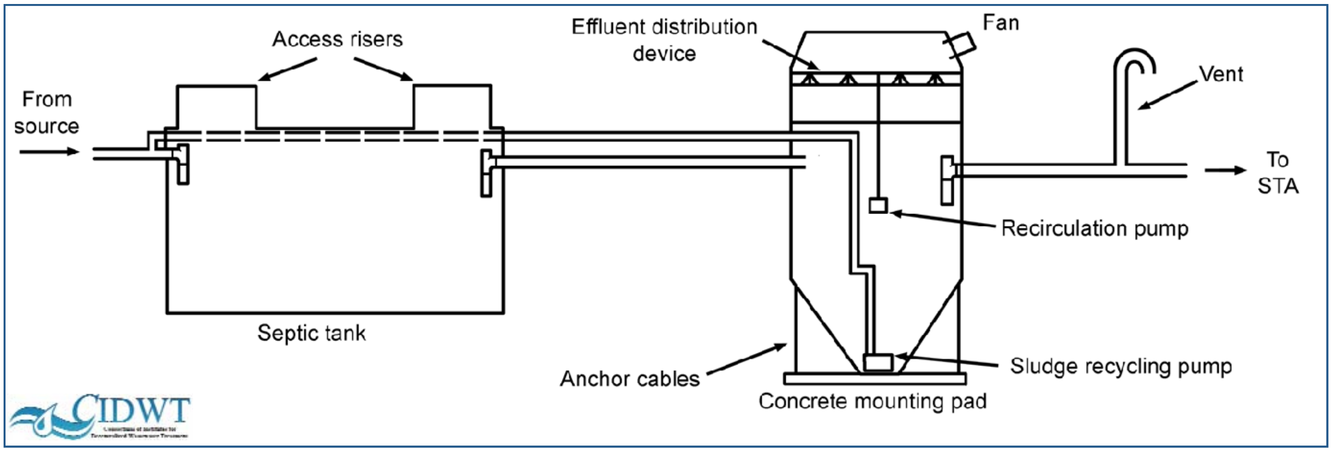
Table 1 - Average and Range of Wastewater Constituents in Typical Domestic Strength Septic Tank (ST), Single Pass Media Filter (SPMF) and Recirculating Media Filter (RMF) Effluent

	BOD[1] (mg/L)	**TSS[2] (mg/L)**	**Nitrate-N (mg/L)**	**Ammonium-N (mg/L)**	**Fecal Coliform (Organisms per 100 ml)**
ST	130-250	30-130	0-2	25-60	105 – 107 (100,000 to 10,000,000)
SPMF	<10 (5-25)	<10 (5-30)	15-30	0-4	$10^2 – 10^3$ (100 to 1,000) (2 to 4 log 10 reduction)
RMF	<15 (5-25)	<15 (5-30)	10-20	0-4	10^3 - 10^4 (1,000 to 10,000) (2 to 3 log 10 reduction)

[1]Biochemical oxygen demand
[2]Total suspended solids

Trickling Filters

Trickling filters are similar to the SPMF and RMFs; however, trickling filters have far greater void space and porosity within their media, which allows for higher hydraulic loading. The higher loading rate and increased void volume promotes a heavier biological growth on the media. This growth will periodically "slough" off and travel with the effluent to a clarifier where it settles out. In larger municipal systems, clarifiers serving the trickling filter will incorporate a *sludge return* to send a portion of the settled biomass to the trickling filter and the remainder to the primary settling tank. Trickling filters are still widely used in small to medium sized communities throughout the world to provide secondary treatment before surface water discharge. They have an advantage over the suspended growth aerobic treatment systems in terms of low maintenance requirements and resistance to upset from variations in wastewater volume and strength. The principle disadvantage of trickling filters is that more land area is needed to provide the treatment.



Example of a trickling filter configuration

How can Fixed-growth Aerobic Treatment be used?

The primary function of aerobic treatment is to remove oxygen demand by providing naturally-occurring organisms with sufficient oxygen to process organic matter, ammonia nitrogen and other compounds present in wastewater. Permit stipulations may allow aerobically treated effluents to be dispersed or discharged into receiving environments that are considered "high risk". The *risk* as used here is based upon the sensitivity of the receiving environment and how much additional treatment can be expected in that environment. A community may have the option to use subsurface soil dispersal, but the soil may be shallow with limited treatment capability. By applying aerobically treated effluent, the soil can more readily finish the treatment cycle and safely disperse the water back into the hydrologic cycle. Likewise if the effluent is discharged to surface waters, the lower oxygen demand will reduce environmental degradation as previously described. Nitrogen-sensitive areas can benefit from increased nitrogen removal provided by RMF technology and thus protect or improve surface and groundwater quality.

Fixed growth aerobic treatment systems are successfully utilized for a wide range of wastewater flows. Small flows (i.e., individual residences) tend to have significant variation water use and organic loading. For example, heavy laundry days tend to produce a large volume of water that is low in organic strength.

Recirculating media filters are well equipped to handle large variations in hydraulic and/or organic loading. Higher loading capacities are especially beneficial in applications where it is necessary to fit a filter into a small site or where the system must handle larger flows.

This treatment technology is easy to scale up for larger flows and is commonly used for clustered housing developments and small communities. As wastewater volume increases, additional media or trickling filters can be added to the system. Whether built-in-place or modular, the components can be expanded in size or number to accommodate an increased volume of wastewater. Modular commercial systems have numerous advantages over built-in-place systems for ease of installation.

Compatibility with the Community Vision

Decentralized systems are often the key to maintaining the charm of the community while effectively treating the wastewater. Shallow burial requirements provide the opportunity to avoid disruption of existing infrastructure and natural features. They can fit into difficult spaces and still provide the necessary services. Trickling filters are generally installed above grade and will require creative landscaping or other methods to limit their visibility. Surface access to SPMFs, and RMFs (with associated recirculation tanks) must also be provided, but they can still be buried in a shallow excavation that is relatively easy to conceal with landscaping and surface-shaping methods. In configurations where units are place directly over the dispersal area, fill is generally mounded around the side of the units and landscaping is used to conceal the components. Vegetation should not be planted so close that it might interfere with operation. When properly maintained and with established setback requirements, odors and noise should be minimal. The community must determine whether individual treatment components will be installed at each connection or if the wastewater will be collected and conveyed to one or more large treatment components.

Fixed-growth systems can be blended into the landscape.

Land Area Requirements

A typical SPMF requires 1 square foot or area per gallon of effluent applied per day. A RMF requires 0.2 to 0.33 square feet per gallon of effluent applied per day. A media filter serving a three-bedroom residence with a design flow of 450 gallons per day (gpd) would require a SPMF (or modular components) with a surface area of approximately 450 square feet or a RMF with surface area of about 150 square feet. A community system generating 50,000 gallons per day would require 1.15 acres of land for a SPMF and 0.38 to 0.5 acres for a RMF. Additional area would be required for primary treatment components, piping and containment as well as area for dispersal of effluent collected from the media filter.

Fixed growth aerobic units generally require larger footprints than suspended growth systems, thus explaining why the latter dominate in urban areas. However, most rural areas and small communities tend to have more land available, so fixed-growth systems may be more compatible with those circumstances.

Photos of single family and cluster development applications of fixed growth aerobic treatment. In the left photo, the structure to the right of the home is a sand filter. The photo on the right depicts a system for a 3,000 gallon per day cluster development.

Construction and Installation

The single biggest advantage of a fixed growth aerobic treatment system may be flexibility in siting. What is critical is the ability of the system to transfer oxygen to the microbes that facilitate treatment. The site must be graded to prevent stormwater runoff from entering the system.

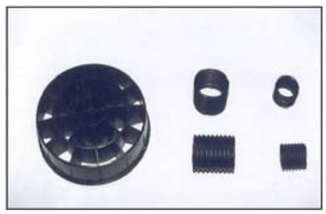
Sand or sand/gravel filters are generally constructed on site with a PVC watertight liner with two feet of sand with a particle size between 0.5 and 2.0 millimeters in diameter for SPMF and 3.0 to 5.0 millimeters for RMFs. An additional two feet

Sand or sand/gravel filters are generally constructed on the site

of gravel ¾" to 1" in diameter is placed beneath the sand as an underdrain. These specifications are designed to provide the recommended surface area for bacterial attachment, adequate void space for passive air flow to provide oxygen to aerobic organisms, and sufficiently large voids to prevent rapid clogging (in media filters) by the combination of filtered solids and biological growth. Availability and cost of sand and gravel with proper specifications is a critical consideration for design and installation.

Proprietary fixed growth aerobic systems are designed with the same concepts in mind and are generally modular in nature. Proprietary media filters use peat, textile coupons or sheets, expanded polystyrene, foam cubes and other media. Proprietary units typically include media, a watertight container, a distribution system and an underdrain component. The containers are typically constructed by the manufacturer and shipped to the site for installation. The media may be shipped separately for installation at the site. Piping to split flow among the units is installed on-site. Manufacturer-specific recommendations for installation must be observed and contractors must typically be certified by the manufacturer.






Examples of proprietary media used for fixed-growth aerobic treatment.

Operation and Maintenance

Most fixed growth aerobic treatment systems incorporate one or more pumps and a distribution component. These components must be regularly inspected and serviced as needed. Control settings must be periodically verified and adjusted as needed. Maintenance of the media container itself includes regular inspection for structural integrity and adequate ventilation. If multiple units are operating in parallel, uniform distribution within and among units must be verified. Fixed growth systems may require less O&M than suspended growth units.

Regular service is important for all systems to ensure best long term performance to protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of the components used.

Media filter must be regularly inspected to ensure that effluent is not ponding on the surface. If it becomes clogged and rejuvenation methods are unsuccessful, media must be removed and replaced. Natural media such as peat may degrade over time and have a limited service life. For planning purposes, replacement of synthetic media may be needed every 10 to 15 years. For natural media, replacement frequency varies between 7 to 15 years.

Personnel who perform maintenance on fixed growth aerobic treatment systems must have appropriate training. The service provider must understand the treatment processes and how to adjust system settings to optimize performance. State or regional training and certification may be required.

Costs for Fixed Growth Aerobic Treatment Systems

Costs for built-in-place sand and gravel SPMFs or RMFs will vary primarily on the basis of wastewater volume and quality; condition of, access to and location of site; cost and availability of suitable media; and nature of electrical power requirements. Proprietary attached growth aerobic units and media filters will vary with the location, the site constraints, and the totality of the performance requirements of any installation. Management costs must also be considered and will vary depending upon the structure of the management program selected.

Costs for built-in-place units vary on the basis of wastewater volume and quantity, site access and location, availability of suitable media and the nature of power requirements.

Some fixed growth aerobic systems use gravity to distribute effluent, but most use one or more pumps for distribution. The pumps and control systems are usually simple and have negligible power requirements. Recirculating systems will have slightly higher energy costs. However, power requirements are still about half of that required for many suspended growth aerobic treatment systems because compressors and blowers are not needed for aeration.

The information provided in Tables 2-3 assumes the construction of a site-built recirculating media filter. The costs of primary treatment or dispersal components are not included.

Table 2 is a cost estimation for the materials, installation, and maintenance of a residential attached growth, recirculating media filter. These costs assume that the contractor would charge 20% for overhead and profit, and there are no sales taxes on materials. Engineering fees and other professional services are not included in the costs. Maintenance costs were based on a part time service provider, and the annualized cost to replace system in 30 years.

Table 2. Estimated cost to install and maintain a residential recirculating media filter.

Materials and installation	Manufactured system, delivery, and installation	$13,000 - $20,000
Annual Electrical ($0.15 per kW-hr)	Recirculation pump power	$8 - $12
Annual O&M	Annualized service provider, plus cost to replace system in 30 years	$600 - $900
60-yr life cycle cost present value (2009 dollars)	Assumes 3% inflation, 5% discount rate, no salvage or depreciation	$35,000 - $52,000

Table 3 estimates the cost of a fixed-growth recirculating media filter treatment system for three flow rates – 5,000, 10,000 and 50,000 gpd. For this example, it was assumed that the installation contractor would charge 20% for overhead and profit. Engineering and other fees are not included in the costs. The maintenance cost is based on a part-time service provider, and rebuilding the system in 30 years.

Table 3. Estimated cost for a community-scale recirculating media filter.

Cost Factors	Daily Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$30,000 - $46,000	$98,000 – $147,000	$287,000 - $431,000
Annual Electrical ($0.15 per kW-hr)	$350 - $500	$900 - $1,400	$4,600 - $6,900
Annual O&M	$4,100 - $6,000	$7,300 - $11,000	$30,000 - $44,000
60 year life cycle cost present value (2009 dollars)	$219,000 - $328,000	$386,000 - $580,000	$1,491,000 - $2,237,000

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

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Fact Sheet T4

Performance & Cost of
Decentralized Unit Processes

Water Environment Research Foundation
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DECENTRALIZED WASTEWATER SYSTEMS

TREATMENT SERIES

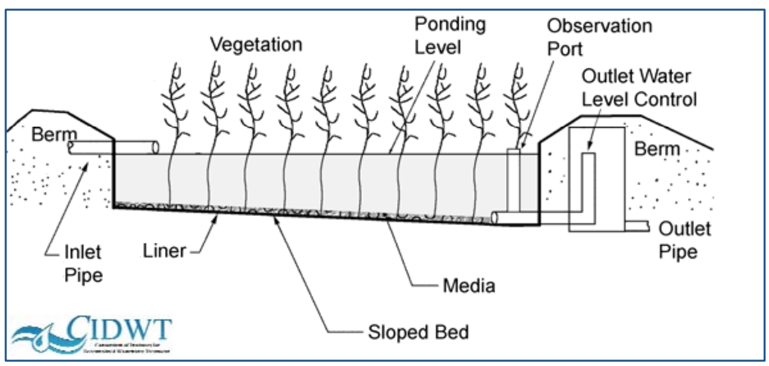
CONSTRUCTED WETLAND SYSTEMS

What are Constructed Wetlands?

Constructed wetlands are passive wastewater treatment components used to produce secondary (and in some cases, tertiary) effluent. At a minimum, incoming effluent must have undergone primary treatment (liquid-solid separation). There are two different types of constructed wetlands. Free-water surface (FWS) wetlands use vegetation grown on bottom sediments and flooded to a specific depth. Subsurface flow (SF) vegetated bed wetlands also use vegetation, but effluent flows beneath the surface of the vegetated bed instead of on top of it. Each configuration has its advantages.

Free-water Surface (FWS) Wetlands

FWS system consists of channels or basins, sometimes with a natural or synthetic liner to prevent seepage. In a FWS constructed wetland, the emergent vegetation is flooded to a depth that ranges from 6 to 24 in. (100 to 450 mm). Plants in FWS constructed wetlands serve a number of purposes. Stems, submerged leaves, and litter provide a place for beneficial bacteria to grow. Leaves above the water surface shade the water and reduce the potential for algal growth.



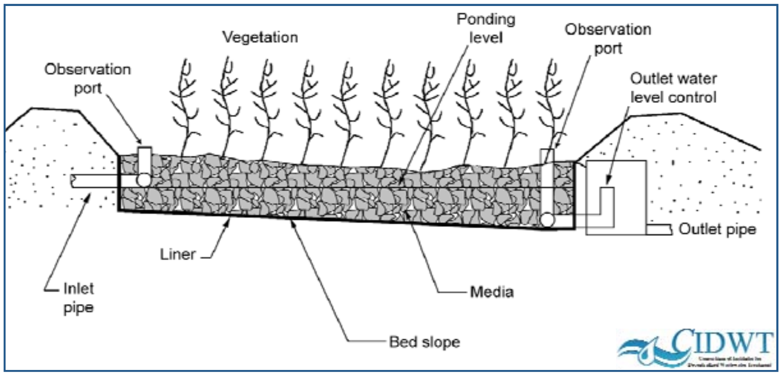
Typical configuration of a free-water surface (FWS) constructed wetland.

A FWS wetland system includes primary treatment (liquid-solid separation) via septic tanks or Imhoff tanks, screening with a rotary disk filter, or stabilization lagoons. They can most effectively be use as tertiary treatment after secondary treatment facilities. Organic loading should be less than 50 pounds of BOD per acre per day. At higher elevations, the loading rate must be lower to account for the decrease in atmospheric oxygen. The plants typically used in FWS wetlands include bulrush, cattail, common arrowhead, common reed, rushes, sedges, yellow flag, arrow arum and pickerel weed. Plants are chosen from locally grown hardy varieties of these plant families.

Constituent removal in FWS wetlands occurs through a variety of processes. Biochemical oxygen demand or BOD (a measure of the organic matter) is removed by microbial activity and the emergent plants help to trap and settle particulate matter suspended in the wastewater. Nitrogen can be removed by providing optimum conditions for microbes that convert ammonium nitrogen to nitrate nitrogen (nitrification) and then convert nitrate nitrogen to nitrogen gas (denitrification). A FWS wetland may be specifically designed for nitrogen removal if appropriately sized. Phosphorous will be removed during start-up through adsorption, and temporarily by plant uptake. Plant uptake of phosphorus during the growing season is rapid, but the phosphorus is released back into the water as soon as the plant dies. Phosphorus can also be released during other times of the year, usually in response to changing conditions within the system. Pathogenic bacteria and viruses are removed in FWS constructed wetlands by adsorption, sedimentation, predation, and die-off from exposure to sunlight (UV) and unfavorable temperatures. Constituent removal is similar to any secondary treatment process if appropriate levels of maintenance are provided.

Subsurface-flow (SF) wetlands

SF vegetated bed systems consists of gravel or other coarse media and emergent vegetation. Compared to FWS wetlands, SF systems require less land area and have fewer odor and mosquito or other vector attraction problems. Disadvantages of the SF systems include the potential for clogging of the media and occasional odor problems.



Typical configuration of a subsurface-flow (SF) constructed wetland.

A complete SF wetland system includes primary treatment (liquid-solid separation) via a septic tank or other primary treatment component. The wetlands can be used to provide additional treatment. The resulting effluent may have low dissolved oxygen, especially if the wetland is heavily loaded. It is thus better to apply effluent from SF wetland systems to subsurface soil dispersal rather than a surface water discharge.

An SF system is normally a lined earthen pond about 2 feet deep filled with rock media. The rock-filled cells typically have vegetation in a top layer of finer rock (pea gravel). Using multiple parallel cells allows the operator to vary loading on individual cells to create appropriate treatment environments. Common plants used in SF wetlands include locally hardy bulrushes, reeds, cattails, and any other non-invasive species. The plants in an SF wetland system take up nutrients during the growing season but nutrients may be returned to the system when the plants die and the plant matter is not removed.

BOD removal in these systems occurs primarily under anaerobic conditions, but filtration of suspended solids also plays a part. The rate of removal is related to detention time and temperature. The limited free water surface limits oxygen transfer, so it has been suggested that these should be designed using lower BOD loading rates than that used for facultative ponds to encourage aerobic decomposition. Loading rates from 15 to 70 pounds of BOD per acre per day have been used depending upon climatic conditions. Nitrogen removal is accomplished by nitrification/denitrification processes. Phosphorous removal and pathogen reduction occur as a result of the same processes as in FWS wetlands.

How can Constructed Wetlands be used?

Constructed wetlands are not generally recommended for systems that treat large wastewater volumes because of the large land area required. Onsite, cluster, or small community scale systems are most appropriate. FWS wetlands are used for achieving secondary treatment, polishing of secondary effluent, and providing wildlife habitat. Using parallel cells allows the operator to vary the flows and balance the loading on the individual cells to create appropriate treatment environments. The plants add little oxygen, but do provide microsites which may assist in treatment. The plants also provide an aesthetically pleasing treatment unit.

Parallel cells offer the flexibility to vary flow and loading.

SF wetlands are used to reduce suspended matter after septic tank treatment at individual homes and clustered developments. The resulting effluent is then dispersed into the soil using appropriate methods.

Compatibility with Community Vision

Constructed wetlands have an attractive natural appearance, and some may provide habitat for wildlife. They are an attractive landscape feature if they do not experience anaerobic conditions.

FWS and SF wetlands are passive treatment systems with a large footprint. This has a number of implications both positive and negative. If there is sufficient space for the wetlands system, it can be made into a very attractive green space since the green grass around the wetlands and the wetland vegetation itself is aesthetically pleasing. However, institutional and physical control of public access is required via fencing and signage in most settings, particularly for FWS systems. It is important that no deep-rooted vegetation be allowed on the banks or in the pond as this will affect the integrity of the berm that contains the wetland.

FWS wetlands have the potential to produce odors and attract vectors. Systems that receive a heavy BOD load may exhibit odor episodes associated with periodic loading or low pressure weather fronts. These usually last from a few hours to a day. The lighter the organic loading the less likely the system is to produce odor. These systems are expandable if space is available.

Constructed wetlands can be attractive green space.

Land Area Requirements

The land requirement for FWS wetland systems is considerable. The total site area will include the surface area of the FWS wetlands, the dike area, the buffer zone (if required) around the wetlands, and the area of the access roads associated with the site. As the size increases the buffer zone and the infrastructure area also increases. While a medium sized FWS system may have a 25 foot buffer zone and no road, a larger system may require a 100-200 foot buffer strip around the site with an access road. Additional space may be needed for a soil-based dispersal component.

SF systems require more space than most secondary treatment alternatives, but less space than a comparable FWS system. The total site area is primarily the surface area of the wetlands since there are no dikes or buffer zones due to less risk of human exposure.

Construction and Installation of Constructed Wetlands Systems

Major issues in installation of both FWS and SF wetlands include providing sufficient flow from the inlet of the plant to the treatment cells to allow flow balancing between the cells. Site preparation for the wetland itself includes grubbing (root removal) and leveling the site. The basin is excavated and dikes are created with a 3:1 to 4:1 run to rise ratio. The excavation may be lined with clay or a 40 mil high-density polyethylene (HDPE) liner. Rock rip-rap may be installed to protect the liner. Weirs are installed to adjust the flow if necessary.

The media used for SF wetlands is double-washed hard rock in the diameter range of ¾ inch to 1-¾ inch. A 4 to 6 inch deep pea rock cap is sometimes placed on top of the media for planting vegetation. Wastewater (influent) is uniformly distributed across the width of the wetland system using perforated pipe laid in coarse rock or by installing a chamber with a level spreader. At the distal end, effluent is collected and is directed to the next treatment component. The collection system also serves as the water level control for the wetland system. Risers must be provided at both the influent and effluent ends for cleaning and making level adjustments. The effluent from the wetlands is either disinfected for surface discharge, stored for irrigation purposes or dispersed into the soil. It is common for larger systems to require an upstream monitoring well and two downstream monitoring wells to insure liner integrity is maintained. Once it is constructed, locally hardy bulrushes, reeds, cattails, and other non-invasive species are established in the cells.

Personnel who install constructed wetlands systems must have appropriate construction expertise in this type of technology. Certification of construction contractors may be required in certain jurisdictions.

Installation of HDPE liner during construction of a wetland cell

Operation and Maintenance of Constructed Wetlands Systems

Flows must be balanced, and water levels in the wetlands adjusted occasionally. In some climates the vegetation must be regularly harvested. Typical failures in FWS wetlands are caused by excess organic loading which turns the wetland anaerobic causing odors and potentially killing the emergent vegetation. Excess solids will create problems for emergent vegetation if allowed to settle in the FSW wetlands.

Service providers who perform O&M for constructed wetlands must have appropriate training and expertise. Licensing and certification may be required depending upon the jurisdiction.

Once it is constructed, locally hardy, non-invasive plants such as bulrushes are established in the cells.

Costs for Constructed Wetlands Systems

There is a wide variation of cost for these systems owing to a lack of design uniformity. The total capital cost of a FWS constructed wetland will include earthwork, pipe installation, liner, seeding and overflow tank installation. SF systems will have the same costs plus those for washed rock media. Either wetland system may be lined, with the liner being the largest cost variable. If a native clay liner is used, the cost may be very reasonable. If a synthetic HDPE liner is used instead, the cost may be much higher. A licensed installation contractor will likely be required. If properly designed with adequate land area available, wetland systems provide passive aeration and do not have a power requirement. If supplemental aeration is needed, then power would be required for blowers or recirculation pumps. Permitting and operation and maintenance costs must also be considered.

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Fact Sheet T5

Performance & Cost of
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DECENTRALIZED WASTEWATER SYSTEMS

TREATMENT SERIES

LAGOONS

What is a Lagoon?

A lagoon is a passive method of providing secondary treatment of effluent. It is a constructed water body that is designed to receive liquid effluent and detain the effluent for 20 or more days as waste constituents are being removed. Some documents and regulations may refer to this treatment method as a pond. This fact sheet assumes that the terms "pond" and "lagoon" are synonymous, and will use the term "lagoon."

Lagoons provide treatment at a slow rate. Adequate time for treatment is ensured by building lagoon cells with large volumes. Large volume and slow treatment are tradeoffs for little to no external energy requirements. The large volumes associated with lagoons also make them resilient to shocks from excessive hydraulic and/or organic loading, from toxins and from sudden temperature changes. Long detention times encourage the die-off of pathogens and increase nitrogen removal.

Lagoons are used for residential, small commercial and small community applications that have suitable, available land. If sufficient land is available, lagoon systems could service flows as large as a million gallons per day. Lagoon systems perform best when there are multiple (usually three or more) cells in series. Single cell lagoons are allowed in some states for single-family residential purposes. Multiple cells maximize treatment by ensuring slower effluent progression through the system. Lagoons can produce effluent that approaches secondary treatment standards for BOD_5. TSS is less reliably removed. They can be an inexpensive solution for treating wastewater generated by a small community.

Lagoons can treat flows as large as a million gallons per day.

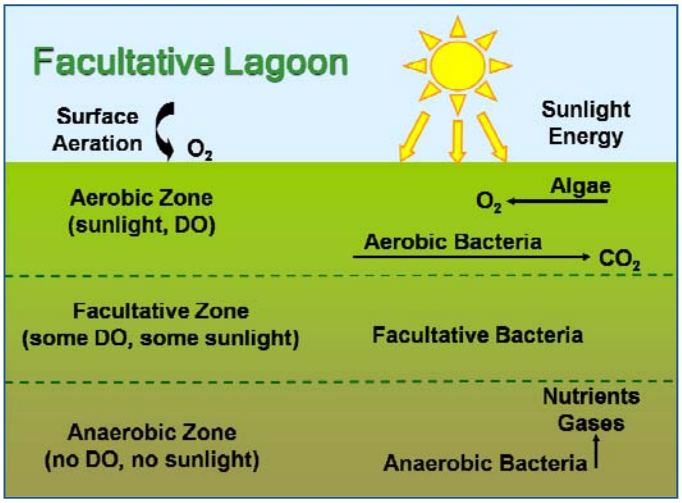
Lagoons provide treatment through physical and biological processes. The rate at which aerobic microorganisms oxidize organic matter is limited by how much atmospheric oxygen becomes dissolved in the water, so lagoons are typically shallow with a large surface area (typically measured in acres). The surface area provides a large interface with the atmosphere to promote oxygen to transfer into the bulk solution (natural aeration). Because most lagoons are large, quiescent water bodies, liquid-solid separation (primary treatment) also occurs. However, for small single-family systems it is strongly recommended that a septic tank be used prior to the lagoon to remove solids. A dispersal component is needed for the lagoon effluent. Disinfection is generally provided if spray irrigation or surface water discharge is used as the means of dispersal. Smaller lagoons systems will often use gravity trenches for dispersal.

Types of Lagoons

There are several lagoon configurations. The differences among them are primarily related to their design depth, external inputs and influent and effluent characteristics. Reducing total nitrogen is desirable in environmentally sensitive areas, and the design chosen will reflect that need where required.

Facultative Lagoons

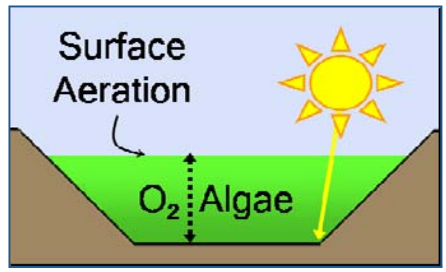
Facultative lagoons are the most common configuration for small community applications. They are typically 3 to 8 feet deep and detention times greater than 30 days. "Facultative" means that both aerobic and anaerobic conditions are present. A facultative lagoon system forms three layers with respect to dissolved oxygen. The top layer is aerobic, the bottom layer is anaerobic, and the middle is facultative. Much of the organic matter is oxidized in the top layer. Dead bacterial cells and other materials that are difficult to degrade will settle and form a sludge layer on the bottom of the lagoon. This anaerobic layer allows for continued (although slow) degradation. Anaerobic degradation processes result in odors because of the volatile fatty acids produced under low oxygen conditions. A particular advantage of facultative lagoons is that the aerobic layer can degrade many of these odorous compounds before they are released to the atmosphere, thus, reducing the potential for odors. The three layers provide a very hostile environment for



pathogens. Having both aerobic and anaerobic conditions encourages the die-off of microorganisms that are not adapted to this environment and also allows for nitrogen removal through nitrification/denitrification.

Aerobic Lagoons

Traditional aerobic lagoons are smaller in volume and, where external power is not used, they are shallower (typically 1-3 feet deep) than facultative lagoons. The goal is for aerobic conditions to exist throughout the depth. These are well suited for warm climates where freezing is not likely to occur. Aerobic ponds typically have a 30 day detention time.



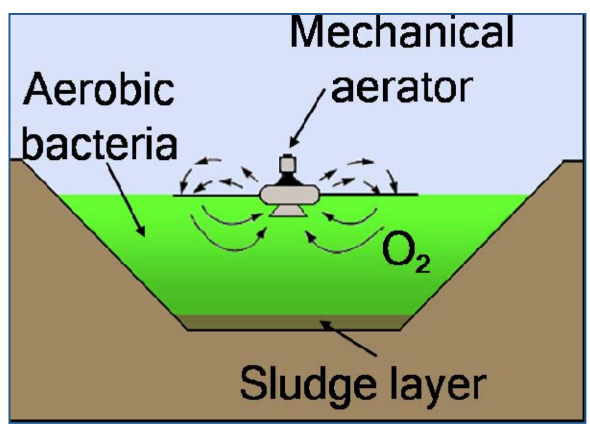
Typical configuration of an aerobic lagoon

Integrated Lagoon System

An integrated lagoon system is a facultative lagoon system with an anaerobic cell imbedded in the first 25% of the facultative lagoon's primary (first) cell. The imbedded anaerobic cell serves a number of purposes. It can break the life cycle of parasites by settling cysts that are a resilient life stage. It can also reduce BOD from 20 to 35% per day depending on food availability and temperature. The anaerobic cell is 15 to 20 feet deep with side dimensions less than 125 feet on a side. The anaerobic cell is frequently made of concrete so the sides are vertical to prevent wind from mixing the contents into the rest of the lagoon. After the anaerobic cell, water flows through a shallow portion of the system. This is an oxygen-rich top layer that helps to prevent odors from escaping from the anaerobic zone.

Aerated Lagoon (Pond) System

An aerated pond system is a pond with either diffused aeration or mechanical aerators. Aerated ponds are typically 15 feet to 25 feet deep and have a 20-40 day detention time. In a two-cell system, the first cell is aerated and completely mixed. The second cell is only aerated for the first 2/3 of the cell length. The last 1/3 is quiescent to promote settling of solids prior to discharge. It is common for these ponds to produce a high amount of total suspended solids or TSS (in excess of 30 mg/L). Because of the mechanical aeration used, these types of lagoons can have a much smaller footprint than other types described here.



Typical configuration of an aerated lagoon

Compatibility with Community Vision

Lagoons have large land requirements. Unlike constructed wetlands, lagoons systems cannot easily be made into attractive green space. However, it can provide a nice open water feature if the system owner or municipality provides the necessary institutional and physical control of public access. This implies a fence and appropriate signage in most settings. The other negative is the potential for odor. If the surface freezes, there is usually a period of odor immediately following the ice breakup. The length of the odor episode is a strong function of organic loading, water temperature, and duration of ice cover. The maximum anticipated odor episode is about 1-2 weeks a year. A heavily-loaded system may also have a short term odor episode associated with wind or a low pressure front. These usually last from a few hours to a day. The occasional odor episode is the trade-off for having a passive system that has no requirement for external energy. These systems are expandable if land is available.

Selection of any wastewater treatment process must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

Land Area Requirements

Naturally aerated (facultative) lagoons require the most land for wastewater treatment so this discussion is limited to land requirements for these types of lagoons. Simple treatment systems are relatively large compared to the complex treatment systems. The land requirements include the free water surface for transfer of oxygen, the dike area, and a vegetative buffer around the lagoon. The buffer may be eliminated around systems for single homes. For a commercial system the vegetative buffer may extend 100 feet from the toe of the dike and for a community system it may extend 200 feet.

<u>Facultative Lagoon Sizing Example</u>

The hydraulic and organic loading rates are evaluated when determining the area required for a facultative lagoon. For this example, it is assumed that a facultative lagoon will be constructed for a small community and the design parameters are based on 75 days of detention and an organic loading rate of 35 pounds of BOD per acre per day. The small community produces a wastewater volume of 50,000 gpd with a BOD of 180 mg/L. Using a design depth of 5 feet, the required surface area would be approximately 2.3 acres. For enhanced pathogen removal, three cells would be constructed, each having a surface area of about 0.78 acre. Including the land area between the cells, the area surrounding the system and the dikes, it is safe to assume that a three-cell lagoon system in this example would occupy 6 acres of land area.

Design parameters, such as detention times, allowable organic loading, and depth are site-specific decisions. Climatic conditions, elevation above sea level, and effluent limitations are the local factors that designers used determine the appropriate loading rates. Table 1 provides additional sizing examples various daily flows.

Table 1. Estimates of land area requirements for a facultative lagoon based on daily wastewater volume

Daily Wastewater Volume (gpd)	[1]Estimated Lagoon Surface Area	[2]Estimated Total Land Area
450	[3]0.04 ac (1,800 ft^2)	0.1 ac (4,530 ft^2)
5,000	0.23 ac (10,025 ft^2)	0.6 ac (26,136 ft^2)
10,000	0.46 ac (20,050 ft^2)	1 ac (43,560 ft^2)
50,000	2.3 ac (100,188 ft^2)	6 ac (261,360 ft^2)

[1]Based on 75 days of detention and 5-foot design depth

[2]Based on lagoon surface area plus land area surrounding the lagoon

[3]For single-home systems, local regulations may add a two-fold safety factor

Construction and Installation of Lagoon Systems

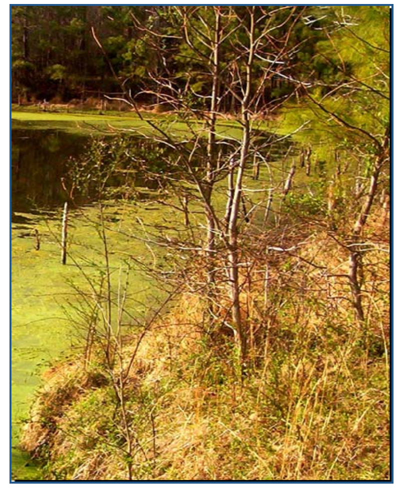
A lagoon system is usually a simple earthen basin with either a clay liner or a synthetic plastic liner to prevent percolation of wastewater into the ground. Typically, the volume of excavated soil is about one-half of the treatment volume. The excavated soil is used to construct the banks and dikes around the lagoon. If there is natural clay soil on the site, it may be adequate to simply bring it to the appropriate moisture content and compact it to create the liner. If the ground is sandy it will be necessary to either bring in clay or purchase a synthetic liner (such as high-density polyethylene or HDPE). Piping between the septic tank and the pond and/or between multiple ponds must be installed on the appropriate grade to promote gravity flow.

Soil excavated during construction of a lagoon is used to construct the banks and dikes.

Operation and Maintenance of Lagoon Systems

Lagoon systems have relatively low maintenance requirements since there are no moving parts. If they are loaded at recommended levels, they should not require solids removal for 8 or more years. Anaerobic digestion slows the accumulation of organic solids.

The primary maintenance issues are related to the physical structure and the surrounding vegetation. Woody vegetation must be prevented from growing in the berms that support the lagoon. Roots can create a pathway for water that may cause the berm to fail. For the same reason, burrowing animals must be excluded. Fencing and signage around a lagoon must be maintained to prevent unauthorized access. Some jurisdictions may require a certified wastewater operator for systems serving anything larger than a single family residence.



It is critical to prevent the growth of woody vegetation on the berm of a lagoon.

Costs for Lagoon Systems

There is a wide variation of capital costs for these systems. The largest variable is the cost of the liner. If a native clay liner is used, the cost may be very reasonable. However, if a synthetic HDPE liner is required, the cost will be much higher. The cost of acquiring and maintaining any permits and design/engineering costs may be substantial. Community-scale systems will require a certified operator to provide operation and maintenance. Accumulated solids (sludge) management is a major concern with lagoons. The cost of removing and disposing of the solids on a regular basis must be considered. See the Fact Sheet on Residuals Management for additional information.

For more information, see:

Fact Sheet T8: Residuals Management

With the exception of aerated lagoons, lagoons do not require electrical service. Treatment energy comes from the sun and wind. The energy requirement for aerated lagoons depends on the mass of additional dissolved oxygen required and the method used to deliver it. Given the remote locations of these systems, alternative energy sources should be evaluated. As mentioned before, an aerated lagoon does not require as much land. However, aeration is frequently added to increase the capacity of an existing facultative lagoon.

Table 2 is a cost estimation for the materials, installation, and maintenance of a residential lagoon. These costs assume that the contractor would charge 20% for overhead and profit, and there are no sales taxes on materials. Engineering fees and other professional services are not included in the costs. Maintenance costs were based on a part time service provider, and the annualized cost to remove sludge on an eight-year cycle. The removed sludge volume is based on two times the daily flow generated in eight years.

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

Table 2. Estimated cost to install and maintain a residential lagoon

Materials and installation	System excavation, liner, and headworks installed	$28,000 - $42,000
Annual electrical ($0.15 per kW-hr)	No supplement aeration provided	-0-
Annual O&M	Annualized service provider, plus sludge removal	$200 - $300
60-yr life cycle cost present value (2009 dollars)	Assumes 3% inflation, 5% discount rate, no salvage or depreciation	$36,000 - $54,000

Cost estimation must include a budget for sludge removal at the appropriate frequency. This is part of the long-term O&M of lagoons.

Table 3 estimates the cost of a lagoon system for three sizes of flows: 5,000, 10,000 and 50,000 gpd. For this example, it was assumed that the installation contractor would charge 20% for overhead and profit. Engineering and other fees are not included in the costs. The maintenance cost is based on a part-time service provider, and the annualized cost of removing sludge on an eight-year cycle.

Table 3. Estimated cost to install and maintain a community-scale lagoon system

Cost Factors	Daily Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and installation	$314,000 - $471,000	$628,000 - $942,000	$3,141,000 – $4,711,000
Annual Electrical ($0.15 per kW-hr)	-0-	-0-	-0-
Annual O&M	$2,400 - $3,500	$4,700 - $7,100	$24,000 - $35,000
60 year life cycle cost present value (2009 dollars)	$397,000 - $596,000	$794,000 - $1,191,000	$3,971,000 - $5,956,000

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Fact Sheet T6

Performance & Cost of Decentralized Unit Processes

Water Environment Research Foundation
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DECENTRALIZED WASTEWATER SYSTEMS

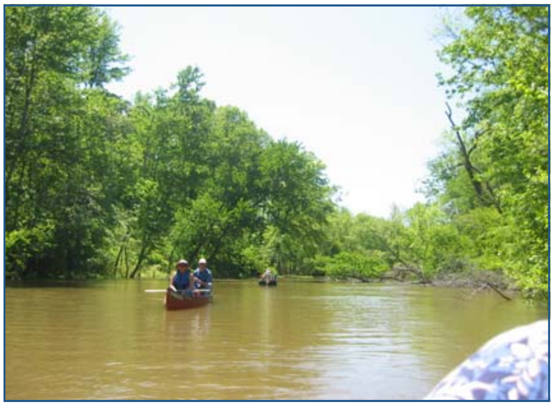
TREATMENT SERIES

NUTRIENT REDUCTION

What is Nutrient Reduction?

Nutrient reduction is a process or series of processes used to reduce the mass of nutrients in sewage. This fact sheet will focus on the reduction of nitrogen and phosphorus in effluent. Depending on how (or where) treated effluent is returned to the environment, these two nutrients could produce a detrimental effect. Some wastewater experts consider nutrient reduction to be a tertiary treatment (a third level), which sometimes includes disinfection. The Fact sheets in this series separate nutrient reduction and disinfection to avoid confusion.

Nitrogen is often more problematic in saltwater environments (oceans, bays and estuaries) while phosphorus is more problematic in freshwater environments (lakes, streams and rivers).



Nutrients are considered excessive if the receiving environment cannot assimilate them without causing excessive growth of aquatic plants or other undesirable organisms. Excessive nutrients in water bodies can potentially cause *eutrophication* (extreme productivity in a water body), *hypoxia* (a low concentration of dissolved oxygen), and habitat destruction. Nitrogen (N) and phosphorus (P) are the two most common nutrients that cause eutrophication of aquatic systems. Nitrogen is typically more of a problem in saltwater environments like oceans, bays and estuaries while phosphorus is more problematic in freshwater environments such as lakes, streams and rivers. Excess quantities of nutrients stimulate excessive plant growth (algae, and nuisance plants weeds), which results in reduced sunlight penetrating the water and a loss of habitat for aquatic animals and plants. As the excess organisms die, their decomposition can cause a decreased amount of dissolved oxygen in the water. These conditions reduce the diversity of species and the overall health of the ecosystem. Hypoxic waters do not have

Hypoxic (low oxygen) conditions can shift fish populations or cause fish kills.

Excessive levels of nitrate can affect the ability of an infant's blood to carry oxygen.

enough oxygen to support fish and other aquatic animals. In situations where the hypoxic conditions develop abruptly, massive fish kills can occur. In other situations where it happens gradually, it causes a demographic shift in populations. Game fish, such as trout, may need as much as 4 mg/L oxygen to thrive. Less desirable species of fish, such as carp, may thrive on oxygen levels of less than 2 mg/L.

In some jurisdictions, there is also concern over nitrogen as a human health issue. Nitrogen in the nitrate form can cause blue baby syndrome (methemoglobinemia) affecting infant blood's ability to carry oxygen. Some studies have also implicated high nitrate levels in increased risk of birth defects.

Nitrogen

Wastewater can contain several nitrogen species: nitrate, nitrite, ammonia, and organic nitrogen. These nitrogen compounds result from the biological decomposition of proteins and from urea, which are discharged as human waste. Primary treatment can remove about 10% of the total nitrogen in wastewater through solids separation. The nitrogen that remains after primary treatment is primarily in the ammonium form.

In soil-based systems that receive septic tank effluent, nitrogen will undergo several transformations within and below subsurface soil dispersal components. The ammonium nitrogen may be taken up by plants or volatilize to ammonia gas under high pH conditions in alkaline soils. Ammonium nitrogen may also be biologically converted to the nitrate form. The process of converting ammonium into nitrate is called *nitrification*.

Like ammonium, nitrate is plant available; however, it is also very water soluble and will tend to move downward to the groundwater and into nearby surface water. Denitrification is the process of converting nitrate into a nitrogen gas, which is released to the atmosphere. This nitrogen reducing process can occur in pretreatment processes or in the soil if there is sufficient carbon present and if low oxygen conditions exist. Under these circumstances, microorganisms can convert nitrate to nitrogen gas.

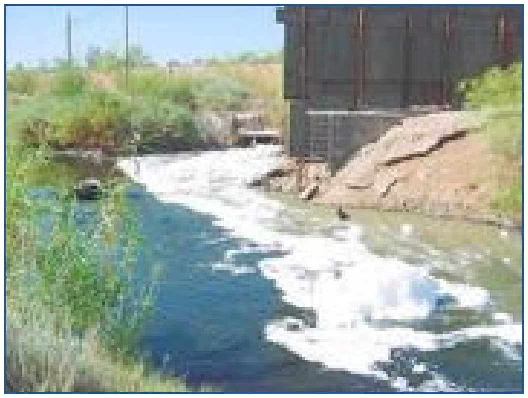
In order for any treatment system to provide predictable nitrogen reduction, the system has to be carefully managed. From the perspective of biological processes, there are two limiting factors. The first is that the microorganism that convert nitrate to nitrogen gas need conditions with low (or no) dissolved oxygen.

Secondly, these microorganism need a source of organic carbon. Creating these denitrifying conditions is problematic because most of the organic carbon was removed during aerobic treatment, which also created the nitrate. A successful solution to this problem is to re-circulate a portion of the nitrate-rich water back through a primary treatment component. This places nitrate in an low oxygen environment with sufficient carbon to stimulate the organisms that conduct the denitrification process.

Passive treatment components like lagoons and constructed wetlands also provide conditions conducive to denitrification by having aerobic zones close to the air-water interface and anaerobic zones near the bottom. In cases where organic carbon continues to be a limiting factor, a media made of bio-available organic carbon may be placed in anaerobic zone or an external source of carbon (such as methanol) can be added to the reactor.

Phosphorus

Forms of phosphorus (P) include orthophosphate, polyphosphate, and organic phosphate. Organically bound phosphorus originates from human waste and food scraps. Upon biological decomposition, organically bound phosphorus is released as orthophosphate. Polyphosphates are used in synthetic detergents and often contribute up to one-half the orthophosphate in wastewater. In raw sewage, the concentration of phosphorus is usually between 5 to 15 mg/L as P. Acceptable levels in sensitive natural water systems may vary from 0 to 3 mg/L.



Detergents are one source of phosphorus.

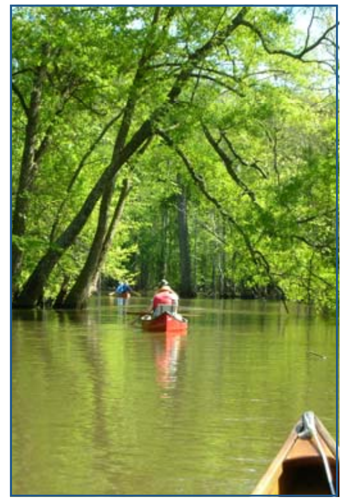
Because phosphorus is a component in many organic solids, liquid-solid separation provides a significant phosphorus reduction. In soil-based dispersal systems, phosphorus is adsorbed by calcium, aluminum, and iron compounds as well as by clay minerals.

Phosphorus reduction can also occur when biomass is wasted from suspended growth systems (i.e., when solids are pumped from an ATU or activated sludge treatment component). With modifications and proper management, phosphorous reduction can be significant. This process is called biological nutrient removal (BNR). A well operated BNR system will reduce phosphorus to 3-5 mg/L, but requires significant expertise and attention to be successful. Phosphorous reduction is unnecessary if the effluent is applied to the soil. If phosphorus reduction is mandated for small surface water discharging systems, a chemical treatment technology is usually the best choice.

Nutrient reduction is theoretically feasible in systems of all sizes. From a practical perspective, it is relatively straightforward to incorporate nitrogen and phosphorus reduction into small scale systems. However, performance is highly dependent upon diligent operation and maintenance (O&M). Successful nutrient reduction requires an extremely knowledgeable operational staff, and frequent operator intervention.

Compatibility with the Community Vision

The issue that is frequently discussed relevant to nutrient reduction is the value of natural waters to the community. If a community's economy relies on tourism, then nutrient reduction may be a critical issue. Another issue is the location of effluent discharge or dispersal relative to the source of a community's drinking water. If there is not a direct connection between the two, then nitrogen reduction may not be a critical issue for the community. Likewise, water reuse can play a major role in local water planning. If the treated wastewater is to be used for irrigation, the nutrients become valuable for plant production and should not be removed.



Land Area Requirements for Nutrient Reduction

For soil-based effluent application, land area requirements are usually based on hydraulic loading, which has historically been adequate to remove phosphorus from effluent. If P reduction is a permit requirement and the soil is inadequate to adsorb the P, increasing the land area for dispersal can address the problem. Communities that have the luxury of large lot sizes can simply make everything larger and let nature remove the phosphorus.

Determining land area requirements for nitrogen reduction is less straightforward. If total nitrogen must be reduced to a moderate level, a recirculating treatment aerobic/anaerobic process can achieve this. If the limit is less than 5 mg/L total N, then a stand-alone denitrification systems with internal carbon sources may be needed to meet this standard. The need for these solutions will vary from location to location, but the technologies are available for use.

Construction and Installation of Nutrient Reduction Mechanisms

Nutrient reduction must be designed into the treatment process. For moderate nitrogen reduction, systems must be built that allow a portion of the nitrified effluent to re-circulate back to an anaerobic zone for denitrification. For phosphorous reduction, conditions must be kept conducive to uptake of phosphorus by microorganisms. Once the phosphorus-rich microbes are removed, an appropriate management program must be in place to handle the residuals. A unit process such as media filter using media with high iron or aluminum content can be used to remove additional phosphorus. Construction and installation will thus be specific to the method required and chosen for the particular nutrient reduction that is needed.

Operation and Maintenance of Nutrient Reduction Processes

Nitrogen

Nitrogen reduction is a multiple-step biological process. Maintenance providers must ensure that the environmental conditions are appropriate for these processes to occur. The conversion of ammonia to nitrate c (nitrification) requires aerobic conditions, and a by-product of this conversion is acid. Thus, maintenance providers need to frequently check the dissolved oxygen concentration and the pH. Converting the nitrate to nitrogen gas requires anaerobic conditions and easily available organic carbon. In some situations, methanol is added as a carbon source.

Phosphorus

Phosphorus can also be removed by biological processes, but for small community systems, this is a difficult processes to maintain. It is generally recommended that if a community has a phosphorus permit limitation, then chemical means should be investigated. Chemicals such as calcium, iron or aluminum coagulants can be added to the effluent on a continuous basis. This mixture reacts with the dissolved phosphorus and forms a solid known as a *precipitant*. Operation and maintenance of this system will require a person knowledgeable in setting chemical dosage, the purchase and handling of the chemicals, and management of the accumulated solids.

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Costs for Nutrient Reduction

The incremental cost of adding a nitrogen reduction system a septic tank system for a 3-bedroom home will range from $5,000 to $20,000 (assuming 20 mg/L of total nitrogen in the influent). The technology selected will be the driving force for cost. If phosphorus is removed by chemical precipitation, then the purchase of replacement chemicals will be an ongoing cost. Energy consumption will increase with the addition of pumps needed to produce the necessary energy for recirculation. Most nutrient reduction processes will not require blowers or aerators. Costs vary from system to system and are essentially tied to the components used.

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Fact Sheet T7

Performance & Cost of Decentralized Unit Processes

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DECENTRALIZED WASTEWATER SYSTEMS

TREATMENT SERIES

DISINFECTION

What is Disinfection?

Disinfection is the process of inactivating pathogenic (disease-causing) organisms or preventing their reproduction. This is a critical process for protecting the public from waterborne diseases such as cholera, typhoid, dysentery, hepatitis and salmonella. Pathogenic organisms commonly found in domestic wastewater include enteric bacteria, viruses, helminths, and protozoan cysts.

E. Coli 157 is a pathogenic (disease-causing) organism)

Disinfection should not be confused with sterilization. Sterilization is the complete destruction of all macro- and microorganisms in water. The goal of disinfection is to reduce the number of pathogens in the treated effluent thereby reducing the risk of disease of disease transmission. Small wastewater systems tend to focus on filtration, predation and natural die-off in the soil, cell-wall destruction by chlorine, and disruption of reproduction by ultraviolet radiation (UV).

Soil Treatment

For many human-based pathogens, the soil is a hostile environment. The body of a mammal is warm, moist, and contains the nutrients needed for pathogen survival. In contrast, soils are cool, have wet-dry cycles, and contain predatory organisms. As effluent moves through unsaturated and aerobic soil, most of the pathogens are removed through physical filtration and adsorption. They become attached to soil particles and are no longer mobile in the environment and/or die. Provided that soil-based dispersal systems are correctly sited and installed, disinfection of pathogens is highly effective within the soil profile. For information on soil-based dispersal options, see the Dispersal Fact sheets included in this series.

Soil has a significant capacity to disinfect effluent through filtration, adsorption and predation of pathogens.

Chlorination

Chlorine disinfects by migrating through the cell walls and destroying the enzymes that facilitate the bodily function of the organisms. Depending upon effluent flow and mixing characteristics, this process generally requires 20 to 60 minutes of contact time for typical chlorine concentrations used to treat effluent. If properly applied, chlorine can be quite effective in the destruction of bacteria. However, 6 to 7 times more chlorine is required to destroy viruses than that needed to destroy bacteria. Further, the destruction of Giardia cysts and Cryptosporidium oocysts may require 8 to 10 times more chlorine because of their resiliency.

Chlorine can be used in the form of gas, liquid or tablets. Gas and liquid forms are typically injected into effluent. Tablet chlorination is achieved by passing the effluent through a chamber that contains the tablets. Regardless of the form of chlorine used, there must be adequate mixing and contact time between the disinfectant and the effluent in order for disinfection to be effective.

Chlorine tablets can be used for disinfection.

Depending on the effluent dispersal method (or permit requirements), it may be necessary to remove the residual chlorine that remains after disinfection. This is especially true when effluent is discharged to surface water because of the potential negative impacts of chlorine on aquatic life. Dechlorination is a chemical process that uses sulfur compounds (typically either sodium bisulfate or calcium thiosulfate) to react with the form of the chlorine that could affect surface waters.

Ultraviolet (UV) Radiation

Disinfection by UV radiation occurs when a specific band of electromagnetic energy from a source (e.g., a UV lamp) penetrates an organism's genetic material (i.e., DNA and RNA), retards its ability to reproduce and eventually causes death. UV radiation is generated by passing an electrical discharge through mercury vapor to produce light in the wavelength range of 250 to 270 nanometers (nm). This radiation range is optimum for pathogen inactivation. The electromagnetic waves are limited in how far they can effectively penetrate into water. UV systems are typically designed to pass effluent through a long narrow chamber, which has a UV source placed along the long axis. Wastewater flows around and close to the source. The length of the chamber and the flow rate through the chamber determines the length of time the effluent is exposed to the UV radiation (dosage).

UV light is generated by passing an electrical charge through mercury vapor. This unit has a horizontally-oriented bulb.

How can disinfection be used?

Some disinfection occurs at all stages of wastewater treatment. Pathogens are frequently attached to suspended solids. Thus, and liquid-solid separation (primary treatment) can remove significant numbers of disease-causing organisms. Additional pathogens are removed during aerobic treatment. When specific pathogen reduction is required, soil treatment, chlorine, and UV radiation provide very predictable results. However, "interferences" must be removed from wastewater in order to ensure adequate disinfection. Wastewater management professionals use the term "interference" when excess suspended solids or other constituents in the wastewater retard or prevent the disinfection process. In order for the disinfection to be effective and predictable, wastewater must undergo significant treatment (liquid-solid separation and organic matter removal) prior to using disinfection methods.

For small wastewater management systems, either a chlorine or UV disinfection system will be used. For larger flows, onsite chlorine generation or UV are the most likely methods, while for the lowest flows, the choice may be between a tablet chlorinator and UV.

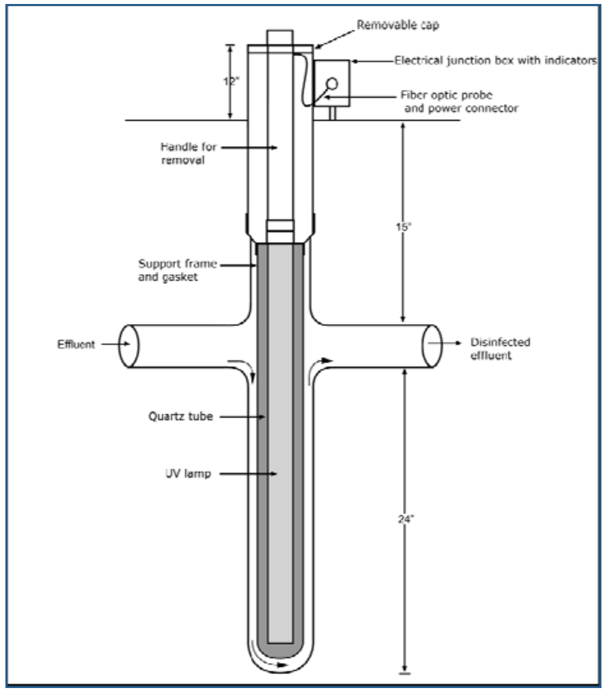
Chlorine is by far the most common method for chemical disinfection at larger and older facilities in the United States. It is available in gas, liquid, or solid form. Gaseous elemental chlorine is the common form for smaller municipal treatment facilities. While this is an economical and effective product, it is also very dangerous to handle and store on the site. Some small communities and clustered housing developments have chosen to use sodium hypochlorite (industrial strength bleach – approximately 12% available chlorine) or calcium hypochlorite (solid tablet – approximately 70% available chlorine). However, these forms of chlorine also present safety issues. One form of chlorine that is gaining popularity is on-site chlorine generation. This option minimizes many of the safety issues that occur with the more traditional chlorination. In very small systems, tablet chlorination has been used for decades, but it is notorious for either overdosing (resulting in aquatic toxicity) or under-dosing (resulting in inadequate disinfection).

Tablet chlorinator

Chlorine is a strong oxidizer, and will react with suspended and dissolved organic matter, sulfur, some metals, and ammonia. In order to have sufficient chlorine available for disinfection, the dosage must include enough chlorine to overcome interferences that are present plus provide disinfection. It is less costly (and safer) to remove most of these interferences through prior treatment. At many larger treatment facilities discharging to surface waters, chlorination followed by dechlorination is the final treatment process before dispersal.

UV radiation has recently gained popularity as a method of disinfecting wastewater. It is safer than chlorine and does not require the same level of oversight. The UV light source can be easily mounted in the treatment train. UV systems are available that can serve a single residence or a large municipal facility. The primary interferences for UV disinfection are solids in the effluent. Suspended solids will “shadow” the radiation, protecting pathogens from exposure. Dissolved carbonates and sulfates can precipitate (form a scale) on the surface of the UV light source and reduce the radiation intensity. Effluent filtration prior to UV exposure is a good solution to suspended solids, but little can be done to prevent scaling. As part of periodic maintenance, UV systems must be taken out of service and cleaned or replaced.

UV unit with a vertically-oriented light. Effluent is disinfected as it flows through the unit and past the light.



Soil treatment is a very effective disinfection process but the results are difficult to quantify. Physical, chemical, and biological components of the soil system significantly reduce pathogen numbers and the risk for disease transmission. Two issues interfere with the soil’s ability to provide disinfection: soil contact time and soil moisture. All soil-based dispersal codes demand some minimum depth of soil above a limiting condition (shallow groundwater or bedrock). It is assumed that this depth of soil can provide final treatment before the water moves back into the hydrologic cycle. The required soil depth for disinfection is based on the soil type, soil structure and dosing conditions. More depth is generally needed in sandy soil and less depth is needed in clayey soil because of the relative speed of effluent movement through each. In clayey soils, movement is slower and thus, contact time is increased relative to sandier textured soils. Soil moisture creates an interference to disinfection because excessive moisture causes saturated conditions, allowing pathogens to survive and move through the soil profile. Wet-dry cycles are optimum for disinfection conditions.

Compatibility with the Community Vision

Disinfection provides more opportunities to safely convert effluent into a valuable resource for reuse. This water could be used for irrigation, aquifer recharge, or industrial process water using **Wastewater Reuse** options. See the Fact Sheet on this topic for more information.

For more information, see:
Fact Sheet D7: Wastewater Reuse

Land Area Requirements

The use of soil-based disinfection requires the largest footprint since the area required is based upon using the soil for dispersal. This means that it is a function of the application rate for the soil and the daily wastewater volume. Components used for Chlorination and UV on individual homes will have a minimal footprint and are typically located within the same area occupied by the aerobic treatment component used within the system. Disinfection components for cluster developments and community applications are often installed in structures with other system components. The area required is not significant in terms of the overall treatment system since the mixing steps are small and the contact reactors may be buried.

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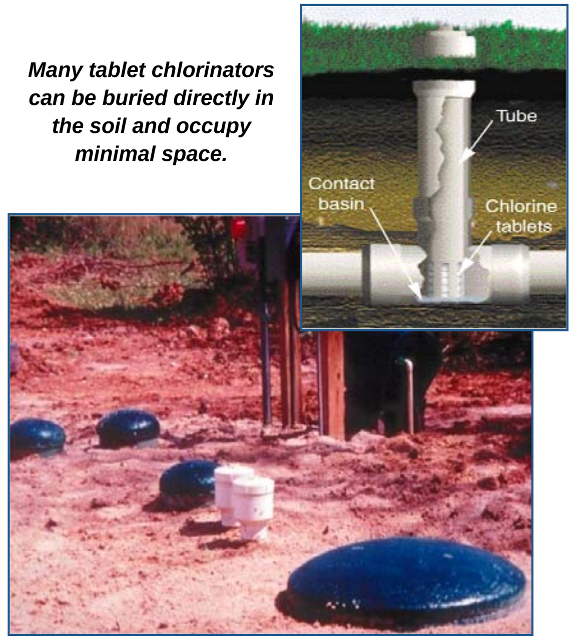
Many tablet chlorinators can be buried directly in the soil and occupy minimal space.



Construction and Installation

Chlorine and UV systems are installed with the overall treatment train. As the facility is being constructed, these devices would simply be installed as a system component. Disinfection is generally the last component of the treatment system. Mechanical and electrical components are required for both UV and chlorine disinfection systems (except tablet chlorinators). Chlorination systems require 20 to 60 minutes of contact time. This is accomplished by including tank or piping capacity just after the point where chlorine injection/mixing occurs.

UV light unit installed inside the riser of a dosing tank

Operation and Maintenance

The use of UV or chlorine disinfection implies that effluent is being discharged to a relatively sensitive environment or that human contact with effluent is possible. There is also significant safety risk associated with disinfecting agents themselves. An understanding of the treatment requirements prior to the unit, proper testing protocol and appropriate operation of the equipment itself adds more complexity. For these reasons, O&M personnel must have a high level of expertise and training.

Soil Treatment

Relying on the soil for disinfection involves ensuring that sufficient aerobic soil is available for the natural processes to effectively occur. This can be accomplished through proper siting, design, installation and maintenance of soil dispersal components.

Chlorine

Although the disinfection processes for small systems are quite simple and undemanding, chlorine disinfection used at individual homes has historically been unsuccessful because of poor maintenance. Thus, a routine operation and maintenance (O&M) schedule must be developed and implemented for any chlorine disinfection system.

For individual residences, monthly O&M includes inspecting the feeder for damage, ensuring that tablets are present and in contact with the effluent and that sufficient contact time has occurred. Chlorine residual in the effluent must also be measured. For larger treatment facilities, operation and maintenance activities for liquid and gas chlorination systems are significantly more complicated. Components such as meters and floats must be periodically disassembled and cleaned. Valves and springs must also be inspected and cleaned. Injector pump performance must be verified and maintained. Safe storage of liquid or gaseous chlorine is of paramount importance. If dechlorination is required, maintenance providers essentially have two chemical systems to operate and maintain. Sampling and analysis for indicator organisms is typically required to measure performance.

Checking chlorine residual using a meter (top) or test strips (bottom) is part of regular maintenance.

Ultraviolet Radiation

Over time, emissions from UV lamps begin to fade. Because of this degradation of strength, lamps must be replaced on a regular basis. Manufacturers provide UV meters that provide a read out of the emission strength, but these are somewhat unreliable. For residential applications, the replacement interval is typically one year. Larger units require lamp replacement about every 12,000 hours of use. This is typically an annual task. Ballasts and transformer must also be replaced every 5 to 10 years and quartz sleeves that shield the lamps must be

UV lamps must be regularly replaced, typically once per year.

replaced every 5 years. Depending on mechanical cleaning arrangements, O&M visits may vary from 1 to 4 times per year. The protective sleeves (either quartz or Teflon) that separate the lamps from the effluent must be regularly cleaned. Inadequate cleaning is one of the most common causes of a UV system malfunction. Most manufacturers offer devices with mechanical wipers for this purpose. Depending on the degree of precipitation (scaling) that occurs, sleeves may need to be removed and acid-cleaned. Chemical cleaning is most commonly done with citric acid.

As with chlorination systems, sampling and analysis for indicator organisms is typically required to gauge performance.

Energy Requirements

In general, disinfection is a low energy process. When using soil-based final treatment, the energy requirement is already accounted for in the dispersal process. This is usually accomplished with gravity, but more frequently via LPD or drip dispersal in larger systems. Chlorine systems have injection devices that operate on electricity, but electrical use is very small. UV radiation has a direct power requirement. These devices are essentially fluorescent lamps and they operate on 120 VAC. Depending on effluent flow rate, power requirements for UV systems range from 1 to 1.5 kilowatts per day of service. When UV is used on pressurized distribution, the lamp is only on while the system is pressurized.

Costs for Disinfection

For the purpose of estimating costs, two disinfection technologies are compared at four wastewater flows. Because of the regulatory issues involved with gaseous chlorine, it is assumed that a small community may choose to use sodium hypochlorite. If a community is comfortable with gaseous chlorine, it is the less expensive form of chlorine disinfection.

The costs given in this document are for sodium hypochlorite and UV radiation. These comparisons are for educational purposes only. The actual cost for a disinfection system will vary depending on local economics. The costs below reflect only those associated with a disinfection system.

Table 1 is a cost estimation for the materials, installation, and maintenance of a residential chlorination/dechlorination tablet feeder. These costs assume that the contractor would charge 20% for overhead and profit, and there are no sales taxes on materials. Engineering fees and other professional services are not included in the costs. Maintenance costs were based on a part time service provider, and the annualized cost to replace the feeder in ten years, and replacement chemicals.

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

Table 1. Estimated cost to install and maintain a residential chlorination system

Materials and installation	Chlorination/dechlorination tablet feeder and installation	$600 - $2,000
Annual electrical ($0.15 per kW-hr)	Flow-through system no electrical requirement	-0-
Annual O&M	Annualized service provider, plus sludge removal	$70 - $200
60-yr life cycle cost present value (2009 dollars)	Assumes 3% inflation, 5% discount rate, no salvage or depreciation	$3,600 - $5,400

Table 2 estimates the cost of a chlorination/dechlorination system for three flows: 5,000, 10,000 and 50,000 gpd. For this example, it was assumed that the installation contractor would charge 20% for overhead and profit. Engineering and other fees are not included in the costs. The maintenance cost is based on a part-time service provider, and the annualized cost of replacing injector components on a ten year basis. Sodium hypochlorite is the chlorine source and calcium thiosulfate is the dechlorination agent.

Table 2. Estimated cost for a community-scale chlorination/dechlorination system

Cost Factors	Daily Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$3,100 - $5,400	$3,100 - $5,400	$3,100 - $5,400
Annual Electrical ($0.15 per kW-hr)	$40 - $50	$50 - $80	$3,100 – 4,700
Annual O&M	$900 – 1,400	$1,700 - $2,500	$7,900 - $12,000
60 year life cycle cost present value (2009 dollars)	$37,000 - $55,000	$65,000 - $97,000	$285,000 - $428,000

Table 3 is a cost estimation for the materials, installation, and maintenance of a residential UV disinfection system. These costs assume that the contractor would charge 20% for overhead and profit, and there are no sales taxes on materials. Engineering fees and other professional services are not included in the costs. Maintenance costs were based on a part time service provider, and the annualized cost to replace the UV unit in ten years, plus replace the lamp every year.

Table 3. Estimated cost to install and maintain a residential UV disinfection system.

Materials and installation	Install and connect UV system	$900 - $1,100
Annual Electrical ($0.15 per kW-hr)	Operates only during dose cycle	$10 - $12
Annual O&M	Annualized cost of unit replacement and annual lamp	$190 - $280
60-yr life cycle cost present value (2009 dollars)	Assumes 3% inflation, 5% discount rate, no salvage or depreciation	$7,600 - $11,000

Table 4 estimates the cost of a UV disinfection system for three sizes of communities: 5,000, 10,000 and 50,000 gpd. For this example, it was assumed that the installation contractor would charge 20% for overhead and profit. Engineering and other fees are not included in the costs. Maintenance cost is based on a part-time service provider and the annualized cost of replacing injector components on a ten year basis. Sodium hypochlorite is the chlorine source and calcium thiosulfate is the dechlorination agent.

Table 4. Estimated cost for a community-scale UV disinfection system.

Cost Factors	Daily Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$1,700 - $2,500	$2,300 - $3,400	$5,200 - $7,800
Annual Electrical ($0.15 per kW-hr)	$14 - $20	$26 - $40	$130 - $190
Annual O&M	$480 - $720	$700 - $1,100	$2,600 - $3,900
60 year life cycle cost present value (2009 dollars)	$18,000 - $27,000	$28,000 - $42,000	$101,000 - $152,000

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Fact Sheet T8

Performance & Cost of
Decentralized Unit Processes

DECENTRALIZED WASTEWATER SYSTEMS

TREATMENT SERIES

RESIDUALS MANAGEMENT

What is Residuals Management?

When waste constituents are removed from wastewater, these constituents must still be managed. Residuals management include ensuring that solids generated and retained in wastewater treatment components are properly handled. Solids accumulate in septic tanks, recirculation tanks, flow equalization tanks, trash tanks and other primary treatment devices as a result of settling (sludge) and floatation (scum). Solids are also generated and accumulate in the clarifier within aerobic unit processes. In filtration units, solids accumulate on media surfaces. All of these solids must be periodically removed so that components continue to properly function. The management methods used to handle and dispose of residuals must be in accordance to protect public health and the environment.

Residuals accumulate in septic tanks (above) and are also generated through suspended growth treatment processes like activated sludge (below).

The anticipated quantity of solids (septage) removed from septic tanks can be estimated based upon the expected pumping frequency and tank capacity. Required pumping frequency will vary on the basis of tank design, user habits, and seasonal temperature fluctuations. For basic planning purposes, a typical value of residuals generation is 60 to 70 gallons per person per year.

The quantity of residuals generated in other treatment components varies on the basis of the technology and is typically expressed on the basis of dry sludge weight produced per volume of wastewater treated. The constituents within the residuals are also an important consideration. Residuals typically include significant amounts of trash, grit, oil, fat, and organic matter. Metals may also be present as by-products from household chemicals or from local industries.

Land Application

Land application of residuals is currently the most commonly used residuals disposal method in the U.S. Residuals may be applied to either the surface or subsurface using various methods chosen on the basis of slope, soil type, application depth, drainage class, hydraulic loading rate and available equipment. Land application methods include spreading residuals from hauler trucks or tank wagons onto sites using spray irrigation, ridge and furrow irrigation, and overland flow. Since residuals must not be applied before or during rainfall or on frozen ground, an interim storage facility is needed. Some states require that residuals be disinfected before application.

Land application is the most commonly used method to dispose of residuals.

Treatment at Wastewater Treatment Plants

A small community may choose to send residuals to a regional wastewater treatment plant (WWTP). If adequate treatment capacity is available, a WWTP may accept residuals and charge the community a tipping fee. This method is should only be considered a short-term solution. As large WWTP approach their design capacity, they may choose to stop accepting residuals from other communities.

Municipal wastewater treatment plants can accept residuals if there is adequate capacity.

Treatment at Dedicated Residuals Treatment Plants

A dedicated residuals treatment facility can be considered if the demand and the proper resources are available. Independent treatment plants condition and stabilize residuals using aerobic digestion, anaerobic digestion, and other forms of biological treatment. Many residuals treatment plants use lime for stabilization before the residuals are dewatered. The liquid residual can be discharged to a wastewater treatment facility. Residuals solids can then be sent to either a landfill, composted, applied to the land, or incinerated.

Residuals can be added to a WWTP upstream of screening and grit removal components.

How can Residuals Management be used?

Residuals management must be a part of any decentralized wastewater treatment program regardless of the technologies selected, the wastewater volume generated, or the population served. Solids will accumulate and they must be managed. The choice that a community must make is how to handle the generated solids and this issue must be considered early in the design and planning stages.

Land application is relatively simple and cost-effective, uses low energy, and recycles valuable organic material and nutrients to the land. With proper management, domestic residuals are a resource that contain nutrients that can condition the soil and decrease the reliance on chemical fertilizers for agriculture. Proper residual management maximizes these benefits while protecting public health and the environment. If sufficient and suitable area is available for land application, it will be necessary to identify both how the residuals will be transported and what equipment will be needed for land application. Storage facilities will be needed for times when wet or frozen soils will prevent land application.

Properly managed land application of residuals returns valuable nutrients back to the land.

Compatibility with Community Vision

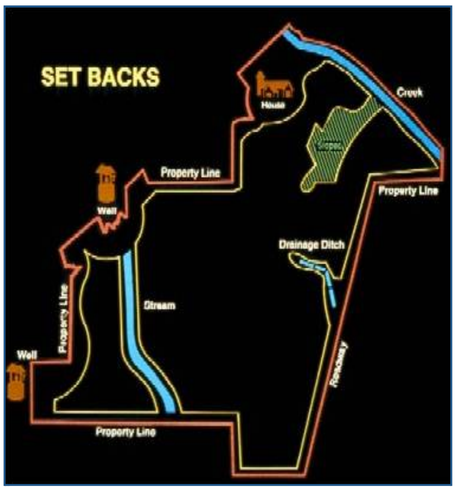
When a community considers options for a wastewater treatment infrastructure, residuals management must be a part of the overall plan and design. Proceeding without considering some form of residuals management is simply not an option. Choosing a management method depends upon the community's perception of whether land resources are more abundant than the funds required to increase the treatment capacity at an existing facility or to establish a new facility.

Ownership of the residuals management facility can vary. The community or another public entity can establish a residuals management facility and thus have control over where and how residuals are treated. The challenge with this approach is a business plan that demonstrates cost effectiveness for the community over other options. Although public ownership of treatment facilities is the norm, private ownership of land for residuals application and independent residuals treatment facilities is increasing. Although the residuals management plan is part of the public planning domain, the program can be given over to or contracted with the private sector, thus keeping the public sector from competing with private entities. Some programs incorporate both approaches.

Another option is the establishment of a Public-private partnership. This option can improve the private residuals industry acceptance of the management plan and ensure their participation in the facility. This choice broadens funding options to include the potential for public grants while at the same time encouraging private capital investment. Public-private partnerships may streamline the permitting process. Involving stakeholders in the process often results in fewer problems with the facility and greater acceptance of the management plan. Regardless of the approach chosen, appropriate tracking procedures must be established and followed to confirm and document the source of the residuals and the ultimate point of disposal.

Land Area Requirements

The area required for a Residuals Management system using land application is a function of the volume of residuals generated, site slope, soil type, drainage class, hydraulic loading rate and the crop to be grown on the site. Human waste contains nitrogen, phosphorous, potassium, and trace elements like calcium, copper, iron, magnesium, manganese, sulfur, and zinc which can be utilized by the crop. Nutrient availability varies upon the type of waste, the season, and the type of application. Additional space will be required to meet appropriate setbacks from property lines, water bodies, residences, etc. EPA has established regulations on the mass of various constituents that can be land applied. The US EPA Biosolids Rule (CFR Title 40, Part 503) is the standard that determines whether a site is suitable for land application.



Adequate setbacks from property lines, water bodies and residences are required for a site to be considered for land application of residuals.

Establishment of Residuals Management Programs

Regardless of the method chosen, residuals haulers who will collect and transport solids must be trained and licensed or certified. Procedures for collection, transport and delivery must be developed and documentation protocol must be established. Many states have established licensing or certification programs in place. Additionally, the National association of Waste Transporters (NAWT) has developed a training program for pumpers.

If Land Application is the chosen method, areas must be identified that have the appropriate soil morphology and site characteristics to support this option. A Soils professional must evaluate the soil and site to determine appropriate loading rates. Nutrient management plans must be formulated and implemented.

If co-treatment at a wastewater treatment facility is chosen, adequate capacity must be identified. A receiving station must be established to receive the residuals from the pumpers. The necessary agreements among the plant and the haulers must be executed. If dedicated residuals treatment is chosen, the plant must be planned, designed, permitted and constructed.

Operation and Maintenance of Residuals Management

Operation and maintenance of Residuals Management components varies according to the method chosen. Land application will require maintenance of transport trucks and application equipment. Nutrient management plans must also be formulated and established. Crops must be harvested as needed. Residuals haulers and land application operators must typically be licensed. They must have appropriate training in safe transport practices and application technologies. Co-treatment and dedicated residuals treatment scenarios require essentially the same expertise, licensing and certification required for sewage treatment plant operators.

Pumpers must receive adequate training to safely handle residuals.

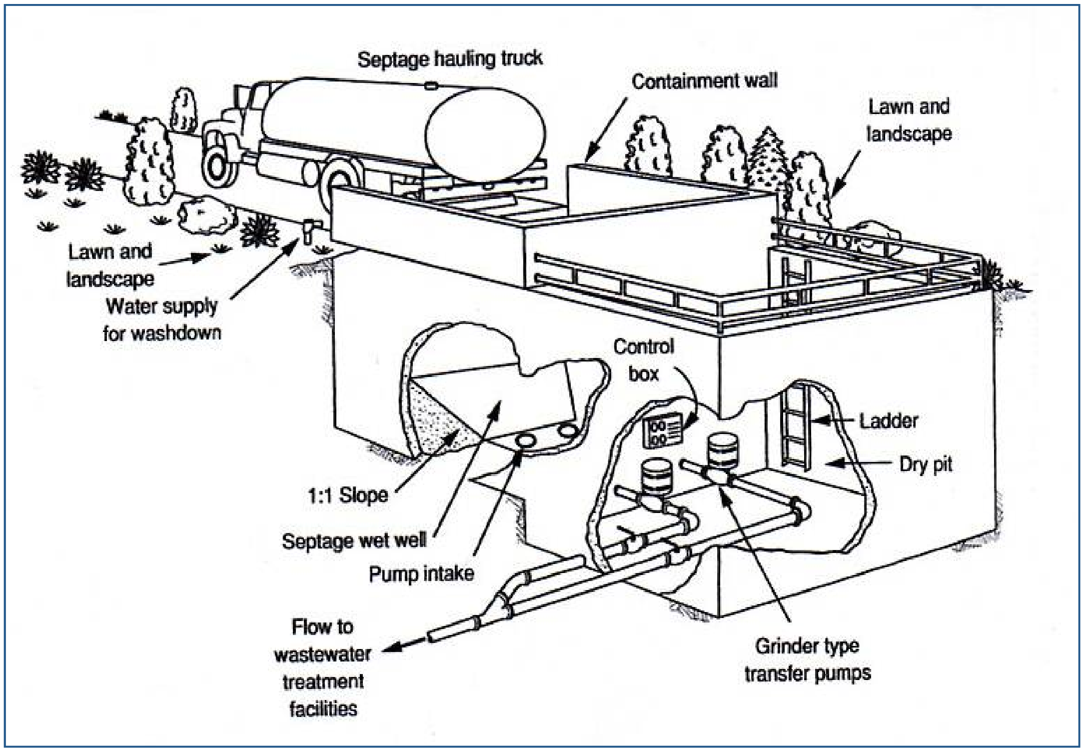
Soil testing must be performed to determine site suitability for land application.

Operators of land application sites must be able to effectively educate and communicate with the public. Citizens who do not understand the nature of land application are often concerned about public health and safety. A conscientious operator with good communication skills is imperative.

Costs for Residuals Management

Cost considerations cannot be generalized because of the wide range of options available for residuals management. The capital cost of a residuals management system is dependent on the treatment and disposal method used and the regulatory requirements in a particular area. Administrators of a residuals management program should be aware of disposal options and the cost involved. The median cost of disposal (or tipping fee) typically ranges from 3 to 6 cents per gallon. Incremental costs of alternatives have been estimated at $50.00 to $355.00 per 1,000 gallons of pump out.

Energy costs for co-treatment at a municipal plant and for dedicated residuals plant treatment are a function of the technologies used plus the fuel costs for transport. For land application, energy costs are a function of the cost of fuel used for collection and application equipment as well as the distance between the collection point and the application point.



Typical design for a receiving station for residuals destined for a WWTP

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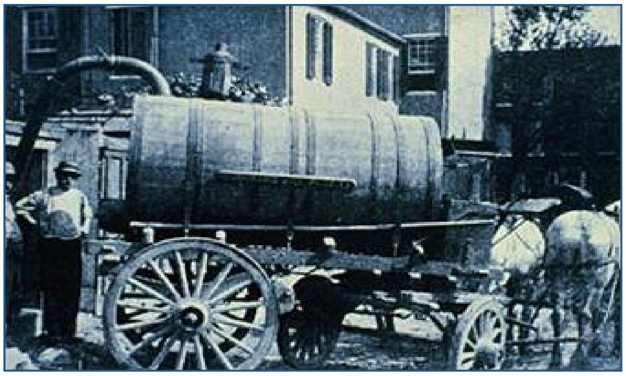

A traditional "honey wagon"

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Water Environment Research Foundation
Collaboration. Innovation. Results.

3.3 DISPERSAL SERIES

Fact Sheet D1

Performance & Cost of
Decentralized Unit Processes

Water Environment Research Foundation
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DECENTRALIZED WASTEWATER SYSTEMS

DISPERSAL SERIES

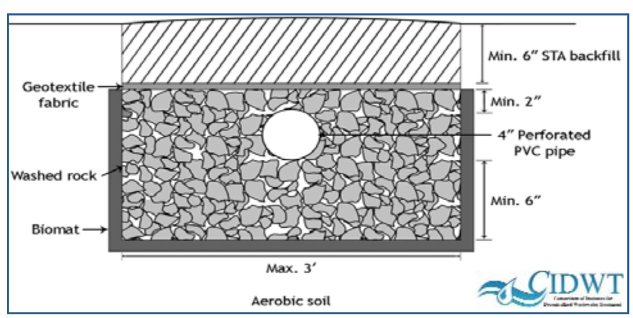
GRAVITY DISTRIBUTION

What is Gravity Distribution?

Gravity distribution is a method of applying effluent to subsurface soil trenches backfilled with porous distribution media. At a minimum the wastewater must have gone through liquid-solid separation (primary treatment). This is usually accomplished using a septic tank fitted with an effluent screen. Primary treated effluent is applied at one end of a trench and flows by gravity across the length of the trench. Thus the term, 'gravity distribution.' Gravity distribution is very effective at providing treatment through oxidation and filtration. However, it is most appropriate for use on low-risk sites (i.e., deep, well-drained soils with sufficient space for the installation). The site must provide sufficient vertical separation to limiting conditions (shallow groundwater, a rock layer or other restrictive horizon) in the soil beneath the excavation in order for treatment processes to be effective. This separation ensures that adequate aerobic soil is available under the trench for removal and/or renovation of the organic matter, nutrients and pathogens in the wastewater. Some wastewater constituents (including pathogens) are filtered out by the media and the soil. Others are consumed by soil microbes or taken up by vegetation. Eventually, almost all of the treated effluent rejoins the hydrologic cycle through groundwater.

Gravity dispersal is most appropriate for sites with deep, well-drained soils.

Trenches are shallow, narrow excavations placed on contour within the distribution area. An individual trench is typically about 3 feet wide, 2 feet deep and less than 100 feet long. The total length of trenches will vary depending on soil and site conditions and the applicable prescriptive codes. Trenches are typically backfilled with distribution media to a depth of about 12" and a perforated lateral is installed in the upper portion. Washed rock has traditionally been used to aid effluent distribution, but other options are now available. These options include bundled pipe,



Typical washed rock trench (cross section)

chambers, polystyrene aggregate, tire chips, large diameter pipe and prefabricated permeable panel block configurations. Geotextile fabric should be placed over the media to prevent infiltration of fine soil particles from the backfill material. Excavated soil is used to backfill the trenches and a final soil cover is placed on top. Grass or other non-woody vegetation is sown to stabilize the installation and prevent soil erosion.

In addition to the primary treatment component, a complete gravity distribution configuration includes a distribution device (a distribution box, drop box or header pipe) to divide effluent among the laterals. Additional piping extends from the distribution device to the laterals within the trenches. Larger systems will include pressure dosing components that use manifolds (configurations of pipe and fittings) to divide the flow among the laterals.

Alternative trench media options (demonstration)

Potential Modifications

Width of Excavation

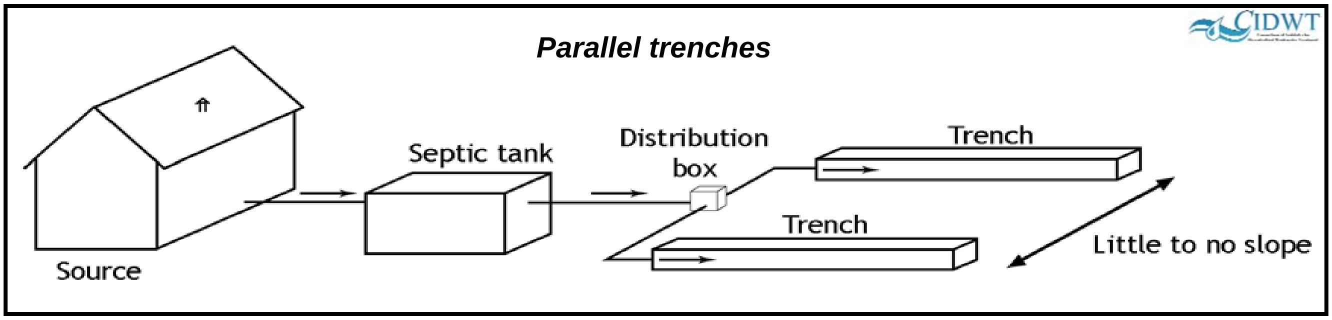
Sometimes a wider excavation is made prior to installing the distribution media and piping network. This is known as a *bed.* Because air exchange in the center of beds is often less than optimum, their use is often restricted.

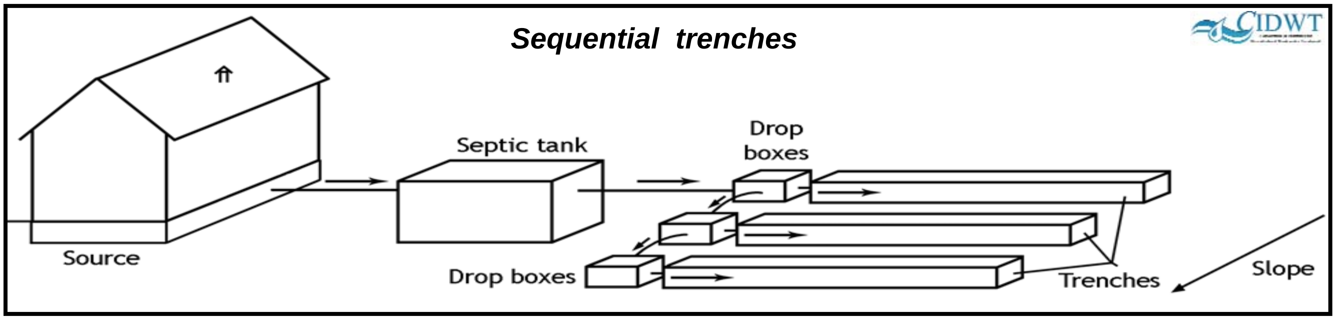
Depth of Installation

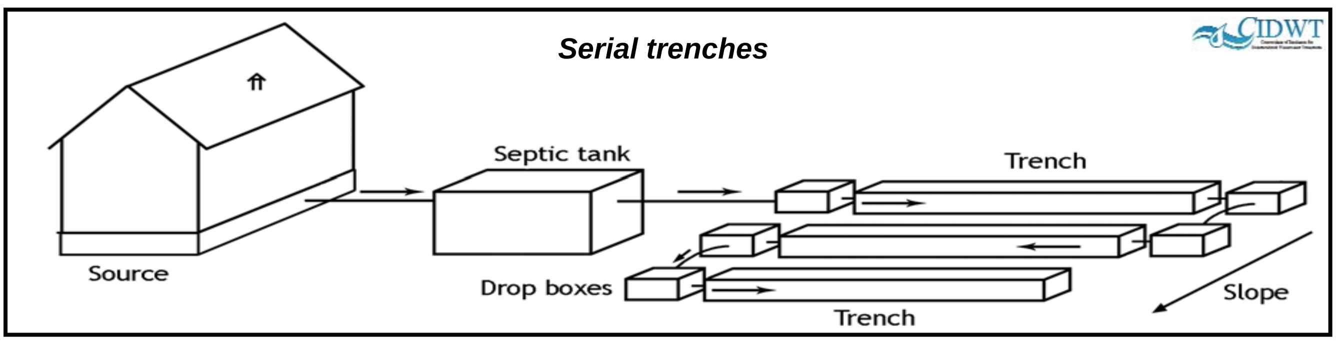
In some jurisdictions, gravity distribution trenches or beds may be installed at the original grade and then covered with native soil. A further modification is the installation of trenches or beds within an areal fill system installed above original grade using imported soil that meets specific standards.

Trench Configurations

Trenches may be installed using parallel, serial or sequential distribution. These options essentially describe the manner in which effluent flows through the components. The choice of a particular configuration is dependent upon soil/site conditions as well as topography. Parallel distribution is most suited to level topography and laterals of equal length. Sequential and serial distribution are best suited for sloping sites. Sequential and serial distribution configurations can include laterals of unequal length because effluent is independently dosed to each trench. Sequential distribution offers an advantage over serial distribution since a clog in one of the laterals does not stop flow to the others. The configurations are illustrated in the figures







below.

How is Gravity Distribution Used?

Greater than 80% of all decentralized wastewater systems use trenches or beds to disperse effluent into the environment. Within a small community, a combination of on-lot and communal dispersal fields can be established. A collection system can be installed to convey effluent from existing residences to a centrally located area. The dispersal areas effectively become green space available for light recreational and other public and private use but should not be used for livestock grazing, athletic fields, or crop production.

If properly sited, installed and maintained, gravity distribution components can provide long-term reliable service; however, once they reach the end of their usefulness, they must be replaced or rested until permeability is restored. According to several state codes, this typically necessitates the establishment of a reserve area of equal size as the original area. Neither the original area nor the reserve should be used for traffic or permanent structures as these activities will compromise the soil characteristics critical to effective treatment and dispersal.

Compatibility with the Community Vision

Subsurface gravity distribution can be scaled to disperse effluent from individual homes, small residential and commercial clusters, and small communities in virtually all climates. This dispersal technology is probably most appropriate for smaller wastewater volumes. Larger flows require a dosing tank and pump to convey the effluent to the trenches. This is known as 'pressure-dosed gravity' or 'pump to gravity'. The relatively large area required for trench systems may make other soil-based options more attractive. However, the surface of the dispersal area is still available for light recreational and other public and private use.

A gravity dispersal system is only as good as its management. Appropriate and sustainable management must be included in the overall plan. Various Management options are described in the Wastewater Basics Fact Sheet, which is included in this series. A community must have a means to disperse treated wastewater. If management fails to maintain the system, then the health of the public health and the environment are at risk. A utility, management association or other entity should be formed to ensure the long term operation of the facility.

Selecting any wastewater dispersal option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

Land Area Requirements

The area required for gravity distribution is a function of soil morphology, site characteristics, daily wastewater volume, wastewater strength and the application rate. Application rates for gravity distribution are typically expressed as gallons per day per square foot (gpd/ft^2) of infiltrative surface (trench bottom) area, as directed by state prescriptive code. Clayey soils require more area to allow for slower movement of effluent through and into the soil. Appropriate application rates should be determined by a soil professional.

Quick tip!

For a given wastewater volume, gravity distribution would typically require more area than Low Pressure Distribution and Drip options, but less than Spray Irrigation or Evapotranspiration. For detailed information on area requirements for this and other dispersal options on a range of soil types, consult the Cost Estimation Tool.

Dividing the daily wastewater volume (gpd) by the application rate provides the square footage of trench bottom required. For example, a 5,000 gpd system built on a clay loam soil may have an application rate of 0.40 gpd/ft^2 and thus require 12,500 ft^2 of trench bottom area. Trenches that are 3 feet wide are typically spaced 9 feet on center, resulting in a total area requirement of approximately 40,075 ft^2 (0.92 acres). Tighter or looser soil textures would require larger or smaller areas, respectively. Site characteristics also influence land requirements. For example, sites adjacent to water bodies and areas using supplemental drainage will have larger footprints as a result of required separation distances. Reserve area (equal to the size of the initial system) for component replacement is strongly recommended for gravity distribution systems on individual lots and is often mandated by regulations.

Construction and Installation

Any site intended for effluent dispersal must be protected from vehicular traffic before, during and after installation to minimize damage to mechanical components and the soil. The installation must occur when soil moisture conditions are neither too wet nor too dry to protect soil acceptance and treatment capacity. Trenches are installed with a level bottom to prevent effluent from ponding in low areas. A backhoe or excavator is used to create the trenches but additional equipment may be needed for backfilling and grading. Distribution media is place in each trench to a depth of 12 inches and a perforated lateral typically 4 inches in diameter is placed in the upper layer of the media. (Note that gravelless options may not require the perforated lateral.) A solid pipe distribution manifold is used to connect the laterals. The media should be covered with geotextile fabric to prevent fine soil particles in the cover material from migrating into the media during the backfill process. The finished grade is shaped to shed surface water away from all system components. In some cases, it may be necessary to allow the site to stabilize prior to establishment of the vegetative cover. Regulatory agencies typically perform inspections over the course of the installation. No permanent structures are permitted over the dispersal area once the installation is complete, but the area can be used for light recreational activities.

Trench installation showing geotextile fabric over washed rock media

Trench and bed installations result in significant but temporary site disturbance. Once installation is complete, valve boxes for monitoring ports (if used) will be visible, but flush with finish grade. Appropriate installation of gravity distribution components requires reasonable access for equipment and materials. Additional space may be needed for staging equipment and media. Personnel who install gravity distribution may be subject to licensure or certification requirements in a given state or region. Certainly, they must be familiar with the specific requirements for the particular application which may necessitate training provided through manufacturers of gravelless media options if they are used.




Operation and Maintenance

Maintenance of gravity distributions systems includes a variety of activities. The area over and around the dispersal area should be regularly inspected for damage (compaction, settling or erosion) and surfacing effluent. The regulatory authority should be notified if effluent is surfacing since this is a threat to public and environmental health. An appropriate, uniform vegetative cover (grass, sod or non-woody perennial plants) should be maintained to help assimilate water and nutrients and stabilize the surface. Primary tanks, distribution boxes and pipes should be checked for accumulated solids. Accumulated solids should be removed as needed. Effluent screens installed in the outlet of primary tanks must be inspected and cleaned as needed.

Regular service is important for all systems to ensure best long term performance to protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of any pretreatment components used prior to dispersal.

Water use and wastewater strength should be monitored. Excessive use (either intentional or due to plumbing leaks) may cause hydraulic failure. Excessive organic loading may occur through lack of regular solids removal, failure of the pretreatment components to properly reduce BOD or through the addition of non- or slowly-biodegradable substances such as fats, oils and grease (FOGs). Commercial food-service establishments must be required to install and maintain grease interceptors. Residential users should be cautioned to against putting FOGs into the system.

Pumps and controls associated with larger flows require regular maintenance, repair or replacement as needed. Personnel who maintain such systems must have adequate training in component maintenance, monitoring and replacement. As always, safety training should be mandatory. State licensure or certification is often required to maintain such systems. Licensure or certification of these service providers is required by roughly half of state jurisdictions.

Costs for Subsurface Gravity Distribution

The primary factor in determining the cost of a gravity distribution system is the land value. For individual systems, the land will likely already be owned by the user. However, there is potentially an opportunity cost if state prescriptive code requires designation of a reserve area that cannot be used except for green space. The amount of land required for gravity distribution is determined by the daily wastewater volume and the ability of the soil to absorb that volume. The components of gravity distribution are relatively inexpensive and the overall maintenance is relatively low. A typical gravity distribution system does not require electricity. However, some systems handling large flows require a pump to transfer the effluent from primary treatment to the dispersal area. If pumps are used, electrical costs will vary according to amount of flow, height of vertical lift and distance to be pumped.

The primary factor in determining the cost of a gravity distribution system is the land value.

For the purpose of estimating capital and long-term O&M costs, four example gravity distribution systems have been developed and priced for flows ranging from 450 to 50,000 gpd. The costs given in this document are for comparison purposes only. The actual cost for a gravity distribution system will vary significantly depending on site conditions and local economics. The costs for the 450 gpd system below reflect only those factors associated with a gravity distribution, which includes a distribution box, associated piping and washed rock trenches installed in medium-textured soil. Costs for larger flow systems include a pump (or pumps) installed within a dosing tank; supply lines from the pump to a manifold; piping to trenches and the trenches themselves. Installation, maintenance and total lifecycle costs for septic tank(s), collection systems, advanced treatment components and disinfection devices are not included here.

Table 1 is a cost estimation for the materials, installation, and maintenance of a gravity dispersal system attached to a single family home. These costs assume that the topography is relatively flat, the contractor would charge 20% for overhead and profit, and there are no sales taxes on materials. Engineering fees and other professional services are not included in the costs. The size of the system is based on a clay loam soil with an application rate of 0.4 gpd/ft^2 of trench bottom surface area. Maintenance cost was based on moving the dispersal system to the reserve area in 30 years. Table 2 estimates the cost of a gravity dispersal system for three sizes of communities – 5,000, 10,000 and 50,000 gpd. Again, it was assumed that the land area is relatively flat, the application rate is 0.4 gpd/ft^2 of trench bottom surface area, and the contractor would charge 20% of overhead and profit. Engineering and other fees are not included in the costs. The maintenance cost is based on a part-time service provider, a seven-year pump life and a 30-year lateral life.

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

Table 1. Estimated cost to install and maintain a subsurface gravity dispersal system at a single-family residence

Materials and installation	Excavation, porous media, perforated pipe, distribution system, and labor	$4,600 – $6,900
Annual electricity ($0.15 per kW-hr)	Assumed gravity flow from primary treatment	0
Annual O&M	Annualized cost to move to reserve area in 30 years	$200 – $400
60-yr life cycle cost present value (2009 dollars)	Assumes 3% inflation, 5% discount rate, no salvage or depreciation	$15,000 - $18,000

Table 2. Estimated cost for a community subsurface gravity dispersal system.

Cost Factors	**Daily Wastewater Volume (gpd)**		
	5,000 gpd or 20 homes	**10,000 gpd or 40 homes**	**50,000 gpd or 200 homes**
Materials and Installation	$54,000 - $81,000	$105,000 - $158,000	$517,000 - $776,000
Annual Electricity ($0.15 per kW-hr)	$80 - $120	$160 - $230	$750 – $1,100
Annual O&M	$2,300 - $3,400	$4,400 - $6,600	$21,000 - $31,500
60 year life cycle cost present (2009 dollars)	$137,000 - $205,000	$266,000 - $398,000	$1,295,000 - $1,943,000

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Performance & Cost of
Decentralized Unit Processes

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DISPERSAL SERIES

LOW PRESSURE DISTRIBUTION

What is Low Pressure Distribution (LPD)?

Low pressure distribution is a method in which relatively low pump pressure is used to disperse effluent to subsurface soil trenches backfilled with porous distribution media. At a minimum the wastewater must have gone through liquid-solid separation (primary treatment). This is usually accomplished using a septic tank fitted with an effluent screen. Secondary treatment may also be used prior to dispersal. Effluent is spread out over the entire trench or bed in contrast to the concentrated application that occurs in gravity distribution. Full utilization of the dispersal area can help to ensure the long-term success of the soil system.

Cross section of an LPD trench (demonstration)

LPD is a modification of the conventional gravity distribution system. Like gravity systems, media-filled trenches are placed along the contours of the land. Small diameter PVC pipes with terminal cleanouts are installed within the media. Small diameter holes are drilled in the pipes at a predefined spacing. When the laterals are pressurized, effluent flows out of the orifices at an even rate. The distribution media has traditionally been washed rock, but (as with gravity distribution) other options include bundled pipe, chambers, polystyrene aggregate, tire chips, large diameter pipe or prefabricated permeable panel block configurations. Before placement of the final soil cover, a geotextile fabric (or equivalent) may be placed over the media to prevent the infiltration of fine soil particles. The final cover supports the growth of vegetation that stabilizes the installation and prevents erosion.

Effluent treatment in LPD systems occurs within the trench and the aerobic soil beneath it but *above* the groundwater table or bedrock. Some wastewater constituents (including pathogens) are filtered out at the infiltrative surface and in the soil. Other constituents are metabolized by soil microbes or taken up by vegetation. Eventually, treated effluent that is not taken up by plants rejoins the hydrologic cycle through groundwater. LPD systems are less likely to develop a restrictive *biomat* as typically occurs within gravity distribution systems because effluent is evenly spread across the dispersal area. Additionally, because the area is fed via a pump system, there are periodic 'dose-and-rest' cycles that maintain aerobic (oxygenated) soil conditions, which are favorable to good effluent renovation.

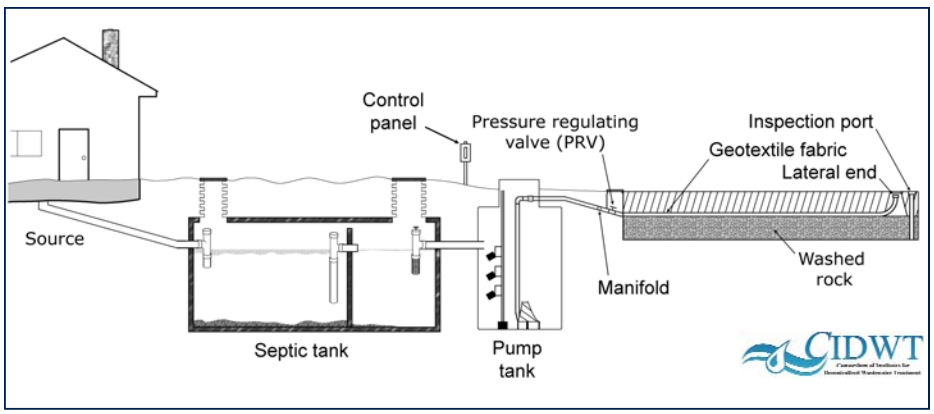
In addition to the primary and potentially secondary treatment components, a complete LPD system includes a pump (or pumps) installed within a dosing tank, a supply line(s) from the dosing tank to a manifold, and the laterals within the field. The dosing tank collects and stores effluent from pretreatment components. A pump delivers effluent from the tank to the manifold. A control system regulates effluent delivery to the field. A timed dosing configuration may be used (and is recommended) to apply effluent in even doses on a regular schedule. At minimum, the wastewater must have gone through liquid-solid separation (primary treatment) prior to dispersal. Advanced treatment of effluent should reduce the maintenance requirements of the LPD system.

Quick Definitions

Biomat:
Layer of biological growth and inorganic residue that develops at the infiltrative surface.

Infiltrative surface:
interface where effluent moves out of the trench media and into the soil.

Typical LPD system components



Potential Modifications

In some jurisdictions, LPD laterals may be installed at the original grade and then covered with the native soil from the trenches. This shallow lateral placement allows some soils that have a limiting condition (shallow groundwater, a rock layer or other restrictive horizon) near the surface to be used for dispersal. A further modification is the construction of a mound system that uses LPD technology to distribute the wastewater in imported material placed above the original grade. Mound systems are sometimes appropriate where limiting conditions are found at extremely shallow depths. There must still be sufficient aerobic soil available to remove wastewater constituents and disperse effluent.

How is Low Pressure Distribution used?

Uniform distribution of the hydraulic and organic load optimizes the soil's ability to renovate effluent because it is spread out along the entire length of the pressurized laterals. LPD may allow the use of some the soils that were previously considered unsuitable for gravity trench systems. Communities may consider LPD on individual lots if there is sufficient space on each lot. A centrally located LPD system facilitates increased housing density in some areas and the creation of green space where the dispersal areas are located. LPD areas should not be used for livestock grazing, athletic fields, or crop production. Sites with slope exceeding 50% are generally not conducive to installation of LPD.

Compatibility with the Community Vision

Low pressure distribution can be scaled for use at individual homes, small residential or commercial clusters, and small communities. Flows well in excess of 10,000 gallons per day (gpd) can be accommodated. LPD systems can be scaled up by the acquisition of additional land. This method of distributing effluent is applicable to a wide variety of climatic conditions, although freeze protection of system components must be provided in regions that experience cold winters. For rural areas, LPD has the advantage of not requiring a three-phase electrical service. Most LPD systems can be satisfactorily operated on 120/240 VAC systems. A backup power supply may be required on larger systems.

Selection of any wastewater dispersal option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

Whatever options are chosen, appropriate and sustainable management must be included. The management options described in the Wastewater Basics Fact Sheet included in this series can be used individually or in combination to ensure best system performance. If multiple wastewater sources are connected to a common system, ownership of the land and responsibility for sustainable management must be determined. A utility or management association is typically formed in these scenarios. Fees are assessed to the users to cover the initial cost of systems and the cost of long term operation and maintenance. This maximizes system efficiency, longevity and performance while protecting public health and the environment.

Land Area Requirements

The area required for LPD is a function of soil morphology, site characteristics, daily wastewater volume, and the application rate. Application rates for LPD are typically expressed as gallons per day per square foot (gpd/ft^2), as directed by state prescriptive code. Clayey soils require more area to allow for slower movement of effluent into and through the soil. Appropriate application rates should be determined by a soil professional.

Dividing the daily wastewater volume (gpd) by the application rate (gpd/ft^2) determines the square footage required. For example, a 5,000 gpd system built on a medium-textured soil may have an application rate of 0.20 gpd/ft^2 and thus require 25,000 ft^2 (0.57 acres). Tighter or more loosely textured soils would require larger or smaller area, respectively. Site characteristics would also influence land requirements. For example, sites adjacent to water bodies and areas that require supplemental drainage will have larger footprints as a result of required separation distances. Additional area would be needed for pretreatment components. Reserve area (equal to the size of the initial system) for component replacement is strongly recommended for LPD systems on individual lots and is often mandated by regulations.

Quick Tip

For a given wastewater volume, LPD would typically require less area than gravity, spray and evapotranspiration systems, but more area than a drip distribution system.

For detailed information on area requirements for this and other dispersal options on a range of soil types, consult the Cost Estimation Tool.

Construction and Installation

Any site intended for effluent dispersal must be protected from vehicular traffic before, during and after installation to minimize damage to mechanical components and the soil. To protect soil treatment capacity, installation must occur when soil moisture conditions are neither too wet nor too dry. Construction of LPD systems is very similar to that for gravity distribution and many different configurations are possible. A typical installation would include trenches 6 to 12 inches wide and 12 to 18 inches deep with a level bottom, and are spaced on five-foot centers. A backhoe or excavator is used to create the trenches but additional equipment may be needed for backfilling and grading. Distribution media is placed in each trench to a depth of 9 to 12 inches and a small diameter lateral is placed within the upper layer of the media. Laterals are typically 1 to 1 ½ inches in diameter with orifices 1/8 to 5/32" diameter drilled in at regular intervals (typically about 60") along the length. Orientation of the orifices will vary. Laterals may be installed within a larger diameter perforated pipe known as a 'sleeve'. A cleanout fitted with a cap is installed at the end of each lateral. The cleanout extends almost to grade and is installed within a valve box to provide access for maintenance. A supply line is installed to deliver effluent from the dosing tank to one or more manifolds that evenly divide the flow among the laterals. The media should be

Clean-out with a cap installed in a valve box at the end of an LPD lateral

covered with geotextile fabric to prevent fine soil particles in the cover material from migrating into the media during the backfill process.

A dosing tank with a pump, water level sensors and a control panel is installed to deliver effluent to the dispersal area. The tank is fitted with an access riser to grade to facilitate maintenance. The pump is ideally placed in a screened vault to prevent solids from being pumped to the piping network. The panel is ideally fitted with an elapsed-time meter (ETM) to track hours of operation and an event counter (EC) to track the number of doses delivered. Supply line(s), manifolds and laterals are fully flushed with clean water prior to making final connections. The finish grade is shaped to shed surface water away from all system components. In some cases, it may be necessary to allow the site to stabilize prior to establishment of the vegetative cover.

Regulatory agencies typically perform inspections over the course of the installation. Permanent structures should not be placed over the dispersal area once the installation is complete, but the area can be used for light recreational activities.

Installation of LPD components results in significant but temporary site disturbance. Once installation is complete, valve boxes for cleanouts will be visible, but flush with finish grade. Economical installation of LPD components requires reasonable access for equipment and materials. Additional space may be needed for staging areas (storage of media and spoil, for example). Personnel who install LPD may be subject to licensure or certification requirements in a given state or region. Certainly, they must be familiar with the specific requirements for the particular application. This may necessitate training provided through manufacturers of gravelless media options if they are used. Personnel who install electrical components must be properly trained and licensed.

Operation and Maintenance

Common maintenance activities for LPD include inspecting the area on and around the system for damage (compaction, settling or erosion) and surfacing effluent. The regulatory authority must typically be notified if effluent is surfacing since this is a threat to public and environmental health. An appropriate, uniform vegetative cover (grass, sod or non-woody perennial plants) should be maintained to help assimilate water and nutrients and stabilize the surface. Primary tanks,

Regular service is important for all systems to ensure best long term performance to protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of any pretreatment components used prior to dispersal.

distribution boxes and pipes should be checked for accumulated solids. These should be removed as needed. Effluent screens installed in the outlet of primary tanks must be inspected and cleaned as needed. Accumulated solids must also be regularly flushed from manifolds and laterals through cleanouts using pump pressure or pressure wash with a jetted nozzle. Performance of pumps associated controls should be regularly assessed. When operational parameters are not met, the system needs maintenance. Pump screens and sensors must be cleaned as needed.

Water use and wastewater strength should be monitored. Excessive use (either intentional or due to plumbing leaks) may cause hydraulic failure. Excessive organic loading may occur through lack of regular solids removal, failure of the pretreatment components to properly reduce BOD or through the addition of non- or slowly-biodegradable substances such as fats, oils and grease (FOGs). Commercial food-service establishments should be required to install and maintain grease interceptors. Residential users should be cautioned to against putting FOGs into the system.

Personnel who maintain LPD components must have adequate training in component maintenance, monitoring and replacement. As always, safety training should be mandatory. State licensure or certification is often required to maintain these components.

Costs for LPD

Energy consumption in a LPD system is a function of the daily wastewater volume and the configuration of the hydraulic network. Because the pressure requirements are relatively low, the electrical expense is also relatively low. However, electrical costs will vary according to amount of flow, height of vertical lift and distance to be pumped. For a residential LPD system, the annual electrical costs are estimated to be only $20 to $30 dollars per year. For a 50,000 gpd community system, a LPD system on relatively level ground could have electrical costs as low as $700 per year. Although not recommended, a LPD system on a downward sloping site could be pressurized using a dosing siphon which does not require electricity. This is not the best alternative since siphons can only be configured for demand dosing.

For the purpose of estimating capital and long-term O&M costs, four example LPD systems have been developed and priced for flows ranging from 450 to 50,000 gallons per day. The costs below reflect only those associated with a LPD system that includes a pump (or pumps) installed within a dosing tank; supply lines from the dosing tank to the field; and the laterals within the field. Installation, maintenance and total lifecycle costs for septic tank(s), advanced treatment components and disinfection devices are not included here.

Table 1 is a cost estimation for the materials, installation, and maintenance of a low pressure distribution system attached to a single family home. These costs assume relatively flat topography, 20% overhead and profit to the contractor, and no sales taxes on materials. Engineering fees and other professional services are not included in the costs. The size of the system is based on a clay loam soil with an application rate of 0.2 gpd/ft^2. Maintenance costs are based on a part time service provider, jetting laterals on a regular basis, a seven year pump life, and system replacement in 30 years.

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

Table 1. Estimated cost to install and maintain a LPD dispersal system at a single-family residence		
Materials and installation	Excavation, porous media, perforated pipe, distribution system, pump, controls, and labor	$9,000 – $14,000
Annual Electrical ($0.15 per kW-hr)	based on ½-hp pump, operating 1 hr/day at $0.15/kW-hr	$20 – $30 per yr
Annual O&M	Annualized cost replace system in 30 years	$540 - $800 per yr
60-yr life cycle cost present value (2009 dollars)	Assumes 3% inflation, 5% discount rate, no salvage or depreciation	$29,000 – $43,000

Table 2 estimates the cost of a LPD dispersal system for three sizes of communities – 5,000, 10,000 and 50,000 gpd. Again, it was assumed that the land area is relatively flat, the application rate is 0.2 gpd/ft2, and the contractor would charge 20% for overhead and profit. Engineering and other fees are not included in the costs. The maintenance cost is based on a part-time service provider, a seven-year pump life and a 30-year system life.

Table 2. Estimated cost to install and maintain a community LPD dispersal system.			
Cost Factors	Daily Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$84,000 – $127,000	$184,000 - $275,000	$1,365,000 - $2,047,000
Annual Electrical ($0.15 per kW-hr)	$140 – $220	$280- $420	$1,382 - $2,074
Annual O&M	$4,900 – $7,400	$10,000 - $15,000	$66,000 - $98,000
60 year life cycle cost - present value (2009 dollars	$262,000 – $393,000	$553,000 - $830,000	$3,726,000 - $5,588,000

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Fact Sheet D3

Performance & Cost of
Decentralized Unit Processes

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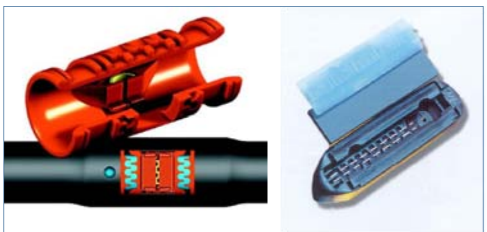
DECENTRALIZED WASTEWATER SYSTEMS

DISPERSAL SERIES

DRIP DISTRIBUTION

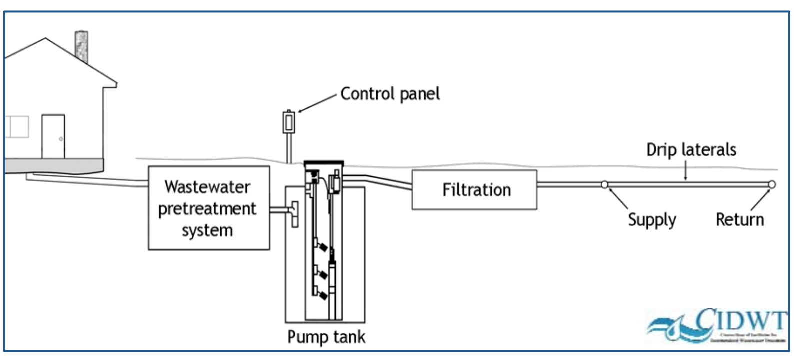
What is Drip Distribution?

Drip distribution is a means of uniformly placing effluent into the subsurface soil. This dispersal method originated from crop irrigation in arid regions of the world where uniform water application results in efficient water use and nutrient uptake by vegetation. For wastewater dispersal, uniform application means that optimum conditions are created for final treatment of effluent. For most drip systems, the drip tubing is a polyethylene material that has a diameter of approximately one-half inch. As the tubing is manufactured, emitters are molded into the tubing wall on a typical spacing of two feet. Tubing is installed 6 to 12 inches below the soil surface and on 2-foot centers, but local spacing variations are possible. This arrangement provides one point of effluent application for each four square feet of dispersal area.



Two proprietary drip emitter designs

Emitters are the heart of a drip system because they control the rate of water discharge into the soil. Depending on the manufacturer, the emitters release approximately one-half gallon of effluent per hour. Emitters control the discharge by forcing water to travel through very small passageways. These passageways are smaller than most suspended solids in wastewater. Thus, a filtration system is required to remove larger suspended particles from the effluent to minimize the potential for clogging emitters in the drip tubing.



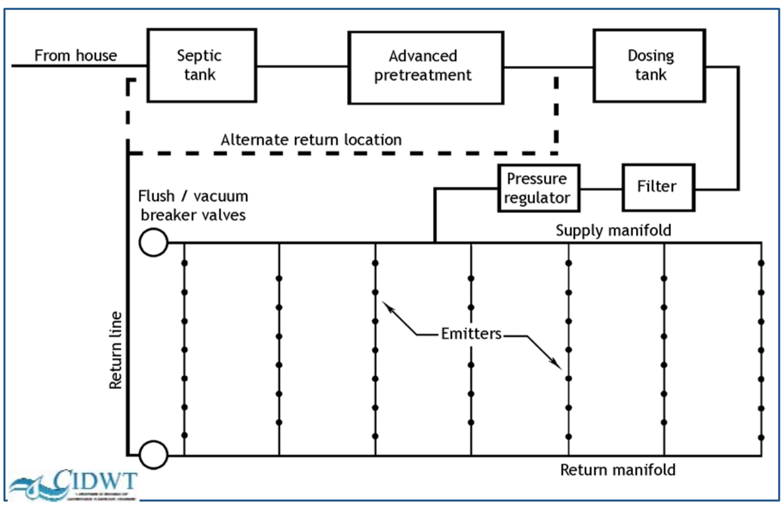
Typical Residential Drip Irrigation System (cross-section)

A complete drip system includes a means to accumulate effluent, a system to transfer the effluent to the field, and a distribution network to apply the effluent to the subsurface soil. Effluent accumulates in a dosing tank. The tank contains one or more pumps that deliver effluent under pressure to the drip tubing in the dispersal area. The effluent then flows through the emitters and into the soil. The layout of the drip system varies according to the landscape features and soils present on the site. A timed dosing configuration is recommended to apply even doses on a pre-set schedule. At a minimum, the wastewater must have gone through primary treatment and pass through a 100 to 120 micron filter prior to entering the drip tubing. It is generally recommended that dissolved organic carbon be removed, via an aerobic treatment process, before drip distribution. The inclusion of aerobic treatment may reduce the long-term maintenance requirements of the drip dispersal system.

Drip tubing demonstration

For more information on aerobic treatment, see:
Factsheet T2: Suspended Growth Aerobic Treatment
Factsheet T3: Fixed Growth Aerobic Treatment

Effluent is applied at a very low rate (0.01 to 0.4 gallons per day per square foot [gpd/ft^2]). Final effluent treatment occurs within the soil beneath the tubing through filtration and adsorption by soil particles, microbial biodegradation and plant uptake of nutrients. Because tubing is installed at or near the surface within the plant root zone, evapotranspiration (the passage of water through a plant from the roots through the vascular system to the atmosphere) and plant uptake of nitrogen may be enhanced as compared to other dispersal modes. Renovated effluent that is not taken up by plants rejoins the hydrologic cycle through deep percolation to groundwater.



Plan view of a typical residential drip distribution system using advanced (aerobic) treatment

How can Drip Distribution be used?

Drip systems are scalable and can be effectively used to disperse effluent from individual homes, residential or commercial clusters, and small communities. Drip systems offer flexibility in geometry, design and construction and distribute effluent more uniformly than many other options. Because of this, drip systems can be used on sites that are considered higher risk. High risk sites are locations with minimal separation to a limiting condition such as shallow groundwater, a rock layer or other restrictive horizon in the soil or sites located near sensitive water bodies. However, there must still be a minimum amount of aerobic soil available for final treatment and dispersal of effluent. The lower profile of the drip tubing can be an advantage for mound systems if their use is allowed by code.

For rural areas, drip distribution has the advantage of not requiring a three-phase electrical service. Most drip systems can be satisfactorily operated on 120/240 VAC systems. Drip system pump power requirements will range from 0.5 to 5 horsepower. A backup power supply may be required on larger systems.

This technology can be used in most climates. In areas that experience cold winters, appropriate precautions must be taken to prevent freezing of components. These precautions include placing the tubing deeper into the soil, putting insulation around valves, designing the hydraulic network to not hold water between dose events, providing a high-quality mulch covering, and establishing a good turfgrass vegetative cover during the growing season. Drip systems are appropriate for use in wooded or landscaped areas, for mild-use recreational areas (i.e., golf courses), and for forage production. Livestock should not be allowed to graze on drip systems because their hooves can cause soil surface compaction.

Compatibility with the Community Vision

Drip distribution may allow some shallower soils to be considered usable for wastewater dispersal in some jurisdictions. As such, homes and businesses can be located on some of the soils that were previously considered unsuitable for gravity trench systems. Communities may consider locating drip systems on individual lots if there is sufficient space. A centrally located drip system is a good option for small communities, allowing increased housing density in some areas and the creation of green space where the dispersal areas are located. Because they are built out as multiple fields and zones, drip systems can be expanded with minimal disruption by acquiring additional land.

A drip dispersal system is only as good as its management. Appropriate and sustainable management must be included in the overall plan. Various Management options are described in the Wastewater Basics Fact Sheet, which is included in this series. A community must have a means to disperse treated wastewater. If management fails to maintain the system, the health of the public and of the environmental are at risk. A utility or responsible management entity must be formed that will ensure the long term operation of the facility.

Selection of any wastewater dispersal option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

Land Area Requirements

For a given wastewater volume, Drip distribution would typically require less area than Gravity, LPD, Spray and Evapotranspiration options. The area needed for drip distribution is a function of soil morphology, site characteristics, daily wastewater volume, and the application rate. Application rates are typically given in gallons per day per square foot (gpd/ft^2). Appropriate application rates should be determined by a soils professional. The size of the dispersal area is determined by dividing the daily wastewater volume (gpd) by the application rate. A 5,000 gpd system built on a clay loam soil may have an application rate of 0.3 gpd/ft^2 and thus require 16,700 ft^2 (0.38 acres). Tighter or looser soil textures would require larger or smaller area, respectively. Site characteristics would also influence land requirements. For example, sites adjacent to water bodies and areas that require supplemental drainage will have larger footprints as a result of necessary separation distances. Some jurisdictions may require that a reserve area be delineated in the event the system must be replaced or repaired and this will increase the overall footprint. This is often the case for residential systems.

Quick Tip

For a given wastewater volume, drip distribution would typically require less area than gravity, low pressure distribution (LPD), spray and evapotranspiration options.

For detailed information on area requirements for this and other dispersal options on a range of soil types, consult the Cost Estimation Tool.

Construction and Installation

Any site intended for effluent dispersal must be protected from vehicular traffic before, during and after installation to minimize damage to mechanical components and the soil. The installation must occur when soil moisture conditions are neither too wet nor too dry to protect soil treatment capability.

Drip tubing is installed on contour (line of same elevation) using vibratory plows, static plows, trenchers, excavators, or ground saws. Additional equipment will be needed for installation of pretreatment components. Once the tubing is installed, the supply and return manifolds are placed in one or more excavations and connected to the tubing. Air/vacuum release valves are installed at the highest point in the supply and return manifolds and placed in valve boxes to provide access for maintenance. The manifolds and drip tubing are fully flushed with clean water prior to making final connections. If tubing is staked on the original surface, fill material is used to cover the tubing. The fill must meet certain specification for depth, texture, moisture content at placement, thickness of lift increments,

Installation of drip tubing using a vibratory plow

amount of organic debris (roots, twigs, etc.) and particle size. Low ground-pressure equipment is carefully used to place fill on the site to prevent soil compaction or other damage.

A dosing tank with a pump and water level sensors is installed to deliver effluent to the dispersal area. The tank is fitted with an access riser to grade to facilitate maintenance. The pump is placed in a screened vault to minimize the amount of solids pumped to the tubing network. Additional filtration is provided in the form of spin screen, disk or sand filters installed in close proximity to the dosing tank. A watertight control panel is installed and fitted with an elapsed-time meter (ETM) to track hours of operation and an event counter (EC) to track the number of doses delivered. This capability may be provided through installation of a Programmable Logic Controller (PLC). Control panels are typically configured for timed dosing of effluent.

Once the drip tubing is installed, it is connected to a manifold.

Once the drip tubing and supply/return manifolds are installed, most jurisdictions require a system inspection. Additional inspections are typically required after pretreatment components have been installed. No permanent structures are permitted over the dispersal area or reserve area (if required) once the installation is complete, but the area can be used for light recreational activities.

Installation of drip distribution results in minimal site disturbance. Reasonable access for equipment and materials is needed and minor additional space may be needed for staging areas (storage of media, for example). Once installation is complete, the valve boxes that house headworks assemblies and air relief devices will be visible but flush with final grade. Personnel who install drip systems may be subject to licensure or certification requirements in a given state or region. Certainly, the personnel must be familiar with orientation and placement of valves and fittings. Specific requirements for proprietary products may necessitate that the installer receive training by the manufacturer. Personnel who install electrical components must be properly trained and licensed.

Installation of drip tubing itself results in minimal site disturbance. However, additional disturbance will result from installation of associated components such as septic and dosing tanks.

Operation and Maintenance

The area over and around the dispersal area should be regularly inspected for damage (compaction, settling or erosion) and surfacing effluent. The regulatory authority should be notified if effluent is surfacing since this is a threat to public and environmental health. An appropriate, uniform vegetative cover should be maintained to help assimilate water and nutrients and stabilize the surface. Drip distribution may be installed in wooded areas or covered with grass, sod, or perennial vegetation.

Drip distribution field with well-established grass

Primary tanks, and other pretreatment devices should be checked for accumulated solids. These should be removed as needed. Effluent screens installed in the outlet of primary tanks, pump screens and sensors must be inspected and cleaned as needed. Performance of pumps and associated controls must be regularly checked to ensure the system is operating at design pressure and flow. Regular maintenance ensures that operational parameters are met. Drip systems require frequent O&M visits—at minimum ever six months.

Regular service is important for all systems to ensure best long term performance to protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of any pretreatment components used prior to dispersal.

To prevent excessive biological growth that could clog the tubing, filters are periodical flushed to remove the accumulated organic solids. This is accomplished by allowing the return side of the drip network to flow back to the primary treatment system. Most commercially available headworks are designed to automatically forward flush the tubing on a frequent basis. Where systems are design to automatically forward flush, regular manual flushing is also done by the service provider.

Water use and wastewater strength should be monitored. Excessive use (either intentional or due to plumbing leaks) may cause hydraulic failure. Excessive organic loading may occur through lack of regular solids removal, failure of the pretreatment components to properly reduce BOD or through the addition of non- or slowly-biodegradable substances such as fats, oils and grease (FOGs). Commercial food-service establishments should be required to install and maintain grease interceptors. Residential users should be cautioned to against putting FOGs into the system.

Personnel who perform operation and maintenance on drip distribution systems must have the appropriate training. Licensure or certification may be required in some jurisdictions.

Costs for Drip Distribution

Electrical costs will vary according to amount of flow, height of vertical lift and distance to be pumped. A community-scale drip system will have higher power requirements. For example, a 50,000 gpd system might require 50 psi at the pump, flow at 60 gpm, and use 14 hours to disperse the effluent. The power consumption to operate the drip system is estimated to be $12 to $18 per year.

For the purpose of estimating costs, four example drip systems have been developed and priced for flows ranging from 450 to 50,000 gpd. The costs below reflect only those associated with a drip system that includes a pump (or pumps) installed within a vault in a dosing tank; a filtration device; supply lines from the pump to the drip field; and supply and return manifolds that connect to the drip tubing. Installation, maintenance and total lifecycle costs for septic tank(s), advanced treatment components and disinfection devices are not included here.

Table 1 is a cost estimation for the materials, installation, and maintenance of a drip dispersal system attached to a single family home. These costs assume relatively flat topography, 20% for overhead and profit to the contractor, and no sales taxes on materials. Engineering fees and other professional services are not included in the costs. The size of the system is based on a clay loam soil with an application rate of 0.3 gpd/ft^2. Maintenance costs are based on a part time service provider, regular filter cleaning, a seven year pump life, and system replacement in 30 years.

The costs provided in this document are for comparison purposes only. The actual cost for a collection system will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

Table 1. Estimated cost to install and maintain a drip dispersal system at a single-family residence

Materials and installation	Tank excavation, pump & controls, filters, distribution system, drip tubing, and labor	$8,300 – $12,000
Annual electrical ($0.15 per kW-hr)	Based on ½-hp pump, operating 1 hr/day at $0.15/kW-hr	$12 – $18
Annual O&M	Annualized cost replace system in 30 years & annual maintenance	$500 – $740
60-yr life cycle cost present value (2009 dollars)	Assumes 3% inflation, 5% discount rate, no salvage or depreciation	$26,000 – $39,000

Table 2 estimates the cost of a drip dispersal system for three sizes of communities – 5,000, 10,000 and 50,000 gpd. Again, it was assumed that the land area is relatively flat, the application rate is 0.3 gpd/ft^2, and the contractor would charge 20% for overhead and profit. Engineering and other fees are not included in the costs. The maintenance cost is based on a part-time service provider, a seven-year pump life and a 30-year system life.

Table 2. Estimated cost to install and maintain a community drip dispersal system.

Cost Factors	Daily Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	\$37,000 – \$56,000	\$85,000 – \$127,000	\$329,000 – \$494,000
Annual electrical (\$0.15 per kW-hr)	\$240 – \$360	\$480 – \$720	\$2,400 – \$3,600
Annual O&M	\$3,300 – \$5,000	\$6,900 – \$10,000	\$31,000 – \$47,000
60 year life cycle cost present value (2009 dollars)	\$162,000 – \$243,000	\$344,000 – \$516,000	\$1,509,000 – \$2,262,000

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Fact Sheet D4

Performance & Cost of
Decentralized Unit Processes

DECENTRALIZED WASTEWATER SYSTEMS

DISPERSAL SERIES

SPRAY DISTRIBUTION

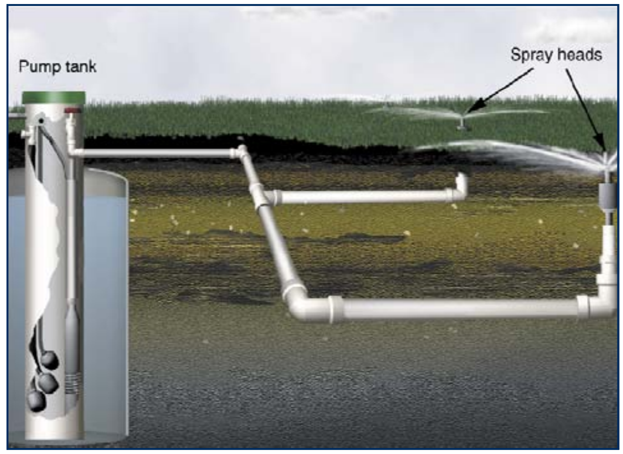
What is Spray Distribution?

Spray distribution is a means of dispersing effluent to the soil surface. This dispersal method originated from crop irrigation where uniform water application results in efficient water use and nutrient uptake by vegetation. This Fact Sheet discusses spray distribution for the specific purpose of dispersing effluent. For information on using this option for purposes such as growing a crop, irrigation of recreational areas, etc., see the Fact Sheet on Wastewater Reuse.

Surface application of effluent is a relatively high risk dispersal method due to potential human contact with odors, contaminants, and pathogens. Large buffer zones, fences and signage are generally needed (and often required) to reduce this risk. At a minimum, wastewater treatment prior to dispersal must include liquid-solid separation (primary treatment) to minimize clogging of nozzles, some degree of organic carbon removal (secondary treatment) to reduce the strength of the effluent applied to the land surface, and disinfection (tertiary treatment) to reduce pathogen levels due to the risk of human contact. Chlorination or UV light is typically used for disinfection. Because effluent is surface-applied, spray irrigation promotes more evaporation than other dispersal methods. Effluent that does not evaporate eventually rejoins the hydrologic cycle through evapotranspiration (via plants), runoff to surface waters, and/or infiltration to groundwater.

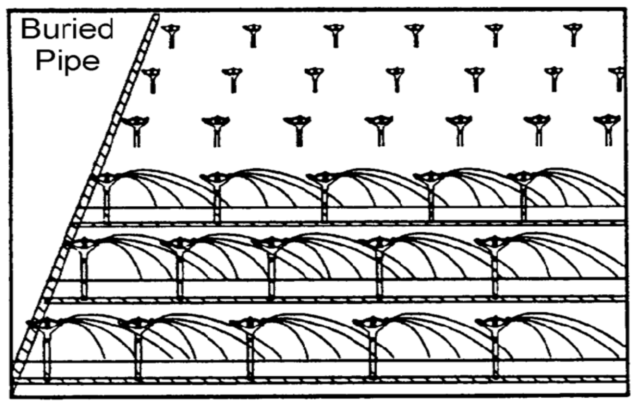
Spray distribution field

A typical residential system layout is shown in the figure to the right. The first component of the spray dispersal system is the dosing tank (or pump tank) that contains one or more pumps. A control panel activates a pump on a timed-dose basis and pressurizes the distribution system with effluent. When the system is at operating pressure, effluent is distributed across the soil surface. In residential systems, the timer is often set to activate very early in the morning to minimize the chance of human contact.



Typical residential drip system configuration

Cluster and community-scale systems have characteristics similar to residential systems but are larger in scale. Most larger systems are solid-set, meaning that the sprayers are permanently set at fixed locations. The sprayers may be pop-up heads which remain below the soil surface when not in use, or they may be mounted on risers. Common sprayers include rotors, impact heads or sprinklers. Community scale spray systems sometimes employ center pivots or traveling guns to apply effluent over much larger areas. For large scale systems, these devices are less expensive to install than solid set systems, but they require more operation and maintenance.



Community-scale solid-set spray system

Traveling gun spray distribution components

Center pivot components (left) and close-up of control panel (right)

How can Spray Distribution be used?

Spray irrigation is not commonly used for individual systems (less than 1,000 gallons per day). The potential human contact demands that large setbacks be established from property lines and structures. Accommodating these setbacks results in large land area requirements for placement of the system. For wastewater volumes from 1,000 to 10,000 gallons per day, use of this option is limited to sites where sufficient land is available. For flows from 10,000 to 50,000, siting constraints still exist yet economies of scale may make its use more viable.

Residential spray irrigation system (above) and close-up of spray head (right)

Spray systems can be used on many different soil types provided there is sufficient infiltration capacity to receive the applied effluent. In some cases, spray dispersal may be a solution that allows use of slowly permeable soils or soils with inadequate depth to a limiting condition such as groundwater or bedrock. An important soil requirement is the ability to support vegetation because it reuses the treated water and the roots and leaves limit erosion and runoff. Sites with steep slopes or areas close to potable water supplies or surface water may not be appropriate for use of this dispersal option due to excessive runoff potential. Although spray distribution is particularly suited for dry climates, it has been successfully used in humid regions. In areas that receive significant annual rainfall, or have periods of frozen soil, large spray systems will usually include 30 days of effluent storage (ponds) to minimize runoff when conditions prohibit application of effluent. Further, in colder climates, freeze protection must be part of the design.

Compatibility with the Community Vision

SPRAY DISTRIBUTION

Selection of any wastewater dispersal option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

Rural or suburban communities with significant amounts of land and low population density near the dispersal area can benefit from use of this dispersal option. While most appropriate for larger flows, clusters of residences can efficiently be served. The spray fields can be expanded provided additional adjacent land area is available. Large spray systems can be used to provide supplemental water to crop production, as long as the crop is not for direct human consumption. See Fact Sheet D7: Wastewater Reuse for more information.

Odors from aerosols will typically be a concern, especially if the dispersal area is up wind from the community. However, a properly operated system should have little if any odors. Although the area could be considered green space, direct use must be limited or prohibited by signage and fencing. If the area selected for effluent dispersal cannot be made secure from human exposure, then subsurface dispersal methods are recommended (see D3 Drip Dispersal). Spray dispersal is a viable option in rural areas.

Pumps and controls depend on electricity and a reliable source of electrical power is required. Systems that have pumps with 10-hp (or greater) motors will require three-phase electrical service. If a backup power supply cannot be provided, then dosing tanks or storage ponds must be sized to accommodate 30 days of flow without pumping.

A spray dispersal system is only as good as the associated management program. Appropriate and sustainable management must be included in the overall plan. Various management options are described in the Wastewater Basics Fact Sheet, which is included in this series. A community must have a means to disperse treated wastewater. If management fails to maintain the system, then public health and of the environment are at risk. A utility or other responsible management entity should be formed to ensure the long term operation of the facility.

For more information on Management Programs, see:

Wastewater Basics for Small Community Decision Makers and Planners

Land Area Requirements

Land area required for spray distribution is a function of the daily wastewater volume to be treated, the application rate, and land use adjacent to the dispersal area. Application rates are also influenced by the climate in the dispersal area. In particular, annual rainfall amounts affect the rates at which effluent can be applied. Clayey soils require more area to allow for slower movement of effluent into and through the soil. Application rates are typically provided in gallons per day per square foot (gpd/ft^2) or inches per hour (in./hr.). Appropriate application rates should be determined by a soils professional.

Dividing the daily wastewater volume (gpd) by the application rate (gpd/ft^2) determines the square footage required. For example, a 5,000 gpd system established on a clay loam soil may have an application rate of 0.10 gpd/ft^2 and thus require 50,000 ft^2 (1.11 acres). Tighter or more loosely textured soils would require larger or smaller area, respectively. Depending upon local codes, spray systems are often located 150 feet from property lines, 200 feet from the residence served by the system and 400 feet from neighboring residences, so additional area is required to meet setbacks. Pretreatment components would be located within the setback area. In most jurisdictions, a reserve area (in case the original area fails to accept effluent) is not required, but exceptions are possible.

For a given wastewater volume, Spray distribution will require more area than Gravity, Low -pressure and Drip options but less area than an Evapotranspiration pond. For detailed information on area requirements for this and other dispersal options on a range of soil types, consult the Cost Estimation Tool.

Quick Tip

For a given wastewater volume, spray distribution would typically require more area than Gravity, Low pressure distribution and Drip options, but less than an Evapotranspiration pond.

Construction and Installation

Construction of Spray distribution may include many different configurations. Common elements of a typical solid set installation are included in this document. The site should be protected from excessive vehicular traffic before, during and after installation to minimize damage to mechanical components and the soil. The installation should occur when soil moisture conditions are neither too wet nor too dry such to protect the soil's treatment capability. Components are installed using a backhoe, trencher or other excavation equipment.

Manifolds, sub-mains and laterals are installed in trenches and distribution heads are placed on grid points so that there is a slight overlap with the adjacent nozzles. This overlap promotes uniform effluent application over the soil surface. Risers for distribution heads are installed within a protective enclosure (such as a concrete collar) to prevent damage from wheel and foot traffic. Switching valves are installed in valve boxes to provide both protection and ready access. A dosing tank with a pump and water level sensors is installed to deliver effluent to the dispersal area. The tank is fitted with an access riser to grade to facilitate maintenance. The pump is placed in a screened vault to minimize the amount of solids pumped to the distribution network. A watertight control panel is installed that includes an elapsed-time meter (ETM) to track hours of operation and an event counter (EC) to track the number of doses delivered. Control panels should be configured for timed dosing of effluent. Manifolds, sub-mains and laterals must be flushed with clean water prior to installing nozzles to remove any debris that entered the pipes during construction. Freeze protection must be provided as appropriate. Secondary and tertiary treatment components (aerobic treatment and disinfection) are installed according to design. Fencing and signage to inform the public and control access to the site is installed concurrent with or immediately after installation of system components. Installation of spray distribution components should result in minor to moderate site disruption.

Personnel who install spray distribution may be subject to licensure or certification requirements in a given state or region. Certainly, they must be familiar with the specific requirements for this particular application which may necessitate training provided through manufacturers of proprietary products. Personnel who install electrical components must be properly trained and licensed.

Operation and Maintenance

While cost is always a factor in the selection of pumps, valves, and spray heads, one must also consider the relative ease with which these components can be replaced. It is also important to assess the availability of personnel with the proper skills to safely operate and maintain the selected components. Fencing and signage should be inspected for integrity and readability. A uniform vegetative cover must be maintained to minimize effluent runoff and to increase infiltration. This vegetation should be mowed regularly and immediately *before* spray application and not after to avoid smearing and compacting the soil. The area over and around the dispersal area should be regularly inspected for damage (compaction, settling or erosion). Distribution heads and nozzles should be regularly inspected for uniform spray patterns and disassembled and cleaned as needed. Integrity and performance of dosing tanks, pumps and controls should be regularly assessed and elapsed-time

Regular service is important for all systems to ensure best long term performance to protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of any pretreatment components used prior to dispersal.

meter (ETM) and event counter (EC) readings should be recorded to track hours of operation and number of doses delivered.

The effluent volume and wastewater strength applied to the site must be known. Application in excess of design may reduce the ability of the soil to accept effluent. Regulatory agencies will specify any monitoring and sampling requirements. Soil and vegetation must be regularly tested and wastewater application should be adjusted in accordance with any applicable nutrient management plans.

Exceeding effluent application limits will likely reduce the ability of the soil to accept the liquid.

Excessive traffic on the surface of the dispersal area results in compaction and is detrimental to longevity and optimum performance. For large spray systems, it is not unusual for service providers to use all-terrain vehicles with oversized tires to prevent compaction of the soil surface as they perform maintenance.

Service providers must have the appropriate training related to the safe operation of system components. They must be able to recognize potential problems and promptly correct them. If proprietary products are used, manufacturer certification of expertise is strongly advised and often required. Electrical expertise is needed for some components prior to the dispersal area itself. State or regional licensure or certification may be required depending upon the jurisdiction. Electrical expertise and knowledge of safe on-site practices for handling disinfection components is required.

Costs for Spray Distribution

The cost of pumping water will vary according to flow rate, vertical lift and distance to sprayers. For a single-family residence, the annual electrical cost for the pump and controls is expected to range from $20 to $30 per year. However, for a 50,000 gpd community system, the cost of moving water will likely be several hundred dollars per year.

For the purpose of estimating capital and long-term O&M costs, four example spray distribution systems have been developed and priced for flows ranging from 450 to 50,000 gpd. The costs below reflect only those associated with a spray system that includes a pump (or pumps) installed within a dosing tank; supply lines from the dosing tank to the field; and the laterals, distribution heads and risers within the field. Installation, maintenance and total lifecycle costs for septic tank(s), advanced treatment components and disinfection devices are not included here. Additionally, these figures do not account for the cost of the land nor the cost of 30 days of effluent storage required in humid climates.

Table 1 is a cost estimation for the materials, installation, and maintenance of a spray dispersal system that serves a single family home. These costs assume relatively flat topography, 20% overhead and profit to the contractor, and no sales taxes on materials. Engineering fees and other professional services are not included in the costs. The size of the system is based on a clay loam soil with an application rate of 0.1 gpd/ft^2. Maintenance costs are approximated by assuming at 25% of the sprayheads would be replaced each year and the pump and controls would be replaced every seven years.

Table 1. Estimated cost to install and maintain a spray dispersal system at a single-family residence

Materials and installation	Pump & controls, dose tank, trenches, pipes, & sprayers	$6,600 - $9,900
Annual electricity ($0.15 per kW-hr)	Estimated at ½ hp, operating 1.5 hr/d	$22 - $32 per yr
Annual O&M	Service provider plus component replacement	$240 - $260 per yr
60-yr life cycle cost present value (2009 dollars)	Assumes 3% inflation, 5% discount rate, no salvage or depreciation	$19,000 - $29,000

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

Table 2 estimates the cost of a spray dispersal system for three sizes of communities – 5,000, 10,000 and 50,000 gpd. Again, it was assumed that the land area is relatively flat, the application rate is 0.1 gpd/ft^2, and the contractor would charge 20% of overhead and profit. Engineering and other fees are not included in the costs. The maintenance cost is based on a part-time service provider, a seven year pump life and a four year sprayer life.

Table 2. Estimated cost to install and maintain a community spray dispersal system.

Cost Factors	Daily Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$138,000 – $206,000	$265,000 – $397,000	$1,260,000 – $1,890,000
Annual electricity ($0.15 per kW-hr)	$240 – $360	$460 – $690	$2,300 – $3,500
Annual O&M	$2,200 – $3,400	$4,300 – $6,500	$21,000 – $31,000
60 year life cycle cost present value (2009 dollars)	$225,000 – $338,000	$420,000 – $629,000	$2,076,000 – $3,113,000

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Fact Sheet D5

Performance & Cost of
Decentralized Unit Processes

Water Environment Research Foundation
Collaboration. Innovation. Results.

DECENTRALIZED WASTEWATER SYSTEMS

DISPERSAL SERIES

EVAPOTRANSPIRATION SYSTEMS

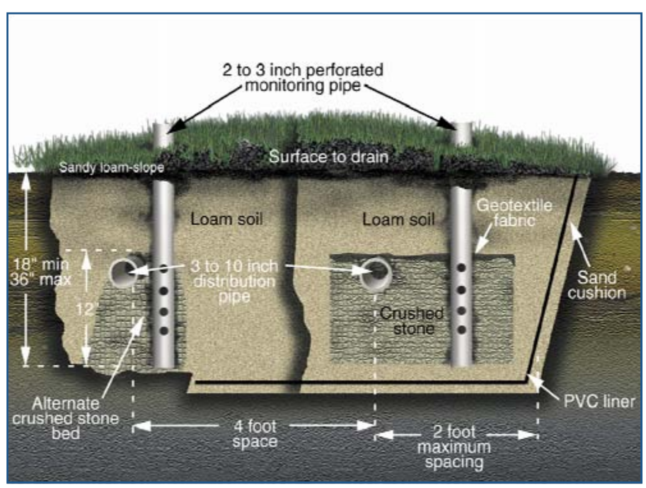
What is an Evapotranspiration (ET) System?

Evapotranspiration (ET) systems are a method of dispersing effluent through evaporation (the change of liquid into vapor that passes into the atmosphere) or transpiration (the passage of water through a plant from the roots through the vascular system [stems and leaves] to the atmosphere). ET systems are designed for full water containment as all of the wastewater treated in the system is evaporated from the exposed surfaces of soils, ponds or plants. This fact sheet will discuss two styles of ET systems: ET ponds and ET beds.

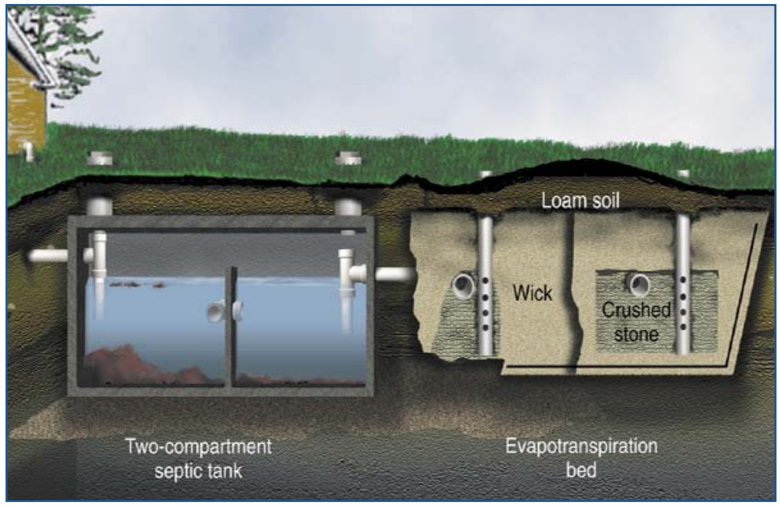
Evapotranspiration (ET) pond with a plastic liner

ET ponds are lined with a synthetic or clay liner to prevent percolation to groundwater. Effluent from a septic tank is conveyed to the pond through pipes. The systems are usually sited in a clear area exposed to both wind and sunlight to promote evaporation of the liquid.

ET beds apply effluent through a distribution network installed within a constructed soil bed. If no liner is used, the bed is often referred to as an evapotranspiration/absorption (ETA) bed which is designed to allow effluent to flow through the bed and into the native soil beneath it. The soil must have adequate capacity to allow the effluent to infiltrate. Both designs include a gravity distribution system consisting of perforated pipes installed in the shallow bed. Wastewater from a septic tank is applied through the perforated pipes. The sand bed is usually 24 to 30 inches (0.6 to 0.75 m)



Evapotranspiration bed (cross-section) thick, and covered with a shallow layer of topsoil, which can be planted with water- and salt-tolerant, locally available vegetation such as grasses, bulrushes or reeds. Treated wastewater is drawn up through the sand by the plant roots and is evaporated, transpired to the atmosphere, or (in the case of ETA beds), allowed to infiltrate into the soil.



ET beds are typically preceded by a septic tank to provide liquid-solid separation (primary treatment).

Potential shocks for ET and ETA beds include lack of water, lack of storage, and excess organic loading. Lack of water during the high evapotranspiration season will cause vegetation to die off. This means that a supplemental irrigation system must be included to ensure long term plant viability. Lack of storage will cause the bed to overflow during periods of low ET and extended wastewater peak flows. Periods of low evapotranspiration occur during the cold and overcast season and extended peak flows occur when increased water usage (during holidays, weekends, etc) results in the generation of more wastewater. In either case, excess wastewater can quickly overwhelm the storage capacity of an ET system resulting in overflows. To mitigate these effects observation wells and storage tanks are installed. The observation wells allow the user to monitor the depth of water in the storage portion of the ET bed. The storage tanks allow the capture of excess liquid which can be store until ample ET conditions exist or can be pumped out and disposed of by a pumper. Excess organic loading in the form of high biochemical oxygen demand (BOD) or fats oils and grease (FOGs) will cause an ET bed to plug, short circuit, and/or overflow. This may result in potential odor, pathogen, and nuisance problems.

How can Evapotranspiration systems be used?

Since these systems rely on the evaporation and transpiration of water, they are best suited for arid climates (low rainfall and high temperatures) such as the southwestern United States. They are a poor choice for areas with high humidity and high rainfall. These may be an appropriate technology in arid, mountainous areas with fractured bedrock where other dispersal options are inappropriate because they might discharge untreated wastewater into groundwater. ET systems are most appropriate for flows up to 10,000 gallons per day. Communities with wastewater volumes greater than 10,000 gallons per day do not typically use this technology because of the large land area required.

Compatibility with the Community vision

ET ponds have large land requirements but they require no direct energy input and have minimal O&M requirements. Communities with suitable climate, enabling laws and large tracts of open land for installation of ET ponds can take advantage of this passive technology. ET and ETA beds can be made into attractive green space and ET ponds constitute open water features. However, if not cared for, they may become an over grown bed of weeds or dead vegetation. Institutional and physical control of public access such as fencing and appropriate signage is required in most settings. Another potential negative is the possibility of odors. A heavily-loaded ET pond may have short term odor episodes associated with wind or a low pressure front. If there is ice cover, odors will be evident immediately following the ice breakup. The duration of odor episodes is a strong function of organic loading, water temperature, and duration of ice cover. Odor episodes usually last from a few hours to a day and the maximum anticipated episode is about 1-2 weeks per year.

Selection of any wastewater dispersal option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

Land Area Requirements

The amount of area required for an ET pond system is determined by comparing the area needed to process the organic load and the area needed for evapotranspiration to occur. The larger of the two areas controls the design specifications. Single-family home ET and ETA beds can vary in size from 3,000 to over 10,000 square feet. Pretreatment processes should be designed to keep the organic load less than 200 mg/L BOD_5 and less than 25 mg/L FOG. The area is calculated using a BOD areal loading rate adjusted for elevation since evaporation rate decreases with increasing elevation.

Single-family residence with an ET bed

The area needed for evapotranspiration to occur is based upon a calculated water balance that includes seasonal sewage flow, annual potential evapotranspiration rates, and annual precipitation rates. However, the difference in potential evapotranspiration in high desert climates between summer and winter is often a factor of 4 or greater. Therefore, it is recommended that winter evapotranspiration rates be used in calculating the required area. This ensures the ET system can handle the lowest evapotranspiration rates throughout any year. If resources and space are a constraint, an investigation of the hydraulic balance can be performed at the proposed site using seasonal evaporation rates. The required area can then be calculated. There are several methods of design in use today. All of the methods use the period in which the lowest rate of evapotranspiration occurs or some combination of the periods with the lowest and highest rates.

Construction and Installation

An ET pond system is usually constructed with a simple earthen basin with either a clay liner or a synthetic plastic liner to prevent percolation of wastewater into the ground. The excavation usually has a 3:1 (run:rise) side slope. If a natural clay soil is present, it may be adequate to simply bring it to the appropriate moisture content and compact it to create the liner. If the ground is sandy a clay liner is established or a synthetic liner is installed. Piping between the septic tank and the pond, as well as between multiple ponds must be installed on the appropriate grade to promote gravity flow. The construction of either a lined pond or a pond with an imported clay liner must be performed by a professional contractor with appropriate experience.

An ET bed is constructed by making a shallow excavation and installing a plastic liner. Perforated pipes are installed in the shallow bed above the liner. The bed is filled in with 24 to 30 inches (0.6 to 0.75 m) of relatively coarse sand. A shallow layer of crowned topsoil and vegetation completes the ET bed. If the soil is capable of treating the effluent, an ETA bed is installed in essentially the same fashion, but without the liner.

ET beds and ponds are constructed by making a shallow excavation and installing a plastic liner (above). If soils are clayey, the plastic liner may be omitted (below).

Operation and Maintenance

ET Ponds have relatively low maintenance requirements since there are no moving parts. If they are loaded at recommended levels, they should not require pumping over the life of the unit. Adjacent trees must be removed so that their roots do not create a pathway for water that may cause a dike failure. For the same reason, burrowing animals must be excluded. Grazing animals (goats and cattle) are a concern because they tend to leave trails that may promote erosion. Fencing and signage around an ET pond must be maintained to prevent unauthorized access. Some jurisdictions may require a wastewater operator license for ET ponds serving anything larger than a single family residence.

Like any other landscape feature, ET and ETA beds must be cared for to keep them attractive and healthy. They must be irrigated during the dry season to protect the vegetation. During exceptionally wet seasons, a pump must be available to divert excessive water to part of the fenced perimeter. This should be a very rare occurrence. No deep-rooted vegetation should be allowed on the banks or in the bed itself.

Typically, little training or certification is needed to maintain an ET bed system once it has been installed and put into use. Some jurisdictions may require licensing or certification.

Regular service is important for all systems to ensure best long term performance to protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of any pretreatment components used prior to dispersal.

Dike failure may result if appropriate vegetation is not maintained.

Costs for Evapotranspiration Systems

The cost of installing an ET bed is dependent on size and location. Excavation cost can increase if the use of heavy equipment becomes necessary, because of large areas or difficult soil types such as in mountainous areas with fractured bedrock. Systems installed at higher elevations may require larger land area which can have a large impact on cost. Costs can also rise if there is no clay or (for ET and ETA beds) sand locally available, making it necessary for the material to be transported long distances to the site. If the ET component must be located far away from the septic tank, the costs of pipe installation will increase as more excavation and pipe will become necessary. ET systems are passive, relying on gravity, wind, and sunshine.

Depending upon the size, Operation and Maintenance of ET ponds may require a licensed operator.

They do not require electrical power unless a pump is used during exceptionally wet periods. This should be a rare occurrence.

Depending on size, the ponds may require a licensed operator but no discharge permit. The ET beds usually require no special operational training, but depending on the jurisdiction may require special regulatory oversight. Capital costs will be similar to slightly higher than a subsurface gravity trench or bed system, with the extra cost of the liner being the primary difference.

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Fact Sheet D6

Performance & Cost of Decentralized Unit Processes

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DECENTRALIZED WASTEWATER SYSTEMS

DISPERSAL SERIES

SURFACE WATER DISCHARGE

What is Surface Water Discharge?

The term Surface Water Discharge is exactly what its name implies: a direct discharge of treated effluent to surface water. Surface water discharges are discrete, identifiable sources such as pipes or ditches that discharge directly and may include individual homes, residential clusters, communities, commercial and industrial sources, etc. Surface water discharge to "Waters of the United States" requires a National Pollutant Discharge Elimination System (NPDES) permit and is often referred to as a *point source*. Individual homes that are connected to a municipal system do not need a NPDES permit because the permit issued to the municipality applies. Individual homes that directly discharge to surface waters may require an NPDES or other permit depending upon state and/or federal regulations. Surface water discharge permits (including NPDES permits) are issued by a delegated state environmental agency or by the USEPA.

Surface waters can assimilate a certain amount of pollution. However, excess pollution has a degrading effect on water quality that may render it unsafe for drinking, fishing, swimming, or use as a potable water source. The NPDES permit program (authorized by the Clean Water Act [CWA]) controls water pollution by regulating sources that discharge pollutants into surface waters of the United States. NPDES permits define limitations on the volume and strength of effluent that is discharged, describe monitoring requirements and spell out fines to be levied for non-compliance.

Properly managed facilities such as publicly owned treatment works (POTWs), as well as separate and combined storm sewer systems play an important role in protecting community health and local water quality. However, due to the cost and complexity of the NPDES program it may not be efficient or economical to pursue permits for individual or very small systems (flows less than 10,000 gallons per day). Surface discharge should not be considered unless soils are unusable and a community soil-based dispersal system is not feasible. The monitoring manpower required could overwhelm local resources.

Compatibility with Community Vision

Surface Water discharge will very likely affect surface water quality. In some cases, the discharge may be of higher quality than the receiving environment, but the reverse is more often the case. With increasing levels of treatment (primary, secondary, and tertiary), environmental protection is increased. However, additional capital and manpower resources are required to ensure that protection. If a sustainable, protective system can be installed without using a surface water discharge, this option is preferred. A surface water discharge should be a last resort for any small community because of the associated paper work, monitoring requirements, the cost and potential affect on surface water quality.

Land Area Requirements

The discharge pipe itself may require extra area to allow access and satisfy setback requirements. Certainly, the collection, treatment and storage facilities used prior to discharge will occupy the majority of space required in relation to a surface water discharge. Collection and treatment options are discussed in other Fact Sheets in this series.

Construction and Installation

Excavation for installation of the discharge pipe is required. The extent of disruption associated with this is a function of the location of the associated storage and treatment facilities that precede the pipe. Access may be the most important variable of all. Easy access for pipe installation and repair is highly desirable. Difficult access from inadequate construction planning can be very costly. Construction personnel must have appropriate training and licensure for installation of this option. Requirements will vary according to jurisdiction.

Operation and Maintenance

NPDES permit requirements include sampling the effluent and reporting the results to EPA and the state regulatory agency. In addition, the permit will require the facility to notify EPA and the state regulatory agency if and when the facility is not in compliance with the permit requirements. EPA and state regulatory agencies also deploy inspectors to determine if the facility is in compliance with the conditions imposed under the permit. Point discharges generally require a higher level of resources relative to other options discussed in the Dispersal series of Fact Sheets because of the permit requirements. In general, the energy demand increases as the level of treatment provided increases. Each facility must be evaluated on a case by case basis.

Costs for Surface Water Discharge

The capital cost associated with surface discharge is the piping from the treatment facility and installing the outfall. Outfall construction will involve working in the water, which will require an aquatic resource alteration (ARAP) permit. Care is needed avoid causing pollution while working in the stream. Another cost associated with surface discharge is the evaluation of the receiving stream's ability to assimilate the effluent. Considerable background information must be collected on the hydrology of the site, the aquatic habitat, and native water quality. The design engineer will usually consult with various environmental specialists to assemble this information.

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Fact Sheet D7

Performance & Cost of Decentralized Unit Processes

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DECENTRALIZED WASTEWATER SYSTEMS

DISPERSAL SERIES

WASTEWATER REUSE

What is Wastewater Reuse?

The hydrologic cycle represents the ultimate reuse of water. From the perspective of wastewater, reuse is the beneficial use of reclaimed wastewater. It is a “reuse” because the user does not have to go to a river or to the groundwater to obtain this water – this water is a by-product of human sanitation and of industrial processes. By reducing the waste constituents from wastewater to an acceptable level, the water can be safely used for agricultural, commercial, residential and industrial purposes. This is termed direct reuse. By volume, agricultural irrigation is the largest user of reclaimed wastewater. Other major users include those who use water for industrial cooling and processing. A second category of reuse is indirect reuse. Highly treated wastewater can be used to recharge aquifers. This is an indirect reuse because the reclaimed water mixes with the groundwater which can serve as a future raw water supply.

Direct Reuse Applications

Reclaimed water for non-potable reuse must undergo some combination of primary, secondary, and tertiary treatment to meet reuse requirements. The number and choice of treatment steps will vary based on how the water will be used. However, most recycled water will undergo some form of disinfection for protection of public health. When disinfection is not used, the reuse area must be isolated from direct human or animal contact by fencing, signs, or other means. The most commonly used non-potable reuse applications are described below.

Irrigation reuse

Irrigation reuse is the direct use of reclaimed wastewater by applying it to agricultural crops or landscaped areas. Irrigation is a value-added means of dispersing the water back into the environment. Spray distribution (described another Fact Sheet in this series) uses similar equipment and methods to apply the water. Spray distribution is designed for dispersal of effluent and does not have the “value-added” component of crop production. It is important to remember that when a crop or landscape does not need irrigation, another means of reusing the reclaimed water must be identified.

The two main categories of irrigation reuse are agricultural irrigation (crop irrigation, commercial nurseries) and landscape irrigation (parks, playgrounds, golf courses, freeway medians, landscape areas around commercial, office, industrial developments, and residential landscape areas). Both agricultural and landscape irrigation reuse may eliminate the cost of nutrient removal, which can be significant. Any size community can incorporate reuse of treated wastewater for landscape feature irrigation. Larger communities can produce sufficient water to make agricultural crop irrigation practical. Smaller communities or cluster-size systems only generate sufficient flow to satisfy smaller demands.

Restricted irrigation reuse is limited to crops that will not be directly consumed by humans (fodder, fiber and seed crops), and is appropriate for relatively small flows. Public access to the irrigated area is controlled. For this type of reuse, wastewater treatment must effectively remove pathogens and organic matter in order to protect public health and eliminate odors. Sites with steep slopes may not be appropriate for irrigation reuse due to excessive runoff potential. Slope may also influence the type of vegetation chosen as described in Table 1.

Table 1. Potential for Utilization of Irrigation Reuse relative to Slope and Vegetation Management

Slope %	Fodder, fiber and seed crops	Turf	Forest
0 – 4	High	High	High
4 – 12	Low	Moderate	High
12 - 20	Excluded	Low	Moderate
> 20	Excluded	Excluded	Low

Unrestricted irrigation reuse requires that wastewater be treated to a very high quality (turbidity less than 2 Nephalometric Turbidity Units [NTUs]) and be disinfected. Recommended microbiological standards published for the unrestricted irrigation water are similar to drinking water quality standards. Public access to the irrigation site is not controlled. However warning signs not to use the water for drinking or to avoid human contact are prominently posted. Using high-quality reclaimed water for unrestricted irrigation of food crops for human consumption is theoretically possible for small community wastewater systems but probably only practical for large systems. The single greatest concern in small wastewater systems is the reliability and maintenance of

the disinfection portion of the treatment train. Golf course and community green-spaces are frequent receivers of unrestricted irrigation.

High quality reclaimed water can be used to irrigate golf courses or make snow at ski resorts.

Industrial reuse

Industrial facilities use reclaimed water primarily for cooling system make-up water (to replace water lost to evaporation in arid climates), boiler-feed water, process water, and general wash down. It can also be used for concrete production on construction projects. Industrial re-users may require that the water undergo additional treatment. Softening (the removal of dissolved salts) is often done to protect the heat-transfer surfaces of industrial cooling towers. These additional treatment components are typically installed close to the point at which the reuse will occur.

Environmental/Recreational reuse

Reclaimed water can be used to create manmade wetlands, enhance natural wetlands, and sustain or augment stream flows. An impoundment of reclaimed water in which recreation is limited to fishing, boating, and other non-contact recreational activities constitutes *restricted recreational reuse.* This form of reuse must be accompanied by appropriate signage. With *unrestricted recreational reuse*, reclaimed water is used in an impoundment of water in which no limitations are imposed on body-contact recreational activities.

Urban reuse

In urban reuse, reclaimed water is used for various non-potable purposes such as decorative water features, dust control, fire protection, and toilet and urinal flushing in commercial, residential and industrial buildings. Irrigation of ornamental landscapes, parks and golf courses (described above in the Irrigation Reuse section) can also be a part of an urban reuse system.

Traditional urban water reuse systems have two major components: water reclamation treatment facilities and a reclaimed water distribution system. Infrastructure is needed to bring wastewater into the treatment facility (sanitary sewers), and a distribution system is needed to take the reclaimed water back out to potential users. Non-potable recycled water goes through a separate pipeline (purple pipe) system, which is completely separate from the drinking water distribution system. This "dual distribution" of potable and non-potable waters is the most expensive component of a reuse system. The non-potable distribution must be constructed to prevent cross-connections with potable water lines and ensure that non-potable water is put to appropriate use. Periodic cross connection tests ensure that the non-potable recycled water pipelines are not accidentally connected to the drinking water system. In addition, there is ongoing monitoring and testing of the non-potable recycled water and drinking water systems to protect public health. To avoid cross connections, all above-ground appurtenances and equipment associated with reclaimed water systems must be clearly marked.

El Paso Water Utilities

PURPLE PIPE NEWS

reclaimed water issues

December 2009 Vol. 3 Issue 1

Dispensing Stations Prove Popular

More than 15 million gallons of potable water have been saved since our dispensing stations were built in 2006. Three automated standpipes, located in northwest and central El Paso, provide 24-hour service to water haulers in the construction and maintenance industries. Without them, construction companies would pay expensive fees to install standpipes off of fire hydrants, as well as higher prices for potable water.

Reclaimed water dispensing station.

Customers can access the standpipe within a few days of paying the small deposit and account setup fee. The account will be active until it is canceled or becomes delinquent.

The transaction is simple. Each dispensing station is equipped with a 3-inch standpipe connection and a 2-inch, fire-hydrant-like, side connection to accommodate both top-fill and side-fill tanks. Stations are activated by entering a user number, a pin number and the amount of water needed.

Reclaimed water is billed at $1.24/1000 gallons with no minimum fees. EPWU tracks the user, date and time of use, amount of water, etc. We download the transactions and bill customers based on the amount of water dispensed.

Applications are available at epwu.org or at our Customer Service Center located at 6400 Boeing Drive.

North Central El Paso To Benefit From Reclaimed Water

Haskell Street Wastewater Plant

Reclaimed water from the Haskell R. Street Wastewater Treatment Plant serves sites such as Ascarate Golf Course, Concordia Cemetery and Bowie High School. The system is being expanded into north central El Paso to serve additional schools, parks and Fort Bliss. The first phase is scheduled to bid in January 2010.

The three-phase project includes miles of pipelines, two reservoirs and two pump stations. Nearly half of the cost for the current phase is being funded by the Environmental Protection Agency; the balance with EPWU capital improvement funds.

EPA requires grant applicants to hold public hearings followed by a 30-day comment period. Moreno Cardenas, Inc., designers for this high-profile project, described the expansion and reviewed environmental impacts at the January 2009 public hearing.

Moreno Cardenas is addressing every issue, and no adverse environmental impacts are anticipated. Traffic will be temporarily disrupted when underground utilities are constructed within the roadways, but the analysis and design will minimize the impact.

Expanding the system offers many advantages. Recreational areas can be enhanced by irrigating with reclaimed water. And reclaimed water costs less than potable water, which reduces customers' bills. The expansion will save about 7 million gallons of potable water per year.

Reclaimed Water Manager Irazema S. Rojas wants to hear from customers who front the proposed pipelines if they are interested in reclaimed water service. She said, "We will review the applications and determine if fees apply before the design is completed. This helps incorporate the service into the project plans and avoids expensive last-minute construction requests."

Both residential and commercial customers who front the proposed pipelines will be considered for connection. There is no charge to connect customers who have a dedicated yard meter for their irrigation system. Those without a yard meter will be connected at a reduced cost.

Landscape Nutrients

Dec. 2008 - Dec. 2009

Average Dec. 2008 - Dec. 2009	Service Area: Northwest lbs/CCF	Central lbs/CCF	Mission Valley lbs/CCF
Nitrogen (N)	0.086	0.084	0.183
Phosphorus (P)	0.010	0.015	0.022

These are the approximate nutrient factors incorporated into your reclaimed water irrigated site from December 2008 to December 2009. Add the usage between this 12-month period, in CCF units, and multiply by the respective factor from this table. The resulting number is an estimate of the total amount (pounds) of nutrients (Nitrogen and Phosphorus) added to the reclaimed water irrigated area overall. Ask your landscape professional if you need to apply fertilizer based on this information. Nutrients are removed during the treatment process for the Northeast Service Area.

Purple Pipe News is an annual publication by El Paso Water Utilities
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EL PASO WATER UTILITIES PUBLIC SERVICE BOARD

El Paso Water Utilities is an example of a municipal scale reclaimed water system

The volume of storage required to accommodate flow variations can be determined from the daily reclaimed water demand and supply curves. In order to maintain suitable water quality, covered storage is preferred to prevent biological growth and maintain chlorine residual where appropriate. If reclaimed wastewater is to be used for fire protection additional design issues must be considered. While urban potable water distribution systems are typically sized based on fire flow requirements, in residential areas, 6-inch diameter pipes may be needed to support fire demands where 2-inch diameter pipes may be sufficient to meet potable needs. Additional storage may also be needed.

Indirect Reuse: Aquifer Recharge

Artificial aquifer recharge (AR) is the enhancement of natural groundwater supplies using manmade conveyances such as rapid infiltration basins or injection wells. Aquifer storage and recovery (ASR) is a specific type of AR practiced with the purpose of both augmenting ground water resources and recovering the water in the future for various uses. ASR wells are regulated as Class V injection wells under the U.S. EPA Underground Injection Control (UIC) program. As such, ASR well owners and operators are required to submit basic inventory information to the primary enforcement agency. EPA may directly implement a program, or a state may have primary enforcement authority, or "primacy". AR and ASR wells are found in areas of the U.S. that have a high population density and proximity to intensive agriculture; dependence and increasing demand on ground water for drinking water and agriculture; and/or limited ground or surface water availability. For further information on AR and ASR technology, the reader is directed to: http://www.epa.gov/safewater/asr/ index.html#inventory.

Compatibility with Community Vision

Historically, few communities have pursued urban reuse programs. The main barrier has typically been cost of the non-potable transmission network described above. In a community where water is plentiful, these systems are very expensive compared to simply dispersing treated wastewater into the ground or into a receiving stream. Public perception of urban reuse systems has not necessarily been positive, which can be attributed to misconceptions regarding associated risks. Certainly, if they are not properly maintained, reuse systems can pose a significant odor nuisance and a health threat. The increasing commonality of droughts and warnings of global climate change are beginning to soften these attitudes. Provided that cross-connection can be prevented, reclaimed water can be used to replace potable water in any application that does not require human consumption. If the community is willing to commit to providing the money and man-power to do the job right, the system will function well and all water brought to the community as potable water can be used at least twice prior to ultimate dispersal back into the environment. As state agencies see the potential value in adopting water reuse incentives, the number of such applications will dramatically increase.

One beneficial reuse is to use treated wastewater to flush toilets. This has been implemented at several national parks and large office buildings. The visitor centers at the Great Smoky Mountains National Park and Grand Canyon National Park are examples of decentralized treatment facilities that use treated wastewater to flush toilets. Several large buildings in New York City, Tokyo, and Australia have installed wastewater treatment facilities on their premises and reuse the water for toilets and fire protection. Many state jurisdictions have been less receptive to toilet flushing as a legitimate reuse application. Irrigation reuse for agricultural crops and landscaped areas has been more widely used, but there are still issues to be addressed and constraints within which irrigation reuse must be implemented. These are summarized in Table 2.

Table 2. Issues and Constraints Associated with Various Types of Wastewater Reuse

Type of Irrigation	Issues/ Constraints
Agricultural, crop and nursery irrigation	Surface and groundwater contamination if not properly managed Marketability of crops and public acceptance Effect of water quality, particularly salts, on soil and crops
Landscape irrigation: parks, school yards, freeway medians, golf courses, cemeteries, greenbelts, and residential	Public health concerns related to pathogens Effect of water quality, particularly salts, on soil and crops Use area (including buffer zone) may result in high user costs

Given the increased areas of water shortages, increased regulatory anti-degradation activities, and other constraints, all communities should consider the reuse of both treated wastewater and stormwater runoff in their overall community plans. One of the major advantages of reusing wastewater for irrigation is that nutrient removal is not required. Some arid states are requiring developers to assure an adequate water supply for 100 years. Irrigation reuse by the community, by commercial interests, and by the agricultural sector is certainly a means of maximizing water resources to meet such goals.

Land Area Requirements for Wastewater Reuse Systems

The amount of area required for non-potable urban reuse will vary according to the demand for reclaimed wastewater and the location and circumstances of the intended reuse. Land area required for treatment and pumping facilities will be depend upon the treatment technology chosen. Typically, one-half acre or less will be required. The majority of the distribution piping and storage will be underground, and thus not interfere with above ground activities. The volume of storage required to accommodate flow variations is determined from the daily reclaimed water demand and supply curves. The more storage required, the larger the land area requirement.

The amount of land required for Irrigation reuse will depend upon the wastewater volume, the local precipitation and evapotranspiration, and the crop to be irrigated. For 100% usage of treated wastewater, storage will likely be required to match the demand for the irrigation water. In other words, the daily demand for irrigation may be greater than the supply of reclaimed water. Off season storage can help satisfy the needs during the irrigation season. The volume of storage in the warm (semiarid and arid) regions will be about 90 days of reclaimed water production. The actual volume is determined by considering the water balance of anticipated precipitation, evaporation and the water that will be used by the selected crop. In cold, humid climates, significantly greater storage volume will be required to comply with restrictions on application to frozen ground.

Construction and Installation of Wastewater Reuse Systems

Urban water reuse systems have two major components: water reclamation facilities (treatment components) and a reclaimed water distribution system. For agricultural irrigation reuse, facilities to collect, treat and convey the wastewater to the point of irrigation must also be established. The nature of the irrigation reuse system construction depends on the type of irrigation system selected and the needs of the crop chosen. Because the components for each of these will vary, community leaders should consult other Fact Sheets in this series once the nature of the system components is determined. To avoid cross connections, all above-ground appurtenances and equipment associated with reclaimed water systems must be clearly marked when installation is complete.

Backflow preventers (in foreground) are required to prevent cross-connections between potable and non-potable water.

Construction personnel must have appropriate training and licensure for installation of pump systems, piping, and storage components for the distribution system. Requirements will vary according to jurisdiction.

Operation and Maintenance of Wastewater Reuse Systems

The reclaimed water distribution system is essentially an additional water utility. This makes a case for consideration of a single, combined water utility. Reclaimed water systems are operated, maintained, and managed in a manner similar to the potable water system. Water reclamation facilities must provide the required treatment to meet appropriate water quality standards for the intended use. In addition to secondary treatment, filtration and disinfection are generally required for reuse in an urban setting. In cases where a single large customer needs higher quality reclaimed water, the customer may have to provide additional treatment onsite, as is commonly done with potable water.

Operation and maintenance (O&M) of urban wastewater reuse systems are very similar to any advanced wastewater treatment facility. There will be regulatory oversight and operator licensure will be required. In some jurisdictions beneficial reuse operators are all required to carry the States highest operational credentials regardless of plant size or process complexity. This will vary according to jurisdiction.

O&M for wastewater reuse systems depends upon the system components and the intended use. Unrestricted reuse will require a disinfection method such as chlorination (above) or Ultraviolet light (below). As with all components, regular O&M by qualified professionals is required.

The O&M requirements for irrigation reuse equipment vary dramatically depending on the technology or method selected for application. Drip irrigation is a high efficiency, high maintenance technology that requires effluent to be treated to a high level. Quarterly or more frequent maintenance is typically required for both the treatment technology and the drip distribution system. Flood or furrow irrigation requires little O&M other than keeping the furrows level and groomed. Regardless of the O&M requirements, the operator must be knowledgeable. It is important that the effluent being irrigated be managed from the perspective of the crop and the soils. Wastewater effluent will usually have a higher amount of total dissolved solids (TDS) than the source it is taken from. This can cause a borderline water to become brackish. Increased care is required in using it for irrigation. The TDS of the water can increase by three to five times as it moves down through the root zone. In areas with sandy soils that receive periodic heavy rains, the soils will be self-maintaining. However, in areas with clayey soils and low rainfall, the operator must manage the salt levels in the soil to protect the long term viability of the system.

In distributed or decentralized reuse systems the O&M requirements are potentially lower owing to the use of more passive, non-O&M-intensive treatment technologies that are located closer to the reuse applications. However, if the reuse opportunities are primarily limited to a few large users, these innate advantages might be reduced. One of the positive aspects of these systems is that they can always be sources of aquifer replenishment if other reuse opportunities are scarce.

Costs for Wastewater Reuse Systems

For the reuse of reclaimed water, the cost components are wastewater collection, wastewater treatment, and reclaimed water distribution. In areas with existing sanitary sewers and treatment facilities, the new cost will be the installation of a non-potable distribution system. There are two basic means of justifying the cost of a reuse system. The first justification is if there is some limitation related to disposal of treated wastewater. As surface water discharge permits are renewed, the water quality standards are often tightened to comply with regulatory-derived Total Maximum Daily Loads (TMDLs). If a stream is listed as "impaired" because of nitrogen, then new nitrogen standards will likely be imposed on the treatment facility. It might be less expensive to divert a portion of the treated wastewater to some type of beneficial reuse rather than invest in additional treatment capacity. A second means of justifying reuse is water shortages. There are many different usages of water, and very few actually require *potable* water. If reclaimed water can be used in place of potable water, then the potable water reservoir is conserved. Further, there is a cost savings of not having to treat raw water to potable water standards to only have it be evaporated in a boiler or used to water a lawn. Remember that there are still costs associated with creating the dual distribution system (potable and non-potable) and storage facilities needed for wastewater reuse.

There is also an expense associated with developing an irrigation system as a means of reuse. Irrigation systems can be distinguished by whether the equipment is permanently installed (stationary system) or whether it can be moved to adjacent fields (traveling system). Stationary systems such as solid-set spray or drip irrigation require less labor to operate, but have a higher initial cost. Traveling systems, such as center pivot sprinkler irrigation, linear-move, or cable-tow systems require more labor to operate but have less capital expense. Depending on the delivery technology used for irrigation reuse water, the majority of the energy used will be for pumps and irrigation sprinklers (moving sprinkling systems). If the system is automated, it will require energy to operate the computerized system to "control" the irrigation. Again, a complex array of options must be evaluated and costs estimated on a case by case basis.

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4.0 WASTEWATER PLANNING MODEL USER'S GUIDE

This section is the user's guide for the Wastewater Planning Model, an Excel-based spreadsheet. The Wastewater Planning Model must be accessed and downloaded from the WERF Decentralized Cost website.

Cost of Individual and Small Community Wastewater Management Systems

Wastewater Planning Model Users Guide, version 1.0

Project Background
The materials presented here were developed in response to a Request for Proposals (RFP) to address the topic of Decentralized System Selection: Unit Processes, Costs, and Non-monetary Factors. The RFP was issued by the Water Environment Research Foundation (WERF), a nonprofit organization that operates with funding from subscribers and the federal government. This project was supported by funding from the US Environmental Protection Agency (US EPA) and administered by WERF as part of the National Decentralized Water Resources Capacity Development Project (NWRCDP).

The 19 Fact Sheets and electronic cost estimation tool included in this package were developed by members of the Consortium of Institutes for Decentralized Wastewater Treatment (CIDWT). The CIDWT is a group of Educational Institutions cooperating on decentralized wastewater training and research efforts. CIDWT members participating in the development process include:

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These factsheets, the Wastewater Planning Model (spreadsheet), and this user's guide can be found on the Water Environment Research Foundation's website.

www.werf.org/decentralizedcost

The costs provided in these documents are for comparison purposes only. The actual costs will vary significantly depending on site conditions and the local economy. This user's guide documents many of the assumptions that are built into the cost estimations generated by the spreadsheet. The planning model and the factsheets are not intended as design guides.

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Cost of Individual and Small Community Wastewater Management Systems

Wastewater Planning Model Users Guide, version 1.0

Abstract
Domestic wastewater must be properly managed in order to prevent damage to both human and environmental health. Homes in rural areas and small communities depend on onsite systems (septic tanks and soil absorption fields) to treat domestic wastewater and return the treated water to the hydrologic cycle. As communities grow, onsite systems often need to be replaced with community-scale wastewater management systems. Wastewater management includes four components: Collecting wastewater from individual sources, renovating wastewater to prevent human and environmental harm, returning the treated water back into the environment, and providing oversight to ensure the system is both fully operational and financially sound. Local officials have many options when planning for wastewater infrastructure improvements. However, these same officials often do not have enough information to make informed decisions among the various options. This spreadsheet is intended to provide cost information about the various collection, treatment and dispersal methods that are commonly used in small communities. For each of these methods, cost information will be provided about the initial capital cost as well as the anticipated long-term maintenance and energy costs. The user must realize that this spreadsheet is a planning tool and not a design tool. One of the objectives in building this spreadsheet was to provide assistance to the planner in communicating with consulting engineers, soils professionals, construction managers and financial personnel about the wastewater management options that are available. The use of this spreadsheet should be limited to daily wastewater flows of 75,000 gallons per day or less. Approximations of cost are based on 2009 dollars.

Introduction

Background Information
This spreadsheet is built in Microsoft Excel® software – it will function with Excel 2003 and 2007. The spreadsheet contains a series of worksheets, each noted as a tab on the bottom of the screen. Users are encouraged to follow the order of these tabs from left to right. Very basic information is asked of the user. From this information, estimations are made about the size and cost of various individual and small community wastewater management systems. Labor and material costs vary with location. On the first worksheet, users should input their local zip code. This program uses the RSMeans[1] location factors to adjust the cost of labor and materials for the user's location. These location factors are based on reference cities. By entering the zip code, the reference city nearest the user's location is identified and used to provide cost adjustments.

Before designing a wastewater infrastructure, two basic questions have to be answered:

1. How many people and facilities will this system service?" and,
2. How much wastewater will be generated?

This model provides a means to estimate these numbers. An inventory of potential wastewater sources is included so that the user can enter the number of homes, businesses, schools, and other facilities that will be connected to the system. Published values, that represent typical daily wastewater generation

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[1] R.S. Means Company. 2009. RSMeans Building Construction Cost Data, 67th Annual Edition. R. S. Means Company, Inc., Kingston, MA, USA.

for each item on the inventory, are then used to estimate the daily volume and the number of connections.

Lastly, the user is asked about local soil conditions. Individual onsite systems and most small community wastewater systems depend on the soil as a means of dispersing treated wastewater back into the environment. Land area requirements for soil-based dispersal depends on the hydraulic properties of the soil and on the daily volume of wastewater received. By entering soil textural classification of the site where wastewater is proposed to be dispersed, a rough estimate of the land area requirements is calculated. It is again important to note that this information is only for the purpose of planning. Soils are highly variable and the determination of an actual wastewater application rate must be assigned by a professional soils evaluator.

With the input information, the model estimates the materials needed to build various components associated with establishing a wastewater infrastructure. This model relies on various standards and guidelines for the system sizing. Aeration systems are based on the 10-State Standards[2]. Pipes diameters were determined based on allowable velocities. Storage devices are based on the recommended detention time. Professional fees, such as engineering, surveying, permits, and soil evaluating are not included in the cost analysis. These fees are too variable to attempt to quantify in this model. An estimated cost for materials, equipment, and installation is generated for each unit process. A range is shown in the output that is plus/minus 20% of the calculated value. These costs are in 2009 dollars.

Output Information
The primary intent of this program is to provide the user with comparative cost information. On three separate worksheets, options for collection, treatment and dispersal/disposal are listed with capital and long-term cost estimates. The developers of this model had to make many assumptions in order to arrive at these cost data. Thus the user must realize that there is no implied precision in these numbers. The program developers do feel that for comparative purposes, the cost relative cost of various wastewater technologies is reasonably accurate. Again, the primary objective of this model is to demonstrate various options that are available to the small community when contemplating changes to the wastewater infrastructure.

Getting Started
The filename of this spreadsheet is "wastewater planning model.xls." Find where this file is located on your computer and double-click on the file name. This action should start both Excel and the wastewater planning model.

Color Convention
Within the worksheets, various cells have been filled with different colors to assist the user in determining input and output locations. The color convention is given as follows.

Background Color	Light peach	
Input cell	Dark peach	
Cell that contains a Formula for Output	Off white	

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[2] Great Lakes—Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers. 2004. Recommended Standards for Wastewater Facilities, Policies for the Design, Review, and Approval of Plans and Specifications for Wastewater Collection and Treatment Facilities, Health Research Inc., Albany, NY.

User and Location Information Worksheet

On the bottom of the screen, click on the *User & Location Information* tab and make sure that you are at the top of the worksheet. The requested information is described in table 1 and demonstrated in figure 1.

Table 1. Description of inputs on "User & Location Information" worksheet.

Inputs	**Description**
User Name	Optional input
Community Name	Optional input
Community Zip Code	Zip code is used to find the nearest reference city. Reference cities are used to better approximate cost differences due to location.
Local Sales Tax	The sales taxes on materials are a significant expense to non-governmental entities or individuals. Enter the sales tax as a percent (ten percent is entered as 10). If sales tax exempt, then enter "0."
Electric Rate	Enter the anticipated cost of electricity (per kW-hr). This does not include any demand charges.
Customary Contractor Charges for Overhead & Profit (O&P)	There are two categories for O&P: The first for Materials and the second for Equipment and Labor. The default O&P rate is 20% for each. The user can enter local values as percentages.
Output	**Description**
Reference City	Reference location for economic information – as determined from the user's zip code.

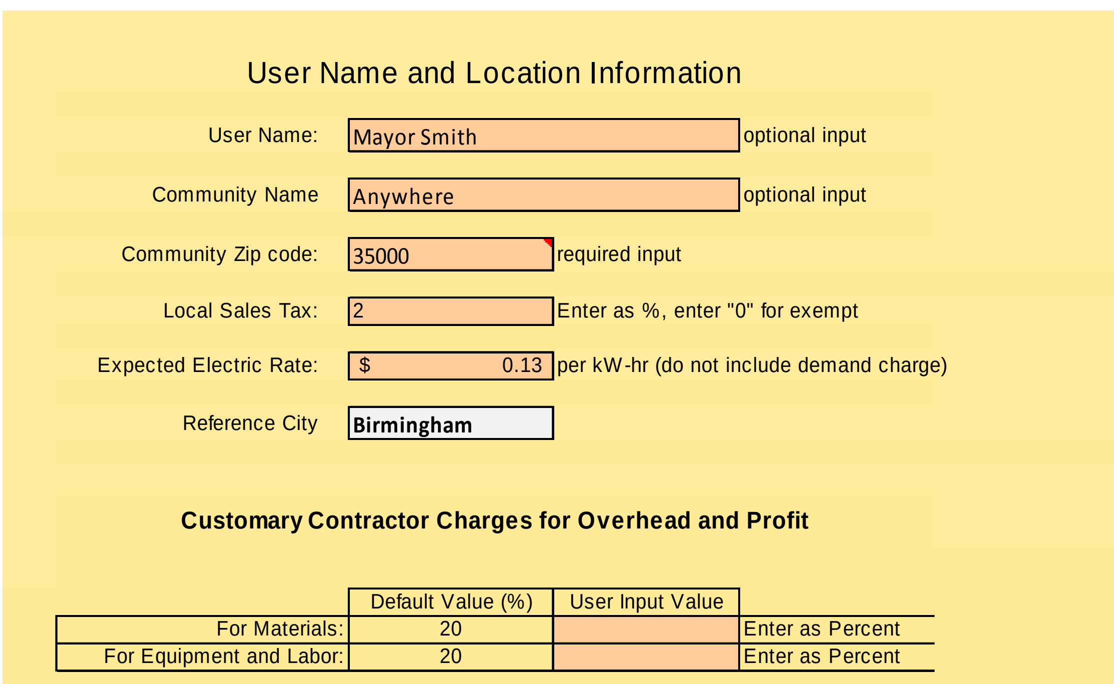

Figure 1. Input information for User and location Information Sheet.

After entering your information, click on the *Wastewater Volume Calculator* tab and make sure that you are at the top of the worksheet.

Wastewater Volume Calculator Worksheet

This worksheet contains an inventory of wastewater sources. As the name suggests, a wastewater source is any home, business, and/or facility that will be connected to the wastewater system. Information generated by this worksheet will be used to determine the number of connections and the daily wastewater volume. Column C of the worksheet is the input location for the number of homes and facilities. This column is summed at the bottom of the page to determine the number of connections. Column G receives the input for the number of units that are associated with the facility. Using "coffee shops" (row 41) as an example, the user enters the number of coffee shops in the community, the total number of customers served on a daily basis by the coffee shops, and the number of workers at the coffee shops.

This worksheet is divided into two sections: Residential Units and Facilities. Under Residential Units, enter the number of homes and apartments that will be connected (column C). Larger homes tend to use more water, so there is a separate row for residential units with more than three bedrooms.
In the Facilities section, the user can choose from a broad selection of commercial, institutional, and industrial wastewater sources. As demonstrated in the "coffee shop" example, some of the selections are divided across two rows – number of customers and number of employees. Industrial sources are very difficult to categorize. If an industry is to be connected and the generated wastewater is more than just restrooms and showers, then the user can directly input the daily water volume into cell J77. It should be noted that wastewater produced by industrial sources may be high strength and need pretreatment before entering the community collection system.

Column Q (in yellow) contains the typical daily wastewater volumes generated by the sources listed on the worksheet. These are listed as a reference to the user. The spreadsheet simply multiples the number of units by the gallons per day per unit given in Column Q to determine the daily wastewater volume generated by that source.

Once all the data has been entered, the estimated number of connections and the total daily wastewater volume are recorded at the bottom of the worksheet (row 82). Now click on the *Soil Types & Application Rates* tab and make sure that you are at the top of the worksheet.

Inventory of Wastewater Sources				
Residential Units	**Number of Residential Units**			**Estimated Daily Wastewater Volume (gpd)**
Number of 2 to 3 bedroom homes	30			7500
Number of homes > 3 bedroom				0
Number 1 bedroom apartments				0
Number of 2 to 3 bedroom apartments				0
Number of apartments > 3 bedroom	0			0
Facilities	**Number of Facilities**	**Units**	**Number of Units**	**Estimated Daily Wastewater Volume (gpd)**
Institutional Facilities				
Assembly hall	0	Seat	0	0
Hospital, medical	0	beds	0	0
		employees	0	0
Hospital, mental		Beds		0
		employees		0
Prison		Inmates		0
		employee		0
Rest home		Residents		0
		employees		0

Figure 2. A portion of the Input page for number of connections and types of facilities.

Soil Type & Application Rate Worksheet

This worksheet provides a rough estimate of land area required to disperse partially treated wastewater into the soil environment. There two parameters for this estimate – the soil texture and the loading rate. Soil texture is a weak parameter for estimating the infiltrative capacity of the soil; however, for the purpose of this model – it can provide ballpark estimate of the land requirements. This worksheet is no substitution for the expertise of a professional soil evaluator.

There is only one user input on this worksheet. A representative soil texture must be selected for the proposed soil application area. Column F contains a column of numbers that correspond to a series of soil textures. Select your soil texture by typing the number in column F into cell F20. For example, if the soils are silt loams, type “9” into cell F20. Doing this lets the program know how to estimate the size of the application area.

A rough estimation of the required application area is now calculated (in acres). Most regulatory jurisdictions have a list of application rates that are allowed in a given soil and with a particular application technology. The application rates (A.K.A., loading rates) used by this model are shown on this worksheet (figure 3).

ation of the land area required for various
cell F20, enter the number of the soil
ribes the soil in the proposed land
planning tool, applications areas must be
essional.

ed wastewater volume and the selected soil
equired. The area required for trenches
that has a maximum length of 100 feet, and
en trenches. For Low Pressure Pipe,
pray Irrigation, the area is the actual wetted

this worksheet does not take into account
quired by local regulations.

	Soil Texture	**Loading Rates by Dispersal Technology (gallon per day per ft^2)**			
		Subsurface Drip Irrigation	**Low Pressure Distribution**	**Gravity Trenches and Beds[1]**	**Spray Irrigation**
1	Sand	0.8	0.40	0.91	0.2
2	Loamy Sand	0.8	0.38	0.79	0.19
3	Fine Sand	0.8	0.38	0.79	0.19
4	Loamy Fine Sand	0.8	0.38	0.79	0.19
5	Very Fine Sand	0.8	0.38	0.79	0.19
6	Loamy Very Fine Sand	0.8	0.38	0.79	0.19
7	Sandy Loam	0.5	0.35	0.60	0.175
8	Loam	0.5	0.35	0.60	0.175
9	Silt Loam	0.5	0.30	0.50	0.15
10	Sandy Clay Loam	0.15	0.20	0.45	0.1
11	Clay Loam	0.3	0.20	0.40	0.1
12	Silty Clay Loam	0.3	0.15	0.36	0.075
13	Sandy Clay	0.1	0.05	0.35	0.025
14	Clay	0.1	0.05	0.34	0.025
15	Silty Clay	0.1	0.05	0.30	0.025

[1]Infiltrative surface loading rate

Selected Soil Texture

Enter the Number beside the Selected Soil Type:					
9	Silt Loam	0.50	0.30	0.50	0.15

Mayor Smith

Anywhere

7,500

30

Estimated Land Area Needed for Effluent Dispersal (acres)				
Wastewater Volume (gpd)	Dispersal Technology			
	Subsurface Drip Irrigation	Low Pressure Distribution	Gravity Trenches and Beds	Spray Irrigation
7,500	0.3	0.6	1.1	1.1

Figure 3. Select the soil type by typing the number of the selected soil in the input box. In this case, a silt loam soil (number 9) was selected.

Basic Results

Preliminary results are provided for the wastewater collection, treatment and dispersal systems commonly used for individual and small community systems. Each the three categories will be discussed.

Collection Technologies

Click on the *Collection Technologies* tab. The collection system is the most expensive component of the initial investment in a wastewater infrastructure. Connecting each source to a common network of pipes requires large expenditures in materials and labor, and requires the establishment of utility easements.

In order to refine a cost estimate, this worksheet has two additional inputs. The model estimates the length of the collection system by the number of connections and by the average distance between connections. In cell C7, the user needs to input a distance (in feet) that represents a typical distance between sources. The model uses the number of connection and the distance between connections to estimate the road frontage. Part of the assumption is that on a given street, there are sources on both sides of the street. The estimated road frontage is given in cell C9.

A second input is specifically related to effluent sewers. Depending on the topography, most effluent sewers are some combination of gravity flow (STEG) and pressurized flow (STEP). If the user is interested in effluent sewers, then the user can input a percentage of the sources that can be served by STEG. This action will reduce the number of STEP pumps than need to be purchased. If the STEG/STEP ratio is unknown, then put a zero in cell E11.

Cost Breakdown of Collection Technologies   The pipe that conveys sewage out of the source (building) and to the collection system is called the building sewer. In a conventional gravity sewer system, it is generally accepted that this pipe is the responsibility of the property owner. Other collection system technologies may require that tanks, pumps and/or controls be installed at each source. Because different communities have different approaches to who is responsible for these on-lot components, this model separates the cost of the on-lot components from the cost of the collection network components.

Table 2. Explanation of on-lot cost and network cost associated with collection systems.

Installation Cost of Collection Network	This column is the estimated cost range to install the collection network. The network cost does not include the collection components that are used to connect sources to the network. This price includes materials, equipment, and labor. This does not include engineering fees.
Installation Cost of On-Lot Components	This is the cost of materials, labor, and equipment needed to connect a source to the collection network.
Total Installation Cost for Collection Network and On-Lot Components	This cost included the materials, labor, and equipment for installing the collection network and for connecting each source to the network
Total Collection System Cost on a per Connection Basis	This number is the cost of installation for the network and individual connections divided by the number of connections.
Annual On-Lot Maintenance Cost	Anticipated cost for providing maintenance to the on-lot components.
Annual Maintenance Cost for both Collection Network & On-Lot Components	Anticipated cost for providing maintenance to the on-lot components and the collection network.

Estimated Road Frontage and Distribution of Pipe Diameters   In small communities, the network of pipes that comprise the collection system can be divided into four groups: Building sewer, lateral, main, and trunk. The building sewer transports wastewater from the source to the lateral. This pipe is generally on private property. Laterals are under the street or in utility easements. They are used to collect wastewater from multiple building sewers and direct the flow to the main sewer. The sewer main collects wastewater from multiple laterals and transports the sewage to a trunk line. Trunk lines collect sewage from the mains and direct it to the treatment facility. In many communities, sewer laterals comprise 70 to 80% of the total system. Standards of practice and regulatory guidelines usually specify the minimum pipe diameter allowed for various collection methods. For example, in conventional gravity sewers, it is well accepted that the minimum pipe diameter will be eight inches. Depending on the ground slope, an eight-inch diameter pipe may convey all the sewage produced by a small community. This spreadsheet provides estimates for pressure sewers (STEP and grinder), gravity sewers (STEG and conventional), and vacuum sewers. Each of these collection methods has particular requirements for pipe diameters. In order to estimate the cost of a wastewater collection system, there has to be a means to approximate the pipes lengths of various diameters that will be needed to carry the flow.

The spreadsheet uses the estimate for road frontage as a means of estimating the total pipe length in the collection system. This assumes that the treatment system is within the community. Many engineering references use four times the daily wastewater flow as a peak flow rate. For example, the accepted maximum flow through a two-inch diameter Schedule 40 PVC pipe is 50 gpm. Using four as the peak flow factor, the average daily flow through a two-inch diameter pipe would be 12.5 gpm. By converting the "time" units to days, the daily flow for a two-inch pipe becomes 18,000 gpd. If the daily wastewater volume is 18,000 gpd or less, the spreadsheet assumes that all the pipes in the pressure sewer will be two-inch diameter. For flows greater than 18,000 gpd but less than 36,000 gpd, the spreadsheet assumes that 90% of the road frontage will be two-inch diameter pipe and 10% will be three-inch diameter pipe.

Table 3. Selection of pipe diameters for a pressurized community sewer (grinder and STEP systems).

Daily Wastewater Flow (gpd)	Percentage of Total Pipe Length in a Particular Diameter			
	2" diameter	3" diameter	4" diameter	6" diameter
up to 18,000	100%	0%	0%	0%
18,000 to 36,000	90%	10%	0%	0%
36,000 to 64,800	80%	15%	5%	0%
64,800 to 144,000	75%	15%	5%	5%

As mentioned previously, the minimum pipe diameter for conventional gravity sewers is eight inches. Assuming a one-half percent slope, an eight-inch diameter pipe can carry the wastewater flow for a community that produces 56,000 gpd – including a four-times peaking factor. For the purpose of estimating the cost of a conventional gravity system, the spreadsheet assumes that eight-inch diameter pipe will be used throughout the collection system (laterals and mains) for communities that produce less than 56,000 gpd. For flows greater than 56,000 gpd, the spreadsheet adds 10-inch diameter pipe to the collection network. The total pipe length becomes the calculated road frontage plus an additional four percent of the road frontage as 10-inch diameter pipe.

The vacuum collection system is based on four-inch diameter pipe for communities that produce 64,800 gpd or less. For flows greater than 64,800 gpd, the spreadsheet assumes 80% is four-inch diameter pipe and 20% is 10-inch diameter pipe.

Pipeline Excavation and Pipe Installation Equipment and labor needed to open the trench, place the pipe, and close the trench was estimated on a per foot basis. The costs shown below have not been adjusted for location.

- Pressurized sewers do not require precision placement and can be installed at a constant depth from the soil surface. $10.50 per foot.
- Vacuum sewers require more precision in placement to ensure plug-flow conditions, but use smaller diameter pipes. $45.00 per foot.
- Conventional gravity sewer must be installed on a slope; as such, progressively deeper trenches are required on flat ground. $90 per foot.
- Manholes – 4-foot diameter, every 300 feet, materials and installation. $2,000 each.

Directional Boring This spreadsheet assumes that one-half of the connections are on the opposite side of the street from the lateral. The cost of directional boring is based on the number of connections divided by two, and by assuming that the average bore is 30 feet long. The cost assigned to directional boring is $18.00 per foot of directional bore. By including the cost of directional boring, the spreadsheet assumes that the road is already in place. If the community being modeled is still under development, then building sewers can be installed before the road is completed – saving the cost of directional boring.

Name:	Mayor Smith
Location:	Anywhere
Daily Wastewater Volume (gpd):	7,500
Number of Connections:	30
Selected Soil Texture:	Silt Loam
Typical Distance Between Sources:	200

Collection Technologies:
in cell C7, the user needs to input a distance (in feet) the represents a distance between sources. The model uses the number of connection and the distance between connections to estimate the road frontage. Part of the assumption is that on a given street, there are sources on both sides of the street. The estimated road frontage is given in cell C9.
If the user is interested in effluent sewers, then the user can input a percentage of the sources that can be served by STEG. This action will reduce the number of STEP pumps than need to be purchased. If the STEG/STEP ratio is unknown, then put a zero in cell E11.

Estimated Road Frontage (feet): 3,000 Assumes that Half of Sources are on opposite Side of Street

Enter the percentage of the effluent-sewer network that will be a gravity-based: 0 percentage (0 to 100%)

Cost Description (Not Including Engineering and other Professional Fees)	Collection Technology: Low Pressure Sewer	Effluent Sewer	Vacuum Collection	Gravity Sewer
Installation Cost of Collection Network[1]	$49,325 to $73,987	$48,713 to $73,069	Not Feasible	$315,150 to $472,725
Installation Cost of On-Lot Components (one connection)	$4,985 to $7,477	$2,806 to $4,208		$1,237 to $1,855
Total Installation Cost for Collection Network & On-Lot Components	$198,869 to $298,303	$132,881 to $199,321	$634,624 to $951,936	$472,725 to $565,485
Total Collection System Cost on a per Connection Basis	$6,629 to $9,943	$4,429 to $6,644	$21,154 to $31,731	$15,758 to $18,850
Annual On-Lot Maintenance Costs (assuming lot owner is responsible for maintenance)	$234 to $351	$56 to $70	Maintained by Utility	$16 to $24
Annual Maintenance Cost for both Collection Network & On-Lot Components (assuming the utility conducts the on-lot maintenance)	$22,872 to $34,308	$10,663 to $15,995	$13,591 to $20,387	$10,080 to $15,120

[1]These cost do not include the purchase and installation of the on-lot components
[2]These cost include one vacuum pod for every two connections

Figure 4. Example output from the collection technology worksheet.

Technology Specific Cost Factors For three of the collection methods there are unique components that have a significant effect on cost. The majority of these components are located at each connection (wastewater source). These methods and components are discussed in the following three tables.

1. STEP/STEG. At each connection, a septic (primary treatment) tank is placed. Effluent from the tank either flows by gravity or is pumped to the sewer lateral. Thus, there are significant on-lot costs that are separate from the collection system cost.

Table 4. Cost values used to estimating the cost of a STEP/STEG system[1].

On-Lot Components	Unit Cost	Unit
1,000 gallon STEP/STEG tank	$992	per connection
Risers and Lids	$157	per connection
Pump	$314	per connection
Pump Controls	$188	per connection
Pipe to Lateral	$260	per connection
Fittings	$110	per connection
Labor and Equipment for On-Lot Installation	$1,400	per connection

[1]A STEG system would not have the cost of the pump and controls. In place of the pump vault, an effluent screen would be used.

2. Pressure Sewers. Pressure sewers depend on small sewage pumps being located at each wastewater source. On a demand-basis, these pumps will activate and remove the accumulated sewage from the pump basis. This style of collection has significant on-lot cost that are separate from the collection network.

Table 5. Cost values used for estimating the cost of a pressurized sewage collection system.

On-Lot Components	Unit Cost	Unit
Progressive Cavity Sewage Pump[1]	$2,500	per connection
Pump Controls	$420	per connection
Pump Basin	$1,600	per connection
Fittings	$230	per connection
Pipe to Lateral	$260	per connection
Labor and Equipment for On-Lot Installation	$1,400	per connection

[1]Sewage pumps can be used in place of progressive cavity pumps

3. Vacuum Sewers. This spreadsheet assumes that a vacuum sewer system cannot be justified for less than 200 connections. The cost of the central vacuum facility is not scalable – it is fixed. Each vacuum pod is assumed to serve two connections.

Table 6. Cost values used for estimating the cost of vacuum sewage collection system.

On-Lot Components	Unit Cost	Unit
Vacuum Pit Package (including installation)	$4,000	per two connections
Network Components		
Vacuum Station	$470,000	per station
Division Valves	$940	per lateral

Treatment Technologies

Click on the *Treatment Technologies* tab and make sure that the top of the page is displayed (cell A1 should be in the upper left corner of screen). A list of basic treatment options and their associated costs are provided on this page. Using published design criteria, the spreadsheet uses the daily wastewater volume to construct a preliminary design so that a cost estimate can be determined.

<u>Liquid/Solid Separation</u> Small communities tend to use tankage for primary/preliminary treatment (liquid/solid separation). This model assumes two styles of non-mechanical devices – primary tanks and settling ponds. Fundamentally, there is little difference between tanks and ponds except for size and materials of construction. The most common example of primary tankage is a septic tank serving a residence or business. A common design parameter for septic tanks is the volume should be two times the daily wastewater volume. In other words, a 500 gallon per day (gpd) source should have 1,000 gallons of active volume. Under design conditions, this allows two days for materials to either settle below or rise above the outlet baffle. Settling ponds have larger storage volumes. A typical application for a settling pond would be to follow a pressure sewer collection system. The grinding action of the individual pumps tends to macerate wastewater solids, resulting in smaller particles. These smaller particles require longer settling times. For this model, the volume of a settling pond is based on 10 days of wastewater volume.

STEP/STEG is included in the print-out of treatment technologies to remind the reader that primary treatment does take place in the collection process. However, the cost of STEP/STEG is presented in the Collection System Technologies worksheet.

Table 7. Cost factors associated with septic/primary tanks.

Cost Parameter	Description	Assumed Unit Cost
Materials	Construction materials and delivery	\$1.46/ gallon
Equipment & Labor	Excavation, clearing, placement, connections	\$1.79/gallon
Annual Electrical	No electrical costs	
Annual Maintenance	Occasional labor to inspect tank and measure solids volume. Annual cost assumed to be 10% of daily flow.	10% of gpd
	Annualized septage removal every seven years	\$360 per 1,000 gal pumped

Notes: These costs assume cast-in-place concrete tanks. Pre-cast tanks, fiberglass reinforced plastic and high density polyethylene tanks will have different unit cost.

Table 8. Cost factors associated with settling ponds.

Cost Parameter	Description	Assumed Unit Cost
Site Work	Equipment and labor to prepare site. Distributed area assumed to be twice the pond surface area – assuming a pond depth of 10 feet.	\$1.80/ft^2
Excavation	Equipment and labor to create storage volume. Storage volume is 10 days of wastewater volume.	\$8.93/ft^3
Liner	Purchase of either 12 inches of clay (before compaction) or plastic liner	\$0.89/ft^3 clay \$0.89/ft^2 liner
Liner Installation	Equipment and labor to place liner	\$1.50/ft^3 clay \$1.50/ft^2 liner
Headworks	Material to build distribution piping to create plug-flow conditions in pond	\$5.00/gpd
Headworks Installation	Equipment and labor to install headworks	\$5.00/gpd
Annual Electrical	No electrical costs	
Annual Maintenance	Occasional labor to inspect pond and measure solids volume. Annual cost assumed to be 10% of daily flow.	10% of gpd
	Annualized septage removal every seven years	\$360 per 1,000 gal pumped

<u>Oxygen Demand Removal</u> Oxygen demand removal devices include site-built recirculating media filters, pre-packaged suspended growth units, and lagoons. Proprietary media filters and proprietary tricking filters are included in the print-out, but no costs are estimated. Similar to pre-packaged suspended growth units, these devices are commercially produced wastewater treatment devices that are pre-manufactured and delivered to the site ready to be connected. There is not much competition in this market and the prices are extremely variable. In contrast, the manufacture of pre-packaged suspended growth units is well established, and competition keeps their prices reasonably predictable.

1. Extended Aeration. Using fundamental design parameter, volumes, surface area, aeration rates, and other engineered processes can be determined. However, treatment systems contain many individual parts and cost estimates can be highly variable. In order to simplify estimating treatment system costs, a survey of several suspended-growth treatment device manufacturers was taken to determine if a relationship existed between cost and gallon per day of treatment capacity. For basic suspended growth oxygen demand removal, the following relationship was found for materials and delivery.

Table 9. Suspended growth–extended aeration plant cost per gpd.

Daily Wastewater Volume (gpd)	Approximate cost for materials and delivery per gpd of treatment capacity
Up to 2,000 gpd	$15
2001-5,000 gpd	$12
5,001-10,000 gpd	$10
10,001-25,000 gpd	$7
25,001-50,000 gpd	$5

Electrical costs for extended aeration are based on the guidelines published in the "10-State Standards." The assumptions include an influent BOD_5 of 150 mg/L and TKN of 30 mg/L. The spreadsheet uses these values and the daily wastewater volume determines the mass of oxygen required. Using the basic assumptions for oxygen transfer efficiency, blower efficiency, and standard atmospheric conditions, an estimate of blower power is calculated.

Maintenance cost is based the anticipated life of the blowers and of the plant as a whole. The maintenance cost represents the annualized cost to replace the blowers every five years, and to replace the whole system in 30 years. Further, the annual salary for a service provider (operator) was estimated at w$0.50 per gpd per year.

2. Recirculating Media Filter. Based on input parameters, the spreadsheet builds a Hines-Pickney recirculating media filter. This model assumes an application rate of 5 gpd/ft^2, 24 inches of 3 to 5 mm fine gravel media, and a 15-inch by 15-inch distribution system. Using the daily wastewater volume and assuming a primary-treated effluent, the media filter is sized, the volume of gravel materials are estimated, and the lengths of pipe and pipe fittings are approximated. Included in the cost estimate are the recirculation tank, pumps, and controls.

- Labor and equipment for construction was estimated at $29 per hour per square-foot of media filter.
- Annual electrical costs were estimated by an assumed pump head of 50 feet of water head and 65 gallons per minute (gpm). The pump(s) run time was calculated based on the time required to pass five daily volumes of effluent through the filter each day.
- Maintenance costs were estimated by assuming a seven year pump life and that the entire recirculating media filter would be rebuilt in 30 years. Further it was assumed that a service provider would cost $0.50 per gallon per day per year.

3. Proprietary Media/Trickling Filters. At this time, no cost estimates are provided in this category of treatment devices. This group represents treatment technologies that are factory produced, and are ready to connect to the system upon delivery. This category is different from extended aeration plants. The extended aeration industry is well established and has to survive in a competitive environment. It is more difficult to provide cost estimations for proprietary wastewater treatment systems because dealer networks are still being established and the cost (and performance) of these devices is difficult to verify. The primary purpose of including a slot for proprietary treatment products in the print out is to remind the user that these products are available and should be evaluated when a dealer is available.

4. Lagoons. Lagoons can be a good option for small communities with sufficient available land resources. This slow-rate treatment provides dependable oxygen demand removal and can produce

high quality effluent. The trade off is the land area required and the potential for odors during changes in weather. The cost of building a lagoon was based on 75 days of detention and a five-foot depth.

Table 10. Cost factors for lagoons.

Cost Parameter	Description	Assumed Unit Cost
Site Work	Equipment and labor to prepare site. Distributed area assumed to be twice the pond surface area – assuming a pond depth of 10 feet.	$1.80/ft^2$
Excavation	Equipment and labor to create storage volume. Storage volume is 75 days of wastewater volume.	$8.93/ft^3$
Liner	Purchase of either 12 inches of clay (before compaction) or plastic liner	$0.89/ft^3$ clay $0.89/ft^2$ liner
Liner Installation	Equipment and labor to place liner	$1.50/ft^3$ clay $1.50/ft^2$ liner
Headworks	Material to build distribution piping to create plug-flow conditions in pond	$5.00/gpd
Headworks Installation	Equipment and labor to install headworks	$5.00/gpd
Annual Electrical	No electrical costs	
Annual Maintenance	Occasional labor to inspect tank and measure solids volume. Annual cost assumed to be 10% of daily flow.	10% of gpd
	Annualized septage removal every seven years	$360 per 1,000 gal pumped

The long detention times provided by lagoons allows for more digestion of biological solids. Crites and Tchobanoglus (1998)[3] provide an estimate of facultative lagoon sludge production of 0.12 ton of dry sludge per million gallons of treated wastewater. Assuming a solids content of 5%, and a specific gravity of 1.01, the volume of generated sludge equates to 0.0006 gallon of sludge per gallon of wastewater. This ratio is the basis for estimating the sludge removal maintenance cost. Further, the salary of a part time service provider is estimated to be $0.50 per gallon of daily flow per year.

<u>Pathogen Removal</u> Disinfection is the removal of pathogens from wastewater. Chlorine, ultraviolet radiation (UV) ozone, bromide, and iodine are means that can be employed for disinfection. For the purpose of this model, cost estimated will be limited to chlorine and UV. Disinfection must be one of the last treatments to ensure the efficient use of disinfectants. Any remaining dissolved organic matter will be oxidized by the chlorine and any suspended solids can block (shade) the UV radiation from microbes. This spreadsheet assumes a pressurized dispersal system. In other words, the methods of disinfection described in this model will use pressure to move the water through the disinfection components.

1. Chlorination/Dechlorination. This spreadsheet assumes that sodium hypochlorite will be injected into a pump tank. This tank accumulates effluent from the previous treatment device and will pump the effluent to a dispersal component on a timed basis. An injector system injects a preset dosage of hypchlorite into the pump tank. The pump tank allows for the contact time needed for the chlorine to work. As the dose pump transfers the effluent downstream, a second injection system injects calcium

[3] Crites, R. and G. Tchobanoglous. 1998. Small and Decentralized Wastewater Management Systems. McGraw-Hill, Boston, MA.

thiosulfate into the line to remove the chlorine residual. The cost assumptions include a 20 mg/L sodium hypochlorite dosage with a 2 mg/L chlorine residual. A dual injector pump system can be purchased for $2,000. Salary for a service provider is estimated to be $0.10 per gallon per day per year.

2. UV Radiation. It was assumed that the UV unit will be mounted in the pipeline that moves effluent to final dispersal and that the UV unit will illuminate whenever the dose pump is activated. The cost of UV units is dependent upon the flow rate. As is discussed in the “dispersal section,” this spreadsheet makes a series of assumptions as to the flow rate going to the dispersal component. Using these assumptions, a UV system is selected to that can treat the assumed flow rate. The prices of UV devices and replacement quartz sleeves and UV lamps are easily available online. Using the following data, a curve-fit equation was developed to determine the cost of various UV units.

Table 11. Cost of UV units by flow rate.

Flow Rate (gpm)	Cost	Wattage
2	$770.00	14
3	$800.00	18
6	$860.00	24
12	$1,000.00	44
20	$1,200.00	54
40	$2,400.00	140
83	$4,900.00	280

Electrical consumption was based on the given wattage and the time required to pump the effluent to the dispersal component. Annual maintenance is based on the cost of a service provider (estimated to be $0.05 per gallon per day per year), replacing the lamp once per year, and the annualized cost of replacing the entire unit every 10 years.

<u>Nutrient Reduction</u> Specific cost estimates are not given for nitrogen and phosphorus reduction. In most situations, nitrogen reduction is provided by including a recirculation component to either a suspended growth extended aeration unit or to a media filter. As described in this model, the recirculating media filter provides denitrification without any additional cost. However, there are situations where the addition of an easily bioavailable organic carbon (for example, methanol) is added to ensure that the denitrifying microorganisms have plenty of carbon to break down to reduce the nitrate. Providing methanol would include a chemical replacement cost, and a manpower cost to oversee the system.

Likewise, phosphorus reduction is often accomplished by chemical precipitation. An iron or aluminum compound is added to the effluent that will bind with the phosphate and form an insoluble precipitant. The costs associated with this procedure include replacement chemicals, removal and disposal of phosphorus-rich sludge, and the manpower to oversee the operation. It should be noted that many soils have the ability to hold substantial amounts of phosphorus. The same iron and aluminum compounds are available in many soils and will bind the phosphate ions.

Dispersal Technologies

Click on the *Dispersal/Disposal Technologies* tab and make sure that the top of the page is displayed (cell A1 should be in the upper left corner of screen). A list of dispersal technologies is shown on this worksheet. Using the daily wastewater volume and the soil-based application rate, the cost of several common dispersal/disposal technologies is estimated. There are several significant assumptions that went into the development of this model. Of greatest potential significance is that the cost of the land is not accounted for by this model. Further, the spreadsheet assumes that there are no limitations that would impede the installation of one of these dispersal systems. For example, it is assumed that the location has level ground, electricity is already available, and no blasting is required to place components in the ground.

It is a good engineering practice to divide large soil-based application areas into zones – especially pressurized distribution systems. Instead of having to use a large capacity pump to pressurize the entire area, zones allow a smaller capacity pump to dose a small area and then switch to an adjacent area. This spreadsheet assumes that zones will be used and creates zones based on common pump sizes. Based on the daily wastewater volume to be dispersed, the zone flow was assigned using equation 1.

$$Flow\ per\ Zone\ (gpm) = 0.1442 * (Daily\ Wastewater\ Volume)^{0.5919} \qquad \text{Eq. 1}$$

The hydraulic components were designed around this flow per zone. For example, a daily wastewater volume of 50,000 gpd is assigned a flow per zone of 85 gpm. Using a drip dispersal system as example, the spreadsheet assumes that the drip laterals will be 250 long, the emitters are spaced on two-foot centers, and the flow per emitter is 0.61 gallon per hour (gph). At 85 gpm, 8,360 emitters could be pressurized, which would require nearly 16,720 feet of tubing, and there would be 67 laterals per zone. If the application rate is 0.10 gpd/ft^2, then 500,000 ft^2 is needed for land application. With a lateral spacing of two feet, 250,000 feet of tubing is required. If one zone is 16,720 feet of tubing, then 14.95 zones are needed. The number of zones must be a whole number and should be an even number. Thus the spreadsheet rounds up this number to 16 zones. This is a “first-cut” design, the professional designer may take a different approach; however, this method allows the spreadsheet to account for hydraulic components required to distribute effluent to the various zones. This same procedure is followed for low pressure distribution, gravity trenches, and spray irrigation. For gravity trenches, the spreadsheet assumes that for a community-scale gravity trench system, effluent will be pumped to the head of each trench to ensure equal distribution.

Cost Breakdown of Dispersal/Disposal Technologies

Table 11. Description of cost components associated with dispersal/disposal.

Installation Cost of Dispersal/Disposal System	Cost of materials, equipment and labor to install system. Cost does not include engineering fees or land cost.
Installation Cost of Dispersal/Disposal System on a per Connection Basis	Cost for dispersal/disposal system divided by the number of connections
Annual Energy Cost	An estimated annual cost to operate pumps and controls
Annual Maintenance Cost	An estimated annual cost for replacement, maintenance, and personnel.
Approximate Area Needed	The square-footage needed to place the dispersal system based on the application rate and daily wastewater volume.
Potential Treatment needed before Dispersal/Disposal	This is a list of treatments that are typically required before effluent can be discharged using one of these dispersal/disposal methods.

Name:	John
Location:	Anywhere
Daily Wastewater Volume (gpd):	50,000
Number of Connections:	200
Selected Soil Texture:	Clay

Dispersal/Disposal Technologies:
The sizing of soil-based wastewater application systems is dependent on knowing how the soil will treat and move the water. A professional soil evaluator is needed to determine a reasonable loading rate. For the purpose of this planning tool, a loading rate has been estimated based on the soil texture that was selected on the *Soil Type & Application Rates* Worksheet. These numbers are not absolutes - These numbers could be plus/minus 100%. If the original loading rate estimation was 0.2 5 gallon per day per square foot and an evaluator determined the loading rate to by 0.15 gallon per day per square foot, then the application area will double in size.

Cost Description	Gravity Trenches/Beds	Low Pressure Distribution	Subsurface Drip Irrigation	Spray Irrigation	Surface Water Discharge
Installation Cost of Dispersal/Disposal System	\$568,772 to \$853,159	\$3,740,390 to \$5,610,585	\$602,350 to \$903,524	\$1,408,412 to \$2,112,617	Cost of Developing a Point Source Discharge is too Dependent on Local Conditions
Installation Cost of Dispersal/Disposal System on a per Connection Basis	\$2,844 to \$4,266	\$18,702 to \$28,053	\$3,012 to \$4,518	\$7,042 to \$10,563	
System Energy Cost per Year	\$653 to \$979	\$1,199 to \$1,798	\$2,066 to \$3,099	\$1,987 to \$2,981	
Maintenance Cost per Year	\$23,043 to \$34,564	\$144,763 to \$217,145	\$40,150 to \$60,225	\$22,855 to \$34,282	
Approximate Area Needed	467,690 ft^2	1,000,000 ft^2	500,000 ft^2	2,000,000 ft^2	
Potential Treatment needed before Dispersal	1	1	1, 2	1, 2, 3	1, 2, 3, 4

[1]The area requirements for the various application methods do not include reserve area, which may be required by local regulations

Treatment - Wastewater Constituents that may be Limited by Permit or by Technology
1 Solids separation - primary treatment
2 Oxygen Demand - reduction of dissolved biodegradable organic compounds
3 Disinfection - reduction of indicator organisms
4 Ammonia Limit - Surface water discharges are usually ammonia limited
5 Nitrate Limit - nitrate can be toxic in drinking water and cause eutrophication in surface waters
6 Phosphate Limit - phosphate can cause eutrophication in surface waters

Figure 5. Example output for the Dispersal/Disposal worksheet.

<u>Specific Assumptions for Costing Dispersal/Disposal Technologies</u> Each of the technologies have unique aspects that affect their cost. Likewise, within each dispersal technology there are many different potential variations on the same theme. This section will outline the specific assumptions that this spreadsheet used to estimate the initial and long-term cost of each of the technologies.

Gravity Trenches. The spreadsheet assumes that the infiltrative surface area of a trench is the trench bottom, and that there is six feet of undisturbed soil between the trenches. The trenches are three feet wide, two feet deep and that 12 inches of porous media will occupy the trench bottom. The remaining trench volume will be backfilled with the native soil. For a community-scale trench dispersal system, it is assumed that effluent will be distributed via a pump-to-trench configuration. If a pump system is required, then the pump tank is sized to hold one day of generated wastewater.

Table 12. Values used for estimating the cost of a gravity trench effluent dispersal system.

Description	Unit Cost	Unit
Washed rock trench media	$10.50	per ton
Pump (if needed)	$700	per pump
Pump Tank (pre-cast or cast-in-place)	$1.80	per active tank gallon
Pump controls	$1,800	per pump
Trench excavation and media placement	$2.00	per foot of trench
Distribution pipe	$5.00	per foot

2. Drip Distribution. The spreadsheet assumes that drip tubing is approximately one-half inch in diameter, the maximum length is 250 feet, the tubing will be placed on two-foot center (laterals), the emitters will be 24 inches apart, the emitter flow rate is 0.61 gph, and the emitters are pressure compensated. Pump tanks are sized to hold one day of generated wastewater.

Table 13. Values used for estimating the cost of a drip dispersal system.

Description	Unit Cost	Unit
Drip tubing	0.54	per foot
Pump	$700	per pump
Pump controls	$1,400	per pump
Filtration system	$2,000	each
Pump tank	$1.80	per gallon
Drip tubing installation	$1.00	per foot
Distribution system installation	$5.00	per foot

3. Spray Irrigation. The spreadsheet assumes a solid-set overhead spray dispersal system. As a starting point this model uses a sprayer capable of 5 gpm and has a wetted radius of 50 feet. It is assumed that spray dispersal will not be allowed during rain events, so 30 days of storage is provided in an earthen basin. Pump tanks are sized to hold one day of generated wastewater.

Table 14. Values used for estimating the cost of a spray dispersal system.

Description	Unit Cost	Unit
Spray heads	$50	each
Pump	$700	per pump
Pump controls	$1,400	per pump
Pump tank	$1.80	per gallon
Distribution system installation	$5.00	per foot
Rainy-Day storage earthen basin	$10.75	per cubic foot
Fence	$12	per foot

4. Low Pressure Distribution. A low pressure distribution system is modification of the gravity trench method. Narrow trenches, backfilled with porous media, are used to store and infiltrate effluent into the soil. The fundamental difference is the use of a pressurized system of pipes in the trench to ensure uniform effluent distribution in each trench and along each trench. Each lateral contains a PVC pipe that has 5/32 inch diameter holes drilled ever 60 inches. These orifices allow effluent to be evenly distributed along the trench length. Flow from each orifice is regulated by the effluent pressure within the pipe. This model assumes a pressure of three feet of water head within the laterals. The trenches

are assumed to be 12 inches wide and 18 inches deep, and are backfilled with 12 inches of porous media. The maximum length of a trench is assumed to be 120 feet.

Table 15. Values used for estimating the cost of a low pressure dispersal system.

Description	Unit Cost	Unit
2" diameter Sch 40 PVC laterals	3.33	per foot
Pump	$700	per pump
Pump controls	$1,400	per pump
Pump tank	$1.80	per gallon
Distribution system installation	$5.00	per foot
Washed rock trench media	$10.50	per ton

5. Surface Water Discharge. There are no cost estimates for effluent disposal to a surface water source. Point source discharges are regulated by the National Pollutant Discharge Elimination Program (NPDES). Obtaining a discharge permit may require significant environmental investigation to determine the ability of the watershed to assimilate any remaining waste constituents in the effluent. Surface discharge will also require greater monitoring and sampling, so there is an increased long-term cost.

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