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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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

[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	

[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.

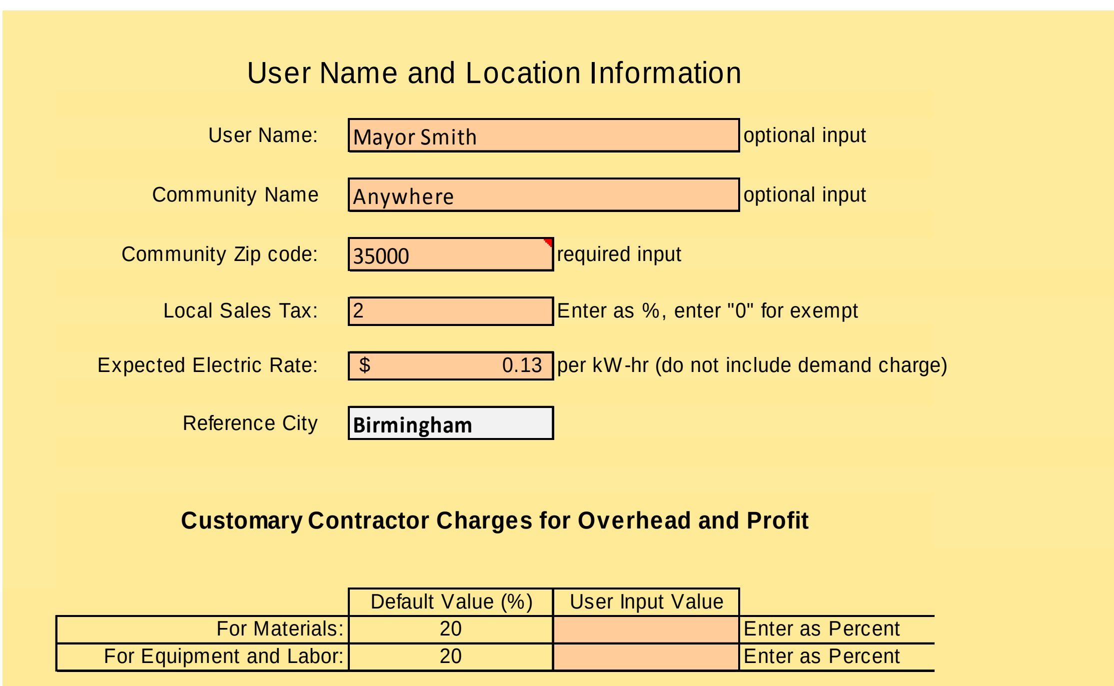
User and Location Information Worksheet

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.



User Name and Location Information

User Name:	Mayor Smith	optional input
Community Name	Anywhere	optional input
Community Zip code:	35000	required input
Local Sales Tax:	2	Enter as %, enter "0" for exempt
Expected Electric Rate:	$ 0.13	per kW-hr (do not include demand charge)
Reference City	Birmingham	

Customary Contractor Charges for Overhead and Profit

	Default Value (%)	User Input Value	
For Materials:	20		Enter as Percent
For Equipment and Labor:	20		Enter as Percent

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,
ray 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 ft²)			
		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

Enter the Number beside the Selected Soil Type:	Selected Soil Texture				
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.

<u>Cost Breakdown of Collection Technologies</u> 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.

<u>Estimated Road Frontage and Distribution of Pipe Diameters</u> 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.

<u>Pipeline Excavation and Pipe Installation</u> 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.

<u>Directional Boring</u> 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.

$$Flow\ per\ Zone\ (gpm) = 0.1442 * (Daily\ Wastewater\ Volume)^{0.5919} \quad \text{Eq. 1}$$

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.