Advanced Designs for Subsurface Sewage Treatment Systems Recommended Standards and Guidance Document

Single Pass Sand Filter

How this document is organized

Important Note to Users of this Guide

This is a guidance document produced by the Minnesota Pollution Control Agency (MPCA) for the benefit of the general public and wastewater treatment professionals alike. **It is in no way intended as a substitute for professional engineering consulting advice.** While the scenarios described in this document may appear to provide solutions for some situations, users of this guide are strongly *recommended* to seek the advice of their own consultants and wastewater treatment professionals who can assess the unique circumstances and address the specific concerns and needs of an individual project. The MPCA and its employees accept no responsibility or liability for the contents of this guidance document, the designs, or advice contained herein. This guidance document is not intended, and cannot be relied upon, to create any rights, substantive or procedural, that can be enforced in litigation or any administrative proceeding with the State of Minnesota or MPCA.

This document is the recommended standards and guidance for single pass sand filters. Single pass filters are public domain treatment technologies (Minn. R. ch. 7083.4000, subp. 1. B. 3.). A public domain treatment technology is a product developed without a patent. Another example of a public domain material is drainfield rock distribution media. The MPCA considers this single pass sand filter document to be a registered public domain treatment technology as required in rule.

The single pass sand filters (SPSF) designed, installed and operated in accordance with this guidance are a Type IV system, capable of meeting Level A treatment parameters. A treatment technology that meets Level A is capable of producing an effluent with a $CBOD_5$ of 15 mg/l, a TSS of 15 mg/l and fecal coliform of 1,000/100mL.

I. Application

Single pass sand filters (SPSF) are fixed film wastewater treatment systems capable of producing high-quality effluent. Although sand filters typically do a good job at nitrifying septic tank effluent, single pass sand filters provide little reduction in total nitrogen. Pathogen reduction has been documented to be very good; making single pass sand filters suitable treatment systems for subsurface discharging systems in non-nitrogen sensitive areas. Single pass sand filters are restricted to domestic strength wastewater applications.

A. Recommended design parameters

Septic tank primary treatment required

- Septic tanks sized for
  - Minimum of 3 X daily flow for gravity collection systems
  - Minimum of 4 X daily flow for pressure collection systems
- Septic tank effluent screens w/maximum 1/8 inch opening required
- Domestic strength waste only
- Septic tank effluent waste strength — less than 170 mg/L BOD_5, 60 mg/L TSS and 25 mg/L O&G
- Applicable to — single family home to 10,000 gpd
- Hydraulic loading rate — 0.8 – 1.0 gpd/ft^2
- Media effective size — < 1.0 mm
- Media Uniformity Coefficient — UC < 4.0
- Media depth — 24 inches
- Pressurized distribution — this is required
- Perforation size — 1/8 inch - 1/4 inch
- Dose volume — 4 doses/day with 4 perforations/ft^2, 8 doses with 4 to 9 perforations/ ft^2 both perforation spacing also must meet at least 5 times the distribution pipe volume
- Flow monitoring — as required by the local operating permit

System Size	Cells	Zones	Pumps	Ft^2/perforation*	Head required at end lateral	Head used to calculate pump discharge capacity
Single family home	1	1	1	9 ft^2	5 ft	1 ft with ¼” to $^3/_{16}$” perforations 2 ft with 1/8” perforations
Other establishments and < 2,500 gpd	1	2	2	9 ft^2	5 ft	2 ft with all perforations
2,500-5,000 gpd	1	3	2	4 ft^2	5 ft	5 ft with all perforations
>5,000 gpd	2	2 per cell	2 per cell	4 ft^2	5 ft	5 ft with all perforations

*Square foot requirements are for distribution laterals only. Two foot lateral spacing with two foot perforation spacing and one foot between lateral and edge of filter meets the 4 ft^2 requirement.

II. How to Use This Manual

A. Scope

Current rules and regulations do not provide recognized design guidance for single pass sand filters as a viable wastewater treatment alternative. This manual is intended to expedite the design and review process for this technology by:

- Providing information on the treatment performance, O&M requirements, size, applicability and cost of single pass sand filter systems
- Acting as a guide to determining the applicability of single pass sand filters
- Advising the designer as to the selection and sensitivity of design parameters
- Providing an overview of the design process
- Providing design criteria for bottom draining sand filters

The manual has application for:

- Treatment of domestic wastewater (sewage) only
- Flows between single family home to 10,000 gpd

The following assumptions on raw wastewater strength have been used throughout the manual:

- Effluent from septic tanks with BOD_5 of 170 mg/L
- Effluent from septic tanks with TSS of 60 mg/L
- Effluent from septic tanks with oil and grease of 25 mg/L

This manual is intended for use by intermediate designers (≤2,500 gpd),advanced designers (2,501 to 10,000 gpd), local permitting authorities, owners, consulting engineers and MPCA review staff, as well as funding source personnel to provide guidance for the successful design of single pass sand filters within Minnesota. Nothing within this manual should be construed or viewed as eliminating additional alternative treatment systems, or alternative design approaches with respect to single pass sand filters.

The design worksheets created by the University of Minnesota Onsite Sewage Treatment Program, in partnership with the MPCA presented in this document, can be utilized by the designer to perform most of the calculations necessary when designing a single pass sand filter system.

B. Terminology

Ammonia – A naturally occurring in organic form of nitrogen in combination with hydrogen. Total ammonia includes unionized ammonia (NH_3) as well as ionized ammonium (NH_4^+). The proportion between ionized and unionized ammonia depends on the pH and temperature of the solution. Ammonia is both toxic to aquatic animal life and a source of nutrition to plants.

Biochemical Oxygen Demand - The five-day biochemical oxygen demand (BOD_5) of domestic wastewater is the measure of the amount of molecular oxygen required to stabilize the decomposable matter present in water by aerobic biochemical action, as determined by a standard laboratory procedure.

Denitrification - The process of biologically converting nitrate and nitrite ($NO_3^-$and NO_2^-) to nitrogen gas.

Filter cell - The total filter area that can be served by a single dosing pump or set of pumps. A filter cell is also separated by a physical barrier such as a liner.

Filter zone - The area of a filter cell that can be dosed by a single pumping event.

Nitrification - The process of biologically oxidizing ammonia (NH_4^+ and NH_3) to nitrate and nitrite (NO_3^- and NO_2^-).

Pathogen - A disease producing microorganism.

Sequencing valve - Valve used to automatically direct flow to two or more final treatment and dispersal components, one or more at a time, and in a prescribed order.

Total Kjeldahl Nitrogen - The sum of the organic and total ammonia nitrogen present.

Total Nitrogen - The sum of organic nitrogen, total ammonia nitrogen and nitrate + nitrite nitrogen.

Total Suspended Solids - Those solids that either float to the surface or are suspended in sewage, which are removable by a laboratory filtration device.

C. Abbreviations of some terms used in this document are as follows:

BOD_5	BOD_5, the five-day biochemical oxygen demand
DO	dissolved oxygen
gpd	gallons per day
gpd/sf	gallons per day per square foot
gpm	gallons per minute
ISTS	Individual Subsurface Sewage Treatment Systems
lb/day	pounds per day
mg/L	milligrams per liter
MPCA	Minnesota Pollution Control Agency
MSTS	Mid-Sized Subsurface Sewage Treatment Systems
ND	not detectable
NH_4	ammonia nitrogen
NO_3	nitrate nitrogen
P, TP	phosphorus, total phosphorus
SPSF	single pass sand filter
SSTS	Subsurface sewage treatment systems
TN	total nitrogen
TSS	total suspended solids

III. Background and Process Description

A. Background of single pass sand filters

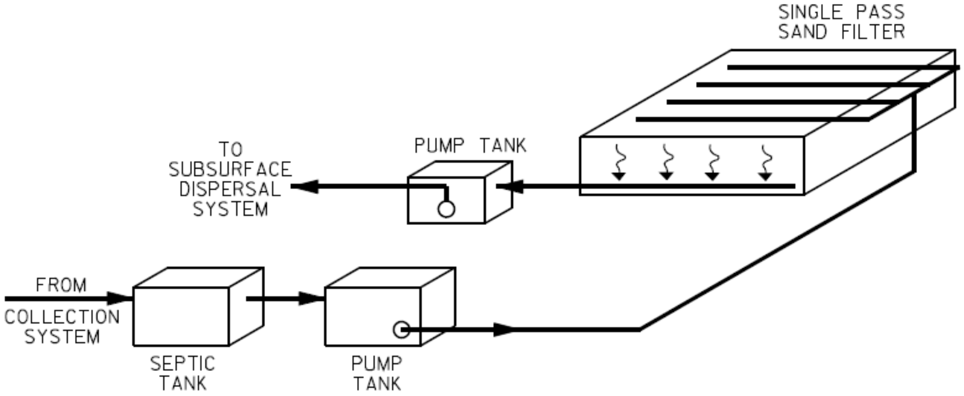
Sand filtration is a term that generally describes an aerobic, fixed-film bio-reactor used to stabilize pre-treated, domestic strength wastewater. Rather than a strictly physical process as implied by the term "filter", media filtration in this context employs a combination of physical, chemical and biological processes to produce a high-quality effluent.

The "media" can be any of a number of physical structures whose sole purpose is to provide a surface to support biological growth. They can be broken down into subcategories based on how many passes through the filter the wastewater makes, whether the filter surface is open to the air or buried, and the relative size and type of media (sand, gravel, textile or other). This manual only covers single pass sand filters.

In all cases, primary treatment of the wastewater to reduce suspended solids, oil and grease and possibly some BOD_5 content of raw sewage is required. Once settling is accomplished, the pre-treated wastewater is applied to the filter surface in small doses, to alternately load and rest the media. As wastewater percolates down through the filter bed, it comes into contact with the bacterial film growing on the media. The filtrate is contained by an impermeable liner and collected in an underdrain. The underdrain pipe directs the filtrate to a pump tank, from which it is conveyed to a subsurface dispersal unit. A schematic of typical media filtration systems is shown in Figure 3-1.

Figure 3-1

Single Pass Sand Filter Schematic



B. Discharge performance capability and limitations

If the parameters of concern are primarily BOD, ammonia, fecal coliform and TSS, single pass sand filters are capable of producing a high quality effluent. The performance of an individual system is influenced by a variety of design and operational issues, each of which will be discussed in this design guidance.

Conventional media filtration will provide partial-to-full conversion of ammonia-nitrogen to nitrate-nitrogen. Unlike recirculating sand filters, there is not a provision for the denitrification of filtrate using influent carbon because of the lack of filtrate return. While some removal of nitrogen is obtained through settling and cell synthesis, SPSFs alone are not suitable for applications requiring reduction of total nitrogen to 10 mg/L. A separate post-denitrification system utilizing supplemental carbon addition to a fixed film anoxic bioreactor would be necessary to reduce nitrate-nitrogen levels.

Bacteria levels, as characterized by fecal coliforms, are reduced in media filtration treatment.

C. Process description

1. Primary treatment by septic tanks

Primary treatment is required for all forms of sand filtration. The goal of primary treatment is to prevent fouling of the filter from suspended solids and from excessive bacterial growth due to BOD_5 overloading. Successful primary treatment can occur in many forms, but this guidance will focus on the most common form, septic tanks. This document assumes septic tank effluent from domestic strength wastewater to contain a BOD_5 of less than 170 mg/L, TSS of less than 60 mg/L and O&G less than 25 mg/L. Refer to Section IV of this document for septic tank sizing requirements.

2. Volume requirements for septic tanks

After establishing the design flow, the next step in the design process involves sizing the septic tanks. Please refer to MPCA’s Subsurface Sewage Treatment Systems – Prescriptive Designs and Design Guidance for Advanced Designers, Section IV B.

3. Filter dosing

After primary treatment, the wastewater flows into a pump tank. This compartment provides a reservoir from which to dose the filter. It houses timer-controlled submersible dosing pumps that are used to move water up to the surface of the filter. Once at the surface of the filter, the water is allowed to percolate down through the filter where it comes into contact with the treatment organisms living on the filter media.

Intermittent application of wastewater, or filter “dosing”, is required so that the filter has time to allow the wastewater to percolate through and then re-aerate. The aerobic bacteria responsible for treatment need air in the pore space of the media in order to obtain oxygen. If a filter were constantly dosed, the aerobic bacteria would not thrive and the bacterial culture would change over to anaerobic or facultative organisms. Anaerobic reactions are much less efficient, produce odorous gases and are not desirable. For this reason the dosing tank needs to be large enough to provide flow equalization and storage of influent flow.

Wastewater in the supply pipe and distribution piping must not be allowed to freeze between doses. To prevent this, the discharge piping must rapidly drain from the pipes and be allowed to drain back to a dosing tank after each dose. This is typically accomplished by drilling a weep hole after the check valve on dual pump systems or not using check valves downstream of single pump systems, allowing the supply pipe and distribution piping to properly drain back to the dosing chamber after each dose.

Many studies have shown performance benefits from increasing the frequency of dosing cycles. For example, Darby et al (1996) reported that removal rates in sand filters dosed 12 times or more per day exceeded removal rates for filters dosed one to four times per day. Darby also found that, as dosing frequency increased from 4 to 24 times per day, Chemical Oxygen Demand (COD) removal increased.

The benefit of increased dosing frequency (smaller volume per dose) can be attributed to less hydraulic pressure being put on the sand filter media to flush water through the pore spaces at a steady state rate. Wastewater is allowed to percolate more slowly, resulting in a greater contact time and a thin film flow over the biomass (Darby, 1996; Crites, 1998). An additional benefit to a shortened dosing interval is that the instantaneous effluent flow rate more closely matches the influent flow rate.

The designer must balance the frequency of a dose with the volume of each dose. Increasing dosing frequency means a decrease in the volume of each dose. The designer should ensure that each dose is at least four times the volume of the distribution pipe network in the sand filter to properly pressurize the pipe, which provides even distribution.

4. Filter media and wastewater distribution

Media is the material or product used to provide support for the attached microbial growth that will provide the aerobic biological treatment. It is not, as the name might imply, used primarily to provide physical filtration of influent solids, although some filtration does occur. Media is among the most important elements of a single pass sand filtration system, and is also among the most costly.

An ideal media will have the following properties:

a) High surface area-to-volume ratio

b) Large enough voids to allow for rapid air infiltration and to minimize fouling

c) Good weathering properties, including

   i. Ultraviolet (UV) resistance if exposed to sunlight

   ii. Physical wear and soundness

   iii. Low solubility in water and acidic conditions

d) Be cost-effective and locally available

e) Grain size

Some of the earliest work on single pass sand filtration was performed by Hines and Favreau in the 1970's using sand media having an Effective Size, or D10 (the diameter at which 10 percent of the material by weight is smaller than), of 0.3 mm (Loudon, 1984). A variety of studies comparing treatment performance and fouling of media for varying effective size have followed, and include Sauer, 1976; Darby, 1996; and Zaplatikova, 2005. In general, these studies have found that both media size and dosing regime had the greatest impact on performance of single pass sand filters.

In these cases, fine-grained media (0.25 – 0.3 mm) will provide better treatment than coarser media due to the high surface area to volume property of fine-grained soils. This difference in performance was reduced by increasing dosing frequency. Once it was demonstrated that similar performance could be expected from a variety of media sizes, media selection became based more on extending the longevity of a sand filter and minimizing maintenance than on treatment performance.

For any effective size, a key element in the selection of sand filter media is the absence of fines. Sand media with too many fines has a greater chance of failing hydraulically (Converse, 1999). Most successful SPSF media specifications require that less than five percent passing a #100 sieve.

f) Uniformity

The other key characteristic of sand filter media is its uniformity. To prevent the accumulation of smaller particles within the void spaces of larger particles, which leads to clogging of the filter, research has recommended a relatively uniform, or poorly sorted, media. The degree of uniformity of the sand filter media is described by the Uniformity Coefficient (UC), which is the ratio of the D_{60} to D_{10}. The lower the number, the more uniform the media. The highest allowed UC is typically 4.0, with many specifications requiring a UC of 2.5 or less. In general, the lower the uniformity coefficient, the less prone to fouling the media will be; however the cost of the media will likely increase due to the additional volume of raw material that must be screened to manufacture the media.

g) Depth

Much of the earlier guidance on single pass sand filters suggested a media depth of 36 inches or more. More recent research has found that less depth is necessary (Anderson, 1985; Darby, 1996). The majority of the biological activity has been found to occur in the upper 9 to 12 inches of the sand filter bed (Anderson, 1985). Darby (1996) reported results using a filter depth of 15 inches that were comparable to those from previous studies using deeper filter beds. As sand media is one of the more expensive elements of a sand filter system, any ability to safely minimize the quantity can result in significant cost savings. Based on these studies, a filter bed depth of 24 inches has been commonly used in Wisconsin, Massachusetts, Rhode Island and other states. It provides for some safety factor, and would allow for the removal of several inches of fouled media, if necessary.

h) Selection

Virtually any granular media will successfully support biological growth that will treat wastewater with some degree of success. There is no one right size and gradation. All, however, offer tradeoffs, and it is the role of the designer to select the best fit for a particular application.

The following general relationships with respect to sand media size have emerged as a result of much research and actual experience. These relationships apply to granular media between 0.3 mm and 5 mm in size.

As media size increases:

i. Time to fouling increases
ii. Maintenance decreases
iii. Allowable hydraulic loading rate increases (filter area becomes smaller)
iv. Media life may be extended

Less prone to freezing

But

i. Treatment may decrease slightly
ii. Better distribution of wastewater may be necessary

i) Wastewater distribution

Once a media size and gradation have been selected, the designer must apply a method of distributing the wastewater over the sand media that is appropriate for that media. Distribution is frequently accomplished by a network of perforated plastic pipe laid on the surface of the filter media and embedded in a layer of coarse stone. The pipes convey wastewater pumped by the dosing pumps and carry it to the filter surface. Wastewater is then applied to the filter surface through a series of perforations, or holes drilled of a specific size in the pipe.

j) Media Cover

There are variations of sand filter designs that place a cover material of mulch, peat, or other organic material over the top of the media. Single pass sand filters may be covered while recirculating sand filter must have distribution media to the surface. If cover material is installed, a maximum depth of 12 inches of suitable material that is graded such that fines will not enter and plug the distribution media. The cover material must also allow for good oxygen transfer. Vegetation on top of the cover media must be managed so that deep rooted vegetation does not plug the distribution system. For single family homes, single pass sand filters are typically covered with six inches of loamy or sandy soil with the upper six inches of loamy topsoil that can support a grass vegetative cover; the surface is then seeded and mulched.

5. Liner and underdrain

Single pass sand filters usually have an impervious bottom and sides so that partially treated wastewater (the filtrate) is collected and directed to the soil dispersal system. However, on suitable sites, the use of unlined, bottom draining sand filters is allowed. Refer to Appendix I on specific design criteria for bottom draining sand filters with flows less than 2,500 gallons per day.

Single family sand filters are sometimes constructed in concrete tanks, but community scale sand filters typically use earthen sidewalls with a synthetic liner placed at the bottom and up the sides. The liner material most commonly used is a 30 mil PVC. Refer to the MPCA guidance on synthetic liner installation at:

High Density Polyethylene (HDPE) liners

http://www.pca.state.mn.us/publications/wq-wwtp5-32.pdf

Polyvinyl Chloride (PVC) liners

http://www.pca.state.mn.us/publications/wq-wwtp5-60.pdf

Perforated collection pipe laid on top of the liner is typically used to convey filtrate which collects on the liner to the soil dispersal system. This underdrain pipe is typically vented to the surface to allow air in, and is often bedded in clean stone of larger diameter than the sand filter media. The underdrain media should be large enough to not blind the underdrain pipe openings (which would impede drainage from the sand filter), and should be sized to support the overlying treatment media. Geotextile fabric must not be placed between layers of media or around the underdrain piping. Early designs using geotextile fabric to separate media layers exhibited high rates of failure due to fouling of the geotextile fabric itself.

IV. Design Guidance

As can be seen from the preceding sections, there are numerous variations on single pass sand filter systems, all of which can be successful, but all of which also offer some trade-offs. No single filter design or operating parameter was found to adequately predict the performance of sand filters (Darby, 1996).

This design guidance will focus on one of numerous potential design approaches that are commonly used for small facilities. **The design examples that follow will utilize this method and alternate approaches are outside the scope of this document.**

A. Design process overview

The general process used by this manual to design a SPSF will be in accordance with the following steps:

1. **Determine design requirements**
    a) Characterize design flow rates
    b) Characterize influent wastewater makeup
    c) Determine effluent soil dispersal location and limits
2. **Size primary treatment unit**
    a) Septic tank size, number and layout
    b) Effluent screens and alarm
3. **Size pump tank**
    a) Pump tank size and layout
4. **Size sand filter and distribution system**
    a) Select hydraulic and organic loading rates
    b) Determine filter size
    c) Determine optimal filter layout
        i. Length
        ii. Width
        iii. Lateral and perforation spacing
        iv. Select head and associated perforation discharge
        v. Calculate required pump flow rate
        vi. Determine number of cells
        vii. Determine number of zones
5. **Size dosing pumps and controls**
    a) Select nominal pump size
    b) Determine number of pumps needed
    c) Provide service provider with recommendations on pump cycle times, dose volumes and frequency based on flow, wastewater strength and system performance
6. **Determine size, number, and location of filter underdrain collectors**
    a) Select liner material
    b) Select number, size and type of underdrains
    c) Select underdrain perforation size, shape, location on the pipe and spacing
    d) Select underdrain bedding media gradation and depth
7. **Size downstream elements**
    a) Soil treatment and dispersal system
8. **Determine hydraulic profile and set elevations**

    In addition to providing guidelines for the design of a single pass sand filter, a set of default design parameters will be given in each section for single family homes to flows up to 10,000 gallons per day.

B. Design requirements

1. Design flow

Use MPCA/University of Minnesota Design Flow Worksheet to determine the average daily design flow.

2. Wastewater loading

SPSF systems are intended for the treatment of domestic wastewaters. High strength residential and commercial or industrial wastewaters are not appropriate for treatment in a single pass sand filter since the filter will be susceptible to biological clogging, or it will quickly become so large so as to not be cost-effective.

Typical domestic wastewater strength parameters should be used to characterize the strength of the wastewater to be treated.

3. Treatment goals

The degree of treatment required is driven by geologic and natural soil conditions at the site. The treatment goals are determined in accordance with the environmental protection standards of Minn. R. ch. 7080. For mid-sized subsurface sewage treatment systems (MSTS) regulated under Minn. R. ch. 7081, the treatment goals are determined in accordance with the environmental protection standards of Minn. R. ch. 7081. SSTS may be subject to a total nitrogen standard of 10 mg/L if located in a nitrogen sensitive area. The designer shall complete the MSTS nitrogen worksheet in Section II F in *Prescriptive Designs and Design Guidance for Advanced Designers* to determine what limits may be applicable. The single pass sand filters designed, installed and operating in accordance with this guidance will be a Type IV system capable of meeting Treatment Level A parameters. Treatment technologies that meet Level A are capable of producing an effluent with a $CBOD_5$ of 15 mg/L, a TSS of 15 mg/L and fecal coliform of 1,000/100mL.

C. Primary treatment units

1. Septic tank sizing

a) STEP systems

Individual septic tanks in STEP/STEG collection system should be sized in accordance with the requirements in Section V of the MPCA document of *Prescriptive Designs and Design Guidance for Advanced Designers.*

b) Community scale septic tanks

Sizing of community septic tanks shall follow the sizing required in the MPCA document *Subsurface Sewage Treatment Systems Prescriptive Designs and Design Guidance for Advanced Designers.*

2. Effluent screens

Effluent screens must be installed in the final septic tank to: 1) help to reduce large particles and scum from the septic tank and plugging the sand filter, and 2) help to minimize plugging of the distribution perforations and media. Effluent screens must be sized smaller than the pressure distribution perforation diameter. All effluent screens must be equipped with a high water alarm.

D. Pump tank

The minimum pump tank should be sized for one day’s average design flow, or 500 gallons, whichever is greater.

E. Sand filter

1. Hydraulic loading rate selection

Hydraulic loading rate is the principal design parameter for sizing the surface area of the filter bed. For domestic strength wastewater applied at or below the recommended hydraulic loading rate, the organic loading rate will be sufficiently low so as not to be of concern. The hydraulic loading rate for single pass sand filters in Minnesota is:

Hydraulic loading rate: Not more than 1.0 gpd/sf

(King County, 1999; Washington State Department of Health, 2007)

2. Header spacing

Provide closely-spaced distribution laterals and perforations along the lateral to promote even distribution of the wastewater. Accepted practice is to place the distribution laterals on two-foot centers. Each lateral is drilled with distribution perforations, also on two-foot centers. This provides even distribution over the filter surface, with one perforation for every 4 ft^2 of filter area (Ball and Denn, 1997). Single homes, and other systems with flows up to 2,500 gpd, may use perforation spacing such that the filter area covered by each perforation is less than 9 ft^2 (7080.2050 subp. 4 F and G). All other sand filters, up to 10,000 gpd, must use 4 ft^2 per perforation. Distribution laterals on two-foot centers and perforations drilled on two-foot centers are considered equal to one perforation for every 4 ft^2.

3. Perforation installation and orientation

For distribution pipe installed in drainfield rock, all perforation holes must be drilled, deburred and cleared of all obstructions because residual plastic shavings can clog holes. For distribution pipe installed in drainfield rock, perforations located at the 12 o’clock position must have perforation shields (also called orifice shields) placed over each perforation to direct the wastewater downward. At least one perforation shall be drilled at the bottom of each header and at all low spots in the distribution system to allow the header to drain. Alternatively, all holes may be placed facing down at the six o’clock position without the use of perforation shields.

4. Header layout

Relatively equal distribution of the effluent can be obtained by designing a pressurized distribution system in which there is at least five feet of head over the most distant perforation. When calculating pump discharge capacity for single family homes and other establishments up to 2,500 gpd, you can use the head requirements specified in Minn. R. ch. 7080.2100 subp.4. B.; all other sand filter systems must use five feet of head over the most distant perforation. The flow rate through each perforation is given by the equation:

$$Q_O = [CA(2gH)^{1/2}][60x7.48]$$

Where:

- Q_O = Perforation flow rate, gpm
- C = Perforation constant = 0.6 (for holes drilled in PVC pipe)
- A = Cross sectional area of perforation, ft^2
- G = Acceleration due to gravity = 32.2 f/s/s
- H = Head, ft of water

Which simplifies to: $Q_O = 11.79\ OD^2(H)^{1/2}$

Where:

- OD = Perforation diameter, in
- H = Head, ft of water

For a residual head (H) of five feet and a 1/8 inch diameter perforation with area (A) = 8.52×10^{-5} ft^2, the flow per perforation is 0.41 gpm. Good distribution of flow requires that the flow from all perforations be nearly the same. Pressure loss should be minimized such that the difference in flow from the first to the last perforation on a lateral is less than ten percent. For the maximum number of perforations per lateral, see Minn. R. ch. 7080.2050 Subp. 4. E. Table VI. In order to meet dosing requirements, consider using pipe and perforation sizing that is on the small end of the table.

The actual operating head of the completed installation can be measured in the field by opening a terminal valve on each distribution lateral, and measuring the squirt height. The initial clean squirt height should be recorded in the O&M manual to allow comparison in the future. All distribution laterals must have a terminal/flushing valve which allows laterals to be flushed or even jetted.

The header layout and size of the perforations will determine the pumping rate. While designing the header layout and sizing the perforations, the pumping rates shall be kept to a minimum. Large capacity pumps will produce large head requirements and will become unmanageable for the service provider.

5. Sand filter layout

The filter area is divided into zones and cells. A filter zone is the area that can be dosed by a single dosing pump at any one time. It is determined by the pump size, lateral length, perforation size and perforation spacing. A filter cell is the total filter area that can be served by a single dosing pump or set of pumps. A filter cell can consist of up to six zones, with each zone being dosed in sequence by the dosing pump for that cell. A sequencing valve, or pumps dedicated to each zone, can be used to control which zone is being dosed at any one time. A generalized layout of the filter system, showing the laterals, cells and zones, is shown in Figure 4-1.

Filter layout minimum requirement are as follows: For single family homes, one cell with one zone and one pump would be the minimum requirements. For Other establishments, and flow up to 2,500 gpd, one cell with two zones and two pumps is required. For flows of 2,500 to 5,000 gpd, one cell with at least three zones and two available pumps per zone is required. For flows over 5,000 gpd, two cells with at least two zones per cell and two separate pumps for each cell (minimum of four pumps) is required. By using sequencing valves, each pair of pumps can serve several zones. As an alternative to sequencing valves for systems that use three or more zones, a dedicated pump for each zone is allowed (one pump per zone).

The overall minimum size of the sand filter is determined by the daily design flow and the hydraulic loading rate:

$$A_f = Q_d/LR$$

Where:

- A_f = Area of filter, sf
- Q_d = Design flow, gpd
- LR = Hydraulic loading rate, gpd/ft^2

There is some flexibility as to the layout of the filter. Site constraints may dictate the length to width ratio. The optimum layout of the overall filter is a square, as liner and perimeter wall material are minimized. In actuality, though, the designer will have to iterate length and width to accommodate lateral spacing and to limit the length of the filter to one that will minimize pressure losses. The length of the filter is limited by the ability to maintain a relatively equal head pressure over the perforations.

As an example for one inch diameter PVC laterals with 1/8 inch perforations, this distance is limited to 40 ft. between the first and last perforation. With one foot of clearance on either end, this sets a maximum filter length of 42 ft. Therefore, the filter simply grows wider as the design flow increase (note: changing the pipe diameter or the perforation diameter will result in different maximum filter length). Using this limitation along with the site constraints, the designer shall select a filter length and width that will provide the required area. Selection of an even footage for width will allow for easier division into cells and zones of equal size.

Once the filter dimensions have been selected, the number of laterals and individual zones can be determined. Allowing for one foot of clearance from the most distant perforation on each end, the lateral length (distance between first and last perforation) will be two feet less than the width of the filter.

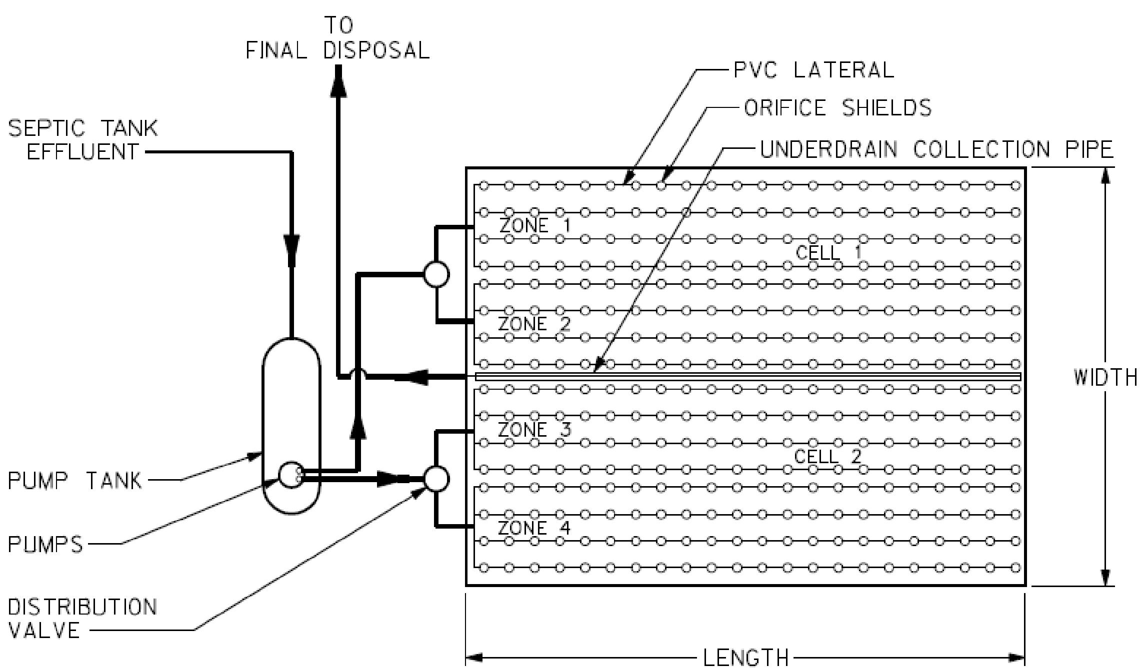
The designer must next determine how many zones can be served by a single pump. Multiple zones can be served from a single pump through the use of a sequencing valve. A sequencing valve, or pumps dedicated to each zone, can be used to control which zone is being dosed at any one time.

The designer will likely need to iterate the lateral length, pump size and filter width to arrive at a design that meets all of these criteria:

- Each cell is served by at least two pumps (single family home only requires one pump)
- Each cell has the same number of zones
- Each zone has the same number of laterals and perforations
- Maximize the number of zones in a cell (up to six)

Once the filter dimensions and configuration of cells and zones has been determined, the designer can produce a layout of the tanks and filter on the site. A generalized layout of a large filter system showing the laterals, cells and zones is shown in Figure 4-1.

Figure 4-1
General SPSF System Layout



To minimize head loss and piping cost, the pump tank should be located near the sand filter. Once the piping can be laid out along with relative elevations, hydraulic calculations can be run to make the final pump selection. It will only be pointed out that design is an iterative process, and that initial assumptions on pump flow rate must be verified, and the design adjusted, as needed, for variations in the actual pump flow rate that may result from the selection process.

6. Media selection

It is required that four individual gradations of media be placed in the filter bed in layers. Media suppliers must demonstrate compliance with the media specification by providing grain size distribution curves for each type of media. Samples of the approved media should be taken to allow comparison to the media delivered to the site to help detect any deviation from the specification. The four media layers are as follows, beginning at the top of the sand filter:

a) Distribution media

The distribution laterals must be embedded in drainfield rock distribution media with six inches of drainfield rock below the pipe. Drainfield rock needs to completely encase the top and sides of the distribution laterals to a depth of two inches above the pipe.

A detailed gradation for recommended media is contained in the MPCA document Drainfield Rock Distribution Media Recommended Standards and Guidance Document (2009). The coarse rocks around the laterals help to distribute wastewater over the underlying sand filter media. The layer of coarse rock above the laterals provides some insulation while allowing for a free flow of air to the sand filter media.

Distribution media registered through the Product Registration Process for use in single pass sand filters can be used in place of drainfield rock distribution media.

b) Filter media

The depth of the sand filter media must be 24 inches at a minimum. A depth of greater than 24 inches is allowable but increased media depth has not been shown to be a significant benefit. As the depth of the sand filter media increases, the ability to transfer oxygen to the lower level decreases**.** Filter media for single pass sand filters must be clean, hard, durable particles that are free from dirt and organic materials. The media must conform to the following requirements:

Effective Size (D_{10})	<1.0 mm
Uniformity Coefficient (UC)	<4.0
Maximum particle size	<3/8 inch
Solubility	<5% in acid for particles

Grain size distribution:

Sieve size	**Passing by weight**
3/8 inch	100%
No. 4	95-100%
No. 8	80-100%
No. 10	0-100%
No. 40	0-100%
No. 60	0-40%
No. 200	0-5%

c) Underdrain media

Filter underdrain pipes must be bedded in a coarse media to allow the partially treated wastewater to flow to the underdrain collection pipes. The coarse underdrain media shall be of sufficient size to support the overlying sand filter media without migration of the sand into the coarse media. The underdrain media must be clean, hard, durable stone. This media must be deep enough to cover the underdrain pipes; where four inch diameter underdrains are used, a coarse media depth of six inches is required. An intermediate layer (pea gravel) of two inches must be placed between the coarse underdrain media and the sand filter media to prevent the migration of sand into the lower layer. The coarse underdrain media must be a total of 12 inches in depth, and consist of two layers, each with the following properties:

i. The lower drainage rock surrounding the collection pipe must meet the MPCA document Drainfield Rock Distribution Media Recommended Standards and Guidance Document.

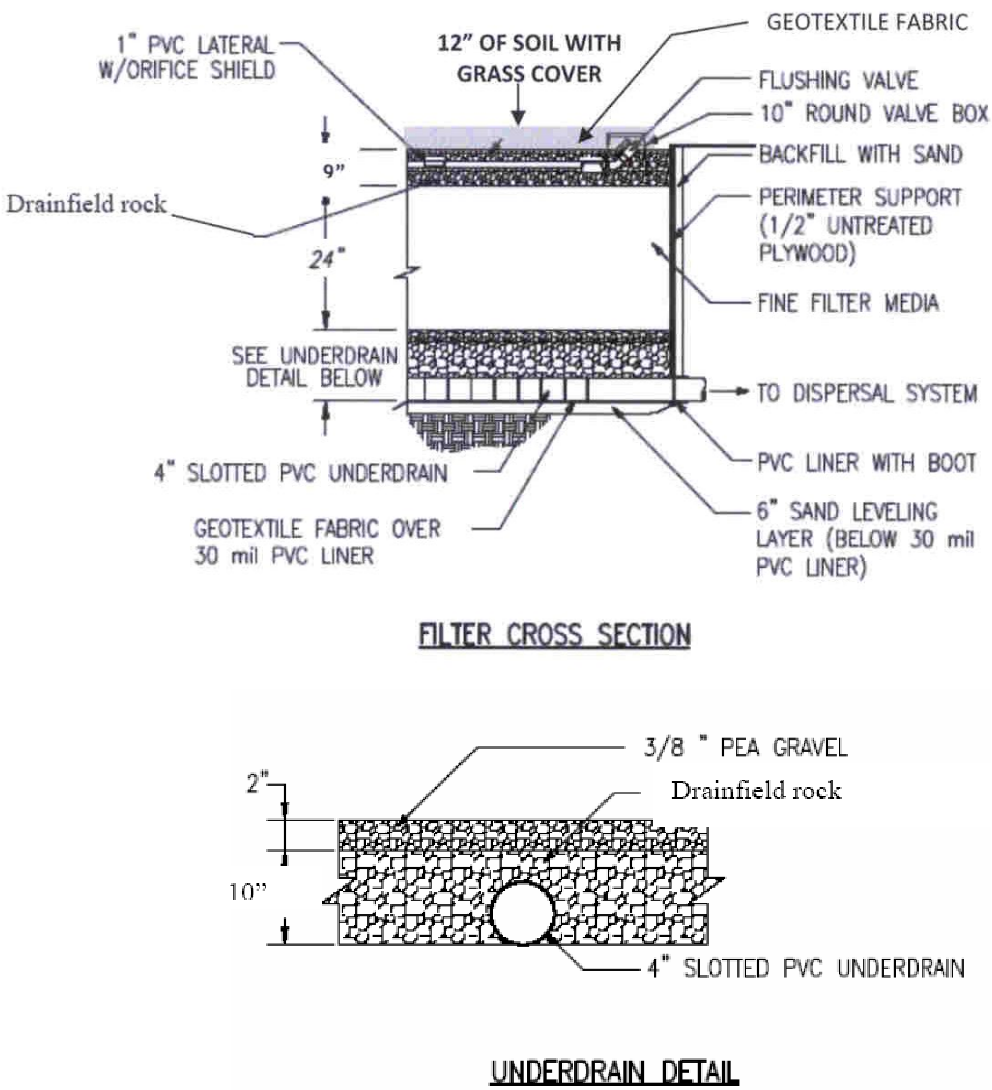
ii. The upper two inches between the coarse underdrain media and the sand filter media must meet the following grain size distribution per ASTM No. 8:

Grain size distribution:

Sieve Size	Passing by weight
½ inch	100%
3/8 inch	50-100%
No. 4	6-84%
No. 8	0-24%
No. 16	0-1%

A cross section of the completed filter, showing the liner, underdrain, layers of media and distribution piping is shown in Figure 4-2. Figure 4-2 provides an example of one possible construction configuration; plywood sides may be replaced with earthen basins provided the soil will support the liner during construction. Backfill must be mineral soil that is free of foreign materials, frozen clumps, oversized stone, rock or other unsuitable materials that would prevent proper compaction (and uneven settlement around the perimeter of the excavation).

Figure 4-2
Cross Section of Single Pass Sand Filter



7. **Filter underdrain**

The job of the filter underdrain is to convey water from the bottom of the filter to the effluent dispersal system and to provide a conduit for air flow into the bottom of the filter. The underdrain must be vented to the atmosphere to allow entry of air into the underdrain system. The underdrain must be sufficiently sized so that water does not back up into the sand filter media, which can lead to anaerobic conditions. The openings in the underdrain pipe must be large enough to allow water to enter freely, while preventing the underdrain bedding media from blocking the openings or entering the pipe. The filter bottom must be sloped at least one percent to the underdrain pipe in synthetically lined sand filters.

Slotted PVC pipe is commonly used, with ¼ inch wide slots on 4 inch centers. Alternatively, corrugated HDPE drain pipe has also been used with success. A minimum of one underdrain, per filter zone, should be provided with a minimum of one underdrain per 20 feet of width.

The upstream end of the underdrain should be directed up, with two 45-degree bends, and be terminated above the sand filter surface to provide access for cleaning.

8. **Inspection pipes**

A total of three inspection pipes should be placed in the filter cells at the following locations and depths:

a) Just above the synthetic liner, with perforations that span the depth of the underdrain rock, typically a depth of 12 inches

b) At the bottom of the sand media, with perforations that span six to eight inches of the lower portion of the sand filter media

c) At the top of the sand media, with perforations that span the depth of rock at and below the distribution network, typically a depth of three to four inches

Inspection pipes typically consist of short lengths of four inch PVC pipe that are capped above the filter surface and open at the bottom. The inspections pipes allow for the monitoring of ponding levels at different depths in the sand filter. This, coupled with observations made from cleanouts at the end of the underdrain network, allows access to determine if biological clogging is occurring. For larger systems, multiple sets of inspection pipes are typically needed to monitor ponding at different locations in the system.

The bottom of the inspection pipe should be fitted with an elbow, tee or cross to secure the pipe at the appropriate depth and to prevent it from being pulled out of the filter media.

Providing the service provider with these observation access points into the filter can help avert a catastrophic clogging incident by being able to see a problem starting and then determining the cause before it becomes a major problem.

9. **Filter liner**

An impervious liner is required to contain the filtrate and allow it to be collected for final dispersal. 30 mil PVC is often used for this purpose. Refer to MPCA synthetic liner guidance for design and construction requirements at:

High Density Polyethylene (HDPE) liners

http://www.pca.state.mn.us/publications/wq-wwtp5-32.pdf

Polyvinyl Chloride (PVC) liners

http://www.pca.state.mn.us/publications/wq-wwtp5-60.pdf

The liner must be watertight; this is defined as maintaining water for 24 hours with a loss of less than 1/16 inch. A 24 hour water balance must be performed on all liner installations. The water balance must be preformed after the underdrain pipe and underdrain media has been placed in the filter. The water level during the test must be above any liner penetrations in the underdrain system and above the underdrain media. The water balance may be performed once the filter is complete.

No field seams will be allowed. Geotextile fabric may be needed on top of liner, according to MPCA's synthetic liner guidance documents, to prevent the liner from being punctured, Geotextile fabric should only be used to protect the liner; use of fabric between layers of media must not be used because of exhibited high rates of failure due to fouling. Pipe penetrations must use a watertight boot connection; they must also be inspected at the time of installation. To ensure material compatibility, liner material must conform to MPCA synthetic liner recommendations. Additional requirements are found in the MPCA synthetic liner guidance.

The excavation sidewalls are often ½ inch to ¾ inch untreated plywood or Oriented Strand Board (OSB). The liner is lapped over the sidewalls at least 18 inches and the space between the excavation and OSB is typically backfilled with sand to stabilize the sidewall and secure the liner. A geotextile fabric should be placed over any exposed PVC to protect it from UV deterioration. A geotextile fabric should be placed between the liner and plywood to protect from damage. Nailing of plywood should only be done from the inside of the filter to the outside.

A geotextile fabric must be installed between the liner and the underdrain media: 1) if equipment will be driven on the filter during construction or 2) when there is concern of damaging the synthetic liner due to construction techniques or angular underdrain media. If the subgrade below the liner contains rock or stone greater than 3/8 inch in diameter, a geotextile fabric must also be placed under the synthetic liner to protect it.

An alternative to the PVC liner is a concrete tank. Concrete tanks must also be watertight and follow the requirements in Minn. R. ch. 7080.

F. Dosing pump controls

For systems serving up to 10,000 gallons per day, a relatively simple control system based on timers and floats should be sufficient. More sophisticated control systems can be applied, but the complexity will increase while the reliability may decrease. All sand filter systems must have event counters and run time meters to be able to monitor daily flows, or other similar devices to monitor wastewater flows.

In general, dosing cycles are initiated by timers based on the anticipated daily flow. High and low level floats provide overrides for when the flow rate is greater than or less than the anticipated flow. If the timed dosing cycles are not sufficient to keep up with the rate of influent, the water level in the pump tank will rise until the high level float is actuated. The high level float will initiate an additional dosing cycle or cause the control to simply switch to a shorter time off interval to help draw down the level in the pump tank. Once the level returns to normal, the control will resume operating at its normal setting.

A low level float can prevent the pumps from drawing the level down too far and running the pumps dry. The control panel shall be able to record low-and high-level events so that the service provider will know that the timer settings may need adjustment.

Initial timer settings based on the design flow of the system are done based on limiting the volume between the minimum pump out volume of four times the volume of distribution piping and the maximum pump out volume of 25 percent of the design flow. For single family homes, and other systems up to 2,500 gpd that are using perforation spacing such that the filter area covered by each perforation is greater than 4 ft^2 and less than 9 ft^2 (Minn. R. ch. 7080.2050, subp. 4. F and G), a minimum of 12 doses per day (based on design flow) is required. In order to maximize the number of doses per day and maintain the minimum dose volume (four times distribution network volume) either 1 inch or 1¼ inch distribution pipe is required to achieve proper dosing of effluent to the sand filter. For systems that use 4 ft^2 per perforation (required for flows between 2,500gpd and 10,000 gpd), a minimum of eight doses per day is required; this will provide for more frequent, short cycles, which have been demonstrated to provide a higher degree of treatment.

The following is one method for determining the number of pumps and dosing cycles per day; an alternative method is found in the design example using the University of Minnesota/MPCA worksheets.

The number of pumps that are required for each dose is based on the total flow to be pumped.

$$N_{pc} = \frac{Q_{SPSF}}{(1440 \text{ min/day} \times Q_{po})}$$

Where:

N_{pc} = Calculated number of pumps per dose

Q_{SPSF} = Total pumped flow, gpd

= Daily design flow, gpd

Q_{po} = Operating pump discharge rate, gpm

The calculated number of pumps N_{pc} is then rounded up to the nearest whole number to get the actual number of pumps N_{pa}. When more than one pump is required, it means that two or more pumps are activated at the initiation of each dosing cycle. A delay timer in the control circuit can be used so that both pumps do not start at exactly the same time, which would increase amp draw and wire-size requirements. The timing sequence is then calculated as follows:

$$T_{\%} = \frac{Q_{SPSF} \times 100\%}{(N_{pa} \times Q_{po} \times 1{,}440)}$$

Where:

$T_{\%}$	=	Daily Run Time, %
Q_{SPSF}	=	Total pumped flow, gpd
N_{pa}	=	Actual number of pumps per dose
Q_{po}	=	Operating pump discharge rate, gpm

The initial timer settings are then based on the time needed to dose a given volume per perforation per dose. Assuming an initial target dose volume of four times the distribution volume per dosing cycle, calculate the total volume the pumps must deliver based on the final layout of the filter.

$$T_d = \frac{V_d}{(N_{pa} \times Q_{po})}$$

Where:

T_d	=	Pump run time per dose, min
V_d	=	Volume of distribution piping, gal
N_{pa}	=	Actual number of pumps per dose
Q_{po}	=	Operating pump discharge rate, gpm

The initial timer settings, in minutes, are then determined by T_d and $T_{\%}$ as follows:

Total pump run time per dose = T_d

Total time per dosing cycle $T_c = T_d/T_{\%}$

Rest time per dose $T_r = T_c - T_d$

The total number of dosing cycles per day is then given by:

$$D_c = 1{,}440 \text{ min/day} \div T_c$$

Where:

D_c	=	Total dosing cycles per day
T_c	=	Total time per dosing cycle

This calculation determined the total number of pump starts for all pumps and all zones of the filter. To determine the actual number of doses each zone of the filter receives, divide the total number of doses per day by the number of active filter zones:

$$D_z = D_c \div F_z$$

Where:

D_z	=	Doses per zone of filter
D_c	=	Total dosing cycles per day
F_z	=	Number of filter zones

D_z indicates how well the filter is being wetted. Short, frequent doses have been shown to provide superior performance. The volume per dose should be adjusted to provide the most possible doses per day to all active areas of the filter, with at least four times the distribution volume pumped each dose. It may be necessary to reduce the pipe diameter and/or the perforation size of the distribution piping to meet these requirements.

The total number of pump starts should also be considered to ensure that there is not too much wear on the motor. Franklin Electric, a supplier of electric motors to the pump industry, recommends that each pump be limited to less than 300 starts per day. The number of pump starts per day for each pump can be calculated by:

$$PS = D_c \div F_c \div 2 \text{ pumps per cell}$$

Where:

PS	=	Pump Starts, each pump
D_c	=	Total dosing cycles per day
Fc	=	Number of filter cells

This equation assumes that redundant pumps are provided for each cell and that the pump control panel will automatically alternate the pumps.

G. Summary of design parameters

The following table provides a quick summary of design parameters for single pass sand filters for individual homes up to Mid-Sized Sewage Treatment Systems (MSTS) with design flows to 10,000 gpd.

System Size	Number of cells	Number of zones	Number of pumps	Ft^2 per perforation* (ft^2)	Head required at end lateral (ft)	Head used to calculate pump discharge capacity
Single family home	1	1	1	9	5	1 ft with ¼ inch to $^{3}/_{16}$ inch perforations 2 ft with 1/8 inch perforations
Other establishments and flow ≤ 2500gpd	1	2	2	9	5	2 ft with all perforations
Flow 2501 to 5000 gpd	1	3	2	4	5	5 ft with all perforations
Flow 5001 but ≤ 10,000 gpd	2	2 per cell	2 per cell	4	5	5 ft with all perforations

* Square foot requirements are for distribution laterals only. Two foot lateral spacing with two foot perforation spacing and one foot between lateral and edge of filter meets the 4 ft^2 requirement.

V. Design Example

Design example and use of University of Minnesota/MPCA Worksheets

This section will go through the preceding design process using numbers for a system with a flow rate of 2000 gpd. This example is a STEP (Septic Tank Effluent Pump) system without an effluent limit for total nitrogen.

A. SPSF filter

The Single Pass and Recirculating Sand Filter Worksheet should be completed as part of the design of a single pass sand filter system. This document can be used to provide additional information and guidance for the user completing the Single Pass and Recirculating Sand Filter Worksheet. The design flow of the system is found in Part 1 of the Design Summary Worksheet. This flow value should be entered in box A1. Check the box indicating the use of a single pass filter in Part A2.

Part B of the worksheet should only be completed for a recirculating sand filter. A recirculation tank is not required as part of this type of system.

The hydraulic loading rate must be specified for a single pass sand filter. The maximum hydraulic loading rate is 1 gpd/ft^2. The minimum required filter area can be determined using the hydraulic loading rate; this is the minimum required area for the sand filter and BOD_5 must be less than 170 mg/L. After the area is known, the appropriate length and width is determined. In this case, a filter width of 40 feet and a length of 50 feet are chosen for a total filter area of 2000 ft^2. The filter area will be zoned appropriately with a minimum of two zones per filter at the design flow of 2000 gpd. Two zones are used for the preliminary layout and pressure distribution calculations.

Drainage media must be selected in Part D. Drainage rock surrounding the collection pipe must meet the MPCA's Drainfield Rock Distribution Media Recommended Standards and Guidance Document, while the remainder can be drainfield rock distribution media or pea gravel. The pipe must be four inch PVC with ¼ inch wide slots spaced four inches apart with an inspection pipe. The filter bottom must be sloped at least one percent to the underdrain pipe. A minimum of two inches of pea gravel (less than 3/8 inch diameter) is required between the drainage rock and the sand filter treatment media. The depth of the drainage media is determined in Part D2 of the worksheet. A minimum of one foot of drainage media is required. After the depth of the drainage media is specified, the volume of drainage media needed can be calculated. The number of drainage pipes must also be determined. A minimum of one pipe per zone is required with a maximum spacing of 20 feet, so a minimum of four underdrain pipes (two per zone) are required for a zone width of 40 feet; additional underdrain pipes are recommended to provide for improved drainage, add air to the system and to help facilitate system recovery.

The type of treatment media is specified in Part E1 of the worksheet. For a single pass sand filter, two feet of sand treatment media is required. The total volume of sand media required is also calculated. The uniformity coefficient must be less than 4.0. The effective size of the sand media must be less than 1.0 mm. It is very important to ensure the treatment media sand is clean. If the sand contains too many fine particles, the treatment capacity and longevity of the system can be jeopardized.

The distribution media is described in Part F of the worksheet. A minimum of eight inches of distribution media is required. This media must be sized between ¾ inch and one inch diameter clean rock. The volume of distribution media is also calculated.

Single pass sand filters may be covered with suitable cover materials while recirculating sand filters must have distribution media to the surface. For single pass sand filters, suitable cover material may be installed with a maximum depth of 12 inches, along with appropriate vegetative cover. In this design example, no cover material is used to help with oxygen transfer.

In order to determine the amount of liner required, the total system height is calculated in Part H of the worksheet. The width and length of liner required is calculated. This calculation assumes that the filter is in the shape of a box with no slope on the sides. If the sides are sloped, more liner would be required.

B. Pressure distribution

The Pressure Distribution Design worksheet is used to determine the setup of the dispersal system. The bed width in Step 1 is the bed width of one **zone** (important to remember that this is per zone). The number of laterals **per zone** is selected in step 3. This value is found using a lateral spacing of three feet on center. The perforation spacing is three feet. This spacing requirement is used to ensure that each perforation doses 9 ft^2. The diameter of the perforations is entered in step 5. The minimum diameter is 1/8 inch and the maximum is ¼ inch. 1/8 inch diameter perforations are used in this example to keep the pump size to a minimum. Note that 1/8 inch diameter perforations require effluent screens to be sized smaller than 1/8 inch openings to prevent plugging of the perforations.

The length of the laterals should be two feet less than the length of the filter bed. This value is given for constructability purposes. Remember this worksheet is set up to calculate one zone at a time and that two zones were selected so the laterals must cover an area of 50 feet by 20 feet per zone (each zone should be the same size).

The number of perforations per lateral is found in steps 7 and 8. This value is then compared with the appropriate value found in Table 1. Use Table 1 along with the perforation diameter, pipe diameter and perforation spacing to find the maximum number of perforations per lateral to ensure less than a ten (10) percent discharge variation. The value in step 8 should be less than or equal to the value found in Table 1. The pipe diameter used in this example is 1.25 inch to ensure a larger number of doses per day.

Step 12 calculates the bed area per zone (50 ft x 20 ft). Note that this area is not the same as the total filter area (50 ft x40 ft). Step 12 finds the discharge coverage per perforation. This value should be less than or equal to 9 ft^2 per perforation. The minimum average head in step 13 is 5 feet for this system. This value is found under Table 3. The perforation discharge is found based on Table 3 with the appropriate head and perforation diameter.

The flow rate found in step 14 is used as the required flow for the Pump Selection Design Worksheet. If the system requires a large flow rate, return to lateral layout and select a configuration with smaller required flow rates. Two zones would require a pumping rate of 50 gpm. To reduce the size of the pump, the number of zones per cell can be increased to a maximum of six zones

The distribution manifold can be set up with either an end or center connection. The manifold pipe diameter should be greater than the lateral pipe diameter.

C. Pump size

The Pump Design Selection Worksheet is used to determine the required flow rate and associated head loss for the distribution system. Pressure distribution must be used for single pass sand filters. Part 2 of this worksheet calculates the required head pressure for the system. The elevation difference is the distance between the pump inlet and the highest of the distribution pipe; this is greatest possible elevation difference that can be created by the system. This value is the static head.

The head loss due to the distribution manifold is entered into Part 2 B. For pressure distribution, enter a value of ten feet. This number is used to ensure that there is at least five feet of head at the end of the distribution system, as required by Minn. R. ch. 7080.2100 Subpart 4, item C. Any additional head loss due to special equipment, etc. can also be accounted for in this section.

The distribution pipe diameter is entered in step 2 D. The minimum pipe diameter is 1.5 inches and the maximum is three inches. The head loss due to friction is calculated in step 2 G using Table 1. Table 1 calculates this loss using the Hazen Williams equation with a C value of 130 based on the use of PVC pipe and is shown for each 100 feet of PVC pipe.

The equivalent pipe length is used to account for losses in the system due to various fittings. A 25 percent increase in effective length has been found to be a good estimate of the friction losses rather than counting the individual pipe fitting throughout the system. Larger systems with many fittings may require detailed head loss determination due to number of fittings. The total head required for the pump is determined at the end of the worksheet.

A pump must be selected that delivers the correct flow rate given in step 1 and step 2, along with the required total head from step 2 - H. Due to reliability requirements, a minimum of two pumps is required. Pumps operate at many different points called a pump curve. This pump curve is found by plotting various flow rate versus required head. A pump will operate anywhere along the pump curve, but can only deliver a certain flow rate to match the corresponding head requirement.

D. Pump tank sizing and dosing

The pump tank is typically sized large enough to accommodate timed dosing of effluent with at least one day of storage volume. Tanks should be equipped with high and low level floats to over ride the timed dosing and protect the pumps. The control system should provide an auto dialer to alert the service provider of pump failure and to turn the second pump on when the high level float is actuated. Tanks prior to the sand filter must have an effluent screen to help minimize the plugging of perforations. Screen size should be less than the perforation size to prevent plugging.

The ideal dosing volume and frequency provides a thin layer of flow over the sand filter media while providing good oxygen transfer between dose events. To enhance treatment, a minimum of eight doses per day is required, with each dose volume having at least four times the distribution pipe volume. The dosing system in this design example must include an alternating two-pump system for each zone.

Tanks selected from the manufacture must have a 2000 gallon operating capacity between the inlet pipes to the pump off float. The dosing volume determination in this worksheet will be calculated for one zone so that the pumping volume will correlate with one pumping event. Step 4 determines the minimum pump out volume which is four times the distribution pipe volume and can be taken from line 17 of the pressure distribution worksheet since that was also calculated for one zone.

Step 6 provides the maximum pump out volume as required in Minn. R. ch. 7080.2100 Subp 4 D. This volume should be based on the design flow for one **zone** or 1000 gpd in this example. To do this on the automated worksheet, you need to go to the Design Summary page and reset the flow to the design flow divided by the number of zones (2000 gpd/2 zones). Step 7 is used to find the design dosing volume which will produce eight doses or more per day. The dosing volume must be between the minimum 105 gallons and the maximum 250 gallons found in steps 5 and 6. The design flow used in this step is the flow that will be pumped to one zone in one day. Picking a dosing volume of 105 gallon, which is between the minimum and maximum values, will provide 9.5 doses per day; this is greater than the required eight doses per day. The eight doses per day is a design parameter intended to create small dose volumes. In practice, the actual flow will be lower than the design flow resulting in fewer doses per day. The system must still be designed for eight doses or more per day and operated as near to eight doses per day as possible.

Setting the timer on this system will result in a run time of 2.2 minutes (called the on time) and an off time of 149 minutes for each zone as seen in steps A 14 and 15. This timer setting must be adjusted in the field as the actual pumping rate will vary from the design pumping rate of 50 gpm.

Minnesota Pollution Control Agency

OSTP Single-Pass & Recirculating Sand Filter Worksheet

University of Minnesota

A. GENERAL SPECIFICA

Project ID:

v 09.20.13

1. Design flow - *from Flow & Soil or LISTS Flow worksheet:* 2000

2. Type of filter *(check)*: ☒ Single-Pass ☐ Recirculating

B. MINIMUM RECIRCULATION/DOSING TANK CAPACITY *(if applicable)*

A minimum of 24 hours (1 day) of hydraulic retention time is required, but can be greater.

Minimum capacity is equal to the Design Flow (1) multiplied by 1.

2000 gpd X ____ day(s) = ____ Gallons

C. FILTER DIMENSIONS

1. Select hydraulic loading rate: 1.00 gpd/ft²

Maximum hydraulic loading rate for single-pass is 1.0 gpd/ft² and 5 gpd/ft² for recirculating.

2. Filter area based on hydraulic loading rate = flow rate (A1) / loading rate (C1):

2000 gpd / 1 gpd/ft² = 2000 ft²

3. Verify organic loading rate is acceptable

Page 1

a. Take design flow (A1) multiplied by estimated BOD_5 multiplied by conversion factor (0.00000834).

2000 gpd / 170 mg/l X 0.00000834 = 2.8356 lbs BOD

b. Divide lbs of BOD by square feet of filter (C2).

2.8356 lbs BOD ÷ 2000 ft² = 0.00142 lbs BOD/ft²

c. Organic loading rate must be less then 0.005 lbs BOD/ft². *Divide lbs of BOD (Line 3a) by 0.005 lbs/ft²*

2.836 lbs BOD ÷ 0.005 = 567 ft²

d. Required filter area is the larger of line C2 and 3c: 2000

4. Select width of filter: 40 ft

5. Length of filter = filter area (C3d) divided by filter width (C3) =

2000 ft² ÷ 40 ft = 50 ft

Number of Zones: 2

1 zone minimum for single family dwelling, minimum of two zones for anything else.

Notes: For filter design with multiple zones on the Pump worksheet at the Design Dose Volume Section change the flow to the design flow divided by the number of zones. The pressure distribution sheet included in design is for 1 zone.

D. DRAINAGE SYSTEM

1. Type(s) of Drainage Media: Drainfield rock & pea gravel

To protect the liner, 6 in. of 3/8- media must be installed under the liner and 2 in. of pea gravel on top of the liner. Drainfield rock must surround the collection pipe. The upper 2 in. must be pea gravel to limit migration of treatment media into drainage media.

2. (a) Total Depth of Drainage Media: 1 ft

Minimum depth is 1 foot with bottom sloped 1% to drainage pipe unless pump is part of filter drainage. Drainage material total should be 18" for pump vault and 12" for gravity drainage

(b) Depth of Pea Gravel: 2 in ÷ 12 = 0.2 ft

Upper 2" of drainage must be pea rock to support the treatment media

(c) Depth of Drainfield Roc 10 in ÷ 12 = 0.8 ft,

Drain field rock should cover the drainage piping.

3. Pea Gravel Volume: Multiply filter area (C2) by drainage depth (2b):

2000 ft^2 X 0.167 ft = 333.3 ft^3

Divide cubic feet by 27 ft^3/yd^3 to get cubic yards:

333.3 ft^3 ÷ 27 = 12.3 yd^3

4. Drainfield Rock Volume: Multiply filter area (C2) by drainage depth (2c):

2000 ft^2 X 0.8 ft = 1666.7 ft^3

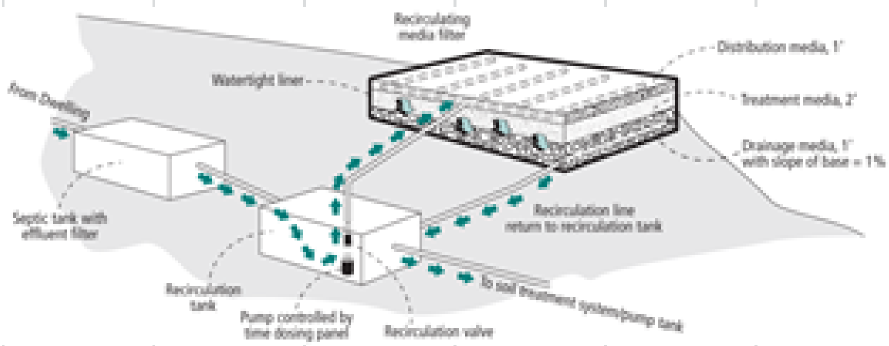
Divide cubic feet by 27 ft^3/yd^3 to get cubic yards (for sand and gravel only):

1666.7 ft^3 ÷ 27 = 61.7 yd^3

5. Number of Drainage Pipes: 2 *One drainage pipe per zone or every twenty feet is minimum; 5' on center is recommended to facilitate system recovery.*

6. Number of Inspection Port 2 *One inspection port per zone is minimum.*

Elevations of pump supply line to filter and return line to recirculation or pump tank should be specified on design plan and confirmed by Installer.



E. TREATMENT MEDIA

1. Type (sand, gravel, etc): **Sand**

2. Depth of Treatment Media: 2 ft *2 feet is required*

3. Treatment Media Volume: Multiply filter area(C2) by treatment depth (E2):

2000 ft² X 2 ft = 4000 ft³

Divide cubic feet by 27 ft³/yd³ to get cubic yards

4000 ft³ ÷ 27 = 148.1 yd³

F. DISTRIBUTION MEDIA

1. Type of Distribution Media: Drainfield rock

If other, please specify:

2. Depth of Distribution Media: 0.67 ft

Minimum depth is 0.67 feet (8 inches = 6 inches below the lateral and 2 inches above)

3. If using rock or gravel, media volume: Multiply filter area (C2) by distribution depth (F2):

2000 ft² X 0.67 ft = 1340 ft³

Divide cubic feet by 27 ft³/yd³ to get cubic yards

1340 ft³ ÷ 27 = 49.6 yd³

Treatment Media Specifications		
	Single-Pass Sand	Recirculating Sand
Effective Size (mm)	0.4 - 0.9	1.5 - 2.5
Uniformity Coefficient	2.5	2
Sieve Size/Number	% Passing	
3/8	100	100
No. 4	77 - 100	70 - 100
No. 8	53 - 100	5 - 78
No. 16	15 - 80	0 - 4
No. 30	3 - 50	
No. 50	0 - 3	
No. 100	0 - 3	
No. 200	0 - 3	0 - 3

G. COVER MATERIAL (if applicable)

Is the system covered with geotextile and soil *(check box)* ?

☐ No ☑ Yes-Depth: 1 ft

Single-pass sand filters may be covered with soil while recirculating sand filter must have distribution media to the surface. If soil cover installed, maximum depth of 12 inches of loamy or sandy material with upper six inches of topsoil borrow is required along with appropriate vegetation.

H. LINER

1. Total system height is sum of depth of drainage(D2), treatment(E2), distribution(F2) & cover(G):

1.0	ft +	2.0	ft +	0.7	ft +
1.0	ft =	4.7	ft		

Assumes vertical walls. If sloped additional liner will be needed.

2. Width of liner is equal to the design width (C4) plus the two times the total system height (H1) plus two additional feet for constructability:

40.0	ft + (	4.7	ft x 2) + 2 =	51.3	ft

3. Length of liner equals the design length (C5) plus two times the total system height (H1) of the filter plus two additional feet for constructability:

50.0	ft + (	4.7	ft x 2) + 2 =	61.3	ft

4. Liner size/area is then determined by multiplying the width(H2) and length (H3):

51.3	ft² X	61.3	ft =	3149.2	ft²

OSTP Pressure Distribution Design Worksheet

Minnesota Pollution Control Agency

University of Minnesota

Project ID: v 09.20.13

Width of one zone

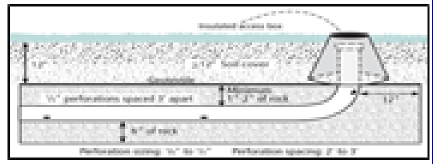
1. Media Bed Width: → 20 ft

2. Minimum Number of Laterals in system/zone = Rounded up number of [(Media Bed Width - 4) ÷ 3] + 1.

[(20 - 4) / 3] + 1 = 7 laterals *Does not apply to at-grades*

3. Designer Selected *Number of L* - 4) / 3] +1 = 7 laterals
Cannot be less than line 2 (accept in at-grades)

4. Select *Perforation Spacing* : 3.0 ft



5. Select *Perforation Diameter Size*: 1/8 in

6. *Length of Laterals* = Media Bed Length - 2 Feet.

50 - 2ft = 48 ft *Perforation can not be closer then 1 foot from edge.*

7. Determine the *Number of Perforation Spaces*. Divide the *Length of Laterals* by the *Perforation Spacing* and round down to the nearest whole number.

Number of Perforation Spaces = 48 ft ÷ 3 ft = 16 Spaces

8. *Number of Perforations per Lateral* is equal to 1.0 plus the *Number of Perforation Spaces*. Check table below to verify the number of perforations per lateral guarantees less than a 10% discharge variation. The value is double with a center manifold.

Perforations Per Lateral = 16 Spaces + 1 = 17 Perfs. Per Lateral

Maximum Number of Perforations Per Lateral to Guarantee <10% Discharge Variation											
1/4 Inch Perforations						7/32 Inch Perforations					
Perforation Spacing (Feet)	Pipe Diameter (Inches)					Perforation Spacing (Feet)	Pipe Diameter (Inches)				
	1	1¼	1½	2	3		1	1¼	1½	2	3
2	10	13	18	30	60	2	11	16	21	34	68
2½	8	12	16	28	54	2½	10	14	20	32	64
3	8	12	16	25	52	3	9	14	19	30	60
3/16 Inch Perforations						1/8 Inch Perforations					
Perforation Spacing (Feet)	Pipe Diameter (Inches)					Perforation Spacing (Feet)	Pipe Diameter (Inches)				
	1	1¼	1½	2	3		1	1¼	1½	2	3
2	12	18	26	46	87	2	21	33	44	74	149
2½	12	17	24	40	80	2½	20	30	41	69	135
3	12	16	22	37	75	3	20	29	38	64	128

9. *Total Number of Perforations* equals the *Number of Perforations per Lateral* multiplied by the *Number of Perforated Laterals*.

17 Perf. Per Lat. X 7 Number of Perf. Lat. = 119 Total Number of Perf.

10. Select *Type of Manifold Connection* (End or Center): ☐ End ☐ Center

11. *Select Lateral Diameter (See Table)* : 1.25 in

12. Calculate the *Square Feet per Perforation. Recommended value is 4-11 ft² per perforation.*

Does not apply to At-Grades

a. *Bed Area* = Bed Width (ft) X Bed Length (ft)

20 ft X 50 ft = 1000 ft²

b. *Square Foot per Perforation* = *Bed Area* divided by the *Total Number of Perforations*.

1000 ft² ÷ 119 perforations = 8.4 ft²/perforations

13. Select *Minimum Average Head*: 5.0 ft

14. Select *Perforation Discharge* (GPM) based on Table: 0.41 GPM per Perforation

15. Determine required *Flow Rate* by multiplying the *Total Number of Perfs.* by the *Perforation Discharge.*

119 Perfs X 0.41 GPM per Perforation = 50 GPM

16. *Volume of Liquid Per Foot of Distribution Piping (Table II)*: 0.078 Gallons/ft

17. *Volume of Distribution Piping* =

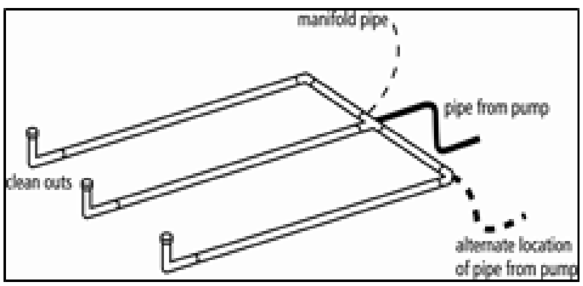
= [*Number of Perforated Laterals* X *Length of Laterals* X (Volume of Liquid Per Foot of Distribution Piping]

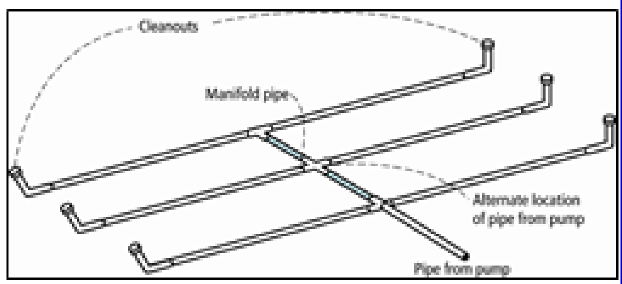
7 X 48 ft X 0.078 gal/ft = 26.2 Gallons

18. Minimum Delivered Volume = Volume of Distribution Piping X 4

26.2 gals X 4 = 104.8 Gallons

Table II Volume of Liquid in Pipe	
Pipe Diameter (inches)	Liquid Per Foot (Gallons)
1	0.045
1.25	0.078
1.5	0.110
2	0.170
3	0.380
4	0.661





Perforation Discharge (GPM)				
Head (ft)	Perforation Diameter			
	1/8	3/16	7/32	1/4
1.0[a]	0.18	0.41	0.56	0.74
1.5	0.22	0.51	0.69	0.9
2.0[b]	0.26	0.59	0.80	1.04
2.5	0.29	0.65	0.89	1.17
3.0	0.32	0.72	0.98	1.28
4.0	0.37	0.83	1.13	1.47
5.0[c]	0.41	0.93	1.26	1.65
1 foot	Dwellings with 3/16 inch to 1/4 inch perforations			
2 feet	Dwellings with 1/8 inch perforations			
	Other establishments and MSTS with 3/16 inch to 1/4 inch perforations			
5 feet	Other establishments and MSTS with 1/8 inch perforations			

Minnesota Pollution Control Agency

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OSTP Basic Pump Selection Design Worksheet

University of Minnesota

1. PUMP CAPACITY

Project ID: v 09.20.13

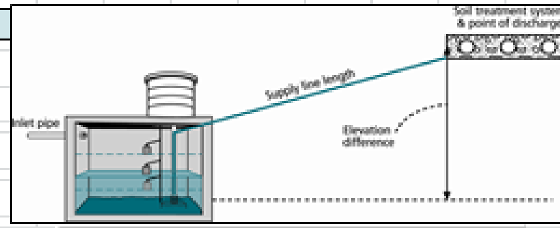
Pumping to Gravity or Pressure Distribution: ○ Gravity ● Pressure — Selection required

1. If pumping to gravity enter the gallon per minute of the pump: [ ] GPM *(10 - 45 gpm)*

2. If pumping to a pressurized distribution system: 50.0 GPM

3. Enter pump description: [ ]

2. HEAD REQUIREMENTS



A. Elevation Difference between pump and point of discharge: 10 ft

B. Distribution Head Loss: 10 ft

C. Additional Head Loss: [ ] ft (due to special equipment, etc.)

Distribution Head Loss	
Gravity Distribution = 0ft	
Pressure Distribution based on Minimum Average Head Value on Pressure Distribution Worksheet:	
Minimum Average Head	**Distribution Head Loss**
1ft	5ft
2ft	6ft
5ft	10ft

Table I. Friction Loss in Plastic Pipe per 100ft

Flow Rate (GPM)	Pipe Diameter (inches) 1	1.25	1.5	2
10	9.1	3.1	1.3	0.3
12	12.8	4.3	1.8	0.4
14	17.0	5.7	2.4	0.6
16	21.8	7.3	3.0	0.7
18		9.1	3.8	0.9
20		11.1	4.6	1.1
25		16.8	6.9	1.7
30		23.5	9.7	2.4
35			12.9	3.2
40			16.5	4.1
45			20.5	5.0
50				6.1
55				7.3
60				8.6
65				10.0
70				11.4
75				13.0
85				16.4
95				20.1

D. 1. Supply Pipe Diameter: 2.0 in

2. Supply Pipe Length: 30 ft

E. Friction Loss in Plastic Pipe per 100ft from Table I:

Friction Loss = 6.10 ft per 100ft of pipe

F. Determine *Equivalent Pipe Length* from pump discharge to soil dispersal area discharge point. Estimate by adding 25% to supply pipe length for fitting loss.
Supply Pipe Length (D.2) X 1.25 = *Equivalent Pipe Length*

30 ft X 1.25 = 37.5 ft

G. Calculate *Supply Friction Loss* by multiplying *Friction Loss Per 100ft* (Line E) by the *Equivalent Pipe Length* (Line F) and divide by 100.

Supply Friction Loss =

6.10 ft per 100ft X 37.5 ft ÷ 100 = 2.3 ft

H. *Total Head* requirement is the sum of the *Elevation Difference* (Line A), the Distribution Head Loss (Line B), Additional Head Loss (Line C), and the Supply Friction Loss (Line G)

10.0 ft + 10.0 ft + [ ] ft + 2.3 ft = 22.3 ft

3. PUMP SELECTION

A pump must be selected to deliver at least **50.0** GPM (Line 1 or Line 2) with at least **22.3** feet of total head.

OSTP Pump Tank Design Worksheet

Minnesota Pollution Control Agency

University of Minnesota

DETERMINE TANK CAPACITY AND DIMENSIONS	Project ID:	v 09.20.13

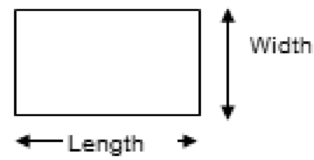
1. A. *Design Flow (Design Sum. IA)* : 2000 GPD

   B. Min. required pump tank capacity: 2000 Gal C. Recommended pump tank capacity: 2000 Gal

   D. Pump tank description:

2. A. Rectangle area = Length (L) X Width (W)

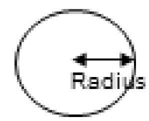
   12.0 ft X 5.5 ft = 66.0 ft^2



   B. Circle area = $3.14r^2$ (3.14 X radius X radius)

   3.14 X ____ ^{2} ft = ____ ft^2

   C. Calculate Gallons Per Inch. Multiply the area from 1.A or 1.B, by 7.5 to determine the gallons per foot the tank holds and divide by 12 to calculate the gallons per inch.



   66.0 ft^2 X 7.5 gal/ft^3 ÷ 12 in/ft = 41.3 Gallons per inch

   D. Calculate *Total Tank Volume*

   Depth from bottom of inlet pipe to tank bottom : 49 in

   Total Tank Volume = *Depth from bottom of inlet pipe* (Line 4.A) X *Gallons/Inch* (Line 2)

   49 in X 41.3 Gallons Per Inch = 2021.3 Gallons

MANUFACTURER'S SPECIFIED TANK CAPACITY (when available):

3. A. Tank Manufacturer:

   B. Tank Model:

   C. Capacity from manufacturer: ____ Gallons

   D. Gallons per inch from manufacturer: ____ Gallons per inch

   E. Liquid depth of tank from manufacturer: ____ inches

Note: Design calculations are based on this specific tank. Substituting a different tank model will change the pump float or timer settings. Contact designer if changes are necessary.

Warning – For Step 6 and the following sections, you need to go to the Design Summary tab and reset the design flow as:
Design flow / Number of zones
(for this example - 2000 gpd/2 zones = 1000 gpd)

DETERMINE DOSING VOLUME

4. Calculate *Volume to Cover Pump* (The inlet of the pump must be at least 4-inches from the bottom of the pump tank & 2 inches of water covering the pump is recommended)

(Pump and block height + 2 inches) X *Gallons Per Inch* (2C or 3E)

(14 in + 2 inches) X 41.3 Gallons Per Inch = 660 Gallons

5. *Minimum Delivered Volume* = 4 X Volume of Distribution Piping:

- *Line 17 of the Pressure Distribution or Line 11 of Non-level* 105 Gallons (minimum dose)

6. Calculate *Maximum Pumpout Volume* (25% of Design Flow)

Design Flow: 1000 GPD X 0.25 = 250 Gallons (maximum dose)

7. *Select a pumpout volume that meets both Minimum and Maximum:* 105 Gallons

8. Calculate *Doses Per Day* = Design Flow ÷ *Delivered Volume*

1000 gpd ÷ 105 gal = 9.5 *Doses*

9. Calculate Drainback:

A. *Diameter of Supply Pipe* = 2 inches

B. Length of Supply Pipe = 30 feet

C. *Volume of Liquid Per Lineal Foot of Pipe* = 0.170 Gallons/ft

D. *Drainback* = *Length of Supply Pipe* X *Volume of Liquid Per Lineal Foot of Pip*

30 ft X 0.170 gal/ft = 5.1 Gallons

10. *Total Dosing Volume* = *Delivered Volume* plus *Drainback*

105 gal + 5.1 gal = 110 Gallons

11. Minimum Alarm Volume = Depth of alarm (2 or 3 inches) X gallons per inch of tank

2 in X 41.3 gal/in = 82.5 Gallons

Volume of Liquid in Pipe

Pipe Diameter (inches)	Liquid Per Foot (Gallons)
1	0.045
1.25	0.078
1.5	0.110
2	0.170
3	0.380
4	0.661

TIMER or DEMAND FLOAT SETTINGS

Select Timer or Demand Dosing: ◉ Timer ○ Demand Dose

Page 2

A. Timer Settings

12. Required *Flow Rate* :

A. From Design (Line 12 of Pressure Distribution or Line 10 of Non-Level*): 50 GPM

B. Or calculated: GPM = Change in Depth (in) x Gallons Per Inch / Time Interval in Minutes

in X 41.3 gal/in ÷ min = GPM

**Note: This value must be adjusted after installation based on pump calibration.*

13. Flow Rate from Line 12.A or 12.B above. 50 GPM

14. Calculate **TIMER ON** setting:

Total Dosing Volume/GPM

110 gal ÷ 50.0 gpm = 2.2 Minutes ON

15. Calculate **TIMER OFF** setting:

Minutes Per Day (1440)/ *Doses Per Day* - Minutes On

1440 min ÷ 9.5 doses/day 2.2 min = 149.0 Minutes OFF

16. Pump Off Float - Measuring from bottom of tank:

Distance to set Pump Off Float=Gallons to Cover Pump / Gallons Per Inch:

660 gal ÷ 41.3 gal/in = 16.0 Inches

17. Alarm Float - Measuring from bottom of tank:

Distance to set Alarm Float = Tank Depth(4A) X 90% of Tank Depth

49 in X 0.90 = 44.1 in

Total Dosing Volume/GPM

110 gal ÷ 50.0 gpm = 2.2 Minutes ON

15. Calculate **TIMER OFF** setting:

Minutes Per Day (1440)/ *Doses Per Day* - Minutes On

1440 min ÷ 9.5 doses/day 2.2 min = 149.0 Minutes OFF

16. Pump Off Float - Measuring from bottom of tank:

Distance to set Pump Off Float=Gallons to Cover Pump / Gallons Per Inch:

660 gal ÷ 41.3 gal/in = 16.0 Inches

17. Alarm Float - Measuring from bottom of tank:

Distance to set Alarm Float = Tank Depth(4A) X 90% of Tank Depth

49 in X 0.90 = 44.1 in

B. DEMAND DOSE FLOAT SETTINGS

18. Calculate *Float Separation Distance* using *Dosing Volume* .

Total Dosing Volume / Gallons Per Inch

gal ÷ gal/in = Inches

19. Measuring from bottom of tank:

A. *Distance to set Pump Off Float* = Pump + block height + 2 inches

in + in = Inches

B. *Distance to set Pump On Float=Distance to Set Pump-Off Float + Float Separation Distance*

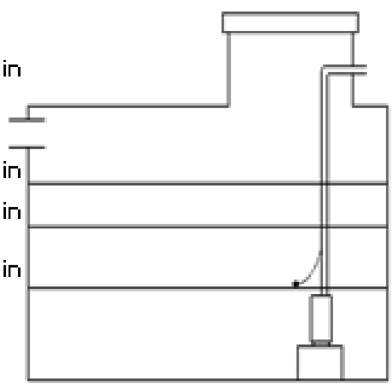
in + in = Inches

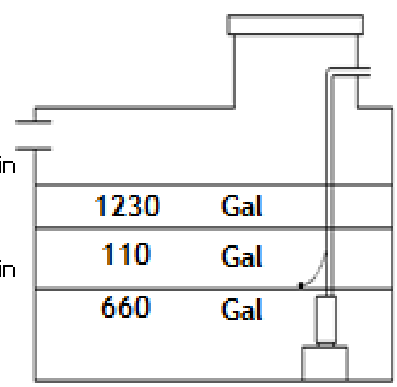
C. *Distance to set Alarm Float* = *Distance to set Pump-On Float* + *Alarm Depth* (2-3 inches)

in + in = Inches

FLOAT SETTINGS

DEMAND DOSING	TIMED DOSING
Inches for Dose ___ in Alarm Depth ___ in Pump On ___ in Pump Off ___ in	Alarm Depth 44.1 in Pump Off 16.0 in





The following is a summary of the design example presented in the worksheets:

Table 5-1

Design Summary of Example from Worksheets

Parameter	**Quantity**	**Unit**
Design Flow	2000	gpd
Effluent Screens		
a) Capacity, each	2000	gpd
b) No. of screens	1	screens
Dosing Tank	2000	gallons
Filter Size	2000	sf
Filter Dimensions		
c) Width	40	feet
d) Length	50	feet
Actual Loading Rate		
e) Hydraulic	1.0	gpd/sf
Doses	9.5	per day
No. of Filter Zones	2	zones
Total No. of Pumps	2	pumps
Pump Capacity, each	50	gpm
Perforated Lateral	7	per zone
f) Perforation diameter	1/8	inch
Zone size	50 x 20	feet
Dosing volume	105	gallons
Distribution pipe diameter	1.25	inches

VI. Cost Estimating

A. Capital costs

1. Capital cost estimating spreadsheet

A spreadsheet showing the major capital cost line items and unit costs that could be anticipated is shown in Table 6-1.

B. Annualized costs

1. Operations and maintenance cost estimating spreadsheet

A spreadsheet showing the major operations and maintenance cost line items and unit costs that could be anticipated are shown in Table 6-2.

2. Significant assumptions

a) Sludge removal

Solids removal every other year should be assumed, with an annual amount built into the budget equal to one-half the cost. Accumulation of sludge to one-day's average forward flow would be a conservative assumption.

Table 6-1
Single Pass Sand Filter Capital Cost Estimating Sheet

Item	Quantity	Units	Unit Cost	Total Cost
Land		acres		
Site work		cy		
Site electrical				
Flow meters		each		
Samplers		each		
Septic tanks		each		
SPSF system				
Earthwork		cy		
Filter Liner		sy		
Underdrain piping		lf		
Coarse filter media		cy		
Fine filter media		cy		
Distribution piping and valves		lot		
Pumps and controls		lot		
Control building (incl. Elec and HVAC)		sf		
Fencing		lf		
Yard piping		lf		
Electrical (ten percent)				
Contractor OH&P (20%)				
Subtotal				
Capital Contingencies (25%)				
Subtotal				
Engineering (20%)				
Legal and administrative (5%)				
Total estimated capital cost				

Table 6-2
Single Pass Sand Filter O&M Cost

Operation and maintenance costs	Quantity	Units	Unit cost	Annual cost
Labor		hours/yr		
Electric power		kWh		
Supplies		lot		
Maintenance and repair				
Laboratory testing				
Sludge disposal		gallons		
Annual O&M cost				

b) Power

Power costs will vary across the state. A current estimate of the cost per kilowatt-hour should be used to estimate annual power costs for the dosing pumps. Power cost for the dosing pumps can be done by multiplying the total number of pumps times the average running time, and converting horsepower into kilowatts as per the following formula:

$$\text{Annual Power Cost} = (N_p)(T_{\%})(24\text{ hours})(HP)(0.75)(\$/\text{kW-hr})(365)$$

Where:
- N_p = Number of pumps
- $T_{\%}$ = Percent daily run time
- HP = Horsepower of each pump

c) Maintenance

An annual set-aside for equipment replacement should be built into the budget. The amount set aside should be based on the original cost of the equipment, and prorated out over the expected design life of the equipment. The annual cost should also account for site maintenance such as grass mowing and snow removal.

d) Labor

The estimated cost for labor should be based on the total compensation for the operating staff, including any benefits, plus any administrative salaries for meetings, billing, etc. The estimated hours needed should consider the monitoring and sampling requirements of the particular facility, and include provisions for travel, periodic maintenance such as vegetation removal, flushing of laterals and regular pump maintenance.

e) Sampling and analysis

The cost for a facility's sampling and analysis program will vary from one facility to another based on the operating permit. The cost should be based on the total number of samples expected in a year, and include the cost of analysis by a certified laboratory, plus the costs of sample collection and delivery.

VII. Operation and Maintenance

A. Operational concerns

1. Filter saturation and ponding

The population of organisms within a single pass sand filter multiplies to balance the organic loading rate. When food is not coming in, the process of endogenous respiration takes over in which the organisms consume each other, a sort of "survival of the fittest" phenomenon. This process keeps the sand filter from building a large organic content of biological cells. If the system is too heavily loaded, biological cells and biodegradation byproducts accumulate, and the pores of the sand system may become filled with organic matter. This then begins to slow the flow through the sand filter and eventually can lead to a sand filter ponding on the surface. Therefore, it is necessary to balance the loading rate with the rate at which the organisms can decompose the applied material and keep the development of a large bacterial cell mass from accumulating.

Wastewater should not be evident at the surface of the sand filter. If a wet spot appears on the surface, it is indicating that the filter media is clogging and that ponding is occurring at that location. The sand filter cell should be examined by uncovering the laterals in several locations to see if some portions of the bed are not being dosed, resulting in localized over-application. If that is found to be the case, then the laterals need to be flushed. The filter cell may be rested for a week (or longer) to allow the biomat to further breakdown before putting the cell back into service.

2. Freezing

Wastewater that is kept moving is less likely to freeze. By using a coarse enough media filter (D_{10}= 0.4-0.9 mm), wastewater will percolate through the media fast enough to prevent freezing, even in Minnesota.

Freezing is a concern with fine or clogged media. In subfreezing ambient temperatures, ponded wastewater may cool to the point where freezing occurs. Once a filter surface freezes, it effectively prevents its use for treatment until it thaws. Allowing an entire bed to freeze would leave a homeowner or community without any secondary treatment.

3. Pumps and electrical

Pumping systems should be provided with a redundant pump to provide reliability. The dosing pumps must be able to meet the worst-case instantaneous flow rate requirement with one unit out of service. Pumps are generally controlled by timers, floats, or less commonly, pressure transducers. One of the following methods must be provided to prevent hydraulic overloading in the event of a power outage; 1) backup generator installed on site, 2) provisions to connect to a portable generator, or 3) at least a location for a licensed maintainer to pump out the tanks in emergencies.

4. Odors

a) Primary treatment units

Odors can originate in the septic tank, but are generally not detectable away from the tank. Adequate venting through the building vent pipes is typically effective; in special circumstances, carbon filters may be required in vent stacks placed on the tanks themselves.

b) Media bed

Odors in the sand filter media are uncommon and are an indicator that something is wrong. As an aerobic system, the products of metabolism are chiefly carbon dioxide and water, which are odorless. Odors are produced under anaerobic conditions and are an indicator that: 1) dissolved oxygen in the filter is being depleted and 2) that BOD and ammonia removals are likely being impacted.

B. Maintenance issues

1. Time required by a service provider

A single pass sand filter is typically operated and maintained by a single service provider, although a backup should be trained for when the primary service provider is unavailable. A management plan for single pass sand filters is contained in Appendix C; an operating permit example is shown in Appendix D.

Depending on the frequency of visits and sampling requirements, the average amount of time spent monitoring a single pass sand filter facility ranges from about two to seven hours per week. For larger facilities, daily visits might be needed while for single family homes, annual inspections are typically required. On non-sampling days, service providers report that the daily checkup should take about 15 minutes. On sampling days, one hour is typically needed to collect samples and prepare them for delivery to the lab. Additional time is required for periodic maintenance of equipment, and for maintenance of the sand filter itself, including an item like lateral cleaning.

For small facilities equipped with an alarm dialer, daily visits may not be necessary.

2. Sampling

The approving local unit of government will define monitoring requirements in the facility’s operating permit. Such monitoring can provide a benchmark level of performance for a system, allowing the service provider to observe trends in performance and address a potential issue before it progresses to failure of the system. The operating permit should identify a minimum recommended sampling protocol for single pass sand filter systems that will provide the service provider with sufficient information on the performance of the system.

An example of monitoring requirements that are specified in local operating permits for different flows might be as follows:

a) Systems serving up to 4 homes (< 1500 gpd)

Influent flow – Monthly recommended

Effluent Fecal Coliform Bacteria – Annual

b) Systems serving between 5 and 15 homes (> 1500 gpd and < 5000 gpd)

Influent flow – Every two weeks recommended

Effluent Fecal Coliform Bacteria – Twice per year

c) Systems serving more than 15 homes (> 5000 gpd and < 10,000 gpd)

Influent flow – Weekly recommended

Effluent Fecal Coliform Bacteria – Quarterly

Periodic sampling for BOD_5 and TSS may also be required by the local permitting authority. Additional operational field monitoring may include dissolved oxygen, odor, color, turbidity, temperature and pH.

3. **Septic tank effluent screen cleaning intervals**

   It is recommended that cleaning of the effluent screens be done more frequently than recommended by the manufacturer initially, until the service provider has a sense of how quickly the screens are prone to clogging. An initial cleaning interval of every one to six months is suggested, depending upon flow and usage. If excessive clogging is not occurring, the service provider can gradually begin to extend the screen cleaning interval. The service provider should look for signs of surcharging, such as a high waterline on the tank wall and debris on top of the screen and overflow pipes. Properly functioning high water alarms for effluent screens should provide sufficient safeguards to minimize system back-up, if the alarm is promptly attended to.

   Effluent screens are typically sprayed off using a high-pressure washer over the head end of the septic tank. Water for cleaning the effluent screen may be from a well, or from a sump pump drawing effluent from an effluent pump tank, if present. If water is not available on site, the service provider may place a spare cartridge into service and haul the dirty effluent screen off site for cleaning. If this is done, the effluent screen will likely retain some wastewater and the service provider will need a way to transport the screen in a manner that minimizes spillage. Examples include wrapping up the effluent screen in a plastic tarp or placing the screen in a leak proof bucket.

4. **Sludge removal**

   Solids accumulate in the septic tank(s), particularly in the first cell of a multi-chambered tank. A properly-sized septic tank will allow for solids to accumulate for up to a year or more. During this period, the sludge will compact and anaerobically digest. A service provider should monitor the level of sludge accumulation, typically every one to three years, using a core sampler or similar device. If excessive sludge accumulation does not appear to be a problem, the service provider can gradually extend the interval of sludge and scum measurements.

   Like the sludge layer, the scum layer that forms at the surface should also be monitored every one to three years. The bottom of the scum layer should not be allowed to get closer than three inches from the bottom of the outlet baffle or effluent screen housing or 25 percent of the tank's liquid capacity contains solids. In some cases, the thickness of the scum layer may be the factor that triggers tank cleanout. A MPCA licensed maintainer is required to properly remove the contents from sewage tanks (septic and pump tanks) when this monitoring indicates that sludge and scum removal is needed.

5. **Pumps and pump tank**

   Effluent in pump tanks should be relatively clear and free of solids. If large solids or debris are observed, it may be an indicator that the effluent screens are malfunctioning.

   The pumps should be observed to operate when called to do so by the control system. The pump run times should be checked and recorded to verify that all pumps are receiving approximately the same amount of run time. Disparities in run times will indicate a failure to alternate or failure of a pump to run when called. Such failures should be investigated and corrected.

   At least one spare pump shall be maintained in reserve in the event a pump needs to be removed for service for more than one day.

   Pump control floats in the pump tank should be suspended on an independent float mount, such as a "float tree" or rack for suspending floats on their cords in the tank. The method of mounting should make it easy to remove the floats for testing and adjustment without disturbing anything else in the tank. The floats should be kept free of debris or grease build-up and should be cleaned as needed.

6. **Distribution piping**

   If the system has a sequencing valve(s), it should be observed to be sequencing the dosing of each filter cell and zone. Using a shovel, the service provider should expose distribution laterals at various locations on the sand filter surface to verify that the area under the laterals is being wetted. If the sand media under the laterals is dry, it may indicate that clogging of the distribution lateral is likely occurring. Clogging is usually evident, first, at the most distant ends of the laterals, and indicates that the laterals need to be cleaned or flushed.

   A simple way to determine if lateral perforations are becoming clogged is to regularly measure the pressure head in the pipe network. This can be done by attaching a clear plastic tube to the end of a lateral and opening the flushing valve during a dosing cycle. The height (or head) of the water in feet above the lateral can be measured in the tube by holding the tube upright. The head should be the same as the design head and as measured when the system was put into service, typically around five feet. If the head is higher, it indicates perforation clogging. If it is lower, it suggests a leak or break in a distribution lateral or a symptom of pump wear.

Lateral flushing can be accomplished simply using the pumped flow to scour out the lines. With the pump running to a zone, remove the end cap or open the valve on each lateral sequentially, one at a time, to flush each line clean. This takes only a few seconds for each line. Wear rubber gloves and take care not to get effluent on yourself. If end caps are used instead of a valve, on each line, loosen all caps before starting the procedure. Surge the flow in each line by rapidly closing and reopening the valve or hold and remove the end cap over the end to stop and start the flow. This can help dislodge solids in the line or in slightly-clogged perforations. Take care to be sure any squirt does not come toward you.

If flushing is not sufficient to dislodge the clogging, a more vigorous method of cleaning is required. High pressure jetting can be done while the lateral is off-line by running the nozzle of a pressure washer up and down the length of each lateral two to three times. Alternatively, a bottle brush attached to the end of a sewer snake or electrician's fish tape can be used to ream solids out of the lateral.

7. **Sand filter media**

The service provider should look for any obvious signs of ponding in the sand filter. For laterals bedded under the media, look for any wetness on the surface, which would indicate localized fouling of the media. The inspection pipes should be observed for ponding. Inspection pipes penetrating to the surface of the sand media should not show ponded wastewater, except perhaps for a brief period after a dose. Where ponding remains for minutes after a dose, the dose volume may be too large or fouling of the media is starting to occur. If either of these conditions occurs, it is an early indication of media clogging, and the service provider should consider taking the filter cell off line and allow it to rest.

The service provider should also observe the biological activity in the sand filter. Look for black deposits. If present, this is an indication of anaerobic overload conditions. It may mean that the organic loading rate is too high. Sometimes black deposits may build during cold weather and dissipate when it warms up. As long as the blackness goes away seasonally, it should not be a major problem.

8. **Vegetation control**

Laterals buried in drainfield rock will not grow many weeds. All weed growth that does occur should be removed. Removal can be accomplished by lightly raking the surface media to dislodge the developing weed roots. If weeds are allowed to get well-started with significant roots into the stone, removal will require hand pulling, probably with follow-up work to prevent plants from getting reestablished from roots that do not come out with the initial attempt. Take care to keep stones arranged over the distribution lines to prevent any surface wetness. This will prevent most weeds from getting a start.

9. **Record keeping**

The service provider should keep a sheet for recording observations made on each visit. Items that should be recorded include:

a) Weather observation (temperature, precipitation)

b) Influent/effluent flow (if metered)

c) Total pump run time, each pump

d) Daily pump run time, each pump (calculated)

e) Total pump starts, each pump

f) Daily starts, each pump (calculated)

g) Cells and zones in service

h) Effluent dissolved oxygen, odor, color, turbidity, temperature and ph

i) Other observations and comments

10. **Site maintenance**

The site should be made secure from passersby and particularly from vehicular traffic, including all-terrain vehicles, which may be attracted to the large, level surface. For larger sand filter systems, woven wire or three-strand fence should be sufficient for this purpose. Locked gates should be used on community systems to allow restricted access. Consideration shall be given to systems that allow easy access for children or for systems that are close to residential houses where children play. For larger sand filter systems, fencing shall be sufficient to keep children out of such areas.

Grass on the berms surrounding the filter cell should be mowed regularly, and clipping should be collected or blown away from the filter surface.

VIII. Check Sheet

This section provides an overview of maintenance activities needed for single pass sand filter treatment systems. The following outline is intended to provide a ready reference to follow for each aspect of a maintenance visit. A link to an example of a field check sheet for keeping notes in the field is also provided.

An example of a service provider checklist, Form 7-1: Media Filters, is found at the following Web site:

http://septic.umn.edu/formsandsheets/bytype/index.htm#maintenance.

A. Control panel and pumps

1. **Start at the control panel**
2. **The control panel should be equipped with a pump run event counter and a total pump run time meter. Identify each. The run time meter will usually show hours, tenths and hundredths of hours. The pump run event counter is just a counter. You may want to label each for future reference if they are not labeled.**
3. **Record meter readings and determine total run time and the number of pump cycles counted since the meters were last read.**
4. **Does the system have a timer override float function?**
   a) If yes, determine the average run time per cycle [(total run time)/(number of cycles)] and compare with timer setting. If the run time per cycle is much longer than the timer setting implies, the system is running on float (demand) basis a significant amount. It may be necessary to shorten the off time to compensate for the fact that the timer setting is not providing enough total run time per day to keep up with the flow.
5. **Determine net pump run time each cycle**
   a) Best done by observation – with a helper
   b) Uncover pipe network near input end
   c) Have helper start pump
   d) With a stop watch, determine time to fill and pressurize
   e) Subtract this from run time per cycle (check actual run time being delivered by timer) to determine effective run time per cycle.
      i. To check actual run time, set timer to short off time
      ii. Stand at control panel and listen for pump to kick on
      iii. With stop watch, determine actual run time
      iv. Compare with timer setting as read off timer dial
      v. Repeat the above for three cycles to check repeatability and accuracy of time measurement
      vi. Use actual measured run time in calculations
   f) Effective run time per cycle is actual run time – time to fill and pressurize: $t_{eff} = t_{act} - t_{fill}$

B. Septic tank

1. **Check for leaks around tank seams, pipe penetrations and risers**
2. **Check scum and sludge in septic tank**
   a) Normal conditions may vary by type of wastewater input, time of inspection including seasonal effects, and location along the tank, from tank inlet to outlet.
   b) Scum on the top may be only floating clumps or may be a continuous mat, which is unusual.
   c) Scum thickness should not exceed a few inches. If scum is consistently more than a few inches in two to three observations, it is time to have the contents of the sewage tanks removed by a maintainer.
   d) Sludge is usually light and fluffy. Be very slow, deliberate and careful in making a measurement to avoid stirring up the sludge excessively.
   e) Sludge and scum volume should not exceed one-quarter of the tank depth anywhere in the tank.

C. Pump tank

1. **Pump tank water level should be between the high and low level floats**
   a) Tank leaks
   b) Recent heavy rain
   c) Groundwater infiltration

High raw wastewater inflow rate, short term

d) Pumps not set to run enough for the incoming flow

e) Flow to the filter is severely restricted

2. Pump tank contents

a) The pH throughout the tank should be near neutral (pH of 7)

b) The incoming sewage should be less than 1 mg/L dissolved oxygen

c) Temperature in the tank near the pumps should be greater than 40°F

D. Single pass sand filter

1. Check for weed growth, shrub and tree growth and excessive grass height

2. Check inspection pipes

a) Inspection pipes to the sand media surface

i. Inspection pipes penetrating to the surface of the sand media should not show ponded water, except a minimal amount toward the end of a dose cycle and possibly for less than a minute thereafter. This is especially true if the inspection pipe is near a perforation in the distribution pipe.

ii. If ponding remains visible on the sand media for several minutes after a dose, either the dose volume is too large (pumps running too long) or the surface of the sand media is becoming clogged and is in need of renovation.

b) Inspection pipes to the bottom of the filter

iii. A few inches of ponding at the bottom of the sand filter can occur, depending on the underdrain configuration. Up to four to eight inches of ponding may be present, especially right after a dose cycle. The ponding depth should be consistent, varying only due to dose timing, precipitation amounts and snow melt.

3. Check appearance of several perforations under the perforation shields

a) Removal of some stone around distribution pipes may be necessary

b) Remove perforation shields

c) Look for any clogging in the perforations. If perforations are pointed down, it may be necessary to use a mirror to get a good look them.

d) Look for black deposits. If present, this is an indication of anaerobic conditions.

e) Replace perforation shields and stone over distribution pipes.

4. Flush the distribution laterals

a) With the pump running to a zone, remove the end cap or open the valve on each lateral sequentially, one at a time, to flush each lateral clean. This should only take only a few seconds for each lateral. Wear rubber gloves and eye protection and take care not to get effluent on yourself on in your eyes. If end caps are used instead of a valve on each lateral, loosen all caps before starting the procedure.

b) Surge the flow in each lateral by rapidly closing and reopening the valve, or hold and remove the end cap over the end to stop and start the flow. This can help dislodge solids in the lateral or in slightly clogged perforations. Take care to be sure squirted effluent does not come toward you.

5. Check pressure in each zone after flushing

a) Use a clear stand pipe or piece of tubing on a support to check the pressure at the end of a lateral in each application pipe zone. The height to which the water rises in a tube is the head or pressure in the pipe, measured in feet of water. One psi of pressure is equivalent to 2.31 feet of water head.

b) Compare head measured with what is supposed to be in the system, when designed, and with the last measurement.

c) If the head increases more than a few inches, it is an indication that perforations are becoming plugged. If the head is approaching 20 percent more than it should be, the laterals must be cleaned to unplug the perforations.

d) If the head has decreased since the last check, it could be an indication of a leak in the network, a partial blockage in the pipe feeding the system or a problem with a pump.

e) Fluctuating pressure would be an indication that the flow to the suction side of the pump is limited. This condition could produce what is called pump cavitation, known to damage pumps and reduce their usefulness. If the pump is in a pump vault, the effluent screen ahead of the pump may be in need of cleaning or the effluent screen around the pump intake is clogged, if so equipped.

6. **Perforation cleaning procedures you may use:**
   a) Bottle brush on a snake
      i. Obtain a stiff bristle bottle brush that is just larger in outside diameter than the inside diameter of the laterals.
      ii. Securely fasten the brush to an electric wire pulling snake longer than the length of the laterals.
      iii. With the pump turned off, push the bottle brush through each lateral, moving it back and forth as you go.
      iv. Clogged perforations are most likely to be at the dead-end of the pipe where flow is lowest and where any solids in the pipe get pushed each time the pump turns on, so be most vigorous when the brush is near that end.
   b) High pressure jetting
      i. Obtain a high pressure jetter with a small hose and jetting nozzle that will fit inside the laterals.
      ii. With the pump off, run the jetter down each lateral two to three times.
   c) Apply suction to the laterals
      i. Make an attachment so that you can fasten a vacuum pump to one or more laterals at a time. A septic tank pumper truck works well for this if it has an adequately sized vacuum pump.
      ii. Close the valve at the pump leading to a distribution zone pipe network.
      iii. Build up a vacuum and quickly open the vacuum to the lateral (s). This will suck out materials that have entered a perforation. It may be necessary to cycle the vacuum on and off several times for each set of laterals to which it is attached.
7. **Recheck pressures as described above to ensure that perforations have been successfully cleaned. System pressure should be restored to the proper level.**
8. **Use the actual head on the system to determine the proper pump run time each cycle. The wastewater application through each perforation should be one to two gallons per dose.**

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Listing of Appendices

Appendix A
Known Limitations in System Use
---Items Not Permitted in Sand Filters---

Sand filters serving homes and commercial establishments need to be properly used and maintained by the system owner. The owner is responsible to ensure that their wastewater treatment system is properly functioning; their wastewater needs to be properly treated and dispersed into the environment.

To help ensure that owners are doing an adequate job in taking care of their system, the local unit of government will issue the owner an Operating Permit. This permit to operate the system is really not too different from a city's or sanitary district's responsibility to properly operate and maintain their treatment facility. An Operating Permit is required by the Minnesota Pollution Control Agency (MPCA); it is important that each treatment system be properly used and maintained to protect public health and the environment from pollutants contained in wastewater.

There are things the owner should **not** do to their sand filter treatment system; it is a biological treatment system that can't be abused or it will break.

- Do not use the wastewater system as a garbage can. Each wastewater system is designed to treat a certain quality and quantity of wastewater; that is, for residential systems, the wastewater from the home from flushing toilets, taking showers, washing clothes and dishing and preparing food in the kitchen.
- Do not flush unusual or high strength wastes into the system. This includes such things as:
  - photographic chemicals
  - excessive water softener backwash
  - cleaners, solvents, oils and other chemicals that kill bacteria
  - toilet bowl fresheners
  - oil and grease from the kitchen
- Do not allow excessive amounts of water to go into the system. This includes leaking toilets and faucets and overuse of water in your household. Divert gutters from any nearby structures away from the system. This extra water is really bad for a system – it can cause premature system failure. So, watch for leaking features in the home or other facilities; don't ignore leaks and fix them right away.
- Do not put things in the septic tank that are inert or decompose slowly. Such things as egg shells, coffee grounds, grease, disposable diapers, tampons, paper towels and kitty litter will not decompose. Use of a garbage disposal is not recommended; it can add large amounts of organic waste into your system.
- Do not use chemical or biological septic treatments; they can be harmful to the wastewater system. Additives do not improve the performance of your system. There are plenty of natural microorganisms that grow in the system well suited to do the job of breaking down and digesting nutrients in wastewater.
- Do not use the area for sledding, snowmobiling and ATV use since these will damage the system and contribute to freezing of the system. Don't feed the deer or pasture livestock over the system.
- Do not put off proper maintenance of the system. At least yearly maintenance is needed to keep the systems functioning properly, and includes such things as:
  - cleaning the effluent screen and flushing distribution laterals
  - checking pumps and controls
  - checking levels of solids in septic and pump tanks

An MPCA-licensed *Service Provider* will provide a valuable service in providing the needed maintenance for continued performance of the wastewater treatment system. For more information, go to MPCA's Web site at www.pca.state.mn.us/programs/ists/registration.html and to the University of Minnesota's Onsite Sewage Treatment Program Web site at http://septic.umn.edu.

Appendix B
Regulator Construction Checklist

When a local permitting authority is completing a construction inspection for a single pass sand filter, three (3) inspections are typically recommended to observe construction of the following items:

Inspection 1. Date:

Inspection Item	Acceptable	Action Needed or Notes
Filter site excavation, correct size, depth and slope		
Plywood properly installed (backfilled with sand)		
Quality of sand filter media, pea gravel and drain field rock		
Proper sub-base preparation for liner (sand leveling layer)		
Liner in place with underdrain piping and lower gravel layer (inspection pipes placed)		
Media placed on liner to prevent damage		
Liner and boot for underdrain pipe tested for watertightness		
Additional items to be inspected at the time of either the first or second inspection		
Sewage tanks watertight tested		
Septic/pump tank with pump, valves, alarm and floats all set		
Sand filter effluent pressure line to the soil dispersal system		

Inspection 2. Date:

Inspection Item	Acceptable	Action Needed or Notes
Sand filter filled with 24 inches approved sand, sand moist during placement; upper rock to pressure distribution network; inspection pipes		
Pressure distribution network assembled with holes drilled; orifice shields; flush valves and valve boxes		
Test adequacy of orifice squirt height and any leaks in pressure line from tank to sand filter		
As-built drawing with accurate measurements done on this inspection		

Inspection 3. Date:

Inspection Item	Acceptable	Action Needed or Notes
Sand filter soil cover placed and graded		
General backfill and grading of system, restoration of system		
Surface water properly diverted		
Electrician completed work; check timer settings; system operational		

Inspector Name ________________________________ **Inspector Signature**_________________________________

Appendix C
Management Plan

UNIVERSITY OF MINNESOTA

Single Pass Sand Filter
Fixed Film Treatment System
Flows ≤10,000 gpd and Domestic Strength Waste

This Management Plan identifies some of the basic requirements for proper operation and maintenance of the Single Pass Sand Filter (SPSF) wastewater treatment device for residential use. Refer to the Operation and Maintenance Manual for detailed instructions on the proper system operation and maintenance. Refer to your soil treatment system management plan (below or above-grade) for additional management requirements.

The Operation and Maintenance Manual was developed by the Minnesota Pollution Control Agency (MPCA) and can be found at the MPCA's Web site: http://www.pca.state.mn.us/programs/ists/productregistration.html.

SYSTEM COMPONENT	TASK	MINIMUM FREQUENCY	RESPONSIBLE PARTY
Single Pass Sand Filter **with Flows less than 10,000 gpd and Domestic Strength Wastewater**	Monitor alarm	On-going	User & Service Provider
	Monitor flow	Annually <1,500 gpd Bi-Annually >1,500 gpd <5,000 gpd Quarterly >5,000 gpd <10,000 gpd	Service Provider
	Check mechanical and electrical components		
	Verify flow splitting devices are performing accurately and adjust as needed		
	Check for excessive odor and verify proper ventilation		
	Check distribution system, flush and clean as needed		
	Check for biomat and ponding in filter		
	Perform operational field tests on influent/effluent quality including odor, color, turbidity, temperature and pH, as appropriate		
	Sample effluent as required in the local Operating Permit*	See Operating Permit and Table on following page	
	For seasonal use, follow MPCA guidelines	As required based on seasonal usage	

Items not permitted in SPSF in the MPCA's Recommend Standards and Guidance.

At the time of each service visit, Form 7-1: Media Filter should be completed. See www.onsiteconsortium.org/omspchecklists.html

Appendix C
Management Plan
(continued)

Sampling requirements may be specified in local operating permits. The protocol for collection of wastewater samples is specified in the MPCA's Recommend Standards and Guidance.

Minimum sampling frequencies:

Treatment Goal	Design Flow (gpd)	Parameter	Minimum Sampling Requirement*
A	≤ 1,500	Fecal coliform	Annually
A	> 1,500 – ≤ 5,000	Fecal coliform	Bi-annually
A	> 5,000 – ≤ 10,000	Fecal coliform	Quarterly

*These minimum sampling requirements assume a system that is operated year round. These values may be reduced if the system is not used year round or as system performance is documented.

Appendix D
Operating Permit Example

King County Environmental Services
123 King Street
King, MN 12345

Prepared 10/14/13

Wastewater Treatment and Dispersal Operating Permit

Operating Permit No. 14

Example Single Pass Sand Filter (with 24 inches sand filter media)
Treatment Level A
per MPCA Design Guidance for Single Pass Sand Filters

Facility Information

Permittee name: George Hamilton   Phone number: 218-852-9583

Mailing address: 9346 Sand Lake Road

City: King City   State: MN   Zip code: 12345

Property ID number (GPS location): PIN = 10693064

King County authorizes the Permittee to operate a wastewater treatment and dispersal system at the address named above in accordance with the requirements of this operating permit. The attached Management Plan is hereby incorporated as part of the requirements of this operating permit.

Issuance date: 09/28/09   Expiration date: 09/28/10

System type: Type IV   Treatment level: Level A

System design flow: 450 gpd   Residential/Commercial: Residential, 3 bedroom, Class I

System components: 1500 gal. septic tank, effluent screen, 500 gal. pump tank, pumps and controls, single pass sand filter w/ 24 inches sand, 500 gal. pump tank, 200 ft drainfield w/pressure distribution, 12 inch soil

Monitoring Requirements

Parameter	Effluent limits	Frequency	Location
Design flow (gpd)	450 gpd	Per Management Plan	Event counter and running time clock
Average flow (gpd)	270 gpd		
$CBOD_5$ (mg/L)	15 mg/L		Discharge from single pass sand filter
TSS (mg/L)	15 mg/L		Discharge from single pass sand filter
O&G (mg/L)	NA		
Fecal Coliform bacteria (#/100mL)	1,000 colony forming units/100 ml	Sample annually	Discharge from single pass sand filter
Total Nitrogen, Total Phosphorus (mg/L)	N/A		
Operational Field Tests: Temperature and Dissolved Oxygen		Per Management Plan	Treatment device
Ponding/Surfacing in soil treatment	Minimal trench ponding; no surfacing	Annually	Drainfield trenches

Maintenance Requirements

Maintenance requirements shall be performed as specified in the Management Plan as prepared by the system's Advanced Designer.

System component	Maintenance	Frequency
Septic tank, effluent screen	Pump septic tank and clean effluent screen as needed	Per Management Plan or Use
Pump tank and controls	Pump to remove solids and scum, check floats and controls	Per MPCA's Recommended Standards and Guidance Document for Single Pass Sand Filters, Management Plan or Use.
Single pass sand filter	Per MPCA Single Pass Sand Filter Guidance Document. Check squirt height, clean distribution network as needed. Maintain vegetative cover.	Per Management Plan or Use
Ponding/Surfacing in soil treatment	Check squirt height, clean distribution network as needed. Maintain cover.	Every 3 years, not less than Management Plan

Monitoring Protocol

Any sampling and laboratory testing procedures shall be performed in accordance with the proprietary treatment product's protocol, Standard Methods and at a Minnesota Department of Health approved laboratory. Results shall be submitted to the permitting authority at: King County Environmental Services, 123 King Street, King, MN 12345 no later than sixty (60) days prior to when the permit to operate the system expires.

Contingency Plan

In the event the wastewater treatment system does not meet required performance requirements as contained in this operating permit, the owner shall notify the local unit of government within 30 days of receiving non-compliant information. The owner is responsible to obtain the services of a Minnesota Pollution Control Agency (MPCA)-licensed Service Provider or other qualified practitioner to complete the required corrective measures.

Authorization

This permit is effective on the issuance date identified above. This permit and the authorization to treat and disperse wastewater shall expire in one year(s). The Permittee is not authorized to discharge after the above date of expiration. The Permittee shall submit monitoring information and forms as required by King County Environmental Services no later than sixty (60) days prior to the above date of expiration for operating permit renewal. This permit is not transferable.

The owner is required to obtain the services of a Minnesota Pollution Control Agency (MPCA) licensed 1) Service Provider to provide ongoing system operation, maintenance and monitoring and 2) Maintainer to pump the system's sewage tanks and components. The owner is responsible to provide the name of the Service Provider business prior to the issuance of this operating permit. The owner has secured the services of SSTS Services, Inc. as the Service Provider for this system (signed Service Provider contract attached).

I hereby certify with my signature as the Permittee that I understand the provisions of the wastewater treatment and dispersal system operating permit including maintenance and monitoring requirements. I agree to indemnify and hold King County harmless from all loss, damages, costs and charges that may be incurred by the use of this system. If I fail to comply with the provisions of this operation permit, I understand that penalties may be issued. If I sell this property during the life of the permit, I will inform the new owner(s) of the permit requirements and the need to renew the operating permit. The Service Provider is hereby authorized to provide the required monitoring data and routine maintenance service records to the local unit of government.

The Operating Permit is hereby granted to: George Hamilton

Permittee
(please print): George Hamilton

Title: Homeowner Date: 09/27/09

Signature: ______

Permitting Authority
(please print): Alice Johnson

Title: SSTS Inspector Date: 09/27/09

Signature: ______

Instructions for Completing an Operating Permit

The following instructions provide an explanation for local units of government to complete the operating permit template. This is intended to provide guidance to local units of governments (LGU) in developing operating permits for Type IV, Type V systems and MSTS, including both residential and commercial systems. Since the Management Plan is considered part of the operating permit, it needs to be attached to the operating permit. A signed contract, between the owner and Service Provider, should be attached to the operating permit to help ensure the owner has made the necessary arrangements to have the system maintained and monitored.

LGU Name, Department and Address – fill in the name, department and address of local unit of government at the top of the operating permit.

Wastewater Treatment and Dispersal Operating Permit No. – assign an operating permit number to be able to track the system over the years.

Permittee Name, Business Name, Telephone Number and Address – fill in the name, address and phone number of the owner. If this is a business, fill in the name of the business, too.

Property Id. Number (GPS Location) – these are simply identifiers used by local units of government in the event the property address changes over time.

Name of Local Unit of Government – fill in the name of the local unit of government. This authorizes the Permittee to operate the wastewater treatment system at the address named above, according to the operating permit, attached Management Plan and contract with the Service Provider.

Issuance Date – fill in the date the operating permit is issued. The operating permit should not be issued until all required information is submitted.

Expiration Date – fill in the date when this operating permit expires. The first time an operating permit is issued to an owner, it should be issued for one (1) year. This helps ensure the owner actually does the required maintenance and monitoring during the first year. If the owner complies, the operating permit can then be issued for a longer period of time as determined by the local unit of government (typically 3 to 5 years). However, if the owner does not comply the first year, the second operating permit could, again, be issued for a period of one (1) year.

System Type – fill in as Type IV system, Type V system or MSTS.

Treatment Level –specify Treatment Level A, A-2,B, B-2, C, TN or TP. Treatment Level A = Carbonaceous Biochemical Oxygen Demand, five day ($CBOD_5$) 15 milligrams per liter (mg/L), Total Suspended Solids (TSS) 15 mg/L, Fecal Coliform Bacteria 1000 per 100 milliliter (mL); Treatment Level A-2 = Carbonaceous Biochemical Oxygen Demand, five day ($CBOD_5$) 15 milligrams per liter (mg/L), Total Suspended Solids (TSS) 15 mg/L, Fecal Coliform Bacteria - no limit; Treatment Level B = $CBOD_5$ 25 mg/L, TSS 30 mg/L, Fecal Coliform Bacteria 10,000 per 100 mL; Treatment Level B-2 = $CBOD_5$ 25 mg/L, TSS 30 mg/L, Fecal Coliform Bacteria – no limit; Treatment Level C = $CBOD_5$ 125 mg/L, TSS 60 mg/L, Oil and Grease (O&G) = 25 mg/L, Fecal Coliform Bacteria – no limit; Total Nitrogen (TN) = 20 mg/L or actual value, or Total Phosphorus (TP) = 5 mg/L or actual value.

System Design Flow – fill in the design flow specified on the construction permit for the system, along with the projected average daily flow for the system. Average daily flow is generally 60 to 70 percent of design flow.

Residential/Commercial – specify if the system is residential or commercial. You may specify additional information, such as classification of dwelling, number of bedrooms; or type of commercial establishment.

System Components – provide a brief description of the system components. An example would be the following: 600 gallon trash tank, 600 gallon Brand X proprietary treatment device, 1 Brand Y Ultra Violet (UV) light disinfection unit, 500-gallon pump tank, pump, floats and controls and 250-foot shallow trenches using pressure distribution.

Monitoring Requirements (Table)

The monitoring requirements specified in an operating permit are unique to the site and soil conditions of the property (its environmental sensitivity) and system complexity. The monitoring requirements include specific parameters to be monitored, target limits and the frequency and location of monitoring. The monitored parameters, at a minimum, would include: 1) wastewater flow - the most basic parameter to know in understanding system performance, 2) ponding in the soil treatment system and 3) surfacing of the soil treatment system. Monitoring for $CBOD_5$, TSS, fecal coliform bacteria and nitrogen are unique to the site, its receiving environment and complexity of the wastewater system. Field tests for temperature, pH and dissolved oxygen can be performed by the Service Provider to serve as general indicators of system performance.

1. **Flow** – flow to each system needs to be determined as specified in the Management Plan or as determined by the local unit of government. Flow can be determined several ways, using water meters, event counters and running time clocks. Telemetry can also be used and has the advantage that flow can be determined continually.

   The determination for the frequency of flow measurement is done on a case-by-case basis. At first, daily flow monitoring may be needed to determine average flow and peak flows to a system. After a period of time, weekly or monthly flow determination may be acceptable. Flow determinations once a year generally provide limited information.

2. **$CBOD_5$** – monitoring for $CBOD_5$ is not typically required for the majority of wastewater systems used for single-family homes generating typical domestic strength effluent. However, monitoring for $CBOD_5$ may be needed periodically. For example, there may be a need to audit systems as part of the product registration process in Minnesota or if the Service Provider is trying to troubleshoot a system. For commercial systems, monitoring for $CBOD_5$ is generally necessary to determine $CBOD_5$ removal efficiencies of proprietary treatment devices and/or organic loading rates to the soil's infiltrative surface.
3. **TSS** – monitoring for TSS is not typically required for most residential wastewater systems that generate typical domestic strength effluent. However, turbidity measurements may be taken in the field by Service Providers. Monitoring for TSS may be needed periodically as part of an audit process for the registration of proprietary treatment products in Minnesota. For commercial systems, monitoring for TSS may be necessary.
4. **O&G** – monitoring for O&G is not typically required for most residential wastewater systems; however, it is an important parameter to monitor for facilities that have food preparation and service and for residences that generate high strength wastewater.
5. **Fecal Coliform Bacteria** – monitoring for fecal coliform bacteria should generally be required for systems listed as Treatment Level A and Treatment Level B systems where reduced vertical soil separation is used.
6. **Total Nitrogen and Total Phosphorus** – monitoring for Total Nitrogen (TN) may be needed in areas identified as nitrogen sensitive environments. Monitoring for Total Phosphorus (TP) may be required in phosphorus sensitive lake environments.
7. **Operational Field Tests** – these are tests performed by the Service Provider to help 'monitor' system performance and identify problems (troubleshooting a system). Although field tests are not a strict monitoring requirement, they are appropriate to list in the operating permit if specified in the Management Plan or in the product's Operation and Maintenance Manual. The local unit of government will determine if the permittee is required to report field test results as part of the operating permit.
8. **Ponding/Surfacing in Soil Treatment** – all systems should be monitored periodically as specified in the Management Plan to determine extent and frequency of ponding in soil treatment systems. A check for surfacing is needed.

Maintenance Requirements (Table)
This table lists some of the basic maintenance requirements for each major component of the wastewater system. Since you can't possibly list all the maintenance requirements in this table, it is best to reference the Management Plan. You could reference the proprietary products Operation and Maintenance Manual.

1. **System Component** – list each system component, including the external grease interceptor, septic tank, trash tank, surge tank, effluent screen, pump tank and controls, proprietary treatment product, disinfection device and soil treatment and dispersal system.
2. **Maintenance** – briefly identify the maintenance requirements of each major system component. For additional information, you could also reference the proprietary product documents listed on the MPCA Web site at www.pca.state.mn.us/programs/ists/productregistration.html.
3. **Frequency** – briefly identify the frequency of maintenance as per the systems Management Plan and Operation and Maintenance Manual.

Monitoring Protocol – this section of the operating permit states that testing needs to be performed in accordance with approved methods and the results submitted to the 1) local unit of government and 2) manufacturer within a specified time frame. Fill in the name and address of both entities in the spaces provided.

Contingency Plan – briefly describes requirements if the system does not function as intended. The owner must notify the local unit of government when they receive non-compliant information. The Management Plan may identify some of the corrective actions required or you will need to consult your Service Provider. The owner is responsible to obtain the services of a MPCA-licensed Service Provider or other qualified practitioner to complete the required corrective measures. More detail could be added here by the local unit of government.

Authorization – fill in the length of time of the operating permit; this is typically one to five years. Fill in the name of the local unit of government in the second blank space. Note that this permit is not transferable.

Next, fill in the name of treatment product's manufacture; the manufacturer is required to train practitioners in servicing the registered treatment device(s). Fill in the name of the Service Provider in the next space; the owner is required to identify who the MPCA licensed Service Provider will be (in a contract). This is needed to ensure the owner has made the necessary arrangements to have the system maintained and monitored. Note: for systems generating high strength wastewater, the following should be added to the operating permit: "If there is a change of use within the facility (i.e. change in menu, increase in food capacity, change in water use fixtures, etc.), the permittee is required to notify the local unit of government (and Service Provider) before the change(s) occurs." Changes to the facility that could potentially impact performance of the wastewater treatment and dispersal system shall not take place until appropriate evaluation has been completed.

In the final paragraph, fill in the name of the local unit of government. Note: the Service Provider is authorized to provide monitoring data and routine maintenance service records directly to the local unit of government and to the manufacturer of the proprietary treatment product.

The Operating Permits Hereby Granted to – print the name of the owner who signed the operating permit.

Signature of Permittee (and date of signature) – the owner signs and dates the operating permit.

By Order of – signature of the permitting authority, title and date.

Appendix E
Single Pass and Recirculating Sand Filter Worksheet

Minnesota Pollution Control Agency

OSTP Single-Pass & Recirculating Sand Filter Worksheet

University of Minnesota

A. GENERAL SPECIFICA Project ID: v 09.20.13

1. Design flow - *from Flow & Soil or LISTS Flow worksheet:* ______

2. Type of filter *(check)*: ☐ Single-Pass ☐ Recirculating

B. MINIMUM RECIRCULATION/DOSING TANK CAPACITY ***(if applicable)***

A minimum of 24 hours (1 day) of hydraulic retention time is required, but can be greater.

Minimum capacity is equal to the Design Flow (1) multiplied by 1.

______ gpd X ______ day(s) = ______ Gallons

C. FILTER DIMENSIONS

1. Select hydraulic loading rate: ______ gpd/ft²

Maximum hydraulic loading rate for single-pass is 1.0 gpd/ft² and 5 gpd/ft² for recirculating.

2. Filter area based on hydraulic loading rate = flow rate (A1) / loading rate (C1):

______ gpd / ______ gpd/ft² = ______ ft²

3. Verify organic loading rate is acceptable

a. Take design flow (A1) multiplied by estimated BOD_5 multiplied by conversion factor (0.00000834).

______ gpd / ______ mg/l X 0.00000834 = ______ lbs BOD

b. Divide lbs of BOD by square feet of filter (C2).

______ lbs BOD ÷ ______ ft² = ______ lbs BOD/ft²

c. Organic loading rate must be less then 0.005 lbs BOD/ft². *Divide lbs of BOD (Line 3a) by 0.005 lbs/ft²*

______ lbs BOD ÷ 0.005 = ______ ft²

d. Required filter area is the larger of line C2 and 3c: ______

4. Select width of filter: ______ ft

5. Length of filter = filter area (C3d) divided by filter width (C3) =

______ ft² ÷ ______ ft = ______ ft

Number of Zones: ______

1 zone minimum for single family dwelling, minimum of two zones for anything else.

Notes: For filter design with multiple zones on the Pump worksheet at the Design Dose Volume Section change the flow to the design flow divided by the number of zones. The pressure distribution sheet included in design is for 1 zone.

included in design is for 1 zone.

D. DRAINAGE SYSTEM

1. Type(s) of Drainage Media: ______

To protect the liner, 6 in. of 3/8- media must be installed under the liner and 2 in. of pea gravel on top of the liner. Drainfield rock must surround the collection pipe. The upper 2 in. must be pea gravel to limit migration of treatment media into drainage media.

2. (a) Total Depth of Drainage Media: ______ ft

Minimum depth is 1 foot with bottom sloped 1% to drainage pipe unless pump is part of filter drainage. Drainage material total should be 18" for pump vault and 12" for gravity drainage

(b) Depth of Pea Gravel: ______ in ÷ 12 = ______ ft

Upper 2" of drainage must be pea rock to support the treatment media

(c) Depth of Drainfield Rock: ______ in ÷ 12 = ______ ft,

Drain field rock should cover the drainage piping.

3. Pea Gravel Volume: Multiply filter area (C2) by drainage depth (2b):

______ ft^2 X ______ ft = ______ ft^3

Divide cubic feet by 27 ft^3/yd^3 to get cubic yards:

______ ft^3 ÷ 27 = ______ yd^3

4. Drainfield Rock Volume: Multiply filter area (C2) by drainage depth (2c):

______ ft^2 X ______ ft = ______ ft^3

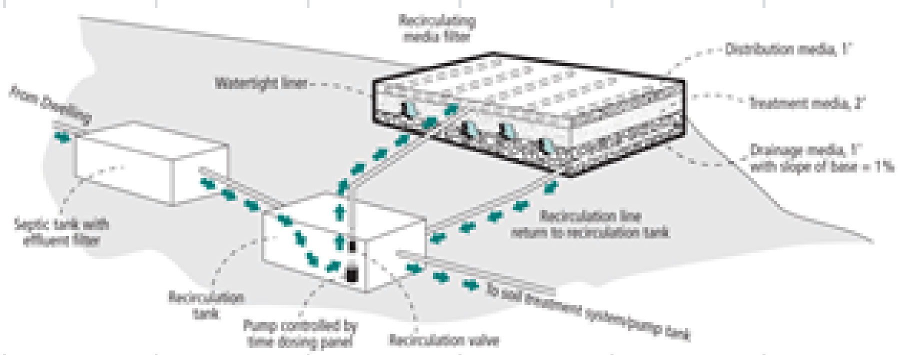
Divide cubic feet by 27 ft^3/yd^3 to get cubic yards (for sand and gravel only):

______ ft^3 ÷ 27 = ______ yd^3

5. Number of Drainage Pipes: ______ *One drainage pipe per zone or every twenty feet is minimum, 5' on center is recommended to facilitate system recovery.*

6. Number of Inspection Ports: ______ *One inspection port per zone is minimum.*

Elevations of pump supply line to filter and return line to recirculation or pump tank should be specified on design plan and confirmed by Installer.



E. TREATMENT MEDIA

1. Type (sand, gravel, etc): ______

2. Depth of Treatment Media: ______ ft   *2 feet is required*

3. Treatment Media Volume: Multiply filter area(C2) by treatment depth (E2):

______ ft^2 X ______ ft = ______ ft^3

Divide cubic feet by 27 ft^3/yd^3 to get cubic yards

______ ft^3 ÷ 27 = ______ yd^3

F. DISTRIBUTION MEDIA

1. Type of Distribution Media: ______

If other, please specify: ______

2. Depth of Distribution Media: ______ ft

Minimum depth is 0.67 feet (8 inches = 6 inches below the lateral and 2 inches above)

3. If using rock or gravel, media volume: Multiply filter area (C2) by distribution depth (F2):

______ ft^2 X ______ ft = ______ ft^3

Divide cubic feet by 27 ft^3/yd^3 to get cubic yards

______ ft^3 ÷ 27 = ______ yd^3

Treatment Media Specifications		
	Single-Pass Sand	Recirculating Sand
Effective Size (mm)	0.4 - 0.9	1.5 - 2.5
Uniformity Coefficient	2.5	2
Sieve Size/Number	% Passing	
3/8	100	100
No. 4	77 - 100	70 - 100
No. 8	53 - 100	5 - 78
No. 16	15 - 80	0 - 4
No. 30	3 - 50	
No. 50	0 - 3	
No. 100	0 - 3	
No. 200	0 - 3	0 - 3

G. COVER MATERIAL (if applicable)

Is the system covered with geotextile and soil *(check box)* ?

☐ No   ☐ Yes-Depth: ______ ft

Single-pass sand filters may be covered with soil while recirculating sand filter must have distribution media to the surface. If soil cover installed, maximum depth of 12 inches of loamy or sandy material with upper six inches of topsoil borrow is required along with appropriate vegetation.

H. LINER

1. Total system height is sum of depth of drainage(D2), treatment(E2), distribution(F2) & cover(G):

	ft +		ft +		ft +	*Assumes vertical walls. If sloped additional liner will be needed.*
	ft =		ft			

2. Width of liner is equal to the design width (C4) plus the two times the total system height (H1) plus two additional feet for constructability:

	ft + (		ft x 2) + 2 =		ft

3. Length of liner equals the design length (C5) plus two times the total system height (H1) of the filter plus two additional feet for constructability:

	ft + (		ft x 2) + 2 =		ft

4. Liner size/area is then determined by multiplying the width(H2) and length (H3):

	ft^2 X		ft =		ft^2

Minnesota Pollution Control Agency

OSTP Pressure Distribution Design Worksheet

University of Minnesota

Project ID: v 09.20.13

1. Media Bed Width: [Width of one zone →] ____ ft

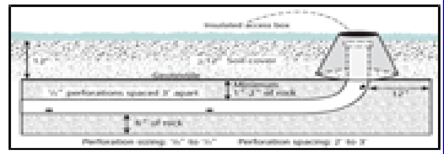
2. Minimum Number of Laterals in system/zone = Rounded up number of [(Media Bed Width – 4) ÷ 3] + 1.

   [(____ - 4) / 3] + 1 = ____ laterals *Does not apply to at-grades*

3. Designer Selected *Number of Laterals* : ____ laterals
   Cannot be less than line 2 (accept in at-grades)

4. Select *Perforation Spacing* : ____ ft

5. Select *Perforation Diameter Size:* ____ in



6. *Length of Laterals* = Media Bed Length - 2 Feet.

   ____ - 2ft = ____ ft *Perforation can not be closer then 1 foot from edge.*

7. Determine the *Number of Perforation Spaces* . Divide the *Length of Laterals* by the *Perforation Spacing* and round down to the nearest whole number.

   Number of Perforation Spaces = ____ ft ÷ ____ ft = ____ Spaces

8. *Number of Perforations per Lateral* is equal to 1.0 plus the *Number of Perforation Spaces* . Check table below to verify the number of perforations per lateral guarantees less than a 10% discharge variation. The value is double with a center manifold.

   Perforations Per Lateral = ____ Spaces + 1 = ____ Perfs. Per Lateral

Maximum Number of Perforations Per Lateral to Guarantee <10% Discharge Variation

¼ Inch Perforations						7/32 Inch Perforations					
Perforation Spacing (Feet)	Pipe Diameter (Inches)					Perforation Spacing (Feet)	Pipe Diameter (Inches)				
	1	1¼	1½	2	3		1	1¼	1½	2	3
2	10	13	18	30	60	2	11	16	21	34	68
2½	8	12	16	28	54	2½	10	14	20	32	64
3	8	12	16	25	52	3	9	14	19	30	60
3/16 Inch Perforations						**1/8 Inch Perforations**					
Perforation Spacing (Feet)	Pipe Diameter (Inches)					Perforation Spacing (Feet)	Pipe Diameter (Inches)				
	1	1¼	1½	2	3		1	1¼	1½	2	3
2	12	18	26	46	87	2	21	33	44	74	149
2½	12	17	24	40	80	2½	20	30	41	69	135
3	12	16	22	37	75	3	20	29	38	64	128

9. *Total Number of Perforations* equals the *Number of Perforations per Lateral* multiplied by the *Number of Perforated Laterals.*

   ____ Perf. Per Lat. X ____ Number of Perf. Lat. = ____ Total Number of Perf.

10. Select *Type of Manifold Connection* (End or Center): ☐ End ☐ Center

11. *Select Lateral Diameter (See Table)* : ____ in

12. Calculate the *Square Feet per Perforation*. *Recommended value is 4-11ft² per perforation.*

Does not apply to At-Grades

a. *Bed Area* = Bed Width (ft) X Bed Length (ft)

[ ] ft X [ ] ft = [ ] ft²

b. *Square Foot per Perforation* = *Bed Area* divided by the *Total Number of Perforations* .

[ ] ft² ÷ [ ] perforations = [ ] ft²/perforations

13. Select *Minimum Average Head* : [ ] ft

14. Select *Perforation Discharge* (GPM) based on Table: [ ] GPM per Perforation

15. Determine required *Flow Rate* by multiplying the *Total Number of Perfs.* by the *Perforation Discharge.*

[ ] Perfs X [ ] GPM per Perforation = [ ] GPM

16. *Volume of Liquid Per Foot of Distribution Piping (Table II)* : [ ] Gallons/ft

17. *Volume of Distribution Piping* =

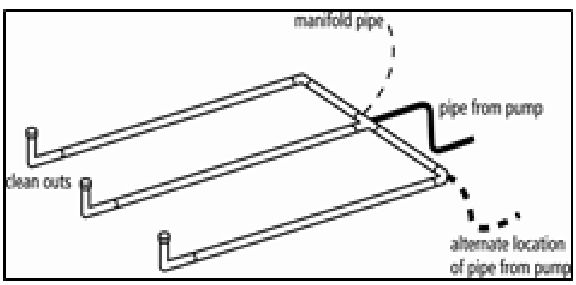
= [*Number of Perforated Laterals* X *Length of Laterals* X (Volume of Liquid Per Foot of Distribution Piping]

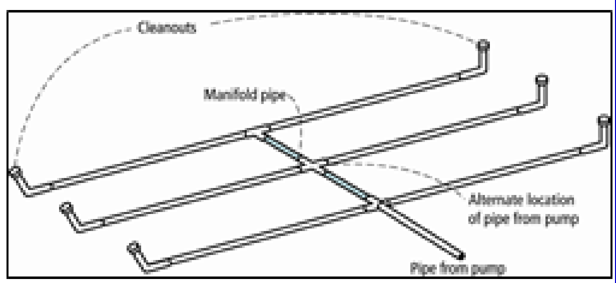
[ ] X [ ] ft X [ ] gal/ft = [ ] Gallons

18. Minimum Delivered Volume = Volume of Distribution Piping X 4

[ ] gals X 4 = [ ] Gallons

Table II Volume of Liquid in Pipe	
Pipe Diameter (inches)	Liquid Per Foot (Gallons)
1	0.045
1.25	0.078
1.5	0.110
2	0.170
3	0.380
4	0.661





Perforation Discharge (GPM)				
Head (ft)	Perforation Diameter			
	1/8	3/16	7/32	1/4
1.0[a]	0.18	0.41	0.56	0.74
1.5	0.22	0.51	0.69	0.9
2.0[b]	0.26	0.59	0.80	1.04
2.5	0.29	0.65	0.89	1.17
3.0	0.32	0.72	0.98	1.28
4.0	0.37	0.83	1.13	1.47
5.0[c]	0.41	0.93	1.26	1.65
1 foot	Dwellings with 3/16 inch to 1/4 inch perforations			
2 feet	Dwellings with 1/8 inch perforations			
	Other establishments and MSTS with 3/16 inch to 1/4 inch perforations			
5 feet	Other establishments and MSTS with 1/8 inch perforations			

Appendix G
Pump Selection Design Worksheet

OSTP Basic Pump Selection Design Worksheet

Minnesota Pollution Control Agency — University of Minnesota

1. PUMP CAPACITY

Project ID: v 09.20.13

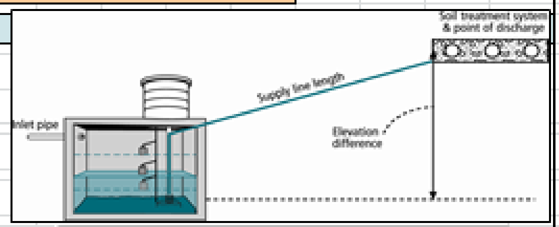
Pumping to Gravity or Pressure Distribution: ○ Gravity ● Pressure — Selection required

1. If pumping to gravity enter the gallon per minute of the pump: ______ GPM *(10 - 45 gpm)*

2. If pumping to a pressurized distribution system: ______ GPM

3. Enter pump description: ______

2. HEAD REQUIREMENTS



A. Elevation Difference between pump and point of discharge: ______ ft

B. Distribution Head Loss: ______ ft

C. Additional Head Loss: ______ ft (due to special equipment, etc.)

Distribution Head Loss	
Gravity Distribution = 0ft	
Pressure Distribution based on Minimum Average Head Value on Pressure Distribution Worksheet:	
Minimum Average Head	**Distribution Head Loss**
1ft	5ft
2ft	6ft
5ft	10ft

Table I. Friction Loss in Plastic Pipe per 100ft

Flow Rate (GPM)	Pipe Diameter (inches) 1	1.25	1.5	2
10	9.1	3.1	1.3	0.3
12	12.8	4.3	1.8	0.4
14	17.0	5.7	2.4	0.6
16	21.8	7.3	3.0	0.7
18		9.1	3.8	0.9
20		11.1	4.6	1.1
25		16.8	6.9	1.7
30		23.5	9.7	2.4
35			12.9	3.2
40			16.5	4.1
45			20.5	5.0
50				6.1
55				7.3
60				8.6
65				10.0
70				11.4
75				13.0
85				16.4
95				20.1

D. 1. Supply Pipe Diameter: ______ in

2. Supply Pipe Length: ______ ft

E. **Friction Loss in Plastic Pipe per 100ft** from Table I:

Friction Loss = ______ ft per 100ft of pipe

F. Determine *Equivalent Pipe Length* from pump discharge to soil dispersal area discharge point. Estimate by adding 25% to supply pipe length for fitting loss.
Supply Pipe Length (D.2) X 1.25 = *Equivalent Pipe Length*

______ ft X 1.25 = ______ ft

G. Calculate *Supply Friction Loss* by multiplying *Friction Loss Per 100ft* (Line E) by the *Equivalent Pipe Length* (Line F) and divide by 100.

Supply Friction Loss =

______ ft per 100ft X ______ ft ÷ 100 = ______ ft

H. *Total Head* requirement is the sum of the *Elevation Difference* (Line A), the Distribution Head Loss (Line B), Additional Head Loss (Line C), and the Supply Friction Loss (Line G)

______ ft + ______ ft + ______ ft + ______ ft = ______ ft

3. PUMP SELECTION

A pump must be selected to deliver at least ______ GPM (Line 1 or Line 2) with at least ______ feet of total head.

Comments:

Appendix H
Pump Tank Design Worksheet

Minnesota Pollution Control Agency

OSTP Pump Tank Design Worksheet

UNIVERSITY OF MINNESOTA

DETERMINE TANK CAPACITY AND DIMENSIONS Project ID: v 09.20.13

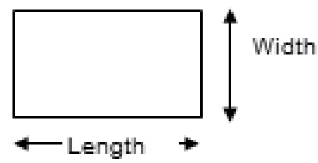
1\. A. *Design Flow (Design Sum. IA) :* ______ GPD

B. Min. required pump tank capacity: ______ Gal C. Recommended pump tank capacity: ______ Gal

D. Pump tank description: ______

2\. A. Rectangle area = Length (L) X Width (W)

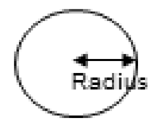
______ ft X ______ ft = ______ ft^2



B. Circle area = $3.14r^2$ (3.14 X radius X radius)

3.14 X ______ ^{2} ft = ______ ft^2

C. Calculate Gallons Per Inch. Multiply the area from 1.A or 1.B, by 7.5 to determine the gallons per foot the tank holds and divide by 12 to calculate the gallons per inch.



______ ft^2 X 7.5 gal/ft^3 ÷ 12 in/ft = ______ Gallons per inch

D. Calculate *Total Tank Volume*

Depth from bottom of inlet pipe to tank bottom : ______ in

Total Tank Volume = Depth from bottom of inlet pipe (Line 4.A) X *Gallons/inch* (Line 2)

______ in X ______ Gallons Per Inch = ______ Gallons

MANUFACTURER'S SPECIFIED TANK CAPACITY (when available):

3\. A. Tank Manufacturer: ______

B. Tank Model: ______

C. Capacity from manufacturer: ______ Gallons

D. Gallons per inch from manufacturer: ______ Gallons per inch

E. Liquid depth of tank from manufacturer: ______ inches

Note: Design calculations are based on this specific tank. Substituting a different tank model will change the pump float or timer settings. Contact designer if changes are necessary.

Design Flow (Gallons Per Day)	Minimum Pump Tank Capacity (Gallons)	
0-600	500	or Altnernating Dual Pumps
601-4,999	100% of the Design Flow	or Altnernating Dual Pumps
5,000-9,999	50% of the Design Flow	and Altnernating Dual Pumps

Warning – For Step 6 you need to go to the Design Summary tab and reset the design flow as:

Design flow / Number of zones

4. Calculate *Volume to Cover Pump* (The inlet of the pump must be at least 4-inches from the bottom of the pump tank & 2 inches of water covering the pump is recommended)

(Pump and block height + 2 inches) X *Gallons Per Inch* (2C or 3E)

(____ in + 2 inches) X ____ Gallons Per Inch = ____ Gallons

5. *Minimum Delivered Volume* = 4 X Volume of Distribution Piping:

- *Line 17 of the Pressure Distribution or Line 11 of Non-level* ____ Gallons (minimum dose)

6. Calculate *Maximum Pumpout Volume* (25% of Design Flow)

Design Flow: ____ GPD X 0.25 = ____ Gallons (maximum dose)

7. *Select a pumpout volume that meets both Minimum and Maximum:* ____ Gallons

8. Calculate *Doses Per Day* = Design Flow ÷ *Delivered Volume*

____ gpd ÷ ____ gal = ____ *Doses*

9. Calculate Drainback:

A. *Diameter of Supply Pipe* = ____ inches

B. Length of Supply Pipe = ____ feet

C. *Volume of Liquid Per Lineal Foot of Pipe* = ____ Gallons/ft

D. *Drainback* = *Length of Supply Pipe* X *Volume of Liquid Per Lineal Foot of Pipe*

____ ft X ____ gal/ft = ____ Gallons

10. *Total Dosing Volume* = *Delivered Volume* plus *Drainback*

____ gal + ____ gal = ____ Gallons

11. Minimum Alarm Volume = Depth of alarm (2 or 3 inches) X gallons per inch of tank

____ in X ____ gal/in = ____ Gallons

Volume of Liquid in Pipe

Pipe Diameter (inches)	Liquid Per Foot (Gallons)
1	0.045
1.25	0.078
1.5	0.110
2	0.170
3	0.380
4	0.661

TIMER or DEMAND FLOAT SETTINGS

Select Timer or Demand Dosing: ○ Timer ○ Demand Dose

A. Timer Settings

12. Required *Flow Rate* :

A. From Design (Line 12 of Pressure Distribution or Line 10 of Non-Level"): ______ GPM

B. Or calculated: GPM = Change in Depth (in) x Gallons Per Inch / Time Interval in Minutes

______ in X ______ gal/in ÷ ______ min = ______ GPM

**Note: This value must be adjusted after installation based on pump calibration.*

13. Flow Rate from Line 12.A or 12.B above. ______ GPM

14. Calculate **TIMER ON** setting:

Total Dosing Volume/GPM

______ gal ÷ ______ gpm = ______ Minutes ON

15. Calculate **TIMER OFF** setting:

Minutes Per Day (1440)/ *Doses Per Day* - Minutes On

1440 min ÷ ______ doses/day ______ min = ______ Minutes OFF

16. Pump Off Float - Measuring from bottom of tank:

Distance to set Pump Off Float=Gallons to Cover Pump / Gallons Per Inch:

______ gal ÷ ______ gal/in = ______ Inches

17. Alarm Float - Measuring from bottom of tank:

Distance to set Alarm Float = Tank Depth(4A) X 90% of Tank Depth

______ in X 0.90 = ______ in

B. DEMAND DOSE FLOAT SETTINGS

18. Calculate *Float Separation Distance* using *Dosing Volume* .

Total Dosing Volume /Gallons Per Inch

______ gal ÷ ______ gal/in = ______ Inches

19. Measuring from bottom of tank:

A. *Distance to set Pump Off Float* = Pump + block height + 2 inches

______ in + ______ in = ______ Inches

B. *Distance to set Pump On Float=Distance to Set Pump-Off Float + Float Separation Distance*

______ in + ______ in = ______ Inches

C. *Distance to set Alarm Float* = *Distance to set Pump-On Float* + *Alarm Depth* (2-3 inches)

______ in + ______ in = ______ Inches

Appendix I
Bottom Draining Filter
Design Criteria for Flows < 2,500 gallons per day

Introduction and background

Design and construction requirements contained in the Single Pass Sand Filter document are to be followed along with specific requirements for bottom draining filters contained in this Appendix.

Bottom draining sand filters are single pass sand filters that do not have an underdrain collection network. They simply have an open bottom that allows the filtered effluent to drain out the bottom and into the underlying suitable soil. Sand filters with open bottoms are intended to disperse filtered effluent into the soil immediately under and adjacent to their footprint. The use of bottom draining sand filters is, therefore, limited to sites with permeable soils that are able to transmit filtered effluent (predominately vertically) down and away from the system. On suitable sites, the flow cannot be impeded by a layer that causes excessive water mounding or lateral movement without the consideration of absorption width and seepage at the surface.

Bottom draining sand filters have been used successfully in the U.S. on sites with space limitations and where soils are both well-drained and permeable (i.e. sands). The use of bottom draining sand filters on sites with finer textured soils (i.e. loam, silt loam, clay loam) is unsuitable because of the low hydraulic conductivity of the finer textured soil in comparison to the sand filter media (and loading rate to the sand filter). A lower permeable soil essentially creates a ‘bath tub’ effect since the filtered effluent cannot move away from the site quickly enough.

Unique requirements for designing and constructing bottom draining sand filters are contained in this Appendix. Bottom draining sand filters designed for less than 2,500 gallons per day are Type IV systems that can be designed by either an Intermediate or Advanced Designer.

Siting conditions

Bottom draining sand filters are used for wastewater treatment and dispersal on sites with suitable site and soil conditions. These sites are typically fairly flat, and have well-drained, permeable soils. On these sites, there is no layering in the soil that impedes the movement of water through the top five to eight feet of soil.

The following items describe basic site and soil conditions with additional design considerations for bottom draining sand filters:

1. Bottom draining sand filters are located on sites with slopes less than six percent.
2. The treated wastewater is expected to move largely vertically away from the sand filter bed. The underlying native soil textures are typically coarse sand, sand, loamy sands, or sandy loams, with the following types of soil structure: single grain, granular, blocky or prismatic structure. Furthermore, there are no limiting layers, bedrock, or zones of periodic saturation at least two feet below the bottom of the sand filter. Field determination of water movement (i.e. saturated hydraulic conductivity) in the underlying soil may be needed where questionable soil conditions occur.
3. Bottom draining sand filters are constructed lengthwise along the existing contour. Contour loading rate is an important design consideration depending upon site specific soil and landscape conditions that influence how water moves through the soil and away from the wastewater system. Contour loading rates range between one and 12 gallons per lineal foot, depending upon site conditions.
4. Sand filters must not be located in depressions, on concave slopes or in drainage ways.
5. All sites must have minimal run-on potential and surface water must be directed away from the wastewater treatment system.

Wastewater flows

The use of bottom draining sand filters are limited to sites that: 1) generate residential strength wastewater and 2) have design flows less that 2,500 gpd.

Design and construction requirements

The following are design specifications for bottom draining sand filters:

1. Bottom draining sand filters need to be designed to facilitate oxygen transfer into the sand filter for treatment and nitrification to occur. No impermeable surfaces or materials are allowed over a finished bottom draining sand filter. The width of sand filters is an important design consideration.
2. Sites must have at least two feet of permeable, well-drained soil (with a minimum soil loading rate of 0.78 gal/ft^2/day or faster) beneath the sand filter.
3. Bottom draining sand filters can be installed partially above grade or mostly below the original ground surface. If installed partially above grade, a PVC or HDPE liner is required covering the above-ground vertical sidewalls of the sand filter.
4. Finished grade of the filter should be a minimum six inches above the elevation of the surrounding finished grade and shaped to prevent surface water from flowing onto the sand filter.
5. Untreated plywood or untreated Oriented Strand Board (OSB) is required on vertical sidewalls, typically down to the bottom of the excavation where: 1) the sand filter is installed partially above-grade, and 2) soil conditions are unstable during construction. The wood must be decomposable so that oxygen transfer is not hindered.
6. Maximum sand filter bed width is twelve feet.
7. Soil preparation at the infiltrative surface for bottom draining sand filters need to meet the same requirements as soil preparation for in-ground systems.
8. Six inches of pea rock may be placed at the bottom of the excavation. Twenty-four inches of sand filter media is placed on top of the pea rock.
9. Incorporation of an air recovery feature may be a design feature of a bottom draining sand filter.
10. Topsoil cover must be six to twelve inches of loamy soil that meet the requirements of Minnesota rules Chapter 7080.1500, Subp. 88. The final grade must be shaped (crowned) so that surface water sheds off of, and away from, the sand filter.
11. A minimum of two four inch inspection pipes are needed at the following depths in the sand filter:
    - At least one inspection pipe is placed at the bottom of sand filter just above the natural soil.
    - At least one inspection pipe is placed at the top of the sand media, with perforations spanning the depth of rock below the distribution network.
12. Filter sand must be placed while it is damp. If the sand is not damp, the sand will not compact properly and settlement may cause dislocation and breakage of the distribution laterals.

Schematic Details for the Bottom Draining Sand Filter (BDSF)