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Sand Mound Technology Assessment and Design Guidance

Iowa Department of Natural Resources

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NOTICE

This document has been reviewed in accordance with the Iowa Department of Natural Resources policies and procedures and has been approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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Application

A mound system provides a method of final treatment and discharging of partially treated wastewater to the soil environment where it receives final treatment by the natural soils prior to contact with the groundwater. When properly designed and positioned on suitable sites the mound system provides adequate treatment and distributes the wastewater evenly over the soil infiltrative surface. Mound systems are suitable for use in domestic strength waste applications.

Performance

A mound system is a method of distributing the wastewater out over a large natural soil infiltrative surface. Primary treatment components and, if used, secondary treatment components treat the effluent to reduce the wastewater strength to acceptable levels prior to the mound component. The mound sand fill, distribution media and the natural soil environment is where the final polishing and treatment of the wastewater occurs. The following tables show the treatment performance expected when loaded with septic tank effluent at the toe of the mound and from the natural soils below the mound.

Performance at the toe of a mound

Constituent	Units	When loaded with septic tank effluent
BOD_5	mg/L	2
Total Nitrogen	mg N/L	18.5
TKN	mg N/L	3.9
Organic Nitrogen	mg N/L	2.3
NH_4-N	mg N/L	1.3
NO_3-N	mg N/L	15
Fecal Coliform	col/100 mL	9

Performance of natural soils when loaded with septic tank effluent

Constituent	Soil Water Quality At	
	24 inches	48 inches
5-day biological oxygen demand (BOD_5)	<1 mg/L	<1 mg/L
Total Kjeldahl Nitrogen (TKN)	0.77 mg/L	0.77 mg/L
Total Nitrogen (TN)	21 mg/L	
Nitrites & Nitrates (NO_3-N)	21.6 mg/L	13.0 mg/L
Total Phosphorus	.01 – 3.8 mg/L	.02 – 1.8 mg/L
Fecal Coliform	<1 MPN/100mL	<1 MPN/100mL

Recommended Design Parameters

Pretreatment required	Two compartment septic tanks required (2/3 volume in first chamber)
Septic tanks size	2 X design flow for gravity collection systems & 3 X design flow for pressure collection system
Design Flow (AWW)	100 gal/person/day
Wastewater Strength	Domestic
Applicable to	25,000 gpd or less
Hydraulic Loading Rate of Sand Fill	$\leq$ 1.0 gal/ft^2/day when BOD5 is >30 mg/L, & $\leq$ 250 mg/L & TSS is > 30 mg/L, & $\leq$ 150 mg/L or $\leq$ 2.0 gal/ft^2/day when BOD_5 and TSS $\leq$ 30 mg/L
Slope of original grade	>2% and $\leq$ 20%
Depth to limiting factor	$\geq$ 24 inches
Suitable soil required	$\geq$ 36 inches including mound sand fill
Dispersal cell width	Based on Linear Loading Rate from Table 4-3
Minimum dispersal cell area	$\geq$ Design flow $\div$ loading rate of the sand fill material
Orientation	Longest dimension parallel with surface grade contours

Design Process
The general design procedure outlined in this manual follows these steps :

<u>Step 1 - Determine design requirements</u>
a. Characterize design flow rates
b. Characterize influent wastewater makeup
c. Characterize native soils textures, and loading rates

<u>Step 2 - Size primary unit</u>
a. Septic tank size, number and layout
b. Tank configuration
c. Effluent screens

<u>Step 3 - Size Dosing Tank</u>
a. Determine base volume
b. Select type of pumps to be used
c. Determine pump cover volume
d. Determine dose operation volume
e. Determine reserve volume

Advantages

Reliability:	Mounds if properly designed and sited will provide many years of excellent treatment performance and dispersal of wastewater.
Low maintenance	Mounds provide adequate treatment of the wastewater with relatively low maintenance costs.
Cell repair or replacement	The dispersal cell can be replaced within the mound without replacement of the entire mound, the cell aggregate and distribution pipe is removed along with the clogged sand layer and a new material is inserted in the same foot print.

Disadvantages

Land area:	Large flows require large land areas.
Sand fill:	Mounds require large amounts of specific sand fill and topsoil trucked to the site.

I. INTRODUCTION

A. Scope

The Iowa Department of Natural Resources (DNR) has commissioned this manual in order to broaden the number of treatment options considered for managing wastewater within Iowa's small rural communities. Current rules and regulations do not recognize sand mounds as a viable wastewater treatment alternative. This manual is intended to expedite the design and review process for these technologies by:

- Summarizing existing research and performance data;
- Acting as a guide to determining the applicability of sand mounds;
- Advising the designer as to the selection and sensitivity of design parameters;
- Providing an overview of the design process; and
- Providing three example designs for populations of 25, 100, and 250 people.

The manual has application for:

- Treatment of Domestic Waste Only; and
- Population Equivalents from 25-250 people.

The following assumptions on waste quantity and strength have been used throughout the manual:

- Design influent BOD of 250 mg/l or less;
- Design influent TSS of 250 mg/l or less;
- Design influent TKN of 40 mg/l or less; and
- Design Hydraulic Loadings of 100 gpcpd

This manual is intended for use by Owners, Consulting Engineers, DNR review engineers and associated DNR personnel, as well as funding source personnel to provide guidance to the successful design for the use of sand mound systems within Iowa. The design approach contained within this manual should be construed as a minimum basis of design. Nothing within this manual should be construed or viewed as eliminating additional alternative treatment systems, or alternative design approaches with respect to sand mound systems, provided that adequate justification and data from actual installations is submitted.

B. Terminology

Definitions of some terms used in this evaluation report are as follows:

ADW	Average Dry Weather Flow Rate. ADW is average daily flow when groundwater is at or near normal and a runoff condition is not occurring. The period of measurement for this flow should extend for as long as favorable conditions exist up to 30 days, if possible
AWW	Average Wet Weather Flow Rate. AWW is the daily average flow for the wettest consecutive 30 days for mechanical plants, or for the wettest 180 consecutive days for controlled discharge lagoons
Biochemical Oxygen Demand, five day (BOD)	A measure of the amount of oxygen required by bacteria while stabilizing, digesting or treating biodegradable organic matter under aerobic conditions over a five-day incubation period commonly expressed in milligrams per liter (mg/L).
Bedrock	1) General term for the solid rock that underlies the soil and other unconsolidated material or any solid rock that is exposed at the surface. 2) Where at least 50% of the material by volume is rock.
Component	A subsection of a treatment train or system.
Device	A subunit of a component.
Part	A subunit of a device.
Dispersal Cell	Part of a mound component where effluent is spread out and into the final receiving environment.
Denitrification	The process of biologically converting nitrate/nitrite (NO_3^-/NO_2^-) to nitrogen gas.
Design Daily Flow	Estimated volume of wastewater for any 24-hour period, used for the design basis for all components of the wastewater treatment system. Also defined as the AWW.

Infiltration	The water entering a sewer system (including service connections) from the ground, through such means as, but not limited to, defective pipes, pipe joints, connections, or manhole walls. Infiltration does not include, and is distinguished from, inflow
Infiltration/Inflow	The total quantity of water from both infiltration and inflow without distinguishing the source.
Inflow	The water discharged into a sewer system (including service connections) from such sources as, but not limited to, roof drains, cellar, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, manhole covers, cross connections from storm sewers and combined sewers, catch basins, storm water, surface runoff, street wash waters, or drainage. It does not include, and is distinguished from, infiltration.
Limiting Factor	Refers to a soil layer or horizon, which inhibits the natural flow of water such as bedrock, slowly permeable soils, compact dense till, or the fringe zone of the groundwater also known as seasonal saturation.
Nitrification	The process of biologically oxidizing ammonia (NH_4^+/NH_3) to nitrate/nitrite (NO_3^-/NO_2^-).
Present Worth	The total present worth method of evaluating sewage treatment systems involves bringing all costs of buildings, operating and maintaining the sewage treatment systems over a 20-year period to a total present worth.
Primary Treatment	Level of treatment involving removal of particles, typically by settling and flotation with or without the use of coagulants; some solids are anaerobically broken down but dissolved contaminants are not significantly removed in this treatment step (e.g. a grease interceptor or a septic tank provides primary treatment).

Secondary Treatment	Any component or combination of components that provides treatment of wastewater to primary, secondary, tertiary and/or disinfection treatment standards prior to conveyance to a final treatment and dispersal component or reuse.
Suspended Solids	Those solids that either float to the surface of, or are suspended in water, sewage, or industrial waste, which are removable by a laboratory filtration device.
Sanitary Sewer	A sewer intended to carry only sanitary or sanitary and industrial wastewater, from residences, commercial buildings, industrial plants, and institutions.

Also see United States Environmental Protection Agency, 2002. Onsite Wastewater Treatment Systems Manual: EPA 625-R-00-008; Glossary

Abbreviations of some terms used in this report are as follows:

ATU	aerobic treatment unit
BOD_5	five-day biochemical oxygen demand
$CBOD_5$	carbonaceous five-day biochemical oxygen demand
cfs	cubic feet per second
DNR	Department of Natural Resources (State of Iowa)
EPA	Environmental Protection Agency (Federal)
gpcd	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
HRT	hydraulic retention time
I/I	infiltration/inflow
IAC	Iowa Administrative Code
lb/day	pounds per day
lb/cap/d	pounds per capita per day
MG	million gallons
MGD	million gallons per day
mg/L	milligrams per liter
MLSS	mixed liquor suspended solids
MLVSS	mixed liquor volatile suspended solids
msl	mean sea level
MWW	maximum wet weather flow rate
NH_4-N	ammonia nitrogen
NO_3-N	nitrate nitrogen
OWTS	on site wastewater treatment system
PHWW	peak hourly wet weather flow rate
TKN	total Kjeldahl nitrogen
TSS	total suspended solids
WWTF	Wastewater Treatment Facility

II. PROCESS DESCRIPTION

A. System Description

1. General

On site wastewater treatment systems comprised of septic tanks and soil dispersal components are commonly used for wastewater treatment in many rural and suburban areas in the United States. In many rural areas, soils with a shallow depth over a limiting layer such as bedrock or slowly permeable soils make it difficult to use conventional subsurface soil absorption systems for wastewater treatment and dispersal. This becomes even more of a problem when flows from larger community systems must be treated and dispersed into the soil. On these sites, mound systems may be an acceptable and cost effective alternative.

The mound is the treatment and dispersal component of a complete on site wastewater treatment system. Other major components of the mound system that are discussed in this manual are the wastewater source, the primary treatment component or septic tank and the pressure dosing component. The main focus of this manual is the final treatment and dispersal component, the mound. In some cases, but not all, the designer will add another component to the system. That component is referred to as the secondary treatment unit in this manual. A secondary treatment unit is used after the primary component (septic tank) and before the pressure-dosing component to provide an additional level of treatment and further reduce the strength of the wastewater.

The final treatment component of the mound system is the native soils into which the partially treated wastewater is discharged. The native soils are the one component of the system that cannot be "designed". The other components of the system must be designed to fit the soils and site available. A thorough and competent soils and site evaluation will provide the designer with a knowledgeable basis on which to make decisions regarding the other components of the system. All of these components make up what is referred to here as the mound system. Each of these components is discussed in more detail in the Treatment Process section of this manual and in Appendix A.

2. History

Conventional septic tank soil absorption systems are unsuitable for some soil types where adequate depth of suitable soils for treatment and dispersal to the environment are not available. As a result, alternative systems such as the mound system have been developed to overcome these limitations. The mound system was originally developed in North Dakota in the late 1940s and called the NODAK disposal system. The mound design in predominate use today was modified from the NODAK design by the University of Wisconsin-Madison in the early 1970s.

The Wisconsin mound system has evolved into a viable treatment and dispersal component of a complete on site wastewater treatment system for the treatment of wastewater from residential sources. Many states have accepted the Wisconsin mound system as an alternative, when conventional in-ground trenches and beds are not suitable. But like all soil based treatment systems, mounds are more adaptable to some sites and situations than others. However, mounds are not suited for all sites.

3. Treatment Process

The treatment process begins at the wastewater source. As previously stated, this manual is focused on the treatment of domestic strength wastewater, which is transported from various residential sources via a collection system designed for that purpose. The collection system may discharge directly to a common septic tank or it may consist of individual tanks located at each residence (Fig. 2-1). A discussion of the strength of typical residential wastewater is found in Section III. Performance Data found later in this manual. Additional information regarding the design and selection of various alternative collection systems can be found in the IDNR Alternative Collection Systems Manual.

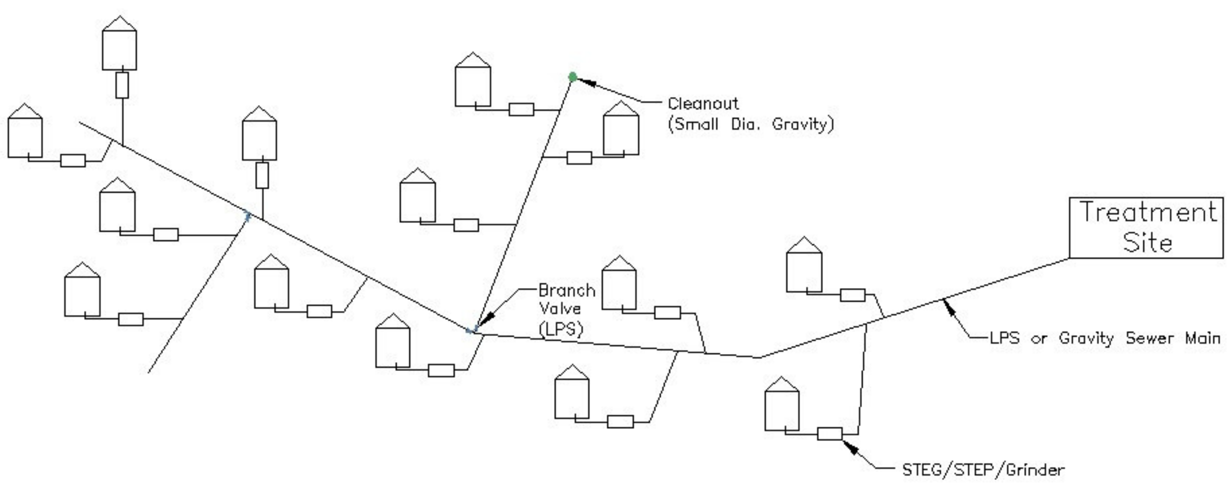


Figure 2-1 Collection System

Once the wastewater is transported to the treatment site the following components are found in the treatment process:

- Primary Treatment - septic tank, if not located at the residence;
- Secondary Treatment Unit – if used;
- Pressure Dosing Component;
- Mound Component including the dispersal cell(s);
- Native Soil Component

The following sections describe the treatment process and function of each component.

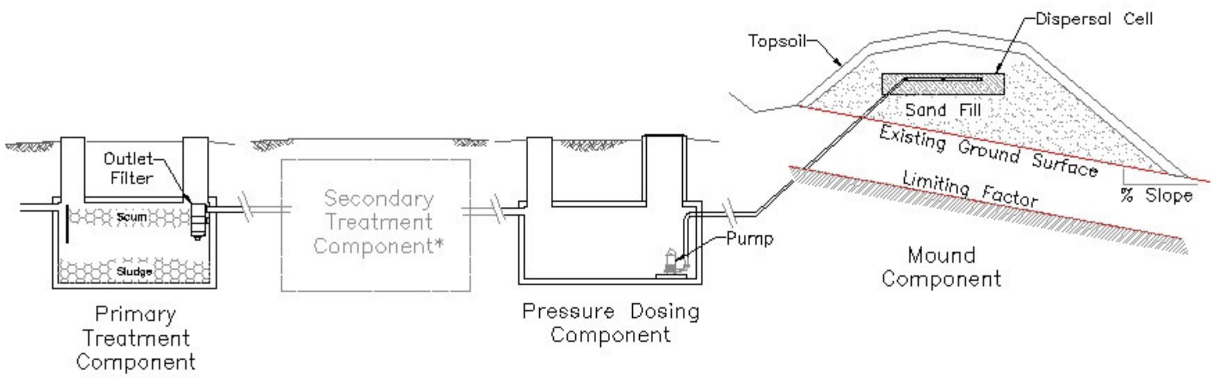


Figure 2-2 Mound System Components
*Note: secondary treatment is an optional component

B. *Primary Treatment Component*

The main function of a septic tank is to remove solids from the wastewater by settling and floatation. To a lesser degree, reducing influent BOD_5 also occurs in the septic tank prior to discharge to downstream treatment and/or dispersal components. The primary goal of the septic tank is to reduce TSS to levels that will not cause fouling of the distribution media. Additional information regarding septic tank function, performance requirements, sizing requirements and layout the designer is referred to the appropriate sections of Appendix A.

C. *Secondary Treatment Component*

In some cases, it may be necessary to add a secondary treatment component to the system. A secondary treatment component is used after the primary component (septic tank) and before the pressure dosing component to provide an additional level of treatment and further reduce the strength of the wastewater. The expected strength of wastewater after secondary treatment is <30 mg/L BOD_5 and TSS. Discharging lower strength wastewater into the soil treatment/dispersal component should prolong the life of that component by reducing or eliminating the biological clogging mat. For this reason the soil loading rate to the infiltrative surface of the treatment/dispersal component can be increased from 1.0 gal/ft^2/day to 2.0 gal/ft^2/day when incorporating a secondary treatment component into the design.

D. Dispersal Cell Resting/Active Operation and Description

If, no secondary treatment unit is provided the final dispersal component shall be designed based on an active/resting cell(s) philosophy. To provide a resting cell(s) the total dispersal cell area required is calculated then multiplied by 1.5. The resultant area is then divided into 3 cells or subgroups of cells divisible by 3. This then becomes the total area of the final dispersal component. In this way one cell or group of cells can be rested annually while the 2 active cell(s) or subgroup of cells receive the wastewater load. Operationally the active and resting cells are rotated annually. Each cell will be active for a 2 year period then rest for 1 year. The purpose of cell(s) resting is to eliminate or greatly reduce the clogging mat at the aggregate/soil interface which will contribute to a longer service life for the dispersal cells and to provide an emergency backup area in the event of an unforeseen malfunction in one of the active cells.

E. Pressure Dosing Component

Dose tanks are generally separate tanks or chambers located downstream from the septic tank and/or secondary treatment unit. As with primary and secondary treatment components, dose tanks must be structurally sound watertight containers with adequately sized access hatchways for maintenance and service of the dosing pumps, control equipment and for periodic sludge removal. Dose tanks are required in a mound system because the application of wastewater to the infiltrative surface must be by use of a pressure distribution network.

While there is no specific treatment process associated with this device, it plays an important role by providing storage and a means of discharging effluent in uniform doses over the 24-hour design period. Small, evenly spaced doses throughout the day, contribute to enhanced performance and longevity in the final treatment and dispersal component by providing resting cycles between doses.

1. Distribution Network

The distribution network is a series of pipes laid out near the top of the dispersal cell. The function of a pressure distribution network is to uniformly spread the effluent dose out over an entire segment of the dispersal cell. Pressure distribution is a method of applying a specific volume of effluent to a specific area of the dispersal cell during each dosing event. A typical dose is discharged through a small diameter (2-inch to 4-inch typical) force main connecting the pump to the distribution network (Fig 2-3). The distribution network in turn discharges the effluent into the stone aggregate or synthetic filter media. A typical distribution network will include one or more 2-inch to 4-inch diameter manifold(s). From the manifold the effluent flows into multiple small diameter (1½inch to 2-inch typical) pressure rated PVC laterals evenly spaced across the dispersal cell. Pipe sizes vary with the size and complexity of the distribution network, see Appendix B of this manual for a detailed description of the design of a pressure distribution network.

Distribution laterals will have evenly spaced holes (orifices) drilled into the pipe at predetermined intervals along the pipe. The number of orifices within the distribution network, the orifice size and the required distal head pressure combine to determine the minimum pump flow rate of the dosing system. Even distribution of the effluent is accomplished by a comprehensive design which includes factors such as: daily design flow, dose interval requirements, lateral pipe size, orifice diameter, orifice spacing, friction losses, static head and desired residual pressures in the network.

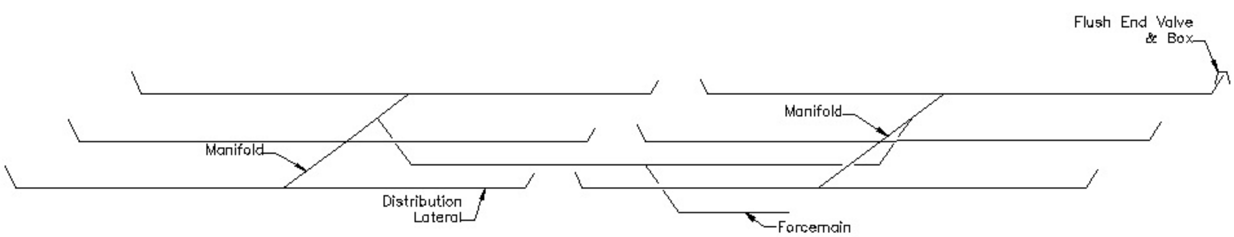


Figure 2-3
Distribution Network

Distribution network lateral construction includes an upturned elbow at the end of each lateral directed to the surface. A manually operated ball valve is located at the end of each lateral in a protective enclosure or valve box. When the ball valve is opened during a pump event the laterals can be flushed out periodically to remove any buildup of biological material from the inside walls of the pipe.

F. Mound Component

The mound is constructed by placing sand fill over the tilled natural or native soils to a predetermined depth. (Fig. 2-4) The depth of the sand fill is based on the depth to the limiting factor. The limiting factor is defined as "a soil layer or horizon, which inhibits the natural flow of water such as bedrock, slowly permeable soils, compact dense till, or the fringe zone of the groundwater also known as seasonal saturation". The minimum natural, undisturbed soil depth required above a limiting factor for a mound designed under these guidelines is 24 inches. While many mounds constructed for single-family applications are located on sites with less than 24 inches of suitable soil to the limiting factor it is not a recommended practice for large flows with multiple users depending on continuous, long-term service.

The required depth of 24 inches to the limiting factor allows for a zone of unsaturated soil below and down slope of the mound in which the treated water must be able to flow unimpeded away from the mound system. The flow of treated water through the unsaturated zone must be able to occur every day all year long. Daily flows to a single-family mound fluctuate more than the flows to a larger community mound. Design flows to a single-family mound are generally conservative and in most cases are rarely exceeded. Furthermore single-family mounds will experience large periods of time when very little or no wastewater is being applied such as during the work day or during vacations. A community mound is more likely to receive flows that are nearer the design flow and there will be less likelihood of large time periods of little or no flow being applied to the infiltrative surface of the mound. Therefore it is much more important to insure that adequate soils are present below the mound to provide the treatment and transportation zone necessary for the small community mound to function as designed.

The thickness of sand fill layer for the mound plus the suitable soil together must equal the minimum required soil treatment depth of 36 inches (see Fig. 2-4). The require soil treatment depth is measured at the upslope edge of the bottom of the dispersal cell and the limiting factor in the natural soil. To qualify as a mound system and therefore meet the performance standards established for treatment, the minimum depth of sand fill allowed is 6 inches. Therefore a site with 24 inches of suitable soil will require a minimum 12-inch layer of sand fill while a site with 30 inches or more of suitable soil will require a minimum sand fill depth of 6 inches.

A small community mound component will consist of the following parts:

- A layer of suitable natural soil;
- A layer of sand fill meeting the requirements set forth in Table 2-1 or 2-2;
- A dispersal cell w/distribution network and media;
- A soil cap and topsoil layer

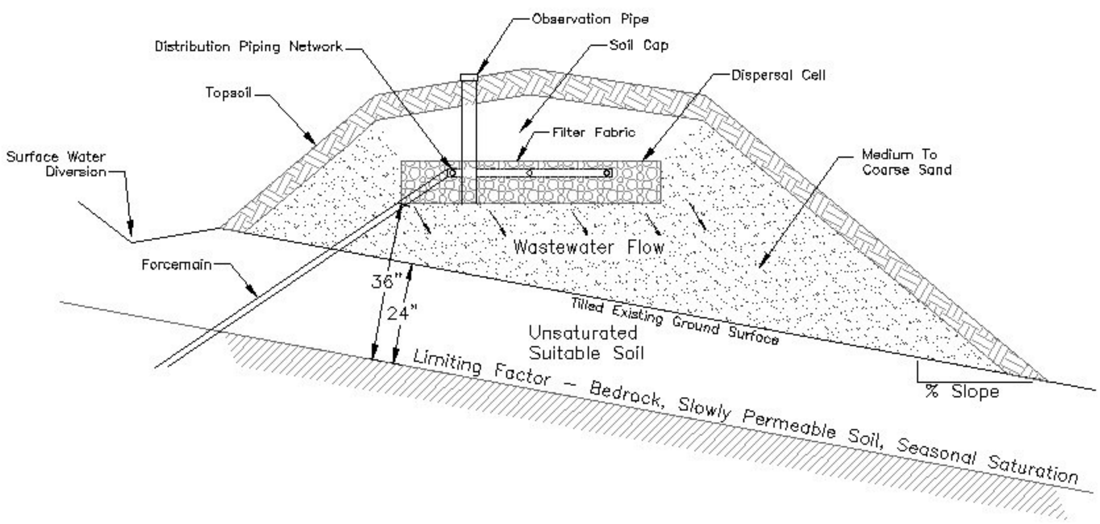


Figure 2-4
Mound Component Cross Section

a) *Sand Fill*

The purpose of the sand fill is to treat the effluent to an acceptable level and disperse the wastewater volume uniformly over the natural soil surface. The loading rates for the sand fill will vary based on the wastewater strength being applied. When septic tank effluent is applied the loading rate is 1.0 gal/sf^2/day. When the wastewater has been treated to secondary levels of >30 mg/L BOD_5 and TSS the sand fill loading rate is 2.0 gal/sf^2/day.

The sand fill size distribution should meet the requirements of either ASTM C-33 specifications for fine aggregate (See Table 2-1) or the Iowa Department of Transportation Aggregate Gradation Table, Gradation No. 1 (see Table 2-2). In addition, the sand fill must not have more than 20% (by weight) material that is greater than 2mm in diameter (coarse fragments), which includes stone, cobbles and gravel. Also, there must not be more than 3% silt and clay (<0.53 mm, 270 mesh sieve) in the fill. Sand with an effective diameter (D_{10}) of 0.15 - 0.30 mm and uniformity coefficient (D_{60}/D_{10}) between 4 and 6 fit within these guidelines provided the coarser (>2 mm) and finer (0.053 mm) fractions meet the guideline. Although the Table(s) give a range, it is best to stay on the coarser side (effective diameter close to 0.30 mm and uniformity coefficient of 4.0) than to be fine and non-uniform.

Table 2-1
ASTM C-33 Fine Aggregate Gradation Requirements

Sieve	Percent Passing
3/8-in.	100
No. 4	95 to 100
No. 8	80 to 100
No. 16	50 to 85
No. 30	25 to 60
No. 50	10 to 30
No. 100	2 to 10
Reference: Wis. DCOMM Mound Manual	

Table 2-2
IDOT Aggregate Gradation Table, Gradation No. 1

Sieve	Percent Passing
3/8-in.	100
No. 4	90 to 100
No. 8	70 to 100
No. 30	10 to 60
No. 200	0 to 1.5

b) <u>*Dispersal Cell*</u>

The dispersal cell is the area where the wastewater is spread out and begins infiltration into the sand fill. A variety of materials are used in the dispersal cell for distribution media. Gravel has historically been the most common material. Gravel used in a dispersal cell must meet the following requirements:

- Size Range - ½ inch to 2 ½ inch;
- Must be washed to remove fines;
- Hardness value of 3 or more on the Moh's Scale of Hardness

Synthetic aggregate materials and chambers are also available for this purpose. Synthetic aggregate includes bundled polystyrene pellets, drainage tile, and leaching chambers. Any product used, in place of the stone aggregate shall be certified by the manufacturer for use in a wastewater treatment system environment.

The distribution media supports the piping network and provides an open space for the introduction of the effluent to the dispersal cell bottom area. Observation pipes are placed in the dispersal cell for periodic monitoring of the infiltrative surface. The dispersal cell using either stone or synthetic aggregate is covered with a synthetic construction fabric to prevent migration of soil particles into the distribution media. Leaching chambers do not require a filter fabric cover.

c) *Soil Cap/Topsoil*

The cover material or cap over the dispersal cell is a soil that will allow air exchange, provide insulation from the cold, reduce disturbance of the aggregate and support plant growth. The gas exchange will increase the treatment performance of the system by providing oxygen to the wastewater. The plant growth will provide additional frost protection in the winter season and prevent excessive erosion. Clay soils may not be used for cover material as they will restrict oxygen transfer. Often, excavated soil from the site can be used. The entire mound shall be covered with topsoil native to the site or with similar characteristics.

G. Native Soils

The soil is the ultimate receiver of the wastewater and the most important part of the mound component. It is also the most variable and must be carefully evaluated. The discharged wastewater moves through the soil vertically and/or horizontally and must remain underground. The linear loading rate of the mound, and thus the width of the dispersal cell, depends upon the horizontal and vertical acceptance rate of the soil (Converse and Tyler, 1986). The mound component must be long and narrow to promote water dispersion away from the system, for gas dispersion beneath the system (Tyler et al., 1986) and dispersion into the groundwater.

At some point away from the system all the wastewater is assimilated into the environment such that it is not detectable or will not influence the system operation. This is called the system boundary. System boundaries are located both horizontally and vertically away from the mound basal area. The boundary could be a surface water discharge point, change in slope, area of convergent flow in the landscape or the groundwater surface. The system boundary for each system is determined during the site evaluation.

Wastewater from the base of the mound must flow through an unsaturated zone for final treatment prior to discharge to the groundwater. The basal area of the mound is the width of the dispersal cell plus the down slope fill width times the length of the dispersal cell. The wastewater applied to the basal area must not exceed the capacity of the native soils to transmit the water away from the basal area. In a properly functioning system all wastewater applied will leave the system, therefore the flow rate of the applied wastewater must be equal to or less than the flow rate in the unsaturated zone.

III. Performance

The factors that determine good performance from a mound system include:

1) A knowledgeable evaluation of the wastewater strength and flow data;
2) A thorough and competent investigation of the site and soil conditions;
3) A design based on low linear, basal and hydraulic loading rates carefully matched to the site conditions;
4) High quality sand fill and media materials;
5) Competent construction practices, and
6) Good operation and maintenance procedures.

Performance data available on mound systems is from studies done on single family home systems. The processes affecting treatment and performance are the same in large systems as it is in small ones as long as they are similar in width. Effluent volumes discharged to the mound component must not exceed the ability of the natural soils to transmit and move the volume of water away from the area of discharge. The following data is compiled from various studies done to measure the performance of components used in a mound system.

A. Performance Data

1. Wastewater Flows

Wastewater flows from residential sources are identified in a couple of ways. If actual metered flows are available a typical range of flows reported is 50 to 70 gallons/capita/day (Crites and Tchobanoglous, 1998). The design flow for a system designed in conformance with this manual shall be 100 gal/person/day. This flow rate allows for a safety factor in the design to account for variables such as fluctuating flows and non-uniform soil conditions. The designer may want to adjust the design population based on allowances for infiltration and inflow depending on the type and age of the collection system. Anticipated future growth in the community over the design life of the system should also be considered when determining the design population total.

2. Wastewater Source

The qualitative characteristics of wastewater generated by residential sources can be distinguished by their physical, chemical, and biological composition. Wastewater flow and the type of waste generated affect wastewater quality. Concentrations of typical pollutants in raw residential wastewaters for systems designed by this guidance manual must meet the criteria for domestic strength wastewater.

3. Primary Treatment – Septic Tank Effluent (STE)

Primary treatment reduces levels of TSS to help prevent fouling of the final dispersal component. Some initial BOD reduction has been documented as well, although experience shows this is often not significant. The performance expectation for a septic tank primary treatment unit is shown in Appendix A of this manual.

4. Secondary Treatment Devices

Secondary treatment components are installed directly downstream of the septic tank and are intended to provide additional treatment prior to discharge of the effluent to the final dispersal component. Examples of secondary treatment units are packed – bed filters such as intermittent and recirculating sand filters, peat and textile filters and aerobic units. The performance goal of secondary treatment is to consistently produce an effluent quality with concentrations of $\leq$ 30 mg/L BOD_5 and TSS and <10,000 col/100mL Fecal Coliforms.

It is highly recommended that the designer work closely with a reliable manufacturer to insure that the unit selected is adequately sized based on factors such as the design flow and the anticipated biological loading the unit will receive. Many secondary treatment unit manufacturers utilize septic tanks as the containment vessel for their technology. In some cases the secondary treatment unit is provided in it's own container or vessel. Sand filters are available from nationally recognized manufacturers in kit form, which simplifies the design process for that device. See the IDNR Recirculating Sand Filter Design Manual for design guidance on sand filters.

Performance of secondary treatment units is directly related to periodic inspection and monitoring. Each of the commonly used technologies has unique requirements for monitoring and inspection. The overall complexity of a wastewater treatment system is increased by the use of a secondary treatment unit. To one degree or another secondary treatment units add more mechanical devices, meters, pumps, motors, controls, etc. to the system. It's very important that the secondary treatment unit be monitored regularly and repaired as needed to prevent discharges of partially treated wastewater to the next downstream component.

5. Sand Fill Treatment Performance

In terms of importance to the long-term performance of a mound system the quality of the sand fill ranks directly along side the evaluation of the native soils. The sand fill has a dual function, it acts as the initial treatment medium and as a transport method to deliver the partially treated wastewater to the surface of the native soil. The sand fill must be neither too fine nor too coarse to accomplish both of these tasks. When sand fill material as specified in Section II of this manual is used, the expected effluent quality at the native soil/sand interface can be expected to be as shown in Table 3-1.

Table 3-1 Mound System Effluent Quality

Constituent	Units	STE
BOD_5	mg/L	2
COD	mg/L	17
Total Nitrogen	mg N/L	18.5
TKN	mg N/L	3.9
Organic Nitrogen	mg N/L	2.3
NH_4-N	mg N/L	1.3
NO_3-N	mg N/L	15
Fecal Coliform	col/100 mL	9
E. Coli	col/100 mL	15
Enterococci	col/100 mL	18

Reference: Effluent Quality in Saturated Mound and Modified Mound Toes Receiving Septic Tank or Aerobically Treated Domestic Wastewater, Blasing and Converse, 2004

6. Native Soils Treatment Performance

The effectiveness of the soil to provide final treatment of the effluent after it infiltrates into the native soils depends on the residence time in the soil and maintaining predominately aerobic (non-saturated flow) conditions (Report #1007406, EPRI & TVA, 2004 & USEPA Onsite Wastewater Treatment Systems Manual, Chapter 3, 2002). Table 3-2 shows typical concentrations of wastewater constituents found in soil 24 inches and 48 inches below a dispersal cell located in native soils. The concentrations shown in this table are based on discharge of septic tank effluent to an in-ground dispersal cell.

Table 3-2 Treatment Performance of Soil
From: Various Sources*

Constituent	Soil Water Quality At	
	24 inches	48 inches
5-day biological oxygen demand (BOD_5)	<1 mg/L	<1 mg/L
Total Kjeldahl Nitrogen (TKN)	0.77 mg/L	0.77 mg/L
Total Nitrogen (TN)	21 mg/L	
Nitrites & Nitrates (NO_3-N)	21.6 mg/L	13.0 mg/L
Total Phosphorus	.01 – 3.8 mg/L	.02 – 1.8 mg/L
Fecal Coliform	<1 MPN/100mL	<1 MPN/100mL

*USEPA Onsite Wastewater Treatment Systems Manual, Chapter 3, 2002 adapted from Anderson et al., 1994

Bacterial and Nutrient Removal in Wisconsin At-grade On-site Systems, Converse, J.C., Kean ME, Tyler EJ, and Peterson JO. 1991

Onsite Sewage System History and Current Practices, Burks B., Minnis M., and Langstroth R., 1998

B. Existing Small Community Mound Systems

Iowa						
Site Name	Location	Daily Design Flow (gpd)	STE or Secondary Treatment (type)	Final Treatment & Dispersal	Installed	Comments
Four Mile School				Mound		No data available
Ames Golf & Country Club				Mound		No data available
Country Terrace Mobile Home Park	Ames Boone Co.	---	Sand Filter	Mound	---	Operation problems observed by IDNR personnel – leakage at toe of mound in three areas. Attempts at adding fill to toe of mound for repair have been unsuccessful.
Mount Liberty Subdivision		Unk.	Unk.	Mound		Operational problems reported.

Minnesota						
Site Name	Location	Daily Design Flow (gpd)	STE Or Secondary Treatment (type)	Final Treatment & Dispersal	Installed	Comment
City of Henriette	Henriette	9,000	Aerobic	Mound	Sept., 2003	Investigation by Ayres & Assoc. indicates inadequate soil & site investigation & inappropriate mound design – design basal loading rate exceeds soil acceptance rate, linear loading rate greatly exceeds allowable code rate.
City of McGrath	McGrath	9,000	Aerobic	Mound	1999	Operational problems due to large square design; community currently seeking a replacement.

Illinois						
Site Name	Location	Daily Design Flow (gpd)	STE or Secondary Treatment (type)	Final Treatment & Dispersal	Installed	Comments
Village of Waynesville	Waynesville Dewitt Co.	23,000 (design) 11,000 (actual)	unknown	Mound	unknown	NPDES reissued 2005 Operational problems reported – toe leakage

Wisconsin						
Site Name	Location	Daily Design Flow (gpd)	STE Or Secondary Treatment (type)	Final Treatment & Dispersal	Installed	Comments
Summer Oaks Condominium	Merrimac. Sauk Co.	6,000	STE	3 cell Mound	1986	No operational issues reported – no known regular inspections
Eagle Point Subdivision 56 lots	Merrimac, Sauk Co.	18,000	STE	Multiple 3 cell mounds 12 to 16 homes/mound	1985 thru 1991	No operational issues reported – inspection program by owner – cells rotated annually
Weston School	Cazenovia, Sauk Co.	10,000	STE	4 cell Mound	1989	No operational issues reported – cells rotated annually
Sandstone Mobile Home Park	Mauston Juneau Co.	6,000	STE	2 cell Mound	1994	No operational issues reported – no known regular inspection, seasonal use
Miller's Woods Subdivision	Beaver Dam, Dodge Co.	12,600	STE	3 cell Mound	2001	No operational issues reported, inspected periodically by certified maintainer
Best Western Motel (residential strength wastewater)	Lodi, Columbia Co.	12,000	Aerobic	8 cell Mound	2003	No operational issues reported – quarterly inspections and wastewater sampling performed
Village of Wyeville Pop. 163	Wyeville, Monroe Co.	17,600	STE	3 cell Mound	unknown	DNR report: Inf BOD – 248 mg/L Effl BOD – <3 mg/L Excedances of TN, NO_3-N, , TDS, recorded in groundwater monitoring wells

C. Conclusion

Studies by E.J. Tyler & J.C. Converse, (see reference list) concluded that the overall performance of mounds was very good. Mounds could be designed to function satisfactorily on fill sites, slowly permeable soils, and locations with seasonal saturation close to the surface and where steep slopes were encountered. Some of the sites studied exhibited leakage of effluent from the down slope toe of the mound during extremely wet conditions. Samples of effluent taken from the toe area of those mounds found the effluent quality was consistently very good with fecal coliform counts generally less than 200cfu/100ml, and reductions of 99% for BOD_5.

Other studies (Burks, et al, Blasing and Converse, Converse, Tyler et al,) have shown that indicators such as fecal coliform counts were not detected at distances greater than 12 inches deep in the native soils when the mound was loaded with aerobically treated wastewater and fecal coliforms were not detected below 36 inches when the mound component is loaded with STE strength wastewater. However nitrogen removal capabilities of the system are limited. Total Nitrogen concentrations are somewhat reduced and / or converted to other forms of nitrogen in the soil. Natural soil processes can somewhat further degrade or attenuate nitrates as the effluent passes through the soil.

Some of the small community mound systems, identified in this study and noted experiencing operational problems and have the following factors in common, which are believed to have contributed to their poor operational performance:

- design criteria used high linear and basal loading rates;
- Inadequate site and soils evaluations done prior to design;
- The mound configuration did not follow the long, narrow design concept as presented in this manual

Trends in the design of mound systems, evolving over many years, has been toward narrower and longer configurations of the mound and dispersal cell components. Mound systems, when properly designed and installed have demonstrated excellent wastewater treatment and performance capability.

It is important to note here that most studies that have been conducted on mound systems have been on single family or small commercial systems and the designer of larger systems should weigh this information carefully before making decisions regarding the design of large flow systems for small communities. A more conservative approach to the design of small community mound systems is needed because of the larger flows being discharged to the environment and the resulting loss of sewer service to a larger number of people if a failure of one of the components occurs. Small community mound systems should incorporate the following strategies into the design to enhance consistent, long-term performance:

- A detailed site and soil evaluation performed by a competent person is the basis for all design decisions effecting the location and landscape position of the mound and therefore is a major factor in long-term performance;
- While single family mounds have been shown to function adequately on sites with less depth to a restrictive horizon, an acceptable site for a small community system will have a minimum of 24 inches of suitable soil for long-term system hydraulic performance;
- A design that includes a long, narrow configuration based on low linear loading rates and basal loading rates matched to the site and soil conditions greatly reduces the effects of groundwater mounding;
- A design including an active / resting cell arrangement (provide 150% of the total dispersal area required, divide the area into multiple segments of 3, then operate 2 active segments while 1 segment rests annually) **or** provide secondary treatment to reduce the strength of the wastewater;
- Redundancy in pumping equipment is essential and some method of keeping track of the actual flows (flow meter, run time meters or pump event counters);
- A design that includes adequate access points to the treatment tanks in the system for ease of operation, monitoring and maintenance;
- An operation and monitoring plan that clearly identifies treatment performance, sampling frequency and locations, record keeping and routine maintenance requirements;

IV. Design Guidance

A. Site and Soil Evaluator Qualifications

The development of a design for a large community mound system begins with a site and soil evaluation performed by a qualified person. In addition to a thorough knowledge of soil science, the site evaluator should have a basic understanding of chemistry, wastewater treatment, and water movement in the soil environment, as well as knowledge of soil-based treatment system operation and construction. The evaluator or team of evaluators should also have basic skills in surveying to create site contour maps and site plans that include temporary benchmarks, horizontal and vertical locations of site features, and investigation, sample, or test pit locations. A general knowledge of hydrology, biology, and botany is helpful. Finally, good oral and written communication skills are necessary to convey site information to others who will make important decisions regarding the best use of the site.

The role of the site evaluator is to identify, interpret, and document site conditions for use in a soil-based wastewater treatment system selection, design, and installation. The information collected should be presented in a manner that is scientifically accurate and spatially correct. Documentation should use standardized nomenclature to provide required information so that other site evaluators, designers, regulators, and contractors can use the information.

B. Site and Soil Evaluation

1. Preliminary Site Evaluation

Because land acquisition is normally a large part of the process when selecting a site for a community mound system, it is often necessary to conduct preliminary evaluations of multiple sites before an extensive evaluation is done on one or two selected sites. A preliminary evaluation can eliminate some obviously unsuitable sites from the selection process based on a site visit and/or review of available data such as property maps, USGS topographic maps, floodplain maps, wetland maps (if available), aerial photos and NRCS soil maps of the area in question. The first step in the preliminary review involves completing a general evaluation of the proposed site. The site or sites should be evaluated for conditions that might inhibit construction or proper operation of the mound component (see Preliminary Site Evaluation form on next page). From the onset it must be recognized that not all site locations will be suitable for a mound component.

Preliminary Site Evaluation

Name of Project: ____

Legal Description: ____

County: ____________________

Client Name, address, and phone: ________________________
____
____
____

General Description of the Project: ________________________________
____
____
____

Approximate Site Dimensions: _________________ Approximate Acreage: _______

A. Preliminary site evaluation of the proposed site should include the following information:

(1) Easements on the property within 50 feet of the proposed system;

easements within 50'? _______Y _______N _____ easements mapped

(2) Floodplain designation and flood elevation within 100 feet of the proposed system;

floodplain within 100'? _______Y ________N _____ flood elev. mapped

(3) Wetland designations within 100 feet of the proposed system;

wetland within 100'? _______Y ________N _____ wetland mapped

(4) Property lines of the proposed site;

property lines shown on map? ________Y _______N

(5) Features requiring setbacks from the system:

habitable buildings within 1000'? _____Y ____N ____ building shown on map

public water supply wells within 1000'? _____Y _____N ____ public well shown on map

private water supply wells within 400'? ______Y _____N ____ private well shown on map

surface water within 400'? ______Y _____N ____ surface water shown on map

(6) Current land use of the site and surrounding areas.

Current land use shown on map? _______Y _______N

Soil survey map with site designated? ________Y ________ N

Page 1

Preliminary Site Evaluation

B. Surface Information.

(1) General description of vegetation: ____
____

(2) USGS quadrangle map of site and surrounding area. ________Y _______N

(3) Site boundaries, setbacks, easements identified, located, and marked. ________Y _______N

C. Surface evidence of disturbed or compacted soil.

(1) Surface evidence of disturbance or compaction? _______Y _______N

Description of surface evidence of compaction:

____

____

____

(2) Areas of compaction or disturbance mapped? . ________Y _______N

D. Flooding or surface drainage features from adjacent properties.

(1) Evidence of flooding or surface drainage features? _______Y ________N

Description: ____
____
____

(2) Flood plain elevation and surface drainage features mapped? . ________Y _______N

E. Landscape position, landform, slope gradient and surface conditions:

Description of surface features:
____
____
____

F. Additional Comments:

____
____
____
____
____
____

Page 2

If the site looks appropriate for a mound component, the general type and direction of groundwater flow should be determined. Groundwater flow direction can often be determined based on various topographical features such as slope and relationship to nearby surface waters. Reference documents such as the USGS Hydrologic Investigation Atlas for the area (if available) and County well index reports of nearby wells are also sometimes helpful in making initial evaluations of the subsurface environment. This information will be helpful during the design process.

In cases of shallow restricting horizons and horizontal flow from a community mound system will need a large amount of owner controlled, down gradient "green space" to fully treat and dilute the effluent. If soils are permeable and flow is vertical, down slope area is less important. Of course drinking water wells should not exist or be placed down gradient of the mound (see IDNR requirements for setback distances). For guidance on land requirements, examples of mound designs for the basic populations identified in this manual can be found later in this section.

2. Detailed Soil Evaluation

The objective of the detailed site evaluation is to evaluate and document site conditions and characteristics in sufficient detail to allow interpretation and use by others in designing, siting, installing, regulating and maintaining the system. Detailed site evaluations should attempt to identify critical site characteristics and design boundaries that affect site suitability and system design. At a minimum, the detailed investigation should include soil profile descriptions and topographic mapping. Several backhoe pits, deep soil borings, ground water characterizations, and pilot infiltration testing processes may be necessary for large community mound infiltration systems. This information should be presented with an accurate site plan.

The detailed evaluation should address surface features such as topography, drainage, vegetation, site improvements, property boundaries, and other significant features identified during the preliminary evaluation stage. Subsurface features to be noted include soil characteristics, depth to bedrock and ground water, subsurface drainage, presence of rock in the subsoil, and identification of hydraulic and treatment boundaries. Information must be conveyed using standardized nomenclature for soil descriptions and hydrological conditions. Testing procedures must follow accepted protocol and standards. The following pages show a standard form, which can be used in the evaluation processes.

Soil Boring Log

Page___ of______

Property Owner:	Property Location: ¼ ¼ , Sec. T R			
Mailing Address:	Lot No.		Parcel I.D.	Subd. Name or CSM#
City	State	Zip Code	Phone	☐ City ________ ☐ Village ________ ☐ Town

Construction: ☐ New ☐ Replacement	Use: ☐ Residential ☐ Public/Commercial	Flow ________ Ave.________ Peak
Population ________	Bedrooms ________	Describe public/commercial use:
Parent Material:	Flood Plain Elev.:	
Comments:		

Boring #	☐ Pit ☐ Hand Boring	Ground Elev. ________ Feet			Depth to Limiting Factor: ________ Inches				Soil Loading Rate GPD/ft²	
Horizon	Depth In.	Dominant Color Munsell	Redox Description Qu., Sz., . Prominence, Color	Texture	Structure Gr. Sz. Sh.	Consistence	Boundary	Roots	Eff#1	Eff#2

Boring #	☐ Pit ☐ Hand Boring	Ground Elev. ________ Feet			Depth to Limiting Factor ________ Inches				Soil Loading Rate GPD/ft²	
Horizon	Depth In.	Dominant Color Munsell	Redox Description Qu., Sz., . Prominence, Color	Texture	Structure Gr. Sz. Sh.	Consistence	Boundary	Roots	Eff#1	Eff#2

Effluent #1 = Basal Loading Rate from Table 4-3 Effluent #2 = Linear Loading Rate from Table 4-3

Project Name: ______________________ Page ___ of ____

Boring #	☐ Pit ☐ Hand Boring	Ground Elev. __________Feet			Depth to Limiting Factor __________ Inches				Soil Loading Rate GPD/ft^2	
Horizon	Depth In.	Dominant Color Munsell	Redox Description Qu., Sz., Prominence, Color	Texture	Structure Gr. Sz. Sh.	Consistence	Boundary	Roots	Eff#1	Eff#2

Boring #	☐ Pit ☐ Hand Boring	Ground Elev. __________Feet			Depth to Limiting Factor __________ Inches				Soil Loading Rate GPD/ft^2	
Horizon	Depth In.	Dominant Color Munsell	Redox Description Qu., Sz., Prominence, Color	Texture	Structure Gr. Sz. Sh.	Consistence	Boundary	Roots	Eff#1	Eff#2

Boring #	☐ Pit ☐ Hand Boring	Ground Elev. __________ Feet			Depth to Limiting Factor __________ Inches				Soil Loading Rate GPD/ft^2	
Horizon	Depth In.	Dominant Color Munsell	Redox Description Qu., Sz., Prominence, Color	Texture	Structure Gr. Sz. Sh.	Consistence	Boundary	Roots	Eff#1	Eff#2

Effluent #1 = Basal Loading Rate from Table 4-3 Effluent #2 = Linear Loading Rate from Table 4-3

Soils Evaluator:	Address:	Telephone:
Signature:		Date of Evaluation:

Based on the proposed design flow, an area equal to 200% of the estimated required treatment area should be investigated. Investigation of additional area will allow some flexibility later in the design stage if preliminary design flow values change or the mound component needs to be shifted up or down slope or horizontally due to physical placement issues that cannot be for seen in the early stages of design.

Test pits should be spaced in a manner that provides a reasonable degree of confidence that conditions are similar between pits. Attempt to place pits so they will not be under the future mound. For small community systems (2,500 gpd to 10,000 gpd), five to ten test pits should be sufficient. They should be generally located around the periphery with one or two in the center of the proposed infiltration area to confirm soil conditions. Larger community projects (10,000 gpd to 25,000 gpd) may require more test pits. Test pit spacing can be adjusted based on landscape position, soil variability, and observed conditions. Hand auger borings or soil probes may be used to confirm conditions between or at peripheral test pit locations. The actual number of test pits will depend on the variability of the soils at the site. Enough soil pits have been constructed when the range of characteristics for the next pit that might be dug can be reasonably predicted. Confirmation of an adequate site takes fewer test pits when uniform soils are encountered than when highly variable soil is found on the site.

A detailed soils evaluation of the proposed area is the basis for design selection, loading rates and configuration of the mound. The purpose of the detailed soils evaluation is to determine if the soils are capable of accepting and treating the design daily flow and if the minimum requirement for the presence of the unsaturated soil below the bottom of the dispersal cell can be met following the full use of the system based on the specified daily flow rate. Some of the test pits should be deep enough to identify the soil conditions at least 10 feet below the ground surface so the designer / soil evaluator can reliably evaluate the site for permeability, unsaturated flow potential and groundwater conditions if present.

See the references section in this manual for resources that will be helpful to anyone performing detailed site and soil evaluations.

a) *Topography*

When reviewing a site for a community mound, topography becomes a very important issue. Community mounds require large areas with long continuously even contours. Mounds should be located as much as possible along straight slopes with the length of the mound parallel with the contours. Alternatively a mound can be located on a convex landscape position such as the nose of a hill but concave contour presentations should be avoided. Surface drainage features should be closely evaluated, the mound must be fit to the site to avoid swales and natural drainage ways.

b) Vegetation

Generally, sites with large trees, numerous smaller trees or large boulders are less desirable for installing a mound system because of difficulty in preparing the surface and the reduced infiltration area beneath the mound. Areas that are occupied with rock fragments, tree roots, stumps and boulders reduce the amount of soil available for proper treatment. If no other site is available, trees in the basal area of the mound must be cut off at ground level. Do not remove the stumps. Some hand tillage may be needed next to the stumps. A larger fill area is necessary when any of the above conditions are encountered, to provide sufficient infiltrative area.

C. Design Criteria

This manual provides design guidance for a complete mound system. The design guidance is summarized in the following Tables. A design report and detailed plans must be submitted for review and approved by IDNR prior to construction.

Table 4-1 Wastewater Flows and Soil Loading	
Population Design Flow (AWW)	25 to 250 persons 100 gal/person/day
Influent Wastewater Strength Average value of Fats, Oil and Grease (FOG) Average value of BOD5 Average value of Total Suspended Solids (TSS)	 ≤ 30 mg/L ≤ 250 mg/L ≤ 150 mg/L
Design loading rate of sand fill	≤ 1.0 gal/ft^2/day when BOD5 is >30 mg/L, & ≤ 250 mg/L & TSS is > 30 mg/L, & ≤ 150 mg/L or ≤ 2.0 gal/ft^2/day when BOD_5 and TSS ≤ 30 mg/L
Design loading rate of the basal area	Table 4-3
Design Linear Loading Rate	Table 4-3

Table 4-2 Mound and Dispersal Cell Details	
Dispersal cell width	Based on Linear Loading Rate from Table 4-3
Minimum dispersal cell area	≥ Design flow ÷ loading rate of the sand fill material
Orientation	Longest dimension parallel with surface grade contours
Deflection of dispersal cell on concave slopes	≤ 10%, see discussion on concave slope installation
Sand fill material depth at up slope edge of the dispersal cell	Min. 6 inches or ≥ 12 inches so combined sand fill depth and suitable native soils ≥ 36 inches.
<u>Dispersal cell depth</u> 1) Gravel Aggregate 2) SyntheticAggregate or Chambers	 minimum 6 inches under the distribution pipe and 2" over the pipe as specified by manufacturer
Distribution cell area per orifice	≤ 12 ft^2
Bottom of distribution cell	Level
Depth of cover material at top center of the dispersal cell area	≥ 12 inches (this is the minimum required for frost protection add more if local conditions warrant)
Depth of cover material at top outer edge of the dispersal cell area	≥ 6 inches (this is the minimum required for frost protection add more if local conditions warrant)
Basal area	≥Design Flow ÷ Infiltration Loading Rate from Table 4-3
Basal area calculation	Cell length x [(# of cells x cell width) + ({# of cells –1} x cell spacing) + down slope width]
Horizontal separation between cells located in the same mound (cell spacing)	Down slope width based on 3:1 slope requirement-Dimension (I) + 30% (Dimension I + (I x 30%) = cell spacing
Horizontal separation between mounds placed up & down slope from each other	15' from down slope toe + 20' construction zone to next upslope toe = 35' minimum mound spacing
Horizontal separation between dispersal cells end to end within same mound	10 feet
Horizontal separation between mounds end to end	15' end slope toe to end slope toe for drainageway between mounds
Slope of original grade	>2% and ≤ 20%
Depth of in situ soil to limiting factor	≥ 24 inches
Vertical separation between dispersal cell infiltrative surface and limiting factor.	≥ 36 inches

Table 4-2 cont. Mound and Dispersal Cell Details	
Sand fill material	Meets ASTM Specification C-33 for fine aggregate (Table 2-3) Or IDOT Gradation No. 1 (Table 2-4)
Effluent application	Pressure distribution network See Appendix B
Pressure Piping Material	Pressure rated pipe
Distribution Media 1) Stone aggregate material 2) Synthetic	 Size Range - ½ inch to 2 ½ inch Must be washed to remove fines Hardness value of 3 or more on the Moh's Scale of Hardness Expanded Polystyrene or Leaching Chambers
Geotextile fabric cover over dispersal cell when stone or synthetic aggregate is used. (filter fabric is not required on leaching chambers)	Meets the requirements of ASTM D4632, ASTM D4533, ASTM D4751, and ASTM D4833
Number of observation pipes per dispersal cell	≥ 2
Location of observation pipes	At opposite ends of the dispersal cell, and 1/5 to 1/10 the length of the dispersal cell measured from the end of the cell
Maximum final slope of mound side slopes	≤ 3:1 (maximum slope recommended for mowing purposes)
Cover material	Soil that will provide frost protection, support plant growth to prevent erosion and excess precipitation or runoff infiltration and allow air to enter the dispersal cell
Grading of surrounding area	Graded to divert surface water around mound system
Limited activities	Vehicular traffic, excavation, and soil compaction are prohibited in the basal area and 15 feet down slope of the basal area, if there is a restrictive horizon that negatively affects treatment or dispersal this dimension should be increased accordingly.
Installation inspection	Designer to confirm compliance with approved plan
Operation & Management	In accordance with this manual and manufacturers recommendations

1. Basal Loading Rates

The soil evaluator and the system designer will need to consider the soil hydraulic properties throughout the natural soil profile. The loading rate tables used to determine required basal area, found in Table 4-3, consider soil horizons with greatly restricted hydraulic conductivity as "limiting factors" (bedrock, slowly permeable soils, compact dense till). A zone of 24 inches of suitable soil is required above the limiting factor. A suitable soil is any soil horizon that does not have a loading rate of 0.0 as listed in Table 4-3. Effluent leaving the sand fill and entering the in-situ topsoil may move into the soil at a rapid rate because most of the organic matter (BOD and TSS) has been removed as it passes through the sand. However, if it then encounters a more slowly permeable limiting factor, flow within the soil then becomes horizontal rather than vertical and may become restricted to the point of having an adverse effect on the mound. Systems on slopes are more apt to produce flow in the down slope direction to assist with draining effluent from under the mound. The function of the mound is to treat and disperse the effluent into the surrounding environment. After passing through the sand, the in situ soils must be capable of transmitting the effluent away from the mound.

Table 4-3 - Basal And Linear Loading Rates

Infiltration rates in gal/day/ft^2 for wastewater of <30 mg L^{-1} BOD and hydraulic linear loading rates in gal/da/ft for soil characteristics of texture and structure and site conditions of slope and infiltration distance. Values assume design wastewater volume of >100 gal/day/person or design safety factor is within design flow. If horizon consistence is stronger than firm or any cemented class or the clay mineralogy is smectitic, the horizon is limiting regardless of other soil characteristics.

Soil Characteristics			Infiltration Loading Rate, gal/da/ft^2	Hydraulic Linear Loading Rate, gal/day/ft — Slope			
	Structure			2-4% Infiltration Distance	5-9% Infiltration Distance	>10% Infiltration Distance	
Texture	Shape	Grade	<30 mg/L BOD	24-48	24-48	24-48	Row
COS, S, LCOS, LS	--	0SG	1.6	6.0	7.0	8.0	1
FS, VFS,LFS,LVFS	--	0SG	1.0	5.5	6.0	7.0	2
CSL, SL	--	0M	0.6	4.0	5.0	7.0	3
	PL	1	0.5	4.0	5.0	6.0	4
		2, 3	0.0	-	-	-	5
	PR/BK /GR	1	0.7	5.5	6.0	7.0	6
		2,3	1.0	5.5	6.0	7.0	7
FSL, VFSL	--	0M	0.5	3.0	3.5	4.0	8
	PL	1,2,3	0.0	-	-	-	9
	PR/BK /GR	1	0.6	4.0	4.5	5.0	10
		2,3	0.8	4.5	5.0	6.0	11
L	--	0M	0.5	3.0	3.5	4.0	12
	PL	1,2, 3	0.0	-	-	-	13
	PR/BK /GR	1	0.6	4.0	4.5	5.0	14
		2, 3	0.8	4.5	5.0	6.0	15
SIL	--	0M	0.2	2.5	3.0	3.0	16
	PL	1,2,3	0.0	-	-	-	17
	PR/BK /GR	1	0.6	3.0	3.5	4.0	18
		2,3	0.8	3.5	4.0	4.5	19
SCL,CL SICL	PL	0M, 1,2,3	0.0	-	-	-	20
	PR/BK /GR	1	0.3	3.0	3.0	3.5	21
		2,3	0.6	3.5	3.5	4.0	22
SC, C, SIC	PL	0M,1,2,3	0.0	-	-	-	23
	PR/BK /GR	1	0.0	-	-	-	24
		2,3	0.3	3.0	3.0	3.5	25
A	B	C	D	E	F	G	H

2. Linear Loading Rates

The hydraulic linear loading rate is the volume of effluent (gallons) applied per day per linear foot of the system along the natural contour (gpd/ft) (Tyler and Converse, 2000). Wastewater applied to the sand fill infiltrates into the sand and eventually moves into the native soils. If the linear loading rate is too high the native soils may not be able to move the effluent away from the mound fast enough. The results can be a break out of wastewater at the toe of the mound. If the flow in the native soils is primarily vertical then the hydraulic loading rate can be higher based on soil hydraulics but there are limits to linear loading based on the supply of oxygen from the sand fill. If the flow is primarily horizontal, because of restrictive layers then the linear loading rate should be reduced. Soil profile observations used to determine soil loading rates based on soil characteristics are also used to determine linear loading rates. Linear loading rates shown in Table 4-3 present values for hydraulic linear loading rates, based on texture, structure and consistence for various soils (Tyler, adapted with permission 2007).

D. Design Daily Flow

For a new system designed under these guidelines the design daily flow (AWW) shall be 100 gal/person/day.

AWW = no. of people x 100 gal/person/day

Table 4-4
Design Daily Flows for Various Populations

Population	Flow/Person	Design Daily Flow
25	100	2,500
100	100	10,000
250	100	25,000

As with any system a careful evaluation of the wastewater source is necessary. The designer should try to determine if there are any sources of unusual flow that may have a significant effect on the anticipated design daily flow. Some items that the designer and the owner/community should be aware of and watchful for are:

- Sump pumps that may add substantial wet weather flows;
- Poor landscaping around access points to the collection system, which may add surface water to the system;
- Leaky plumbing fixtures;
- Condensate drains from furnaces;
- Water softener discharge.

If any of these items will pose a significant increase in expected flow rates, adjust the design population accordingly.

E. Wastewater Source & Strength

Mound systems designed under this guidance manual should be capable of accepting and processing hydraulic flows from residential sources while providing the necessary pollutant removal efficiency to achieve performance goals. The concentrations of typical pollutants in raw residential wastewaters and average daily mass loadings are summarized in Table 3-1. Table 3-2 shows typical strength of residential wastewater that can be expected after primary treatment in a septic tank.

F. Primary Treatment Component – Septic Tanks

See Appendix A for design criteria, layout and configuration of the primary treatment component.

G. Secondary Treatment Component

Consult manufacturer for design criteria, layout and configuration of the secondary treatment component, if used.

H. Dosing Component

1. Dose Tank

The pressure-dosing component is a watertight vessel, which stores the effluent, pumps and level sensing switches. All of these parts, functioning as a complete system, will provide a reasonably uniform application of effluent to the distribution media at selected dose volumes and times to be determined during the distribution network design. It should be noted that even in applications where secondary treatment is used and the effluent quality is visually clear, there can still be a biological build up that will occur in the “quiet” zone below the dosing pumps.

Periodic monitoring and removal of this material is required for all dose tanks. Sludge removal intervals for this device should be based operator inspection and periodic measurements of the sludge depth.

2. Pumps

Pumps provide the energy needed to get the wastewater to the dispersal component. The two types of pumps commonly used in on site wastewater treatment systems are centrifugal and turbine pumps. Centrifugal pumps create low head but pump high volumes in a short time, while turbine pumps are the opposite. A system with a large distribution network generally requires a centrifugal pump because of the volume of water required to provide uniform distribution is high. While turbine pumps generally provide lower flow rates, they can be used in conjunction with pressure actuated distribution valves, or electrically actuated multi-port valves, which effectively separate the distribution network into multiple zones.

a) Comparisons of pump types

Turbine pumps are more capable of keeping orifices in the distribution network unplugged because of the high head capabilities but centrifugal pumps provide more volume for large distribution networks. Turbine pumps are typically used only with screened or filtered effluent or following secondary treatment components that remove most of the suspended solids. Even with STE the maximum particle size allowed to pass through the filter is 1/8-inch and therefore solids handing capabilities by the pumps is not critical or required. Turbine pumps are usually installed within a flow collar (6-inch to 8-inch pipe) or an effluent filter enclosed pump compartment (See Fig. 4-1). Turbine pump installation should include the provision for a low water, redundant off water level sensor to protect the pump from running dry.

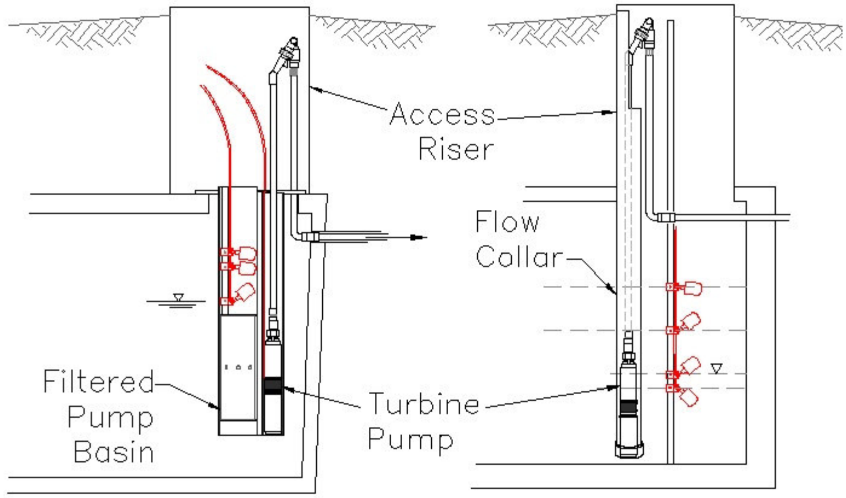


Figure 4-1 Turbine Pump Installation Options
Photo Courtesy of Orenco Systems®

Centrifugal pumps are more commonly used in septic tank system dosing applications and most installers will be more familiar with installation, trouble-shooting and replacement of this type of pump.

Pump selection needs to match the maximum flow rate needed to pressurize the distribution network and the total dynamic head (TDH) created in the system. Pumping requirements will vary for every project but common elements to all mound systems are:

- Accessibility-riser required over each pump;
- Pumps need to be removable without entering the tank;
- Duplex pumps required w/alternating mechanism

3. Distribution Valves

Valves used in conjunction with the dosing pumps to evenly divide flows to multiple cells can be electrically actuated or pressure actuated valves. Pressure actuated distribution valves (Fig. 4-2), are often used in recirculating sand filter distribution networks but can be adapted to almost any pressure distribution network including those found in a mound system. The major advantage of a distribution valve is the reduction in the pump dosing rate and therefore the use of a smaller horsepower pump, while still maintaining uniform distribution. Disadvantages of the pressure actuated valve include:

- Substantially increases total dynamic head conditions;
- Susceptibility to freezing;
- Malfunctions are difficult to detect; and
- Additional device that requires routine inspection and maintenance.

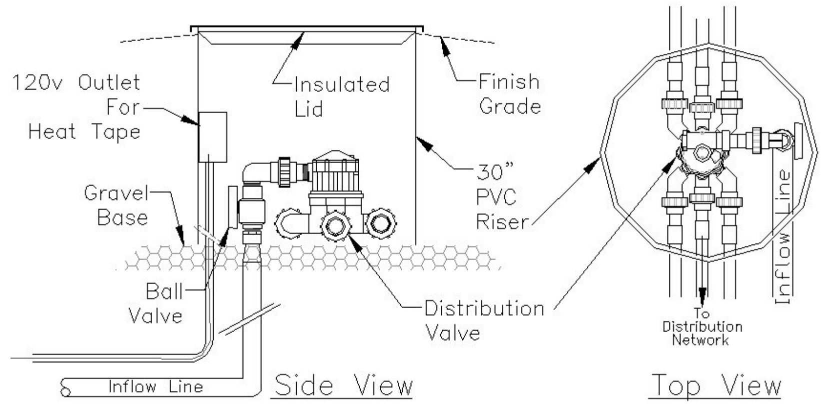


Figure 4-2 Distribution Valve
Photo Courtesy of Orenco Systems®

If a distribution valve is used it should be placed in a central location within the distribution network to provide for even distribution of the head loss values across the system. Other types of electrically actuated control valves may also be used to provide for even distribution of the wastewater to the distribution network.

a) *Freezing Issues*

Freezing is a concern with any type of valve used in this application but may be more of an issue with the pressure actuated distribution valve because of the landscape position it needs to be in for correct operation. The valve must be located at a high point above the distribution laterals so that when a dose event is completed and the internal rotating disk is no longer under pressure, it will automatically "switch" to the next outlet in the valve. The requirement to be located higher than the discharge point also allows the valve and connector piping to drain into the laterals which somewhat reduces the potential for freezing. Never the less, it is recommended that when installing this valve, especially for a mound distribution network, an insulated cover be used, soil is banked up to directly below the underside of the access lid, and an outlet for a water pipe type heat tape be provided to maintain a temperature above freezing within the valve structure.

4. Water Level Switches

Various types of water level switches can be used such as standard mercury floats, pressure switches or level sensors responding to changes in the water levels in the dose chamber controlling the pump operation. Water level switches must be provided for the following functions:

- Low water switch;
    - Provides a solids settling space below the pump and pump submergence to cool the pump during operation
- Timer enable on and peak override timer switch;
    - Provides space for the daily dosing operation volume requirements
- High water/lag pump on switch;
    - Provides reserve volume for surge flows and notification of pump failure and/or incoming flows beyond the capacity of the pumps

5. Timed Dosing

Discharge to the distribution network shall be accomplished by “timed” dosing. Timed dosing operations are activated by the water level sensors and operates the pumps at predetermined intervals throughout the day based on the timer programming. The pumps discharge small frequent doses of wastewater to the distribution network as long as the timer enable level sensor is in the on position. Override timing can be incorporated into the dosing setup to handle occasional peak flows. The advantage of timed dosing is more accurate regulation of the discharge to the final dispersal component, surge flows will remain in the dosing chamber until the timing system catches up and eventually pumps them out. Timed dosing systems require more careful consideration of dosing tank volumes but in terms of overall system performance they are the required method of discharging the flow to the mound component because the flow within a 24-hour design period can be regulated such that no excess discharges are allowed. Instead the excess or surge flows are held in the tank until “timed” out over lower flow time periods. The additional volume required in the dose tank for timed dosing setups is discussed in the following Section.

6. Dose Tank Volume

A widely accepted method of sizing this device is to begin with a volume equal to the design flow. This volume may be increased or decreased depending on the particular needs of the system being designed. The volume provided in the dosing tank is made up of the following sections or volumes:

- Pump Submergence Volume
- Dosing Operation Volume
- Reserve Volume

The final sizing of the dose tank should be made based upon consideration of the following information, (also see Fig. 4-3).

a) *Pump Submergence*

(1) Centrifugal Pumps

While many of the small centrifugal pump manufacturers advertise a capability of running dry without causing damage, it is a good practice to provide a water level in the tank for pump submergence. The pump submergence volume, when using a centrifugal pump, includes the pump height plus a space below the pump for a stand off block for solids settling. The standoff block under a centrifugal pump will usually be 4-inches to 6-inches high. If incoming wastewater is septic tank effluent use the higher stand off block, if the incoming wastewater is treated to a secondary level, the lower stand off block could be used.

Pump Submergence Required = Standoff block height + pump height
= pump cover

(2) Turbine Pumps

On turbine pumps the inlet is generally located about 12-inches up from the bottom of the pump and therefore does not need a standoff block below the pump. Turbine pumps are generally installed with a "flow collar" to create water movement past the motor for cooling purposes (Figure 4-3). The flow collar also provides some protection from solids entering the pump inlet. Commercially available turbine pump vaults encase the pump in a filtered flow collar device to prevent solids being picked up by the pump. The space requirements within the dose tank for turbine pump submergence is usually greater than what is required for centrifugal pumps because of the length of pump. The designer should consult the pump manufacturer to determine the actual height of the water needed for the particular pump they anticipate using.

b) *Dosing Operation Volume*

The dosing operation volume is dependent on the actual flows and the timed dosing program adopted for a particular system. The dosing operation volume includes the space between the initial timer enable switch and the high water alarm/lag pump on switch. This space or the volume represented by the distance between the water level switches includes the volume required for normal timer and peak timer operation. At a minimum this volume should be based on the following calculation:

60% to 75% X AWW = Dosing operation volume.

Example using 25 people:
60% 25 x 100 x = 600 gal.
75% 25 x 100 x = 750 gal.

For a system serving a population of 25 the minimum dosing operation volume considered should be 600 to 750 gallons. This volume may need to be adjusted depending on the actual timer settings used. The volume selected may be divided equally between the enable timer operations and the peak timer operations. For instance if the distance required between switches to provide the dosing operation volume is 24", then the peak timer switch will be 12" above the initial timer switch and the alarm switch will be 12" above the peak timer switch.

c) *Reserve Volume*

The emergency storage or reserve volume stores additional effluent generated after the alarm float is activated. The alarm may be activated due to a pump malfunction or because the timing selected has not kept up to the incoming flows. The storage volume allows the facility to operate until the pump is repaired or timing adjustments can be made.

Measures such as duplex pumping equipment used in conjunction with override controls can reduce the emergency storage volume required. The provision for this volume should be based on the designer's experience with timed dosing programs and a judgment of the operator's ability to react to alarms in a timely manner. The minimum volume considered should equal 30% of the design flow.

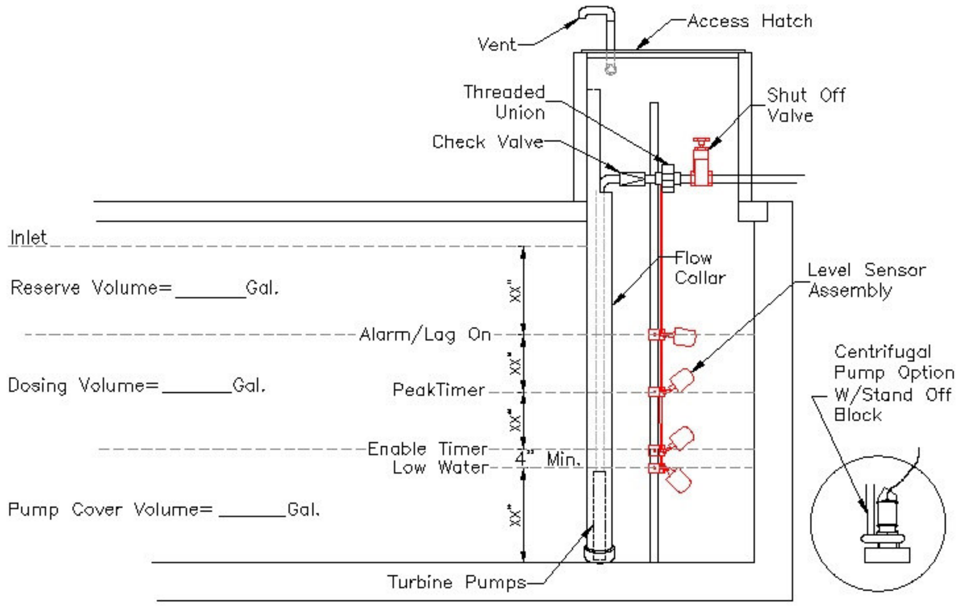


Figure 4-3 Dose Tank Cross Section

If the designer is planning on using precast or manufactured tank for this device, the manufacturer should supply data such as the liquid depth of the tank, the inside dimensions and the volume per inch or foot so that calculations can be made to verify that the correct volumes are being provided. For site constructed tanks the designer will need to adjust the length, width and height of the tank until adequate volumes are provided.

Example of calculating dose tank volume requirements.

______ inches-pump cover = ________ gal.
(tank bottom to height of pump or low water switch)

\+ _______ inches- = ________gal.
(low water switch to enable timer switch – 4" minimum)

\+ _______ inches-dosing volume = ________gal.
(enable timer to alarm sensor)

\+ _______ inches-reserve volume = ________gal.
(minimum 30% of the design flow)

= _______ total inches-total dose tank volume ________gal.

Select or design a tank that will provide a minimum volumes listed above. Providing additional volume, above and beyond the minimums indicated above, will provide more temporary storage in the event of higher surge flows than anticipated or an equipment malfunction.

7. <u>Controls and Alarms</u>

a) *<u>Controls</u>*

The control panel, if located outside, shall be a weather proof, rain tight, NEMA 4X enclosure, equipped with all necessary mechanisms for duplex pump operations, run time meters, event counters and must be capable of all required alarm functions. Electrical surge protection and lightening arrestors should also be incorporated into the panel.

b) *<u>Alarms</u>*

Because many times mounds are located in remote areas, where visual and audible alarms can go unnoticed for extended periods of time, consideration should be given to providing a dedicated phone line and an automatic alarm dialer for notification of alarm conditions. An alarm dialer may not be necessary for smaller systems with a built in surge capacity of 24 hours or more and if there is an Operation and Maintenance schedule that includes daily inspections of the system by a qualified operator. Monitoring flows and alarm conditions can also be accomplished by other methods that include a range of options from standard automatic alarm dialers to computerized or web based systems that allow remote monitoring and manipulation of system operation while still providing all of the standard alarm functions. Alarm dialers and remote monitoring systems require a dedicated phone line to the control panel. Decisions regarding the alarm notification and/or remote operation options should be based on the design flows, the complexity of the treatment system and the operators ability to respond to emergency situations that will arise. Some remote monitoring systems will require a heated enclosure for operation.

8. Distribution Network

The following publication is recommended for use when designing the distribution network:

> Pressure Distribution Network Design by James Converse, Small Scale Waste Management Project (SSWMP): University of Wisconsin, Madison, Wisconsin. www.soils.wisc.edu/sswmp. This publication can also be found in Appendix B of this manual.

Lateral and manifold sizing is determined using a series of graphs and tables after the designer has selected the desired orifice size and spacing and the distal pressure in the network. These graphs and tables were derived by calculating the change in flow and pressure at each orifice between the distal and proximal ends of the network. The method is meant to result in discharge rates from the first and last orifices that differ by no more than 10 percent in any lateral for a dose event.

To achieve uniform distribution, the density of orifices over the infiltration surface should be as high as possible. However, the greater the number of orifices used, the larger the pump must be to provide the necessary dosing rate. At a minimum the number of orifices required equals 1 per 12 sq. ft. of dispersal cell. To reduce the dosing rate, the orifice size can be reduced, but the smaller the orifice diameter, the greater the risk of orifice clogging. The minimum orifice diameter allowed is 1/8-inch and only when a secondary treatment component is also part of the design. When the designer chooses an orifice diameter of 1/8-inch, it is recommended that a pressure filter be installed on the dosing pump outlet to reduce the risk of discharging particles large enough to clog the orifices (see Fig. 4-4).

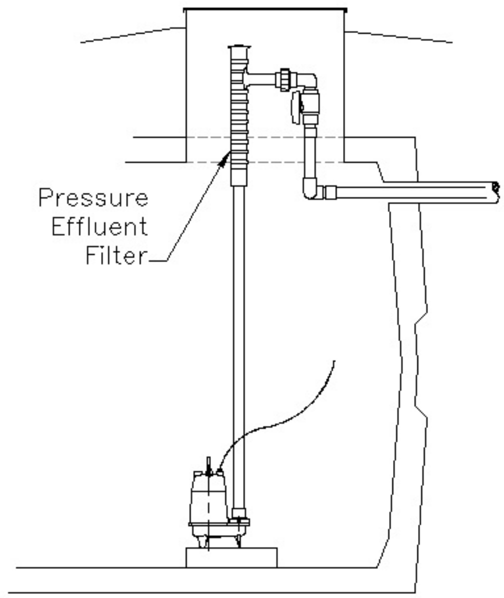


Figure 4-4 Dose Tank w/Pressure Filter

Orifice spacing ranges from 0.5 to 5 feet, but the greater the spacing, the less uniform the distribution because each orifice represents a point load. It is up to the designer to achieve the optimum balance between orifice densities and pump size. The dose volume is determined by the desired frequency of dosing and the size of the network.

During filling and draining of the network at the start and end of each dose, the distribution is less uniform. The first holes in the network discharge more during initial pressurization of the network, and the hole at the lowest elevation discharge more as the network drains after each dose. To minimize the relative difference in discharge volumes, the dose volume should be greater than five times the volume of the distribution network. Distribution lateral orifices are manually drilled into the pipe at the predetermined intervals.

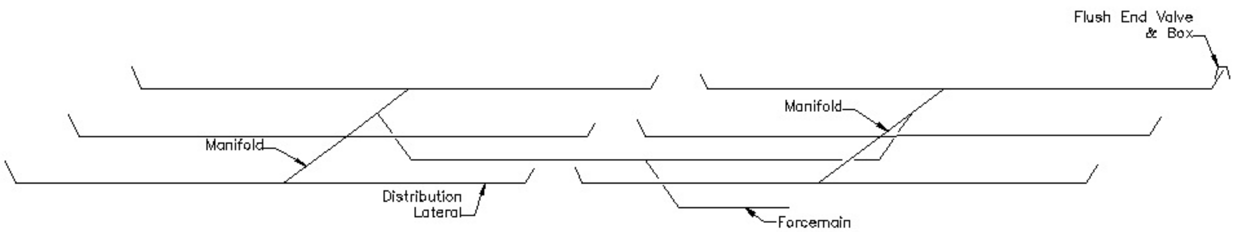


Figure 4-5 Distribution Network

Distribution network lateral construction includes an elbow at the end of each lateral directed to the surface (Figure 4-6). A manually operated ball valve is located at the end of each lateral in a protective enclosure for maintenance purposes. When the ball valve is opened during a pump event the laterals can be blown out periodically to remove any buildup of biological material from the inside walls of the pipe.

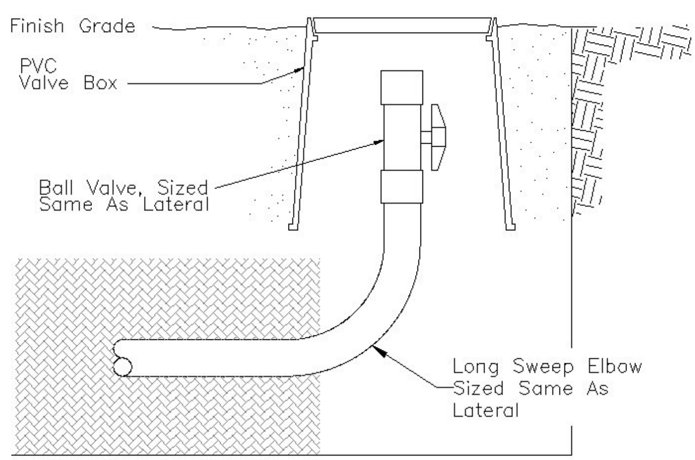


Figure 4-6 Flush End Valve & Box

I. Mound Component

1. Groundwater Mounding Considerations

Groundwater mounding or perching may occur when wastewater from a dispersal cell is applied at a rate that exceeds the capacity of an underlying soil horizon to vertically transmit the water downward. The ground water mound may rise to the elevation of the base of the infiltration dispersal cell or the elevated saturated soil may intercept the ground surface to the side of the cell. Beneath mound systems the ground water mound should not be allowed to be above the original ground surface or into the sand fill. Ground water mounding can be estimated based on soil characteristics and using either an analytical or numeric modeling method.

Some analytical and numerical methods for predicting ground water mounding are complex. Because the input values are, by nature, variable and difficult to measure or estimate the precision of results from complex methods may be no better than those derived using simpler methods. Only more direct analytical methods are presented here. If the input values have low variability and there will be strict control of the infiltration dispersal cell more complex numerical methods may be justified. A discussion of both analytical and numerical methods can be found in the literature (Poeter, McCray et al. 2005)(Bower, 1999).

Ground water mounds can be estimated after completion of a dispersal cell or mound system design. In some situations the mound will be higher than acceptable and the design will need to be modified. It is better to set the maximum ground water mound elevation leaving an unsaturated soil zone between the infiltration surface of the dispersal cell or set it at the elevation of the base of a mound system and calculate the width and wastewater loading rate to stay below that elevation.

There are two major situations to estimate mounds. The first assumes a mound is formed in a horizon of hydraulic conductivity, K_1, over a horizon of much lower conductivity, K_2. There is no perched natural water table over the low conductivity horizon. Wastewater added at a rate greater than the rate of acceptance of the lower horizon will perch water in the shape of a mound. The situation is shown in Figure 4-7 and has been defined (Khan 1976) and used for defining mounding under large onsite wastewater infiltration systems (Poeter, McCray et al. 2005).

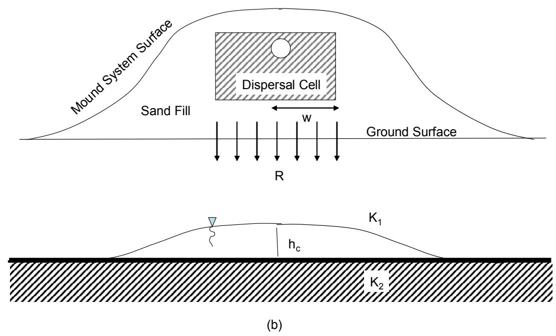


Figure 4-7 Groundwater Mounding Over a Slowly Permeable Horizon Without Natural Perched Water Beneath a Mound System

The equation is:

$$\frac{h_c}{w} = \left[\frac{K_2}{K_1} \left(\frac{R}{K_2} - 1 \right) \left(\frac{R}{K_2} \right) \right]^{1/2}$$

Where h_c is the mounding height at the center of the mound, w is half the cell width, K_1 is the hydraulic conductivity of the upper more permeable horizon, K_2 is the hydraulic conductivity of the slowly permeable subsurface horizon and R is the recharge or loading rate of the wastewater. If K_1 were 30 cm da^{-1}, K_2 were 0.5 cm da^{-1}, the loading rate or recharge were 1 cm da^{-1} and w, the half width of the cell, were 40 cm the estimated mound would be 11 cm or 4.3 inches above the slowly permeable horizon. If the K_2 were greater than R there would not be a mound. Note that in the next equation an upper case W is used as a symbol for the total width.

Calculating the cell width, w, and the loading rate or recharge rate assuming an acceptable mounding height is more useful for design. For example, as depicted in figure 1(a), if the distance from the infiltration cell to the slowly permeable horizon were 120 cm or just over 47 inches and a 90 cm (36 inch) separation distance was desired then a mound height, h_c could be 30 cm high. Assuming values of K_1, K_2 and R from the example above and the equation, the calculated maximum cell width, 2w, could be 328 cm or almost 11 ft. This is based only on hydraulics. Depending on the oxygen demand of the wastewater this could be far too wide.

The second situation is a more permeable horizon over a less permeable horizon but natural water perches in the upper horizon over the lower (Figure 4-8). In this situation the addition of wastewater raises the elevation of the existing groundwater beneath the dispersal cell. A discussion of one method using a solution by Hantush (1967) along with a calculator for Microsoft Excel® has been created (Poeter, McCray et al. 2005). A method based on Dupuit-Forchheimer assumptions was used for estimating dispersal cell trench widths for mounds during early development periods of the Wisconsin Mound System (Bouma, Converse et al. 1975).

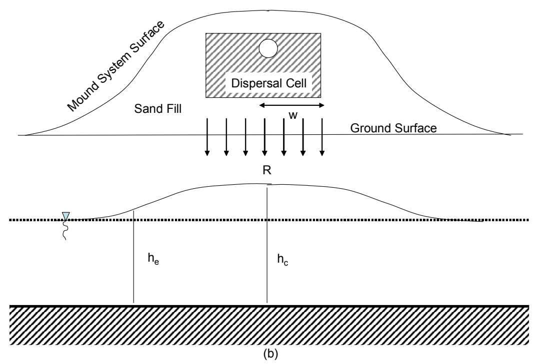


Figure 4-8 Groundwater Mound Over Seasonal Soil Saturation Beneath a Mound System

The equation (Bouma, Converse et al. 1975) is similar in format to many others and is:

$$h_c^2 - h_e^2 = \frac{RW^2}{2K}$$

The symbols have been changed from those in the literature to be consistent with the previous figure and equation. Note that W is the total cell width not the w for the half width as in the previous equation. If it is desired to calculate the cell width as a basis for design and the soil conductivity, K, is 40 cm da^{-1}, the cell loading rate or recharge rate, R, is 5 cm da^{-1}, h_c is 30 cm to allow the separation distance desired and h_e, the height of the natural perched groundwater above the less permeable or impermeable horizon is 25 cm then the calculated cell width is 66 cm or 26 inches. From site evaluation it is necessary to determine the depth and nature of the less permeable or impermeable horizon even if it below the elevation of the estimated season saturation or limiting layer. Hydraulic conductivity may be estimated from soil morphology or from measurements.

Similar procedures could be used to design for a loading rate, R, as the variable to be changed. Also, it might be useful to determine the value of the product of R and 2w to use for varying the loading rate and cell width simultaneously. This sets all the values set by site evaluation and design separation distance on the right side of the equation and the design variables of loading rate and cell width on the left.

$$RW^2 = 2K\left(h_c^{\ 2} - h_e^{\ 2}\right)$$

Using the values from the last example:

$$RW^2 = 22{,}000$$

Therefore, if R were set at 5 cm da^{-1} then W would be 66 cm or 26 inches. However, if R were set at 2 cm da^{-1} then W would be 105 cm or about 41 inches. If a specific cell width were desired such as 90 cm or 36 inches, then the loading rate R could be 2.7 cm da^{-1} and still maintain the desired separation distance.

The previous examples were for a dispersal cell of one unit. In some situations multiple parallel cells are desired. A calculation similar to those already shown could be used except that R is the average loading rate. Average R was previously used to estimate mounding under multiple cells (Poeter, McCray et al. 2005).

Spacing between dispersal cells may be great enough that the average loading rate, R, is low but the loading rate beneath each cell could be much higher. It is important to confirm that the ground water mound beneath individual cells of a multi-cell system be within design limits by calculating the ground water mounding under a cell as in earlier examples.

Regardless of the estimating procedures, the site evaluation must provide a basis for determining saturated hydraulic conductivity and the depth to the slowly permeable horizon even if it is below the limiting layer of seasonal soil saturation.

Designers that are aware of the potential problems caused by a rise in the groundwater height will incorporate design practices that will either eliminate or greatly reduce the potential for increased groundwater mound heights. These practices include long, narrow dispersal cells, placing mounds along the surface contours on adequate slopes to increase gravitational forces pulling the water away from the discharge point, and dividing the dispersal area into separated subareas if necessary.

2. Configuration and Layout

The mound configuration is based on the provision for low linear loading rates. To provide low linear loading rates a mound must be constructed in a long and narrow configuration. The more restrictive the soil profile, the narrower and longer the mound component will be. Table 4-3 provides loading rates and dispersal cell widths based on soils present at the site.

Special siting and construction considerations for large mound systems are:

- A configuration as long, narrow as possible.
- Locate mounds parallel with site contours with the special consideration that they don't act as dams for surface or subsurface flow across the site.
- If more than one mound or more than one dispersal cell within the mound is required, which is usually the case with larger flows, adequate distance side to side and end to end should be allowed for construction and to assure they do not interfere with one another hydraulically.

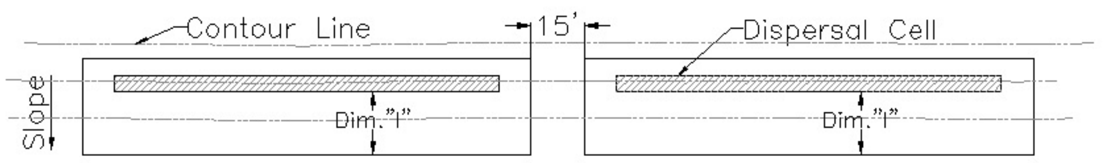


Figure 4-9 Mounds on Same Contour

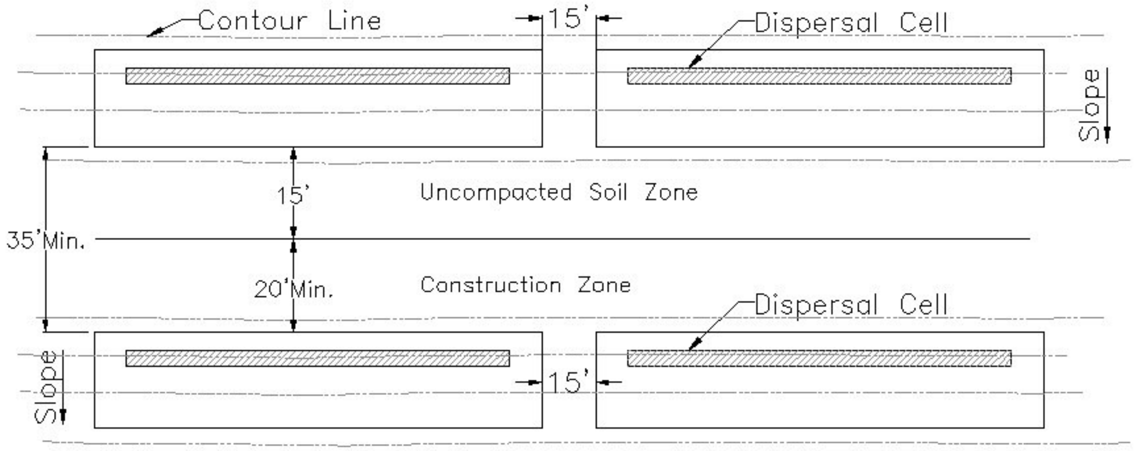


Figure 4-10 Multiple Mounds Positioned On The Same Slope

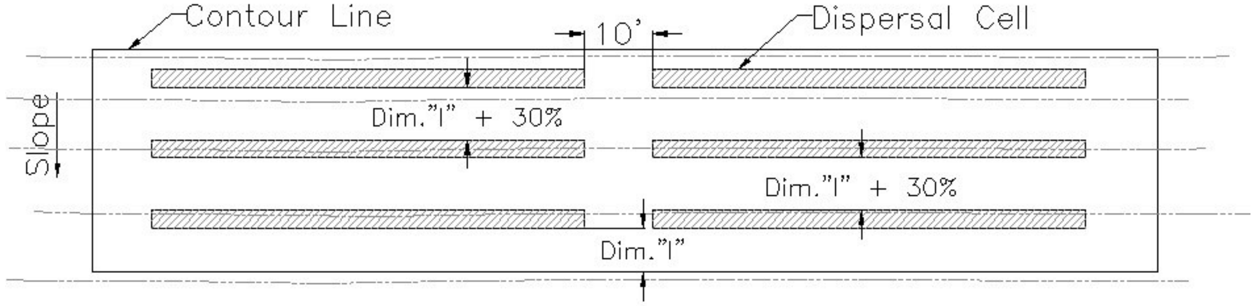


Figure 4-11 Multiple Cells Within One Mound

Site slopes are generally not a limitation for locating the mound component. An upper limit of 20% is recommended based on construction safety concerns. Mounds on steep slopes with slowly permeable soils should be long and narrow to reduce the possibility of toe leakage. Drainage of surface water around the upslope edge of the mound is always a concern with very long mounds. Steeply sloped sites have the potential to create erosion problems and very flat sites can increase the difficulty of the design of any surface water diversion features. A lower site slope limit of 2% is also recommended to further avoid issues with groundwater mounding under the dispersal cell.

The maximum length of any distribution cell is dependent on the site conditions and the distribution network design and constraints. The distribution cell is aligned with its longest dimension parallel to surface grade contours. The bottom of the distribution cell is level so one area of the distribution cell is not overloaded.

3. Mounds on Concave Slopes

The maximum deflection of a concave distribution cell of a mound system is 10%. The percent of deflection of a distribution cell is determined by dividing the amount of deflection by the effective distribution cell length of the concave distribution cell. The deflection is the maximum distance between the down slope edge of a concave distribution cell to the length of a perpendicular line that intersects furthest points of the contour line along the down slope edge of the distribution cell. The effective distribution cell length of the concave distribution cell is the distance between the furthest points along the contour line of the down slope edge of the concave distribution cell. (Figures 4-12 and 4-13).

The deflection of a distribution cell on concave slopes is calculated using Formula 1.

Formula 1

Percent of Deflection = (Deflection ÷ Effective distribution cell length) x 100

Where;

Deflection =	Maximum distance between the down slope edge of a concave distribution cell to the length of a perpendicular line that intersects furthest points of the contour line along the down slope edge of the distribution cell.
Effective distribution cell length =	Distance between the furthest points along the contour line of the down slope edge of the concave distribution cell
100 =	Conversion factor

The actual distribution cell length must be checked to determine if the cell area is sufficient. The actual distribution cell length is calculated using Formula 2.

Formula 2

Actual distribution cell length = [(% of deflection x 0.00265) + 1] x effective distribution cell length

Where;

% of deflection =	Determined by Formula 1
0.00265 =	Conversion factor from percent to feet
1 =	Constant

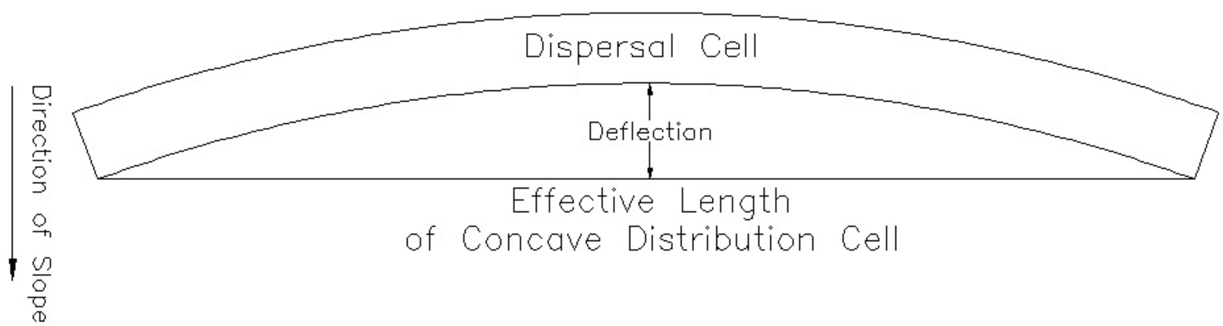


Figure 4-12 Simple Concave Distribution Cell

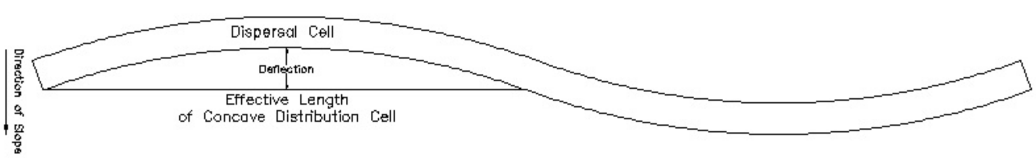


Figure 4-13 Complex Concave Distribution Cell

4. Mound Design Calculations

Specific mound dimensions can be determined based on the calculations shown on the following pages. The identifying letter found in Figures 4-14, 4-15 and 4-16 for each dimension corresponds to the letters shown in the calculations section.

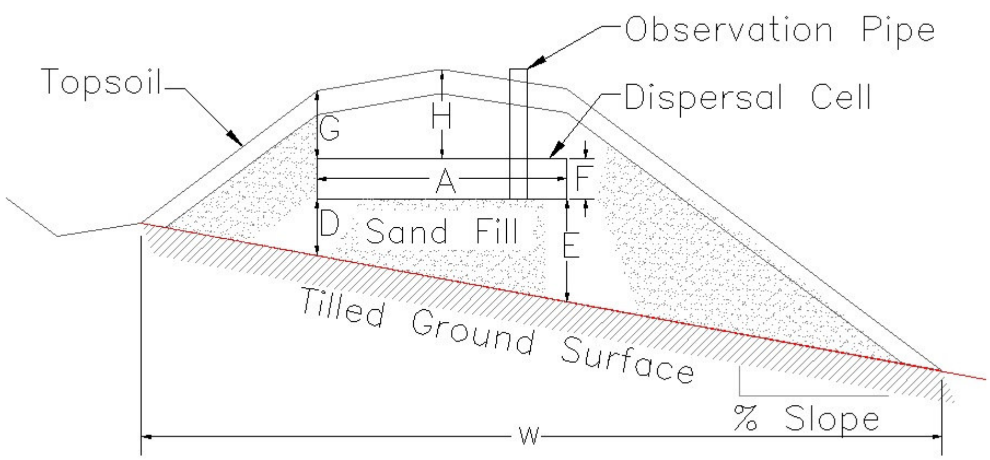


Figure 4-14 Mound Cross-Section Dimensions

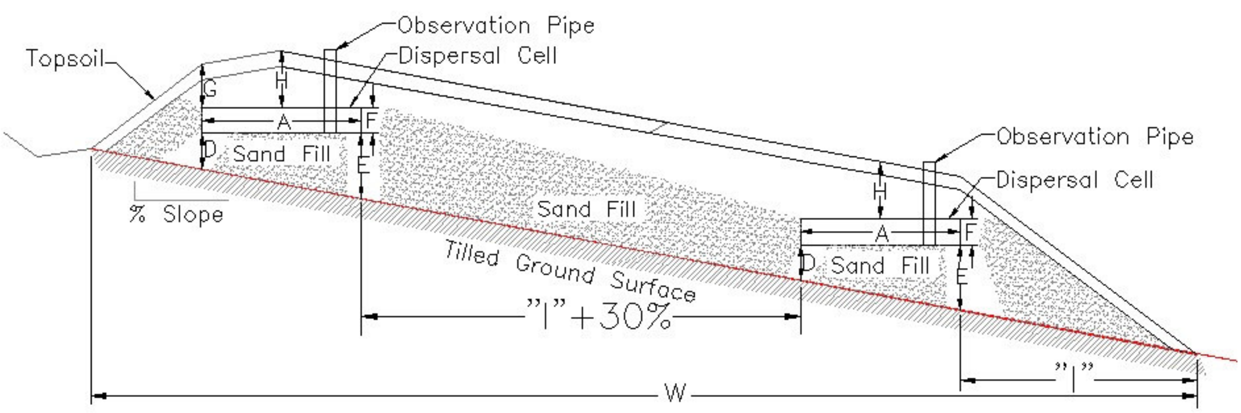


Figure 4-15 Multiple Cells in Same Mound

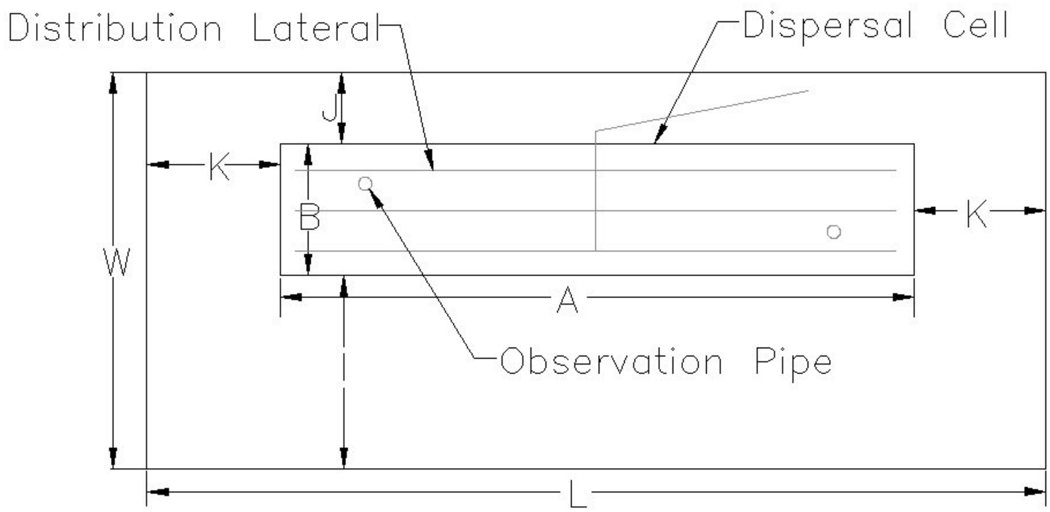


Figure 4-16 Mound Plan View Dimensions

a) *Size the Mound*

The mound dimensions are based on the site conditions and loading rates established for the site. Use the dimension letters in Figures 4-14, 4-15 and 4-16 to calculate the dispersal cell area and the footprint of the mound. These calculations will provide the dimensions for a single mound, when multiple cells are included within the same mound adjustments to the width and length will be required (see examples in the Land Area Requirements / Design Examples section).

Design Flow Rate – 100 gal/person/day

Sand Fill Loading Rate –
1.0 gal/ft^2/day (if BOD_5 or TSS > 30 mg/L, <220mg/L), or
2.0 gal/ft^2/day (if BOD_5 and TSS ≤ 30 mg/L)

Adjust calculated dispersal cell area required to comply with cell(s) resting/active operation (150% of required area) if secondary treatment is not provided.

Basal loading rate = _______ gal/day/ft^2 from Table 4-3

Linear loading rate = _______ gal/day/ft from Table 4-3

Dispersal Cell Length (A):

A = AWW ÷ linear loading rate from Table 4-3

A = ______gal/day ÷ _______gal/day/ft = ______ft

Dispersal Cell Width (B):

B= Linear Loading Rate ÷ Sand Fill Loading Rate
(1.0 or 2.0 gal/ft^2/day)

B = (_____ gal/day/ft) ÷ (_____ gal/ft^2/day) = ______ft

Depth D: The sand fill depth below the dispersal cell must be at least 6 inches. The depth to the limiting factor in the native soils determines the depth of the sand fill. The required separation distance from the dispersal cell bottom to the limiting factor, such as bedrock or seasonal saturation, is 36 inches, If the limiting factor is at 24 inches then (D) must be a minimum of 12 inches which is measured at the up slope edge of the dispersal cell.

Depth E: This depth is a function of the surface slope and width of the dispersal cell (A) as the dispersal cell must be level.

E = D + (% natural slope expressed as a decimal x B)

E = ______ inches + (_____ x_____ feet x 12 inches/ft)

E = __________ inches

Depth F: This depth depends on the type distribution media used. When using gravel this depth is:
6” min gravel under the distribution pipe + the distribution pipe diameter + 2” of gravel cover over the pipe.

F = _6_ inches + _Dia._ inches +_2_ inches =___ inches

When using synthetic aggregate or chambers the depth is set by the product used, normally 12”. Check with the manufacturer to verify this dimension.

Depth G and H: Cover Material

1) Depth at center of dispersal cell area (H) ≥ 12 inches
2) Depth at outer edges of dispersal cell area (G) ≥ 6 inches

The (H) depth is > (G) depth to provide a crown to promote runoff from the mound top.

The purpose of the shallow depths at this point is to allow for more oxygen diffusion to the dispersal cell while still maintaining enough cover for frost protection. It is important that the mound be able to breathe to allow oxygen to diffuse into and below the dispersal cell. (Converse & Tyler, 2000)

The mound topsoil cover also provides material for growth of a suitable vegetative cover. Heavier soils such as clay loam, silty clay loam and clay should be avoided because they restrict oxygen diffusion. Likewise thicker soil depths over the dispersal cell are not recommended because they also reduce oxygen transfer. The recommended soils for mound cover materials are: sandy loam, loamy sands and silt loams.

Total Mound Hght. = $[(D + E) \div 2] + (F + H)$

Slope Width (I): The down slope width (I) is a determined by the mound depth at the down slope edge of the dispersal cell, the minimum side slope of 3:1x the appropriate down slope correction factor found in Table 4-5. The correction factor adjusts the down slope fill dimension (I) and the up slope fill dimension (J) for the slope of the site.

I =	(E + F + G) x 3 x slope correction factor
I =	(___ft + ____ ft + ___ft) x (3 x slope correction)
I =	_______ ft (the slope correction factor may not provide a large enough basal area check basal area requirements as shown below)
Slope Width (J):	Up slope width (J) is determined by the mound depth at the up slope edge of the dispersal cell, the minimum side slope 3:1 x the up slope correction factor.
J =	(D + F + G) x 3 x slope correction factor
J =	(___ft + ___ ft + ____ft) x (3 x slope correction)
J =	_______ ft

Basal area calculation for single cell mound

Length (A) x Width (I + B)= A (I + B)

= (_____ft) (____ft + _____ft) =________ft$_2$

Check the basal area:

Basal area required =	Daily wastewater flow ÷ soil loading rate (See Table 4-3.)
=	_______gal/day ÷ ____ gal/ft^2/day = _______ft^2

Basal area calculation for multiple cell mound.

Cell length (A) x [(# of cells x cell width) + ({# of cells – 1} x cell spacing) + down slope width] (B + I)

= _____ft x [(____ x _____ft) + ({_____ -1} x _______ft) + _____ft]

= ______________ft^2

Is available basal area sufficient? _____yes ______no

Determine total mound width

Total Mound Width (W) =	(J + B + I)
W =	(___ft + _____ft + _____ft) = ______ft
	Note: In multi cell mound add all cells and cell separation widths.

End Slope Length (K): The end slope length (K) is determined by the mound depth at the center of the dispersal cell and the minimum end slope of 3:1. Because this dimension is along the slope no correction factor is applied.

K = {([(D + E) ÷ 2] + F + H) x 3

K = [(____ feet + ____ feet) ÷ 2] x 3 = _______ft

Total Mound length (L):
L = A + 2K
L = _______ft + (2 x _______ft) = _______feet

Table 4-5
Slope Correction Factors

Slope %	Down Slope	Up Slope
2	1.06	0.94
3	1.10	0.915
4	1.14	0.89
5	1.18	0.875
6	1.22	0.85
7	1.27	0.83
8	1.32	0.81
9	1.37	0.79
10	1.43	0.77
11	1.49	0.75
12	1.56	0.735
13	1.64	0.72
14	1.72	0.705
15	1.82	0.69
16	1.92	0.675
17	2.04	0.66
18	2.17	0.65
19	2.33	0.64
20	2.50	0.625

b) *Observation Pipes*

It is essential that all dispersal cells have observation pipes extending from the infiltrative surface (aggregate/sand interface for mounds) to the ground surface for observation of effluent ponding in the dispersal cell. Two (2) observation pipes per cell are required. One (1) pipe should be placed at approximately 1/10 the length of the dispersal cell from each end of the cell. Figure 4-17 shows two methods of installing and anchoring the observation pipe. The bottom 6 inches must be perforated or slotted to allow ponded effluent to enter and exit the pipes.

To aid the operator in locating the observation pipes and to prevent damage to them from mowing equipment a marker post should be set near the pipe.

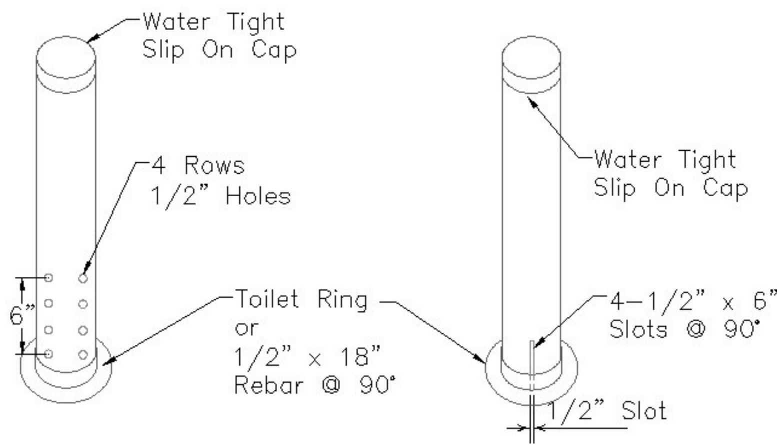


Figure 4-17 Observation Pipes

5. Land Area Requirements/Design Examples

Adequate area for a community mound includes providing space for the mound fill, treatment tanks, yard piping, site grading and separation distance for setbacks to property lines, drainage ways, cut banks, etc. The following calculations are made using the basic flows identified in this manual for systems serving 25, 100 and 250 people. The following is presented to give the designer and / or owner an approximate gross parcel size requirement for this type of treatment system. Two calculations are provided for each design population.

a) Secondary Effluent Application

Wastewater treated to secondary standards all ready has higher levels of dissolved oxygen within the effluent and therefore it is expected that a clogging mat will not form at the infiltrative surface and therefore a cell resting cycle will not be required. One example provided is based on the application of wastewater treated to secondary standards to the mound cell(s).

b) Cell Resting/Active Operation

Another example is based on a design where septic tank effluent quality wastewater is being applied and uses the active/resting cell concept. The active/resting cell design practice is used to enhance system performance and to provide a system, which will be more robust and durable over the design life of the system. To provide cell resting the total dispersal cell area calculated for treatment must be determined then multiplied by 1.5. The cell area is then divided into increments of three so that a third of the area remains dormant (resting) while the other two-thirds provide the full treatment area required. This may result in multiple cells or groups of cells, in either case the number of cells must be divisible by 3.

Example:

The total area required for the dispersal cell equals 6,000 s.f. To provide a resting cell the total must be increased by 150% to 9,000 s.f. The number of cells selected must be in increments of 3 such as:

Three cells equaling 3,000 s.f. each is divided so that two of the cells (6,000 s.f.) will operate while one (3,000 s.f.) rests;

Or

The number of cells selected is 6, then 4 cells (6,000 s.f.) are active while 2 cells (3,000 s.f) are resting.

In this way one-third of the dispersal area is rested annually while the remaining two-thirds receive the wastewater load. The active cells represent 100% of the total required area for treatment of the wastewater.

The purpose of cell resting is to provide a period of inactivity for segments of the dispersal cell(s) and allow them to dry out and reduce or eliminate the clogging mat thickness at the aggregate sand fill interface. The practice also provides a backup area if an active cell becomes overloaded or short-term surge flows are encountered. Rotation of the cells annually is recommended to allow the resting cell(s) to go through at least one summer period. Warm air is expected to enhance oxygen diffusion within the dispersal cell, which in turn helps reduce the clogging mat thickness and improve permeability through the cell(s).

Design Note:

One of these methods of enhancing system performance is required for all systems. The following calculations are based on the dimensions and formulas found in this manual. Mound Design Calculations are found earlier in this section.

c) <u>*25 People*</u>

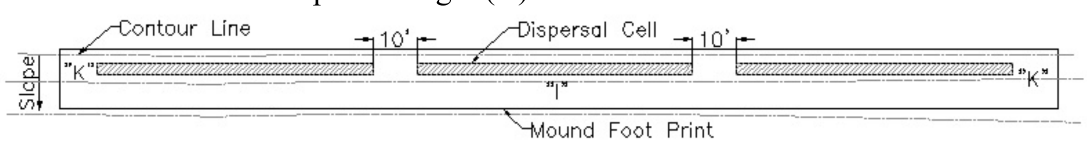
(1) Design Example No. 1 Based on Cell Resting and STE Loading.

The design flow is 2500 gal/day.
The dispersal cell sand loading rate = 1.0 gal/ft^2/day
For this example the following parameters are used:

- basal loading rate of 0.4 gal/ft^2/day
- linear loading rate of 6 gal/day/ft
- land slope of 10%
- sand fill depth of 1.0'
- active/resting areas required

2500 gal/day ÷ 1.0 gal/ ft^2/day = 2500 ft^2 of dispersal cell required
2500 gal/day ÷ 6 gal/day/ft = 417 lf of dispersal cell required
417 lf of dispersal cell X 1.5 = 625.5 lf of dispersal cell
625.5 lf ÷3 cells = 208.5 l.f. = min. length required for one cell
6 gal/day/ft ÷ 1.0 gal/ ft^2/day = 6 ft wide dispersal cell allowed.

Cell layout Selected:
3 cells (2 cells active, 1 resting) - 6' wide x 208.5' long placed along the same contour with a separation between the ends of the cells of 10' and an end slope fill length (K) of 10'



Note: If the length shown below is not available, mounds can be separated and placed on different landscape positions.

Area & Linear Loading Rate Check
Area = 2 cells* - 6' wide x 208.5' long = 2 x 6 x 208.5 = 2,502 ft^2
(meets minimum dispersal cell area requirement)
LLR = (2500 gal/day ÷ 2,502 ft^2) x 6' = 5.99 gal/day/ft
(meets linear loading rate requirement)
*2 cells active, 1 resting

Mound Length: (includes both resting & active cells)
(Single cell length x # of cells) + (cell end separation distance – 10' x (# of Cells-1)) + (end slope length-(K) x 2)
208.5' x 3 + (10' X (3-1)) + (10' X 2) = 665.5 feet
Note: Actual cell length may need to be adjusted based on the distribution network design.

Mound Width:
Sum of the up slope fill width (J) + dispersal cell width (B) + down slope fill width (I)

6' + 6' + 13' = 25 feet

Area Required for Mound Alone:
25' x 665.5' = 16,638 ft^2

Check Basil Loading Rate
design flow ÷ (dispersal cell width + down slope fill width x length of single cell x # of active cells)
2500 gal/day ÷ [(6 + 13') x (208.5 x 2)] = 0.32 gal/ ft^2/day
(meets basal loading rate requirement)

Area Required for Mound & Buffer Zone:
Note: Buffer zone includes area for treatment tanks, yard piping, site grading & setbacks to property lines, etc. Every site is different so this will change with every project; 50' on all sides is used here for calculation purposes only.

= ((50 x 2) + 25') X ((50 x 2) + 665.5') = 95,668ft^2
or <u>2.2 acres.</u>

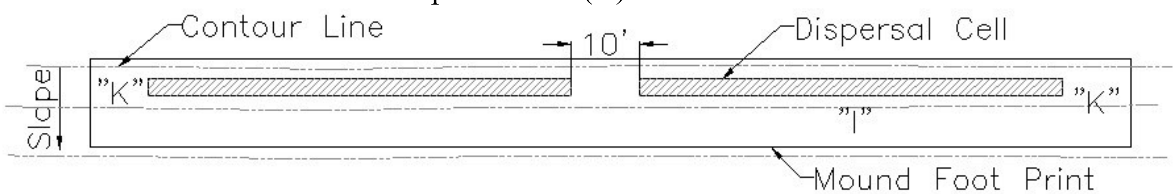
(2) Design Example No. 2 Based on Secondary Treatment

The design flow is 2500 gal/day.
The dispersal cell hydraulic loading rate = 2.0 gal/ ft^2/day
For this example the following parameters are used:

- basal loading rate of 0.4 gal/ ft^2/day,
- linear loading rate of 6 gal/day/ft
- land slope of 10%
- sand fill depth of 1.0'

2500 gal/day ÷ 2.0 gal/ ft^2/day = 1250 ft^2 of dispersal cell required
2500 gal/day ÷ 6 gal/day/ft = 417 lf of dispersal cell required
6 gal/day/ft ÷ 2.0 gal/ ft^2/day = 3 ft wide dispersal cell allowed

Cell Layout Selected:
2 cells - 3' wide x 208.5' long placed end to end along the slope. For this example the separation distance between cells end to end is 10' and the end slope distance (K) is 9'.



Note: If the length shown below is not available, mounds can be separated and placed on different landscape positions.

Area & Linear Loading Rate Check
Area = 2 cells - 3' wide x 208.5' long = 2 x 3 x 208.5 = 1,251 ft^2
(meets minimum dispersal cell area requirement)
LLR = (2500 gal/day ÷ 1,251 ft^2) x 3' = 5.99 gal/day/ft
(meets linear loading rate requirement)

Mound Length:
(Single cell length x # of cells) + (cell end separation distance – 10' x (# of Cells-1)) + (end slope length-(K) x 2)
208.5' x 2 + (10' X (2-1)) + (9' X 2) = 445 feet
Note: Actual cell length may need to be adjusted based on the distribution network design.

Mound Width:
Sum of the up slope fill (J) + dispersal cell width (B) + down slope fill (I)

6' + 3' + 12' = 21 feet

Area Required for Mound Alone:

21' x 445' = 9,345 ft^2

Check Basil Loading Rate
design flow ÷ (dispersal cell width + down slope fill width x length of single cell x # of active cells)
2500 gal/day ÷ [(3 + 12') x (208.5 x 2)] = 0.40 gal/ ft^2/day
(meets basal loading rate requirement)

Minimum Area Required for Mound & Buffer Zone:
Note: Buffer zone includes area for treatment tanks, yard piping, site grading & setbacks to property lines, etc. Every site is different so this will change with every project; 50' on all sides is used here for calculation purposes only.

= ((50 x 2) + 21') X ((50 x 2) + 445') = 121' x 545' = 65,945 ft^2
or 1.5 acres.

d) *100 People*

(1) Design Example No. 1 Based on Cell Resting and (STE) Loading.

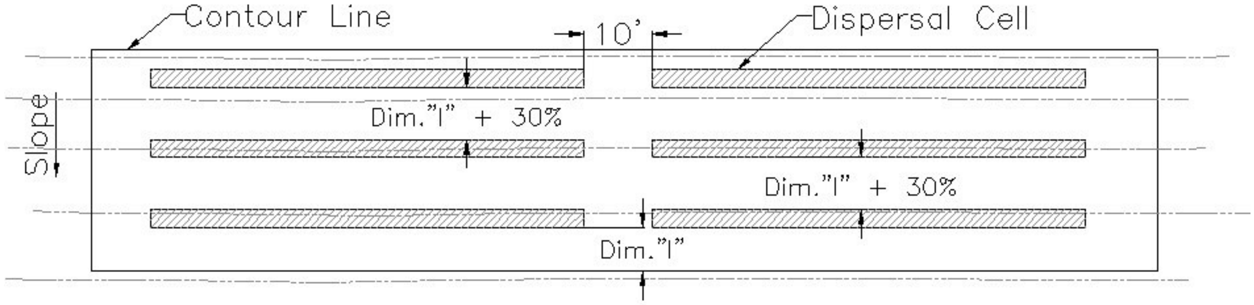
The design flow is 10,000 gal/day.
The dispersal cell sand loading rate = 1.0 gal/ft^2/day
For this example the following parameters are used:

- basal loading rate of 0.4 gal/ft^2/day
- linear loading rate of 6 gal/day/ft
- land slope of 10%
- sand fill depth of 1.0'
- active/resting areas required

10,000 gal ⁄day ÷1.0 gal/ ft^2/day = 10,000 ft^2 of dispersal cell
10,000 gal/day ÷ 6 gal/day/ft = 1667 lf of dispersal cell required
1667 lf of dispersal cell X 1.5 = 2500 lf of dispersal cell
2500 lf ÷6 cells = 417 ft. min. cell length required for one cell
6 gal/day/ft ÷ 1.0 gal/ft^2/day = 6 ft wide dispersal cell allowed

Cell Layout Selected:
Single mound with 6 separate dispersal cells 3 placed up and down slope of one another and 2 cells end to end. The cells will be separated by the distance required for the down slope width (I) + 30%. For this example the down slope fill width (I) based on slope is 13', therefore: a distance of 17' is needed to reduce impacts of the up

slope cell on the adjacent down slope cell. The end slope dimension (K) is 10', the separation distance between cells end to end is 10'.



Area & Linear Loading Rate Check
Area = 4 cells* - 6' wide x 417' long = 4 x 6 x 417 = 10,008 ft^2
(meets minimum dispersal cell area requirement)
LLR = (10,000 gal/day ÷ 10,008 ft^2) x 6' = 5.99 gal/day/ft
(meets linear loading rate requirement)
*4 cells active, 2 resting

Mound Length:
(Single cell length x # of cells) + (cell end separation distance – 10' x (# of Cells-1)) + (end slope length-(K) x 2)

417' x 2 + (10' X (2-1)) + (10' X 2) = 864 feet

Note: Actual cell length may need to be adjusted based on the distribution network design.

Mound Width: (includes all cells active and resting)
Sum of the upslope fill width (J) + (3 x dispersal cell width) + (the cell separation distance (I + 30%)x (# of cells – 1) + (the down slope fill width (I)) = Mound Width

6' + 18' + 34' + 13' = 71 feet

Area Required for Mound Alone:

71' x 864' = 61,171.4 ft^2

Check Basil Loading Rate
design flow ÷ (dispersal cell width + down slope fill width x length of single cell x # of active cells)
10,000 gal/day ÷ [(6 + 16'*) x (417 x 4)] = 0.33 gal/ ft^2/day
*average down slope width (meets basal loading rate requirement

Area Required for Mound & Buffer Zone:
Note: Buffer zone includes area for treatment tanks, yard piping, site grading & setbacks to property lines, etc. Every site is different so this will change with every project; 50' is used here for calculation purposes only.

= ((50 x 2) + 71') X ((50 x 2) + 864') = 171' x 964' = 164,651 ft^2 or 3.8 acres.

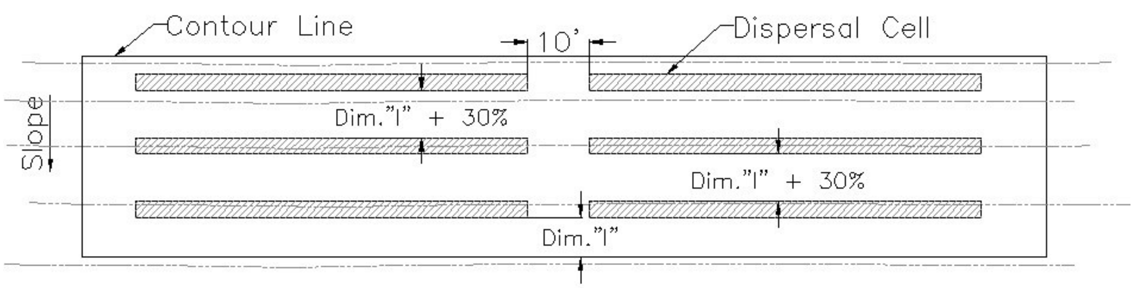
(2) Design Example No. 2 Based on Secondary Treatment

The design flow is 10,000 gal/day.
The dispersal cell hydraulic loading rate is 2.0 gal/ft^2/day
For this example the following is assumed:

- basal loading rate of 0.4 gal/ ft^2/day,
- linear loading rate of 6 gal/day/ft
- land slope of 10%
- sand fill depth of 1.0'
- secondary treatment component is used

10,000 gal/day ÷ 2.0 gal/ft^2/day = 5,000 ft^2 of dispersal cell required
10,000 gal/day ÷ 6 gal/day/ft = 1,667 lf of dispersal cell required
1667 lf ÷ 6 cells = 279 lf per cell required
6 gal/day/ft ÷ 2.0 gal/ft^2/day = 3 ft wide dispersal cell allowed.

Cell Layout Selected:
Single mound with 6 separate dispersal cells 3 placed up and down slope of one another and 2 cells end to end. The cells will be separated by the distance required for the down slope width (I) + 30%. For this example the down slope fill width (I) based on slope is 12', therefore: a distance of 16' is needed to reduce impacts of the up slope cell on the adjacent down slope cell. The end slope dimension (K) is 9', the separation distance cell end to cell end is 10'.



Area & Linear Loading Rate Check
Area = 6 cells - 3' wide x 279' long = 6 x 3 x 279 = 5,022 ft^2
(meets minimum dispersal cell area requirement)
LLR = (10,000 gal/day ÷ 5,022 ft^2) x 3' = 5.97 gal/day/ft
(meets linear loading rate requirement)

Mound Length:
(Single cell length x # of cells) + (cell end separation distance – 10' x (# of Cells-1)) + (end slope length-(K) x 2)

279' x 2 + (10' X (2-1)) + (9' X 2) = 586 feet

Note: Actual cell length may need to be adjusted based on the distribution network design.

Mound Width:
Sum of the upslope fill width (J) + (3 x dispersal cell width) + (the cell separation distance (I + 30%)x (# of cells – 1) + (the down slope fill width (I)) = Mound Width

6' + 9' + 32' + 12' = 59 feet

Area Required for Mound Alone:
59' x 586' = 34,574 ft^2

Check Basil Loading Rate
design flow ÷ (dispersal cell width + down slope fill width x length of single cell x # of active cells)
10,000 gal/day ÷ [(3 + 15'*) x (279 x 6)] = 0.33 gal/ ft^2/day
*average down slope width (meets basal loading rate requirement

Minimum Area Required for Mound & Buffer Zone:
Note: Buffer zone includes area for treatment tanks, yard piping, site grading & setbacks to property lines, etc. Every site is different so this will change with every project; 50' is used here for calculation purposes only.

= ((50 x 2) + 59') X ((50 x 2) + 586') = 159' x 686' = 109,074 ft^2 or <u>2.5 acres</u>.

e) *<u>250 People</u>*

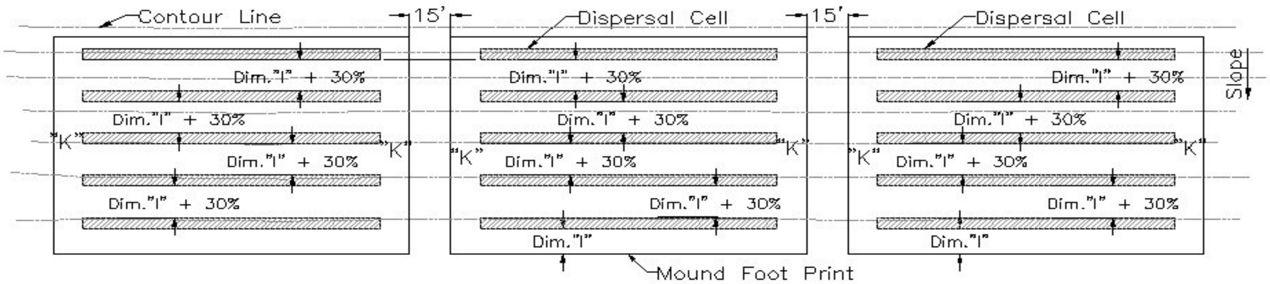
(1) Design Example No.1 Based on Cell Resting & STE Loading.

The design flow is 25,000 gal/day.
The dispersal cell sand loading rate = 1.0gal/ft^2/day
For this example the following is assumed:

- basal loading rate of 0.4 gal/ft^2/day
- linear loading rate of 6 gal/day/ft
- land slope of 10%
- sand fill depth of 1.0'
- active/resting areas required

25,000 gal/day ÷ 6 gal/day/ft = 4167 lf of dispersal cell required
25,000 gal/day ÷1.0 gal/ft^2/day = 25,000 ft^2 of dispersal cell
4167 lf of dispersal cell X 1.5 = 6250 lf of dispersal cell
6250 lf ÷15 cells = 417 ft. min. cell length required
6 gal/day/ft ÷ 1.0 gal/ ft^2/day = 6 ft wide dispersal cell allowed.

Cell Layout Selected:
Three mounds with 5 separate dispersal cells placed up and down slope of one another. The cells will be separated by the distance required for the down slope width (I) + 30%. For this example the down slope fill width (I) based on slope is 13', therefore: a distance of 17' is needed to reduce impacts of the up slope cell on the adjacent down slope cell. The end slope dimension (K) is 10', the separation distance from mound end to mound end is 15' minimum to provide drainage between mounds.



Area & Linear Loading Rate Check
Area = 10 cells* - 6' wide x 417' long = 10 x 6 x 417 = 25,020 ft^2
(meets minimum dispersal cell area requirement)
LLR = (25,000 gal/day ÷ 25,020 ft^2) x 6' = 5.99 gal/day/ft
(meets linear loading rate requirement)
*10 cells active, 5 resting

Mound Length: (single mound)
(Single cell length) + (end slope length (K) x 2)

417' + (10' X 2) = 457 feet/mound

Note: Actual cell length may need to be adjusted based on the distribution network design.

Mound Width:
Sum of the upslope fill width (J) + (5 x dispersal cell width(B)) + (4 x cell separation distance (I+30%)) + (I) down slope fill width)

6' + 30' + 81' = 117 feet

Area Required for Mound Alone:
457' x 3 mounds + (15'x 2) x 117' = 163,357 ft^2

Check Basil Loading Rate
design flow ÷ (dispersal cell width + down slope fill width x length of single cell x # of active cells)
25,000 gal/day ÷ [(6 + 16'*) x (417 x 10)] = 0.27 gal/ ft^2/day
*average down slope width (meets basal loading rate requirement

Area Required for Mound & Buffer Zone:
Note: Buffer zone includes area for treatment tanks, yard piping, site grading & setbacks to property lines, etc. Every site is different so this will change with every project; 50' is used here for calculation purposes only.

= ((50 x 2) + 117’) x ((50 x 2) + (457’ x 3 +30’)) =
217’ x 1501’ = 325,117 ft^2 or 7.5 acres.

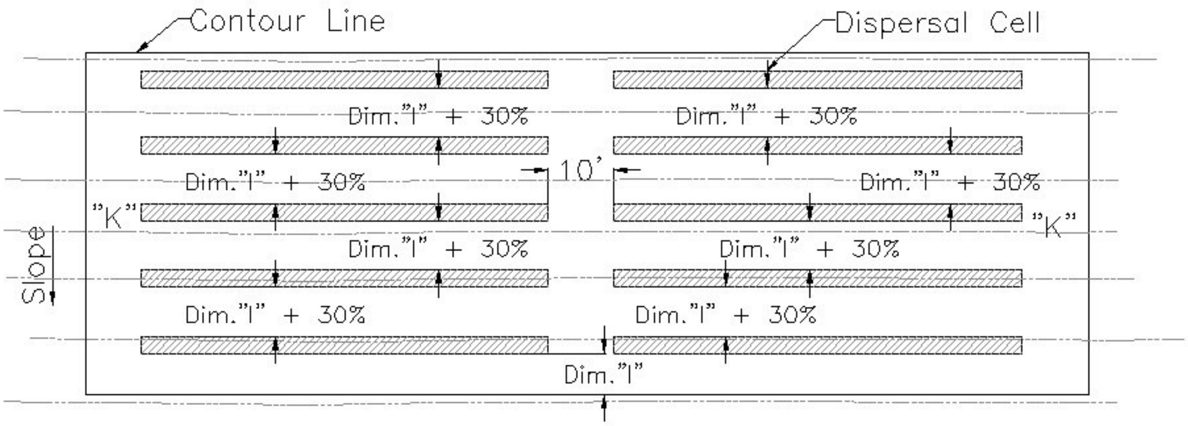
(2) Design Example No. 2 Based on Secondary Treatment

The design flow is 25,000 gal/day.
The dispersal cell hydraulic loading rate is 2.0 gal/ ft^2/day
For this example the following is assumed:

- linear loading rate of 6 gal/day/ft
- basal loading rate of 0.4 gal/ft^2/day,
- land slope of 10%
- sand fill depth of 1.0’
- secondary treatment component is used

25,000 gal/day ÷ 2.0 gal/ft^2/day = 12,500 ft^2 of dispersal cell required
25,000 gal/day ÷ 6 gal/day/ft = 4167 lf of dispersal cell required
4,167 lf ÷10 cells = 417 ft. min. cell length required
6 gal/day/ft ÷ 2.0 gal/ft^2/day = 3 ft wide dispersal cell allowed.

Cell Layout Selected:
A single mound with 10 separate dispersal cells is selected, 5 cells up and down slope of one another and 2 cells long. The cells must be separated side to side by the distance required for the down slope width (I) plus 30%. For this example the down slope width (I) required based on slope is 12’, a width of 16’ is required to reduce the impact of the up slope cells on the adjacent down slope cell. The end slope dimension (K) is 9’, the separation distance cell end to cell end is 10’.



Area & Linear Loading Rate Check
Area = 10 cells - 3' wide x 417' long = 10 x 3 x 417 = 12,510 ft^2
(meets minimum dispersal cell area requirement)
LLR = (25,000 gal/day ÷ 12,510 ft^2) x 3' = 5.99 gal/day/ft
(meets linear loading rate requirement)

Mound Length:
(Single cell length x # of cells) + (cell end separation distance – 10' x (# of Cells-1)) + (end slope length-(K) x 2)

417' x 2 + (10' x (2-1)) + (9' x 2) = 862 feet

Note: Actual cell length may need to be adjusted based on the distribution network design.

Mound Width:
sum of the up slope fill width + (5 x dispersal cell width) + (5 x down slope fill width)

6' + 15' + 76' = 97 feet

Area Required for Mound Alone:
97' x 862' = 82,752 ft^2

Check Basil Loading Rate
design flow ÷ (dispersal cell width + down slope fill width x length of single cell x # of active cells)
25,000 gal/day ÷ [(3 + 15'*) x (417 x 10)] = 0.33 gal/ ft^2/day
*average down slope width (meets basal loading rate requirement
Minimum Area Required for Mound & Buffer Zone:

Note: Buffer zone includes area for treatment tanks, yard piping, site grading & setbacks to property lines, etc. Every site is different so this will change with every project; 50' is used here for calculation purposes only.

= ((50 x 2) + 97') x ((50 x 2) + 862) =
197' x 962' = 189,514 ft^2 or <u>4.4 acres</u>.

V. Mound Construction

Construction of a mound system is just as critical as the design of the system. A good design with poor construction results in system failure. Because the native soils play such an important part in the hydraulic capabilities of the mound it is emphasized that the soil only be tilled when it is not frozen and the moisture content is low to avoid compaction and puddeling. The construction plan to be followed includes:

A. Pre-construction Conference

A pre-construction conference including all stake holders in the system is highly recommended. Stake holders include by may not be limited to the following : system designer, contractor, equipment suppliers, local utility representative owner's representative and regulatory representative. The pre-construction conference should include discussion of the construction procedures, equipment & material deliveries, site access and any other issues effecting the construction of the mound(s).

B. Equipment

Proper equipment is essential. Track type tractors or other equipment that will not compact the mound area or the down slope area are required.

C. Traffic Routes

Construction of large systems with multiple mounds or a single mound with multiple cells will require particular attention placed on traffic routes for construction equipment to avoid compaction to the infiltrative soil. The contractor should establish a traffic plan identifying corridors in which trucks delivering materials for the mound can travel. The route should be flagged or marked in a suitable manner to clearly identify where vehicles can and cannot go on the site.

D. Construction Procedures

Check the moisture content of the soil to a depth of 8 inches. Smearing and compacting of wet soil will result in reducing the infiltration capacity of the soil. Proper soil moisture content can be determined by rolling a soil sample between the hands. If it rolls into a 1/4-inch wire, the site is too wet to prepare. If it crumbles, site preparation can proceed. If the site is too wet to prepare, do not proceed until it dries.

1. Lay out the fill area on the site so that the distribution cell runs perpendicular to the direction of the slope.

2. Establish the original grade elevation (surface contour) along the up slope edge of the distribution cell. This elevation is used throughout the mound construction as a reference to determine the bottom of the distribution cell, lateral elevations, etc., and is referenced to the permanent benchmark for the project. A maximum of 4 inches of sand fill may be tilled into the surface.

3. Determine where the force main from the dosing chamber will connect to the distribution system in the distribution cell. Place the pipe either before tilling or after placement of the fill. If the forcemain is to be installed in the down slope area, the trench for the force main may not be wider then 12 inches.

4. Cut trees flush to the ground and leave stumps, remove surface boulders that can be easily rolled off, remove vegetation over 6 inches long by mowing and removing cut vegetation. Prepare the site by breaking up, perpendicular to the slope, the top 7-8 inches so as to eliminate any surface mat that could impede the vertical flow of liquid into the in situ soil. When using a moldboard plow, it should have as many bottoms as possible to reduce the number of passes over the area to be tilled and minimize compaction of the subsoil. Tilling with a moldboard plow is done along contours. Chisel type plowing is highly recommended especially in fine textured soils. Rototilling or other means that pulverize the soil is not acceptable. The important point is that a rough, unsmeared surface be left. The sand fill will intermingle between the clods of soil, which improves the infiltration rate into the natural soil.

5. Immediate application of at least 6 inches of fill material is required after tilling. All vehicular traffic is prohibited on the tilled area. For sites where the effluent may move laterally, vehicle traffic is also prohibited for 15 ft. down slope and 10 ft. on both sides of level sites. If it rains after the tilling is completed, wait until the soil dries out before continuing construction.

6. Place the approved sand fill material, around the edge of the tilled area being careful to leave adequate perimeter area, not covered by the sand fill, on which to place the soil cover. There should be approximately two feet of basal area adjacent to the mound perimeter that is not covered by the sand fill. This area serves to tie the soil cover into the natural surface material that has been tilled and helps seal the toe from leakage. Work from the end and up slope sides. This will avoid compacting the soils on the down slope side,

which, if compacted, affects lateral movement of the treated wastewater away from the fill and could cause surface seepage at the toe of the fill on slowly permeable soils.

7. Move the fill material into place using a small track type tractor with a blade or a large backhoe that has sufficient reach to prevent compaction of the tilled area. Do not use a tractor/backhoe having tires. Always keep a minimum of 6 inches of fill material beneath tracks to prevent compaction of the in situ soil.

8. Place the fill material to the required depth.

9. Form the distribution cell. Level the bottom of the distribution cell. If using leaching chambers, hand tamp fill where chambers will be located.

NOTE: If using leaching chambers go to step 15.

10. Install the required observation pipes with the bottom 6 inches of the observation pipe slotted. Installations of all observation pipes include a suitable means of anchoring.

11. Place the stone aggregate in the distribution cell. Level the stone aggregate to the design depth.

12. Shape the sides with additional fill to the desired slopes.

13. Place the effluent distribution lateral(s), as determined from the pressure distribution design, on the stone aggregate. Connect the lateral(s) using the needed connections and piping to the force main pipe from the dosing chamber. Slope the piping from the lateral(s) to the force main pipe. Lay the effluent distribution lateral(s) level. All pipes must drain after dosing.

14. Place stone aggregate over the distribution network and the entire distribution cell until the elevation of the stone aggregate is at least 2 inches above the top of the distribution network.

NOTE: If using stone aggregate go to step 17.

15. Install the leaching chambers and pressure distribution piping as instructed by the leaching chamber manufacturer’s instructions.

16. Install an observation pipe in each row of leaching chambers.

17. If stone aggregate is used, place geotextile fabric conforming to requirements of this guidance manual, over the stone aggregate.

18. Place cover material on the top of the geotextile fabric and extend the soil cover to the boundaries of the overall component.

19. Complete final grading to divert surface water drainage away from mound. Seed and mulch the entire mound component and surrounding disturbed area.

VI. Operation Monitoring and Maintenance Issues

In cluster wastewater systems, there is more focus on flexible operation and a greater need to monitor how well a system is doing. Monitoring adds an additional burden, to the owner-operator as well as the regulatory agency, because of the need to track, evaluate and change (or add to) a system based on its operating record.

A. Operational Concerns

1. Primary Component

a) Sludge Management

Periodic measurements of the combined sludge and scum depth are required. by a trained operator. When the depth of these two items reaches 1/3 of the liquid depth of the tank, the tank should be pumped. A suggested frequency of monitoring this component is shown in Table 5-1.

b) Odors

Odors associated with the system will occur, the anoxic environment in the septic tanks can create strong odors, which most people find objectionable. In most cases, if the lids are kept in place properly, the strongest odors will occur when the solids are pumped out of the tank. This should only last for the short time period when the actual pumping event. If strong odors are continually present remedies such as charcoal filters and raising vent pipes high into the air have been successful at alleviating many of the problems. Locating the system in a somewhat remote location to begin with will make odor issues more manageable.

Table 5-1 Operation & Monitoring Schedule

	Frequency								
System Component	W	M	Q	S	A	2YR	3YR	OTHER	Comment
Primary Component									
1st Tank									
Sludge Depth					X				
Pump Contents								As needed	
2nd Tank									
Sludge Depth						X			
Pump Contents								As needed	
3rd Tank (if supplied)									
Sludge Depth							X		
Pump Contents								As needed	
Baffles (all tanks)			X						
Outlet Filter(s)			X						
Wastewater Sampling		X	X						Dependent on design flow
Secondary Treatment Component									
Process Operation									Based on manufacturer's recommendations
Dosing Component									
Pump Operation	X								
Alarms & Meters	X								
Sludge Depth					X				
Wastewater Sampling		X	X						Dependent on design flow
Pump Contents								As needed	
Soil Dispersal Component									
Ground Surface			X						
Observation Ports			X						
Flush Laterals					X				
Flow Diversion Valves					X				Adjustable w/operator experience

W - Weekly, M - Monthly, Q - Quarterly, S - Semi-Annually, A - Annually

c) *Structural*

This device should be checked routinely for structural abnormalities such as defective lids and leaking, cracked or broken joints at pipe entry and exit points and riser sections. Baffles should be checked periodically to insure that they are in place and not clogged with debris.

d) *Effluent Filter*

Effluent filters should be checked on a routine basis as suggested in Table 6-1. The interval for cleaning this device should be adjusted based on the wastewater strength and characteristics of the particular system.

2. Secondary Treatment Component

Secondary treatment units can encompass a variety of technologies. Operation, monitoring and maintenance of this component should be based on the manufacturer's recommendations for the particular unit used in the design.

3. Dosing Component

a) *Sludge Management*

Periodic measurements of the sludge depth are required. When the sludge depth reaches a level that interferes with the dosing equipment or controls, the sludge should be removed.

b) *Structural*

The dose chamber should be checked routinely for structural abnormalities such as defective lids and leaking, cracked or broken joints at pipe penetration points and riser sections. Surface water runoff should never be allowed to sit around risers or enter the tank through leaking riser sections, pipe connections or broken lids.

c) *Pumps, Controls & Electrical*

Monitoring of this component includes periodic recording of the run time meters and/or event counters. A record of operating hours or pumping events can be used to determine the actual amount of wastewater discharged to the dispersal component. This information will be a great asset for any trouble shooting needed on the system or in discussions about future expansion of the system.

Alarms need to be checked at routine intervals to insure proper function. If a water meter is included with this device, recording of the meter should be a routine O & M task. A suggested frequency of monitoring this device is included in Table 5-1.

d) *Distribution Network*

(1) Lateral Flush Valves

Each lateral is equipped with a turned up end terminating in a ball valve located in a protective enclosure. The purpose of this valve is to allow for access to the lateral for flushing and cleaning if required. It is suggested that the valve be exercised annually while a pump is operating to flush out biological material that may have accumulated in the distribution lateral.

(2) Flow Diversion Valves

The distribution network may include electrically actuated zone valves, hydraulic index valves which will require routine monitoring and maintenance. The frequency of inspection and cleaning of these valves is dependent on the quality of the effluent being discharged to the distribution network. For systems where effluent is treated to secondary levels the valves will require less frequent inspection and cleaning, system's discharging septic tank effluent quality wastewater will require more frequent inspections. The operator should adjust the scheduled monitoring of this item based on experience with the system. During routine inspections the valve should include checking for proper operation and cleaning if necessary. The initial inspection of the valve should occur at no later than 12 months after operation of the system begins and then adjusted to fit specific system conditions.

All other manually operated valves in the dosing component should be exercised on an annual basis to insure proper operation.

4. Mound Component

a) *Hydraulic Overloading -Dispersal Cell*

Ponding of wastewater within the dispersal cell can occur in the following situations:

- The volume of wastewater delivered to the cell over an extended period of time is greater than the ability of the sand fill to transmit the water away.

- A clogging mat forms on the infiltrative surface of the dispersal cell.

In either case the condition should be closely monitored at the observation pipes. Keeping a record of any effluent ponding observed will aid in trouble shooting problems early and may prevent costly repairs by early detection of the condition. Ponding of effluent in the cell bottom may indicate hydraulic overloading of this part of the component. Adjustments should be made in the dosing scheme if continuous ponding is observed. This item should be checked more frequently if ponding is observed. Care should be taken to not make observations of this item immediately following a dosing event.

b) Down Slope Toe Leakage

Routine monitoring of the mound component should include observation of the down slope toe of the mound. Soggy or wet areas located at the toe may indicate saturated conditions at the sand/native soil interface. This indicates that the loading rate to the native soil is excessive and some alteration such as extending the toe of the mound may be necessary.

5. Freezing

Freezing of a mound system is not usually a problem as long as it receives a steady flow of wastewater. The main concern is with the piping leading up to and away from the component. Installing piping at proper depths, insulating shallow pipes and/or making sure they drain back and empty between doses is the standard approach to frost protection. The mound area should be allowed to develop a healthy stand of vegetative cover after late summer. A thick mat of grass will provide a very good insulation blanket for the mound.

6. Site Maintenance

a) Mowing

Mowing the mound is only necessary to keep trees from gaining a foothold. Tree roots can create problems in the distribution network. Mounds with 3:1 side slopes will require mowing with great care and use of equipment that will not create ruts that contribute to erosion problems. Mowing once or twice per year should be sufficient.

7. Record Keeping

The maintenance record keeping system for a mound system treatment facility can be effective while being kept fairly simple, due to the facility's size. The operation, monitoring and maintenance record keeping system should include the following features:

Equipment Maintenance & Replacement Records
Calendar Schedule of Maintenance
Dose Pump Counter Events & Run Time Meter Readings
Secondary Treatment Component Monitoring
Septic Tank Pump Outs including volumes and dates
Sludge Depth Measurements
Effluent Filter Cleaning Frequency
Dispersal Cell Monitoring Results
Wastewater Sampling Results

The maintenance record keeping system may be modified to best suit the needs of the facility. It is very important that the system operator keeps the record system up-to-date by recording and filing in an orderly manner any information pertaining to the operation and maintenance of the facility.

Equipment maintenance records assure that information on operation and maintenance of facility equipment will be available should there be absences or changes in operations personnel. The system operator should make sure that any information obtained on the equipment (either through operation, maintenance, or correspondence with equipment representatives) is recorded on equipment maintenance record cards or filed in an orderly manner. Regular review of the equipment maintenance files can alert the operator to problems, which might be developing at the facility, so that they can be corrected before costly emergency repairs are needed.

VII. Cost Estimates

Due to the extreme variably of local markets for labor and materials, it is not possible to estimate universally the cost of construction and operation of sand mound systems. Cost differentials are significant across local geographies and economies. Therefore the reader of this manual is advised to consult local markets for specific data.

A. Capital Costs

A major determinant in the overall cost of a project is its size. The larger the project, the greater the benefit from economies of scale. Therefore the reader of this manual is advised to consult with knowledgeable individuals for specifics relating to costs of construction for a particular project.

1. Capital Cost Estimating Spreadsheet

The next page details a typical cost estimating spreadsheet for estimating overall capital costs for a sand mound treatment system. The spreadsheet identifies major components of the proposed construction and allocates units for each component. Upon completion of a standard design, actual units of installation may be inputted into the spreadsheet. Costs per unit must be obtained from local sources due to the aforementioned extreme variability in local markets.

Table 7-1
Mound System Capital Cost Estimating Sheet

Capital Costs

Item	Quantity	Units	Unit Cost	Total Cost
Land		Ac.		
Site Work (Treatment Tank Area)		L.S.		
Primary TreatmentComponent				
Septic Tanks, Complet w/Bypass Valves		Ea.		
Effluent Filter(s)		Ea.		
Secondary Treatment Component		Ea.		
Treatment Unit, Complete w/Controls		Ea.		
Treatment Tanks		Ea.		
Site Electrical (3 Phase)		L.S.		
Dosing Component				
Dose Tank		Ea.		
Dose Pumps, Complete w/Control Panel		Ea.		
Pressure Filter		Ea.		
Distribution Valve & Vault		Ea.		
Control Valves		Ea.		
Forcemain		L.F.		
Flow Meter		Ea.		
Mound Component				
Earthwork		L.S.		
Filter Fabric		S.Y.		
Gravel		C.Y.		
Synthetic Media		Ea.		
Sand Fill		C.Y.		
Distribution Piping and Valves		Ea.		
Observation Ports		Ea.		
Topsoil (incl. seed & mulch)		C.Y.		
Control Building (incl. Elec and HVAC)		L.S.		
Fencing		L.F.		
Yard Piping		L.S.		
Electrical (10%)		L.S.		
Mob./Demob., Bonding/Ins. (7%)		L.S.		
Subtotal				
Capital Contingencies (25%)				
Subtotal				
Engineering (20%)				
Legal and Administative (5%)				
Total Estimated Capital Cost				

Table 7-2
Mound System O&M Costs

Operation and Maintenance Costs	Quantity	Units	Unit Cost	Annual Cost
Labor		hours/yr		
Electric Power		kWh		
Supplies		L.S.		
Maintenance and Repair		L.S.		
Laboratory Testing		L.S.		
Sludge Disposal		Gal.		
Annual O & M Cost				

B. Annualized Costs

1. Operations and Maintenance Cost Estimating Spreadsheet

A spreadsheet showing the major operations and maintenance cost line items that could be anticipated is shown in Table 7-2.

2. Significant Assumptions

a) Sludge Removal

Bi-annual sludge removal from the first septic tank and a three year period between sludge removal operations for the remaining treatment tanks should be assumed for estimating purposes, with an annual amount built into the budget. Accumulation of sludge will vary from project to project and from one tank to another, the actual number of sludge removal events will be based on routine measurements of the sludge depth.

b) Power

Power costs will vary across the state, but a rate of $0.10 per kWh 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:

$$\text{Annual Power Cost} = (N_p)(T_{\%})(24 \text{ hours})(HP)(0.75)(\$0.10)(365)$$

Where:
Np = 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 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 provision for 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 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 delivery.

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IX. Suggested Reading

A. Site & Soils Evaluations

Publications recommended for further investigation of the details of site and soils evaluations for on site wastewater treatment system.

1. EPA Onsite Wastewater Treatment Manual, Chapter 5
2. Wisconsin Department of Commerce Code *Comm 85* "Soil and Site Evaluations"
3. NRCS Soil Survey Manual
4. University Curriculum Development for Decentralized Wastewater Management, Site Evaluation Module

Appendix A
Primary Treatment Units

Appendix B
Pressure Distribution Network Design