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<tr><td rowspan="2">Permit to Install Guidance
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Final</td><td colspan="2">Small Subsurface Flow Constructed Wetlands with Soil Dispersal System</td></tr>
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<tr><td colspan="3">This guidance document does not affect the requirements found in the referenced rules.</td></tr>
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Purpose

The purpose of this guidance document is to provide recommendations for minimum design standards and maintenance issues to be addressed for subsurface flow constructed wetland systems.

Background

This guidance document should be referenced for designs of subsurface flow systems that will treat up to 10,000 gallons per day of domestic wastewater and whose overflow structures discharge to the soils only. Larger systems or those that discharge to waters of the state will need to be designed to meet other criteria, such as lower effluent limits, so this guidance document may not be applicable.

Procedure

Contact the office listed below for more information.

Related Policy or guidance

USEPA, 1993, Subsurface Flow Constructed Wetlands for Wastewater Treatment

For more information contact:

Ohio EPA, Division of Surface Water
PTI, Compliance Assistance, & CAFO Unit
(614) 644-2001

State of Ohio
Environmental Protection Agency

Division of Surface Water

Guidance Document for Small Subsurface Flow Constructed Wetlands with Soil Dispersal System

Apple Pie Inn, Morrow County

November 2007

Ted Strickland, Governor
Chris Korleski, Director

Acknowledge

The following Ohio EPA staff deserves recognition for their important contributions to this project:

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State of Ohio Environmental Protection Agency
Division of Surface Water Guidance Document

Abstract

This Subsurface Flow Constructed Wetland System with soil dispersal guidance document was developed to provide recommendations for minimum design standards and maintenance issues to be addressed for subsurface flow constructed wetland systems. This guidance document will include specifications on media types, overflow structures, and hydraulic residence times. Design issues should be discussed with the Ohio EPA prior to a submittal of a permit to install application.

This guidance document should be referenced for designs of subsurface flow systems that will treat up to 10,000 gallons per day of domestic wastewater and whose overflow structures discharge to the **soils** **only**. Specifications and various other related technical information were compiled from various reference articles, design manuals, and current state regulations, including Ohio EPA's design flow rule OAC 3745-42-05. A full list of all documents referenced is located in the Reference section.

Wastewater Parameters

To fully understand the treatment aspect of a subsurface flow constructed wetland system, one must know both the parameters the wetland will be able to treat and the possible negative impacts to the environment if the system does not function properly.

Biochemical oxygen demand, 5-day (BOD_5) is a measure of the amount of dissolved oxygen used in the breakdown and/or oxidation of organic wastes in a water sample by micro-organisms over a period of five days. Thus the BOD_5 test is an indicator of the concentration of organics in the water sample. High concentrations can cause the dissolved oxygen levels to decrease which can result in taste and odor problems in drinking water. High concentrations can clog soil absorption areas and cause short circuiting of the wastewater and potential failure of the system.

Total suspended solids (TSS) are solids in water that can be removed from the water sample by filtration and they usually contribute directly to turbidity (cloudiness) and/or sludge deposits. High concentrations of total suspended solids entering the soil adsorption areas over time can cause it to clog which could lead to short circuiting, and failure of the system.

Total Kjeldahl Nitrogen (TKN) is a test that measures the total organic nitrogen and ammonia nitrogen in a water sample.

Ammonia Nitrogen (NH_3) is a decomposition product from urea and protein. NH_3 is the principal form of toxic ammonia. Toxic levels are both pH and temperature dependent – toxicity increases as pH increases and as temperature increases.

Nitrate (NO_{3-}) is a breakdown product of ammonia that can have potentially serious health effects in humans and animals. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication (abundant accumulation of nutrients that support a dense growth of algae and other organisms). The maximum contaminant level (MCL) for nitrate in drinking water is 10 milligrams per liter (mg/L). This is the maximum allowable level of nitrate that may be present in drinking water without a high risk of causing health problems. Pregnant women and infants are most susceptible to excess nitrate in drinking water.

Total phosphorus (P) is a measure of the total concentration of phosphorus occurring in various forms in a water sample. Excess concentrations of phosphorus, along with forms of available nitrogen (nutrients), can lead to excessive algal blooms and potentially a decrease in the dissolved oxygen in the water – harming the aquatic wildlife if the system failed and discharges to waters of the state.

Coliform bacteria are a collection of relatively harmless micro-organisms that live in large numbers in the intestines of humans and warm- and cold-blooded animals. They aid in the digestion of food. A specific subgroup of this collection is the fecal coliform bacteria, the most common member being *Escherichia coli*. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals. The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of man or other warm-blooded animals. This could indicate contamination by pathogens or disease producing bacteria or viruses which can also exist in fecal material. Such waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. Ohio EPA’s criteria for bathing waters is fewer than 200 colonies/100 mL; for primary contact (fishing and boating), fewer than 1000 colonies/100 mL; and for secondary contact, fewer than 5000 colonies/100 mL.

History of Constructed Wetlands

Wetlands act like nature's kidneys, filtering out sediments and pollutants from rivers, lakes, streams, or any other bodies of water. Wetlands are defined by the US Army Corp of Engineers as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Marshes, bogs, and swamps are all examples of naturally occurring wetlands. A "constructed wetland" is defined as a wetland specifically constructed for the purpose of pollution control and waste management, at a location other than existing natural wetlands. Nature has been using wetlands as a natural way of filtering out water for millions of years. It wasn't until the early 20th Century that wetlands were designed to treat domestic wastewater.

Ground breaking research in the 1950's by Dr. Kathy Seidel of the Max Planck Institute in Germany brought recognition to constructed wetlands as a viable treatment technology. While European municipalities throughout numerous countries continued to use constructed wetlands as a means to treat wastewater, the treatment technology did not start to catch on in the United States until the 1970's Environmental Movement. The creation of the Environmental Protection Agency helped spur creative thinking on different ways to treat wastewater. This movement helped encourage the use of constructed wetlands as a viable wastewater treatment option. The technology was given a further boost in the 1980's when the Tennessee Valley Authority conducted research and published guidance documents on using these constructed wetlands to treat wastewater.

As time and technology advanced, more constructed wetlands were being designed and used as a wastewater treatment technology and even expanded into systems that would treat storm water run-off, industrial, mining, and agricultural wastes. Today constructed wetland systems often are a viable secondary treatment technology for treating wastewater in the State of Ohio. As this guidance document will show, there are many positive benefits to using constructed wetland systems as preliminary wastewater treatment systems.

Subsurface Flow Constructed Wetlands

There are two types of constructed wetland systems:

- Free Water Surface (FWS)
- Subsurface Flow Constructed Wetlands (SSFCW)

For the purpose of this guidance document, SSFCW with soil dispersal will be discussed. The Ohio EPA recommends SSFCW over FWS systems because:

- Mosquito's are less problematic, usually negligible, with SSFCW compared to FWS.
- SSFCW pose smaller threats for human contact with partially treated wastewater compared to FWS.
- SSFCW tend to have less odor issues compared to FWS.
- The media provides a greater surface area which supports the development and retention of attached growth micro-organisms.
- SSFCW provides the wastewater better thermal protection in cold climates.

A properly designed SSCFW system should generally follow the same principles that affect performance of naturally occurring wetlands. Constructed wetland systems with soil dispersal can effectively treat and disperse wastewater safely back into the environment. Constructed wetland systems can be installed just about anywhere, making this a very versatile system. Some of the advantages and disadvantages of these systems are:

Advantages:

- Generally inexpensive and simple to build and maintain.
- Require little or no energy to operate.
- Provide effective secondary effluent treatment and partial tertiary treatment.
- Aesthetically pleasing additions to businesses and neighborhoods.
- Viewed as an environmentally friendly technology.

- Passive systems that do not require much routine maintenance.
- Flexible design allows installation on most sites with a smaller footprint than a tile based system
- Generally do not have any odors.

Disadvantages:

- Not appropriate for treating high concentrations of certain pollutants.
- The performance of wetlands may vary based on usage and climatic conditions.
- Potential slow initial start-up period before vegetation is adequately established.

Currently, there are 20 operating SSFCW with soil dispersal systems in the State of Ohio approved by the Ohio EPA. Anywhere from churches, metro parks, to Boy Scout camps have utilized SSFCW as their onsite sewage treatment system. The distribution of SSFCW:

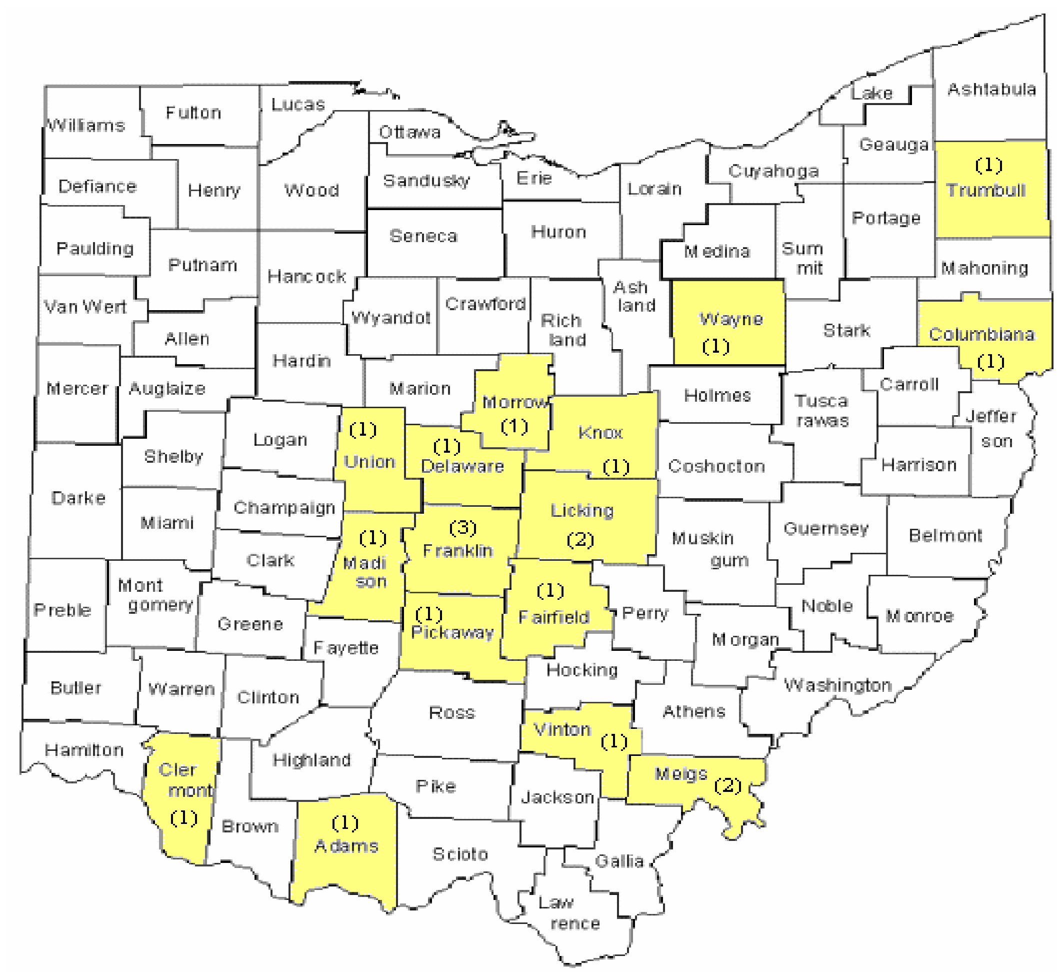


Figure 1: Map of approved Ohio EPA subsurface flow constructed wetlands

How does a SSFCW work?

To properly design a SSFCW with soil dispersal, one must understand the mechanics of wastewater treatment so that the design will allow the wastewater to be safely discharged without negatively impacting the environment. As discussed above, typical domestic wastewater contains the following contaminants:

- BOD
- TSS
- TKN (which include ammonia, nitrates, nitrites)
- Total Phosphorus
- Pathogens (which include bacteria & viruses)

The following figure is a visual representation of how wastewater is treated:

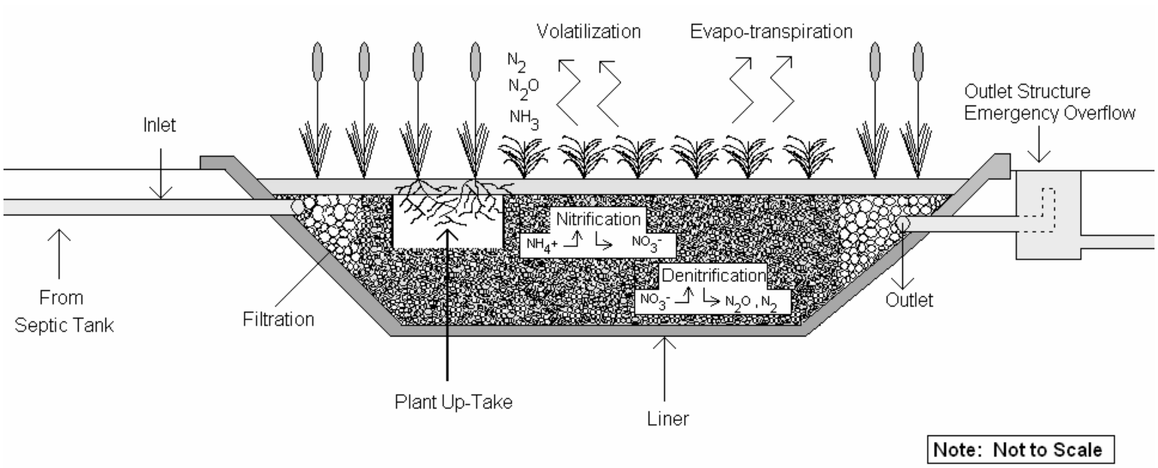


Figure 2: How SSFCW treats the wastewater

First, the constructed wetland system with soil dispersal system must have a septic tank for primary settling of the wastewater. The septic tank should be a dual compartment septic tank and should have an effluent filter. If the wastewater is considered high strength, per Ohio Administrative Code 3745-42-05, additional pretreatment may be incorporated to reduce the wastewater to normal domestic wastewater concentrations prior to entering the constructed wetland cells. To determine whether or not the proposed design flow is considered high strength, please refer to the organic loading rates in Ohio Administrative Code 3745-42-05.

The inlet structures of the constructed wetland cells should be designed so that they equally distribute the wastewater. A perforated pipe manifold will allow the wastewater to be equally applied across the inlet of the constructed wetland cells. Larger treatment media should be placed around the inlet to help prevent clogging. As the wastewater trickles through the inlet media, TSS is being filtered out through the process of sedimentation. Micro-organisms attached to the media aid in the breakdown of organic matter. Oxygen diffusion from the atmosphere and the inflow of oxygen produced by the hydrodynamic motion of air within the constructed wetland cells aides in the ammonia conversion of the nitrates (nitrification). The oxygen supply from plant roots is minimal, if not negligible in the design and does not play a significant role in the aerobic process. The primary purpose of the plant roots serves as surface area for attachment of the micro-organisms that actually degrade the wastewater stream.

As the wastewater flows through the constructed wetland cell, plants up-take the wastewater in a process called transpiration. This process will somewhat reduce the overall volume of wastewater but will increase the concentrations of the nutrients. Lower portions of the constructed wetland cells do not receive enough oxygen to maintain aerobic conditions and become anaerobic. This zone will transform the nitrates (produced by the nitrification process), into compounds that are easily removed. This process, denitrification, breaks those components down into nitrogen and nitrous oxide gas. These gases are then released into the atmosphere through a process called volatilization.

Depending on the level of phosphorus removal desired, the constructed wetland may be designed to optimize its removal. Removal can occur by the adsorption of phosphorus to the gravel media, precipitation of insoluble phosphates with ferric iron, calcium, and aluminum found in media, or small amounts will be absorbed by the constructed wetland vegetation.

Fecal coliform reductions in the constructed wetland cell systems depend on the hydraulic residence time. If a greater reduction of fecal coliform is desired, then the design should reflect this need. Fecal coliform reduction in wastewater is attributed to natural die-off of the pathogens while passing through the media.

The same media that is placed around the inlet pipe should also be used around the outlet pipe to help reduce any potential clogging. Effluent from the first constructed wetland cell will proceed to an overflow structure (see Figure 5) and flow into the second cell. Effluent from the second constructed wetland cell will flow into an overflow structure and discharge into a properly designed soil dispersal system (refer to Table 1).

Site & Soil Evaluation

Site Evaluation

One of the first steps that must take place when designing a SSFCW is to conduct a site and soil evaluation of the proposed site. The appropriate Ohio EPA district office should be contacted for a preliminary discussion of the proposed system. This meeting should include a professional soil scientist, the applicant and the design engineer. This preliminary site evaluation will help determine the best suitable location and layout for the SSFCW. The SSFCW should lie along the contour which will help promote even distribution. The site evaluation will also show what site specific conditions are present that may impact the placement of the system. The site evaluation should determine the following, but is not limited to:

- Property set-backs
- Any existing tankage or soil absorption systems on site.
- Low lying areas
- Trees, rocks, etc. that would block the placement of the system in the area
- Any disturbed area
- Contour and elevation of site
- Any existing or proposed buildings, side walls, driveways, paved areas or other hardscapes.
- Locations of streams, wells, or other features that need to be avoided

Note: The site evaluation data should be filled out using the appropriate Ohio EPA form for site/soil evaluations. The applicant should also refer to OAC 3745-42-03 for a complete list of information that will need to be included in a permit to install application.

Soil Evaluation

A soils professional should conduct an in depth soil analysis to determine the site specific characteristics of the soils and determine the proper location for the wetland and soil dispersal system. The soils professional must identify the following soil characteristics, including but not limited to:

- Depth to limiting condition
- Nature of limiting condition
- Soil classification per USDA nomenclature
- Estimated permeability of soil horizons that will be used for soil absorption
- Determine the soil's linear loading rate

Note: A limiting condition is defined as any condition present in the subsurface soil that limits the treatment and/or dispersal of wastewater. Limiting conditions include:

- Seasonal high ground water
- Ground water
- Sand/gravel lenses
- Bedrock
- Fractured bedrock
- Compacted soils (impervious layer)

Note: The separation between the bottom of the infiltrative surface and the top of the most limiting condition is also referred to as the vertical separation distance.

Placement of System

A suitable area should be chosen and marked with visible markers so that the soil absorption area is not compromised during construction. If the soil absorption area is disturbed or compacted, then that area will be deemed unsuitable for soil absorption and a new area must be selected. The design should make sure that the soil dispersal system lies on contour.

Design of SSFCW

The design of a SSFCW must follow rules set forth in Chapters of OAC 3745-42. These rules provide general guidelines, applicability criteria, and minimum requirements that the design of the system must follow. For additional design and related constructed wetland cell information, please refer to the Reference section of this document for a listing of other resource materials. For proper design when sizing the subsurface flow constructed wetland, Ohio EPA recommends following the 1993 USEPA document entitled, “Subsurface Flow Constructed Wetlands for Wastewater Treatment”.

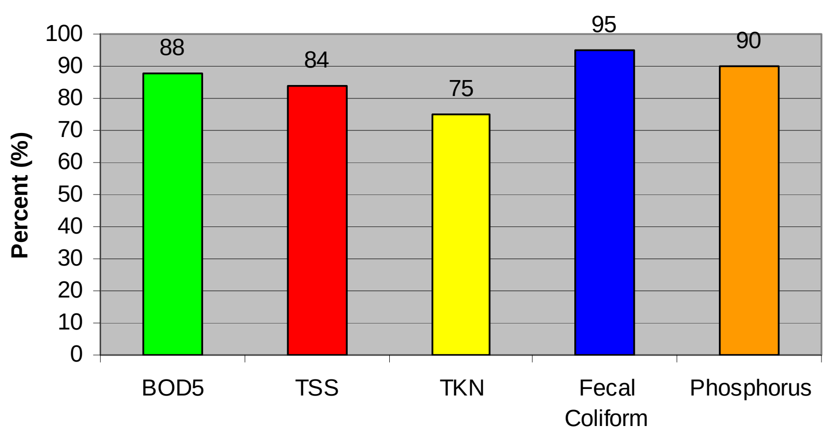
Wastewater Treatment & Removal

The water quality of the effluent is strongly dependent on how effectively the constructed wetland cells can remove contaminants. The physical removal of both BOD_5 and TSS generally occurs in the septic tank and through settling of the particles (primary treatment) throughout the constructed wetland cells. Pea gravel is an example of media that will provide adequate void space for the micro-organisms to attach and provide treatment. It is very important that a good supply of oxygen is provided to allow for the nitrification process to occur.

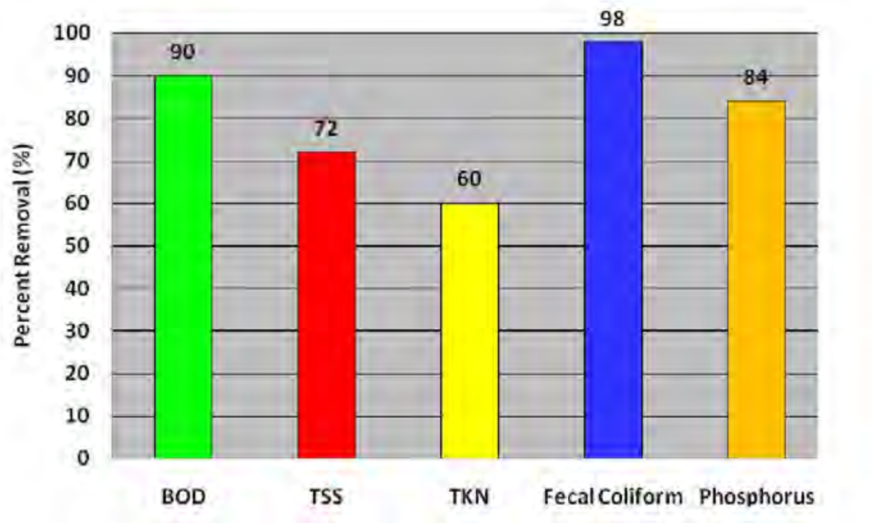
Phosphorus removal/reduction in constructed wetland systems is limited. Phosphorus is removed from the wastewater through sorption, binding, or precipitation. Phosphorus binding media that is rich in iron or calcium will help promote reduction of the total phosphorus. However, because constructed wetland media is typically not calcium or iron rich materials, alternative measures should be taken to further reduce the phosphorus concentrations in the wastewater if lower concentrations are needed.

Fecal coliform reduction in constructed wetland systems generally range anywhere from one to four log reductions. The greater the hydraulic residence time incorporated in the design, the greater the reduction of fecal coliform. Also utilizing a multiple series cell configuration will help promote fecal coliform reduction. Disinfection may be incorporated into the design to ensure fecal coliform and pathogens are reduced. Disinfection will be evaluated on a case by case basis.

Note: Septic tank effluent concentrations of nutrients in the wastewater prior to entering the constructed wetland cells are typically <200 mg/L BOD_5, <100 mg/L TSS, <100 mg/L TKN and $10^6 – 10^8$ cfu/100ml fecal coliform. SSFCW typically reduce wastewater to less than 30 mg/liter BOD_5 (biochemical oxygen demand, a measure of organic material), less than 25 mg/liter TSS (total suspended solids), and less than 10,000 cfu/100mL fecal coliform bacteria.



Graph 1: Potential Removal Rates within a constructed wetland systems



Graph 2: Actual Removal Rates from constructed wetland systems in Ohio

Note: Results in **Graph 2** represents sampling data collected by several local health departments which include: Highland, Logan & Lorain Counties.

Wastewater Flow

Once the proposed site has been inspected and a proper site and soil evaluation conducted, the next step is to determine the proposed average daily design flow for the onsite sewage treatment system. It is imperative that all sources of wastewater are taken into account, including all toilets and sinks. Other sources of wastewater include:

- Floor Drains (no industrial wastewater shall go to the soil absorption system)
- Kitchen
- Showers
- Dishwasher
- Clothes washer

To determine the appropriate flow values to incorporate in the design of the onsite sewage treatment system, refer to the Ohio EPA design flow rule, OAC 3745-42-05. Water use records might be substituted for the flows set forth in the design flow rule. Please refer to the design flow rule for specific procedures on water use records. Water use records will be evaluated on a case by case basis by the Ohio EPA.

Organic loading should rely on data provided in the design flow rule, OAC 3745-42-05. Loading rates should be 0.1 lbs/units*/day of BOD. Any deviation from this value should be discussed with the Ohio EPA on a case by case basis.

* Units refer to people, seats, parking spaces, etc.

Note: Flow meter installation is recommended at the front of the system to monitor the amount of wastewater entering the system.

Precipitation/Evaporation Data

It is imperative that the design include all sources of wastewater/water entering the SSFCW system. The previous section documented all internal sources of wastewater that is used in the design of the system, however, to properly account for the total flow into the SSFCW, the system needs to consider all external sources of flow as well. Thus, precipitation and evaporation data needs to be factored into the design. This data is incorporated in the overall water balance of the system. The precipitation and evaporation data should be collected from a nationally recognized meteorological organization and must be included with the permit to install application. Organizations that have this data include:

- NRCS
- NOAA

Note: Average precipitation rates in Ohio are 37 inches of precipitation per year while evaporation is 30.5 inches per year.

Hydraulics

Because SSFCW systems maintain wastewater levels below the media surface, this presents several design problems that could potentially impact treatment efficiency. The design water level should be 2-3 inches below the media surface. Maintaining a proper organic loading rate and hydraulic gradient throughout the constructed wetland cells can pose difficult challenges but can be obtained to allow for proper function of the system. Although there are no scientific methods that are directly applicable, Darcy's Law (**Appendix 2**) is the only reasonable design model that will provide proper hydraulic design. Darcy's Law assumes:

- Laminar flow conditions
- Flow is constant and uniform

The hydraulic gradient and the aspect ratio (L:W) of the SSFCW are dependent on each other. According to Darcy's Law, as the hydraulic gradient increases, the aspect ratio decreases and vice versa. These two parameters are inversely proportional. An iterative design needs to be applied so that an optimal hydraulic gradient and aspect ratio are determined for the SSFCW to allow for maximum treatment. It is recommended that an adjustable outlet, slightly sloped bottom (< 1%) and relatively low aspect ratio (less than 3:1) be used. This should provide an adequate hydraulic gradient throughout the media cell and maintain a horizontal flow path.

Inlet/Outlet Structures

It is necessary to provide a design that will uniformly distribute the wastewater throughout the width of the SSFCW; making the design of the inlet/outlet structures very important. Some issues that need to be considered before designing the structures are:

- How flexible are the outlet structures for future adjustments?
- How accessible is the inlet manifold for maintenance?
- How can clogging of the inlet manifold be prevented?

An inlet manifold, with access, should be designed so that the manifold can be flushed out. This design should allow for maximum flexibility for adjustments and maintenance. If maintenance is needed, the owner/operator should have an easy way of checking the manifold and making the necessary repairs. It is also recommended that coarse rock is placed along the manifold to help reduce the potential for clogging.

Most outlet structure designs include weir boxes or similar gated structures, and a subsurface manifold. The overflow structure should be directly connected to the final discharge pipe for dispersal. Disinfection may be added after the manifold, but before the overflow structure to provide final removal of pathogens. The biggest key to remember is to design the perforated subsurface manifold as an adjustable outlet to provide for flexibility and reliability.

Location of the inlet/out structures can also help dictate the amount of oxygen that the SSFCW receives. By installing the inlet structure higher in the constructed wetland cell than the outlet structure, this will cause what is known as hydrodynamic movement of air. This action will provide more oxygen to the system to help further the aerobic breakdown of the organic matter.

Note: SSFCW implies the wastewater levels remain below the surface of the constructed wetland cells. To ensure these conditions remain, the design should integrate a positive hydraulic gradient, adjustable outlet structures, and design for proper horizontal flow through the media, which will help reduce the probability of wastewater moving to the surface of the treatment cells.

Calculations

A water balance of the proposed SSFCW must be performed to account for all sources of water/wastewater in and out of the system. Precipitation and the average daily flow are the total Q (flow) **In** per day, while evaporation and plant uptake (evapo-transpiration) are the Total Q **Out** of the system. The system should be designed to handle at least a 2 year 24 hour rain event, or roughly 5 inches of precipitation per day. The wastewater balance of the system is represented by the equation below, where Q_{Δ} is the amount of flow the overflow structure will be required to disperse during major storm events:

$$Q_{\Delta} = (Q_{precipitation} + Q_{wastewater})\ \text{In} - (Q_{evaporation} + Q_{evapo\text{-}transipration})\ \text{Out}$$

For typical domestic sewage, the hydraulic residence time (HRT) should be designed for a minimum storage of two days for the entire system but can be designed for up to six days depending on the level of treatment desired. It should be noted that removal of BOD and TSS occurring after two days is marginal and if ammonia removal is critical, a higher HRT should be used. Other contributing factors to the HRT are media type, hydraulic gradient, and root depth penetration.

Note: SSFCW are not designed to collect storm water run-off during rain events. A list of design formulas and equations are located in the Conversion Factor section of this guidance document.

Design Configuration/Parameters

The layout of the SSFCW will depend on several site factors including amount of space available, contour of site, surface restrictions that will not allow the placement of the SSFCW, and other issues that are site specific. The configuration of the SSFCW to properly handle, treat, and disperse the wastewater can be flexible. There are three generic configurations that most SSFCW layouts will follow. They are provided below:

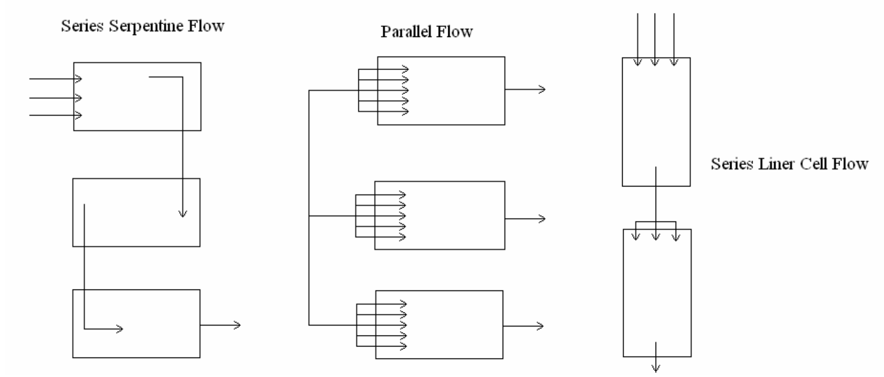


Figure 3: Constructed Wetland Configurations

The configuration of the SSFCW should contain a minimum of two constructed wetland cells in series to maximize the amount of treatment the constructed wetland cell will provide. A minimum criterion is set to provide more treatment and allow flexibility in case of maintenance issues, which is discussed in the Operation & Maintenance section. The bottom of the cells may be slightly sloped (< 1%) to help maintain a positive hydraulic gradient. This internal flow pattern that is created from the sloped bottom and adjustable outlet structures help promote mixing and better treatment of the wastewater.

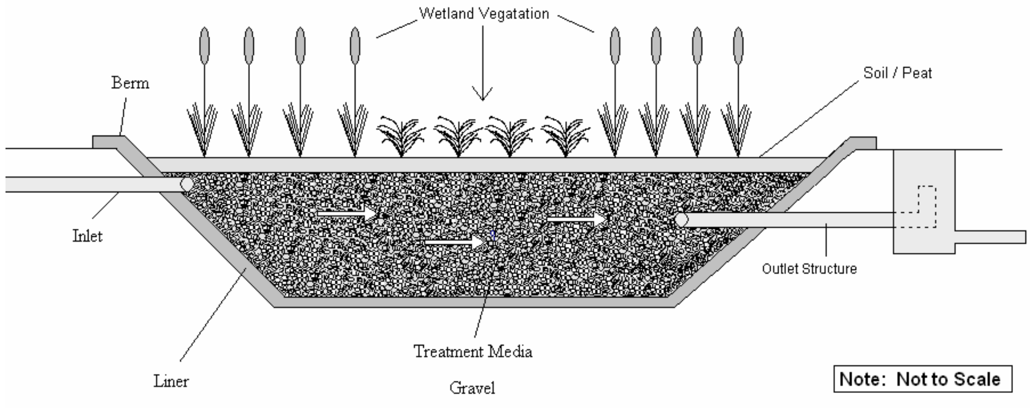


Figure 4: Cross Sectional View of Constructed Wetland Cell

The inlet and outlet areas of the SSFCW filled with coarse gravel or rock to prevent clogging in these areas. (See Appendix for recommended media size at inlets) Wastewater enters the system below the gravel through the inlet structure manifold. All SSFCW must contain overflow structures that flow to the next cell in series or the final soil dispersal system and must be designed for easy access to the owner/operator.

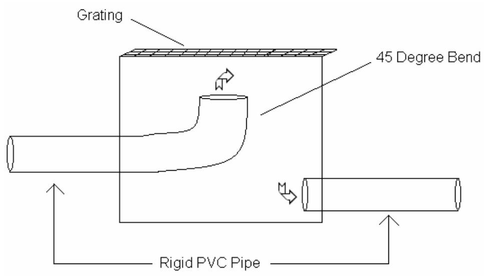


Figure 5: Cross sectional of overflow structure

Note: Operators must be able to clean out the overflow structure if clogged. Piping used to transfer wastewater from one cell to another should be rigid PVC pipe.

Media and Liners

Choosing the treatment media is critical in the design of the SSFCW. Designers must carefully consider the type, size, uniformity, porosity and hydraulic conductivity of the media material. These characteristics affect the flow of wastewater in the system and the system performance and should be tested prior to installation. It is recommended that larger media be used in the first several feet after the inlet and several feet before the outlet to help reduce the clogging issue. Refer to Table 2 and 4 for media requirements.

The design needs to make sure the media is as uniform in size as possible. When different sized media are placed together the finer materials settle into the open spaces leaving little room for the wastewater flow. Darcy’s Law assumes laminar flow for the application of the equation, so by using smaller rock sizes, this will allow flow conditions to nearly reach laminar flow.

Depth of media is recommended to be anywhere from 18-24 inches. Plant roots have shown that they will only penetrate to about 2 feet below the media surface. The depth of a constructed wetland cell may be deeper than 2 feet but shall be determined on a case by case basis. Make sure that the **gravel is washed** before laid in the constructed wetland cell.

It is recommended that a geotextile fabric be laid over the liner before the media is applied to prevent the media from puncturing the liner and/or prevent roots from puncturing the liner.

Typical liners range from 30-45 mil. Liner materials are:

- PVC (polyvinyl chloride)
- PPE (polypropylene)
- HDPE (high density polyethylene)

<u>Note:</u> Compacted clay is not recommended for liner material in smaller systems but may be considered for larger SSFCW.

Overflow Structure

The key to remember is that no SSFCW is designed without a discharge (overflow structure). The overflow structures' sole purpose is to disperse additional flow that is not evaporated or up-taken by the plants during storm events into either the next constructed wetland cell or the final soil dispersal system. When SSFCW systems rely on the soil for final dispersal of the effluent, it is recommended that a minimum of 12 inches of vertical separation from the point of dispersal to the limiting condition be maintained. Certain soil conditions may prohibit the usage of the standard overflow structures. If the limiting condition is either fractured bedrock and/or sand/gravel lenses, additional, conservative measures must be taken. The table below is a matrix of overflow structures that may be considered based on design flow parameters:

Design Flow (gpd)	Gravity Lines	Pressure Dist.	Unlined 3rd Cell	Land Application (spray)
<1000	Y	Y	Y	Y
$1000 \leq x \leq 10,000$	Y	Y	N	Y
> 10,000	N	Y	N	Y

Table 1: Overflow Structure Matrix

<u>Note:</u> Where the limiting condition is less than 12 inches, the situation shall be evaluated on an individual basis.

Plants

As important as it is to choose the appropriate media, liner, and SSFCW layout, it is equally important to plant the appropriate plants in the constructed wetland cells to help aid in the treatment of the wastewater. A planting plan should be developed in conjunction with the design of the SSFCW. The use of native plants and species in the SSFCW is highly recommended. Plants typically used in SSFCW in Ohio are:

- Broad-leaved cattail (*Typha latifolia*)
- Bulrushes (*Scirpus, Schoenoplectus, Bolboschoenus*)
- Sedges (*Carex*)

Other common native wetland grass and grass-like plants include:

- Spike-rush (*Eleocharis*)
- Rushes (*Juncus*)
- Grasses (*Calamagrostis canadensis, Spartina pectinata, Glyceria striata, Leersia oryzoides*)

Design should avoid noxious and invasive plants. Invasive plants that must not be planted in the constructed wetland are:

- Narrow-leaved, southern, hybrid cattails (*Typha angustifolia*, *T. domingensis*, *T.* x*glauca*)
- Eurasian buckthorn (*Rhamnus frangula, R. cathartica*)
- Purple Loosestrife (*Lythrum salicaria*)
- Reed canary grass (*Phalaris arundinacea*) *European species only
- Eurasian Water-Milfoil (*Myriophyllum spicatum*)
- Curly pondweed (*Potamogeton crispus*)
- Eurasian naiad (*Najas minor*)
- Giant reed (*Phragmites australis* subsp. *australis*)
- Flowering rush (*Butomus umbellatus*)

Note: If the overflow structure utilizes an unlined constructed wetland cell, the usage of aesthetically pleasing plants may be incorporated into the planting plan. Refer to the Ohio EPA for guidance. Native reed canary grass may be incorporated into the constructed wetland cell planting design if it can be determined that the plant is the native species and not the European version. For additional information regarding habitat, distribution, and control, of invasive plants visit the web sites provided in the Reference section.

Earthen Berm

To make sure that surface water run-off does not enter the SSFCW, an earthen berm must be designed to surround the constructed wetland cells. The earthen berm should be at a minimum of 12 inches above the top of the media. Berms may be vertical or sloped up to 2:1 on the cell interior and have a maximum slope of 3:1 on the exterior. The earthen berm should be made of compacted native soils.

Construction/Installation

Soil Issues

Before construction starts on the SSFCW, if a soil absorption/dispersal area is proposed for the overflow structure, it should be marked with visible markers so that during construction the soil absorption area is not comprised. If the soil absorption/dispersal area is disturbed or compacted, then that area will be deemed unsuitable for soil absorption/dispersal and a new area must be selected.

Construction Issues

Installers must be careful to avoid creating low spots or preferred flows down a particular side of the SSFCW that will encourage short circuiting. Grading of the constructed cell will be a very important task, but equipment traffic over the constructed cell may impair performance of the cell. Proper care of the constructed cell area should be an utmost priority to the installer. To ensure that no wastewater is absorbed through the bottom of the constructed wetland cells, the use of a liner is mandatory, however, if a third constructed wetland cell is being used as the overflow structure, it may be unlined. The use of native soils to compact and use as a liner for smaller constructed wetland cells is discouraged. The liner should be placed over the compacted native soils. As stated above, a geotextile fabric should be placed over the liner before the media is placed in the constructed cells. This serves as puncture protection from the media and roots.

The installer will need to make sure that the bottom of the constructed cell is completely flat or slightly sloped (< 1%) to the outlet of the cells. This will aid in the horizontal path of the wastewater through the cell and will help promote better mixing and overall treatment.

Media Issues

Clogging of the media at the initial start up, due to material collected on the media from soil, dust and fines, is a concern the installer needs to be aware of during installation. To help prevent clogging of the SSFCW only washed stone or gravel should be used. Construction activity has been linked as a primary cause of clogging, so every possible option should be taken to prevent unwanted material from being incorporated with the media.

Planting Issues

When plants are being put into the constructed wetland cells, it is recommended that a small layer of mulch or peat be placed on top of the media surface to help promote root development and provide thermal protection for the roots. A minimum three inches of material should be sufficient. Water levels should be maintained slightly above the media surface during planting and for several weeks after to suppress weed development and promote growth of the planted species. Planting of the constructed wetland cells is best during the spring or fall. If plants are struggling to survive, a moderate application of fertilizer may be applied to the plants to help promote plant growth, but the Ohio EPA should be consulted before doing so. A planting plan should also be included with the submission of the permit to install.

Operation and Maintenance

Repair

When maintenance work on a constructed wetland cell is needed, the applicant must be able to isolate the specified cell so that work can be performed without additional wastewater entering the cell. Therefore the design of the system must allow the applicant to bypass any particular cell when such instances arise. Due to the nature of the bypass design, all SSFCW will need to be designed with a minimum of two constructed wetland cells.

Costs

The SSFCW is a passive treatment system, meaning there is less need for daily maintenance of the treatment system. Based on overall operational costs of SSFCW, costs will range from $200-$500 per year. This includes pumping the tank, repairs, maintenance, and electricity. A maintenance contract or management plan will usually be required to be submitted along with the permit to install to insure the SSFCW runs effectively.

Management Plan

General upkeep of the constructed wetland cells are of vital importance. A management plan needs to be developed for the owner/operator that includes such things as:

- Inspection of the SSFCW and what to look for (e.g overgrowth of planted SSFCW plants, fibrous plants which include tree saplings, or any invasive species, damage to cells/liners, etc).

- How and where to dispose of overgrown plants in the wetland cell. The best option would be to create a compost pile on site for the owner/operator to properly dispose of the plants once they are removed from the constructed cell. Another option may be to contact your local refuse collector and determine whether or not a compost facility exists to deposit the removed plant matter.

- Inspection schedule/frequency of the constructed wetland cell(s), septic tank, tankage, and any mechanical parts associated with system design.

- Emergency contacts in case of malfunctioning and/or failure

- Contact information for hauler who will pump out septic tanks

- How operation and maintenance records will be maintained

Pest Control

Pest control is another issue that the management plan must address. Burrowing animals present problems in some SSFCW systems. Different control methods are available, including natural solutions, such as trapping and relocating animals. Specific pest control measures should be addressed on a case by case basis, but general options or contact information should be included in the plan.

Freezing Issues

If freezing is a concern, a thicker layer of mulch or peat above the media will help provide thermal protection for the constructed wetland cells. Another method that can be used to reduce the probability of freezing is by designing the water to be lower in the subsurface cells. This will allow several more inches of media between the top of the ground and water, thus reducing the chance of freezing.

Appendix 1

Type	Effective Size (D)	Porosity (n) %	Hydraulic Conductivity (k_s)
Fine Gravel	16	38	7500
Medium Gravel	32	40	10000
Coarse Rock	128	45	100000

Table 2: Typical Media characteristics

Bed Type	Root Depth (ft)	Final Effluent Quality (mg/L)		
		BOD_5	TSS	NH3
Bulrush, Scirpus	2.62	5	4	2
Reeds, Phragmites	1.97	22	8	5
Cattails, Typha	0.98	30	6	18
No Plants	0	36	6	22

Table 3: Vegetated SSFCW cells

Media	Size
Inlet	1.5 in. – 3 in. or No. 57 / No. 6
Treatment	¾ in. – 1 in. or No. 9 “Pea Gravel”
Outlet	1 ½ in. – 3 in. or No. 57 / No. 6
Planting Media	Soil, Peat or Mulch

Table 4: Recommended media size for constructed wetland cells

Appendix 2

Conversion Factors

1 Hectare	=	2.47 Acre
1 Acre	=	43,560 $feet^2$
1 ft^3	=	7.48 gal
1 ft	=	12 inches
1 m	=	3.281 ft

<u>Darcy's Law:</u> **(EQ 1)**

$$V = k_s * A * S$$

V	=	flow per unit time (gal/day)
k_s	=	hydraulic conductivity of a unit area of media perpendicular to flow direction (ft/day)
A	=	Total Cross Sectional Area perpendicular to flow (ft^2)
S	=	Hydraulic gradient of water surface in flow system (ft/ft)

<u>Hydraulic Residence Time (HRT):</u> **(EQ 2)**

$$t = (n * L * W * D) / Q$$

n	=	effective porosity of media (% as a decimal)
L	=	length of bed, (ft)
W	=	width of bed (ft)
D	=	average depth of liquid in bed (ft)
Q	=	average flow through bed (ft^3/day)

<u>Hydraulic Loading Rate:</u> **(EQ 3)**

$$q = Q / A$$

Q	=	average flow rate (gpd)
A	=	area of wetland (ft^2)

<u>Surface Area:</u> **(EQ 4)**

$$A_s = q / Q$$

Q	=	average flow rate (gpd)
q	=	hydraulic loading rate (ft^2 / gpd)

<u>Note:</u> Make sure all units are consistent when designing the SSFCW!!!!!!

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