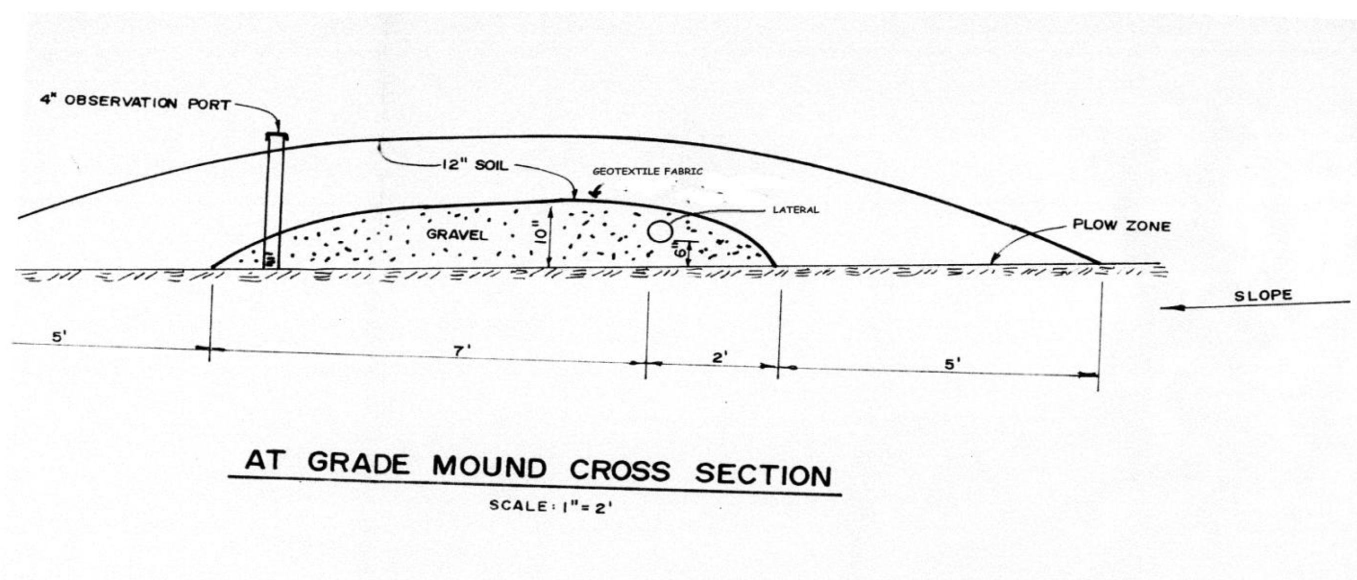
Design and Construction Manual For Maryland At-Grade Mound Systems



State of Maryland
Department of the Environment
Water Management Administration
Wastewater Permits Program
On-Site Systems Division

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ACKNOWLEDGEMENTS

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Much of the material presented in this manual was adapted from research guidelines and design manuals developed by the College of Agricultural and Life Sciences, University of Wisconsin, Madison, as part of the Small Scale Waste Management Project. The author also acknowledges and appreciates the assistance of each of the county health departments and property owners throughout the State of Maryland that have cooperated and contributed to this effort.

In the early 1990s, at-grade mounds were used in Maryland as innovative systems for repairs to existing houses and on certain vacant lots of record. In 1994, at-grade mounds were considered an alternative system by MDE policy. On May 12.2014, COMAR 26.04.02 was revised which made at-grade mounds a conventional system.

SECTION ONE

INTRODUCTION

1.1 PURPOSE

This manual provides information on site selection, design and construction of at-grade sewage disposal systems in Maryland. The manual has been prepared for use in Department training programs and applies to small residential systems with typical domestic strength wastewater. Larger at-grade systems with a design flow greater than 750 gallons per day and systems receiving wastewater with high biochemical oxygen demand or high suspended solids may require more detailed soil- hydrogeologic investigations, different sizing criteria and additional advanced pretreatment.

In the following sections procedures are presented for:

- Selecting a site
- Determining the at-grade dimensions
- Designing the pressure distribution network and pumping system
- Constructing the system

1.2 DESCRIPTION

The at-grade system is an on-site sewage disposal system that utilizes a raised bed of gravel or stone over the natural soil surface with a pressure distribution system constructed to equally distribute the pretreated effluent along the length of the gravel bed.

The operation of the at-grade system is a two-prong process involving both wastewater treatment and dispersal into the underlying soil. Final treatment is accomplished by physical and biochemical processes within the soil. The physical characteristics of the effluent, the loading rate, and the receiving soil can affect the physical and biochemical processes.

The at-grade system contains a distribution network placed on the raised gravel bed, which is constructed on top of the plowed or properly scarified soil dispersal area. The gravel bed and distribution network are covered with non woven geotextile fabric and quality topsoil. A soil setback of at least five (5) feet surrounds the gravel bed. Effluent is equally distributed into the bed where it moves into the soil and undergoes final treatment and dispersal processes. Figures 1, 2 and 3 depict the basic layout of an at-grade system.

A pressure distribution network allows effluent to be uniformly applied to the topsoil over the entire length of the gravel bed. Unsaturated flow conditions are created, enhancing treatment, and allowing the effluent to move laterally until absorbed into less permeable subsoils. Gravity distribution is not permitted.

The at-grade's soil cover material provides frost protection and allows moisture retention sufficient to maintain a vegetative cover. The original soil below the gravel bed serves as the final treatment and dispersal medium for the effluent.

When sited, designed, installed and maintained in accordance with this manual, regulatory requirements and basic maintenance guidelines, the at-grade system provides treatment and dispersal of domestic wastewater in conformance with Code of Maryland Regulations 26.04.02.

Figure 1: Profile of an At Grade System

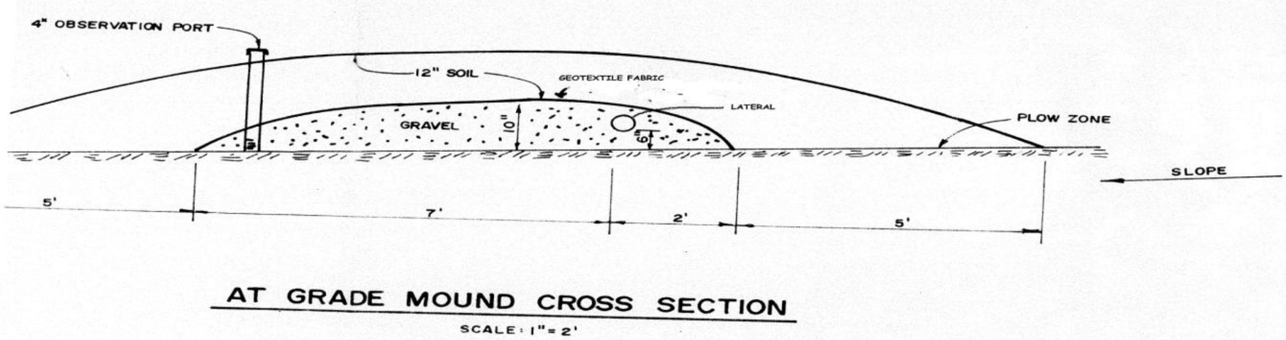
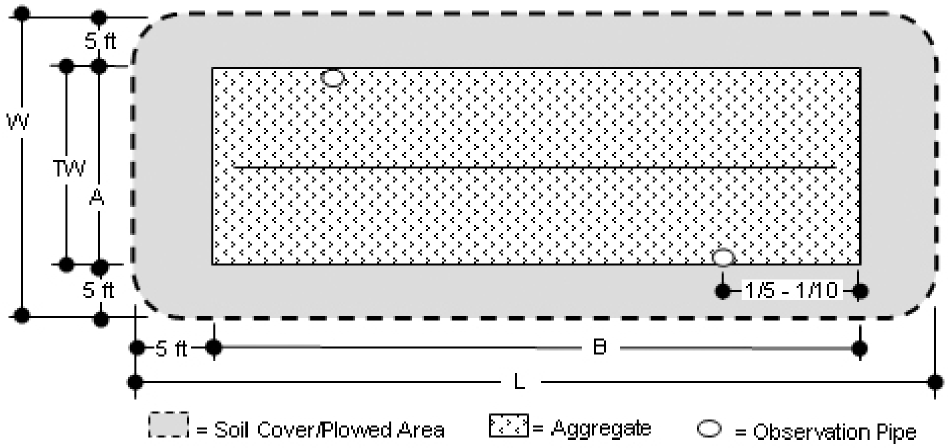
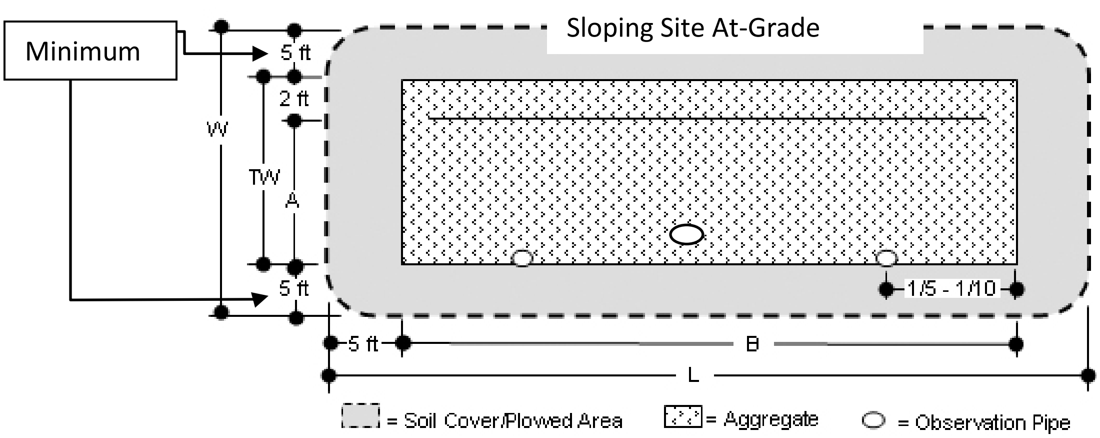


Figure 2 - A cross-section of an at-grade system on a level site



A = Effective Bed Width
B = Effective Bed Length
TW= Total Bed Width
L = Total At-Grade Length
W = Total At-Grade Width

Figure 3 - A cross-section of an at-grade system on a sloping site



A = Effective Bed Width
B = Effective Bed Length
TW= Total Bed Width
L = Total At-Grade Length
W = Total At-Grade Width

SECTION TWO

SOIL AND SITE REQUIREMENTS

General 2.1

This section summarizes site criteria used to determine if a site is suitable for an at-grade system.

A detailed site evaluation, conducted by local health department staff, the delegated approving authority or by a qualified soils consultant, must be performed at each site to determine suitability. The site evaluator must have a thorough knowledge of the principles and practices associated with proper soil and site evaluation, as well as an understanding of the design and function of at-grade systems. Evaluation techniques from the current version of the MDE *Site Evaluation Training Manual for On-Site Sewage Treatment and Disposal Systems* must be employed along with the relevant requirements in 26.04.02. This includes the "Cylinder Infiltrometer Test Method" described in Appendix J of the *Site Evaluation Training Manual*.

As with all on-site systems, approval of a site for construction of an at-grade system requires evaluations of landscape position, slope, setbacks, soil descriptions and permeability rates. Soil descriptions should include horizon, texture, structure, consistence, color, and depth.

2.2 Soil Depth, Evaluation and Testing Requirements

The design of every at-grade system is dependent upon specific soil and site characteristics. The design approach is based on criteria that assure that all applied wastewater is successfully transported away from the system, in a manner that will not influence later wastewater inputs, and that provides for adequate treatment of the effluent.

COMAR requires that the percolation rate is measured with an apparatus that limits horizontal movement such as the cylinder infiltrometer. Soil loading rates are based on percolation rates derived from cylinder infiltrometer testing conducted in the least permeable horizon in the uppermost 30 inches of the soil profile. Loading rates are outlined in Table 2.2.

It is important to recognize that care should be used when sizing the system absorption area based on percolation rates only and soil descriptions should be used for comparisons and determinations of a reasonable soil loading rate.

2.3 Slopes

On a crested site, the distribution cell can be situated such that the effluent can move laterally down both slopes. A level site allows lateral flow in all directions, but problems may present as the water table may mound beneath the distribution bed in slowly permeable soils on these sites. Sloping sites allow the effluent to move in only one direction away from the distribution bed. Depending on the landscape type the location of the lateral may be affected, or in the case of sloping sites, multiple laterals may be used if necessary.

On sloping sites and sites with slowly permeable soils and restrictive horizons, at-grade systems rely on lateral (horizontal) effluent movement away from the system via the upper soil horizons. Lateral movement becomes increasingly important as soil permeability decreases. Attention to the linear loading rate is very important.

Concave sloping sites are sites that have convergence of surface and/or subsurface drainage. Such landscape topographies that retain or concentrate surface and subsurface flows; such as swales, depressions or headslopes, are considered unacceptable for installation of an at-grade location.

In all cases, surface and subsurface flow from upslope areas is to be diverted from the site, or other methods employed to direct surface flow around the at-grade system.

2.4 Wooded and Rocky sites

Generally, sites with large trees, numerous smaller trees or large surface rocks and boulders are less desirable and may be unacceptable for installing an at-grade system. These sites create difficulty in preparing the surface and reduce the infiltration area beneath the at-grade system. Rock fragments, tree roots, stumps and boulders occupy a portion of the basal area, thus reducing the amount of soil available for proper treatment. If no other site is available, trees in the system area of the at-grade must be carefully cut off at ground level and boulders that are setting on the ground surface must be removed without excessively disturbing the infiltration area. Increasing the infiltrative area is necessary to provide sufficient effective distribution bed area; especially when any of the above conditions are encountered that combined exceed 20% of the ground surface. If the site has excessive amounts of surface rock and boulders (>50 percent) it should not be tested. These areas should be evaluated carefully on a case by case basis.

2.5 Setback Distances

The setbacks for on-site sewage disposal in the Code of Maryland regulations 26.04.02 are applicable for all components of at-grade systems as well as the setbacks in Table 2.1.

2.6 Location

Open areas in fields with exposure to sun and wind increase evaporation and transpiration, aiding in the dispersal of wastewater.

TABLE 2.1
SITE AND SOIL CRITERIA FOR AT GRADE SYSTEMS

Item	Criteria
Landscape Position	Well to moderately well drained areas, level or sloping. Crests of slopes or convex slopes are most desirable. Avoid depressions, bases of slopes and concave slopes
Slope	0 to 12% for soils with percolation rates equal to or faster than 60 min./inch.
Minimum Horizontal Separation Distances from Edge of Basal Area to:	
Wells	50 feet in confined aquifer 100 feet in unconfined aquifer
Surface Water, Streams, Springs	100 feet
Rock Outcrops	25 feet
Flood plain Soils	25 feet
Property Line	minimum of 10 feet*
Downslope foundations/driveways	25 feet
Downslope Soil Protection Setback	minimum of 25 feet; or greater if limiting horizon is present*
Soil Requirements	
Profile Description	Soils with a well-developed and relatively undisturbed A horizon (topsoil) are preferable.

TABLE 2.1
SITE AND SOIL CRITERIA FOR AT GRADE SYSTEMS

Soil Requirements con't

Unsaturated Depth	48 inches of unsaturated soil should exist between the original soil surface and seasonally saturated horizons
Depth to Bedrock, or Coarse fragments >50 % by volume	48 Inches (4 feet)
Percolation Rate	2 to 60 minutes/inch*
Infiltration Loading Rates*	0.8 gpd/ft2 (Perc Rate 2 -15 mpi) 0.6 gpd/ft2 (Perc Rate 16-30 mpi) 0.4 gpd/ft2 (Perc Rate 31-60 mpi)
Linear Loading Rate	Less ≤9 gpd/linear foot of bed
Length on contour required	Sufficient to provide ≤ 9 gpd/linear foot of bed*
Absorption Area	Divide the appropriate design flow by the appropriate infiltration loading rate

* Consideration should be given to structures with foundations on adjacent properties and if present, 25 feet is preferred from edge of basal area to property line.

* This Downslope Soil Protection Setback must be designated on a plan as an area protected from compaction and grading and free of structures such as buildings and driveways

* Cylinder infiltrometers are used to measure percolation rates. Tests are run in the least permeable soil horizon in the upper 30 inches.

* Based on wastewater with the equivalent strength of typical domestic sewage.

* Assumes no restrictive (slowly permeable) horizon exists within 4 feet beneath the ground surface.

TABLE 2.2

Maximum Loading Rates for Systems with Design Flow Less than 750 gallons per day with typical domestic sewage *

Percolation Rate in Minutes for 1- inch drop after prewetting	Maximum Loading Rate (Gallons per Day per Square Foot)
2 - 15	0.8
16 - 30	0.6
31 - 60	0.4

* Based on wastewater with the equivalent strength of typical domestic sewage. 26.04.02 requires effluent quality stronger than 300 mg/l biochemical oxygen demand or 300 mg/l suspended solids to employ a pretreatment unit to reduce the wastewater strength.

This design manual presents design guidance for typical residential applications. Systems with flows exceeding typical residences may require individually engineered designs and more conservative loading rates, or extensive site evaluations.

TABLE 2.3

EXAMPLES OF AT GRADE SYSTEM DIMENSIONS AND AREA REQUIREMENTS FOR SLOPING SITES

DESIGN FLOW (gpd)	BASAL LOADING RATE (gpd/ft)	EFFECTIVE BED AREA (sq. ft.)	EFFECTIVE BED WIDTH* AND LENGTH (ft. × ft.)	LINEAR LOADING RATE** (gpd/ft)	AT-GRADE FINAL DIMENSIONS* (ft.)
300	0.8	375	5 × 75	4	17 × 85
	0.6	500	5 × 100	3	17 × 110
	0.4	750	10 × 75	4	22 × 85
450	0.8	562.5	5 × 112.5	4	17 × 122.5
	0.6	750	10 × 75	6	22 × 85
	0.4	1125	10 × 112.5	4	22 × 122.5
600	0.8	750	10 × 75	8	22 × 85
	0.6	1000	10 × 100	6	22 × 110
	0.4	1500	15*** × 100	6	27 × 110

* Effective gravel bed width recommended not exceeding 10 feet if possible. The total widths under at grade final dimensions include the 2' setback of horizontal gravel upslope from the distribution lateral pipe, the effective gravel bed width and the downslope soil setback.

**Linear Loading Rate not to exceed 9 gpd/ft. If a restrictive (slowly permeable) horizon exists within 4 ft of the ground surface, the linear loading rate must be lower.

*** Bed widths of 10 to 15 feet and greater may present problems with construction of the system without compacting the infiltrative surface.

SECTION THREE

AT- GRADE DIMENSIONS

3.1 General

This section presents a procedure for sizing and shaping at-grade systems. Background data from a proposal or permit application and site evaluation data are used select the best orientation of the system. Design of the at-grade system is based on the design wastewater flow and soil characteristics. It must be sized to accept the daily flows and loads without causing surface seepage or groundwater pollution. Consequently, the effective gravel absorption area must be sufficiently large enough to absorb the effluent onto the underlying soil.

Design of the at-grade system dimensions includes the following three steps (1) calculating the design wastewater flow, (2) design of the gravel bed and (3) design of the entire at-grade system.

3.2 Wastewater Flow

For residential at-grade systems the minimum design flow may not be less than 300 gallons per day (gpd) and 150 gpd per bedroom. For at-grade systems that serve commercial or institutional establishments, discharging only domestic strength waste, the design flow may not be less than 400 gpd.

EXAMPLE

three (3) bedroom residence = 450 gallons per day

therefore wastewater flow = 450 gpd

3.3 Design of the Gravel Bed

To determine the required area needed for the effective gravel bed absorption area of the system, follow these steps.

a) Determine the infiltration loading rate for the site. If the cylinder infiltrometer test readings indicated one (1) inch movement in 13 minutes and the soil descriptions justify this, using Table 2.2, we can determine the loading rate is 0.8 gpd/ft2.

b) Determine the **effective area of the gravel bed required**. The effective area of the gravel bed is calculated by dividing the design wastewater flow by the loading rate.

EXAMPLE

Effective Area of Gravel Bed ft^2 = Design Flow /Infiltration Loading Rate

=450 gpd / 0.8 gpd/ft^2

= 562.5 ft^2

c) Choose an effective gravel bed width that does not exceed 10 feet. Divide Effective Area of Gravel Bed by 10 feet to get effective bed length (Verify if that length on contour is available in the field). The effective bed length is calculated by dividing the effective area of the gravel bed by the effective gravel bed width. Ideally, the at-grade will be constructed as long and narrow on a site as possible especially if a restrictive horizon exists in that situation, the width of the bed can be determined by dividing the effective area of the gravel bed by the length available on contour.

EXAMPLE

Length of Effective Bed = Bed Area / Effective Gravel Bed Width

= 562.5 ft^2 / 10 ft

= 56.25 ft (round up)

= 57 ft

Therefore the effective bed dimensions are 10 ft by 57 ft

However the actual bed area needs to allow for gravel supporting the distribution lateral to slope away from the pipe. This horizontal width of gravel upslope of the pipe is two (2) feet. Adding two (2) feet of gravel upslope of the pipe increases the bed width to 12 feet.

Thus, the final bed dimensions are

12 ft by 57 ft

d) Linear loading is calculated by dividing the design wastewater flow by the distribution bed length. The linear loading rate cannot exceed 9 gallons per day per square foot. If the linear loading rate exceeds 9 gpd/ft^2 then reduce the gravel bed width.

EXAMPLE

Linear Loading Rate = Design Flow / Length of Bed

= 450 gpd / 57 ft

= 8.0 gpd/ft, which is <9 gpd/ft and is acceptable*

***This assumes no restrictive horizon exists within 4 feet of the surface**

3.4 Design the Final Dimensions

In accordance with COMAR, a minimum distance of 5 (five) feet of soil setback surrounds the gravel bed regardless of the slope of the ground. Once the effective width and length of the absorption area are determined, the design must determine the best layout for the site within the approved sewage disposal area. On some sites it may be necessary to divide the effective bed area into several beds if there isn't sufficient length along the contour within the approved area. **Various** configurations may be used. The most common is the single bed that is placed on contour.

EXAMPLE

Final width =

effective width of bed + 2 feet gravel upslope of the pipe + 5 feet upslope soil setback + 5 feet downslope soil setback

Final width = 10ft + 2 ft + 5 ft + 5 ft

Final width = 22 ft

Final length =

length of gravel bed + 5 feet sideslope soil setback + 5 feet sideslope soil setback

Final length = 57 ft. + 5 ft + 5 ft

Final Length = 67 feet

Final At-Grade dimensions = width of bed by length of bed

22 ft × 67 ft

Summarizing the example,

Design Flow = 450 gpd

Minimum absorption area = 562.5 sq. ft.

Effective bed dimensions = 10 ft × 57 ft.

Bed Dimensions = 12 ft × 57 ft

Final Dimensions = 22 ft × 67 ft

3.5 Cover for the At-Grade

A minimum of 12(twelve) inches of quality topsoil is required to cover the at-grade system. The top of the at-grade system should be graded to allow precipitation to run off. This should be a silt loam. Clay is not to be used.

3.6 Observation Ports

Capped observation ports extending from the gravel/soil interface to or above final grade are placed in the absorption area to provide easy access for observing ponding in the gravel. Seepage at the toe of the at-grade may result from excessive ponding, and may be the most probable mode of failure. Observation ports should be placed in the gravel bed just upslope of the soil berm, and in the gravel bed just below the distribution lateral. An observation port consists of 4 inch diameter PVC pipe with slots or holes in the lower portion of the pipe. They must be anchored so that they don't pull out when removing the cap. The ports may be cut off at final grade and recessed slightly to avoid being damaged by lawn mowers. Screw type or slip caps are commonly used for the cover.

3.7 Protection of Receiving Environment

A minimum 25 feet wide area downslope of the mound must be designated on a plan as an area to be protected from compaction and free of structures such as buildings and driveways. The purpose is to protect the underground flow path the sewage will take upon exiting the mound. When limiting zones are shallow beneath the mound, this distance should be increased accordingly.

SECTION FOUR
PRESSURE DISTRIBUTION NETWORK AND PUMPING SYSTEM

4.1 GENERAL

This section presents a procedure for designing at-grade system pressure distribution networks and pumping systems. The function of the pressure distribution network in at-grade system is to distribute effluent through small diameter holes uniformly along the length of the bed and then allow it to move vertically downward through the aggregate where it infiltrates into the soil. The pressure throughout the distribution network must be nearly equal so that the volume of effluent discharged from each perforation is nearly equal during each dose. The pressure distribution network configuration will vary depending upon the size and dimensions of the absorption area. For level sites with narrow absorption areas, a single lateral in the center along the length of the absorption area will suffice. Although some circumstances may suggest a multiple lateral configuration is needed; for sloping sites, one lateral row placed 2 ft from the upper gravel bed edge is favored. For long beds a center feed network may be needed.

The design of the pressure distribution network consists of selecting the perforation diameter and spacing, sizing the lateral's length and diameter, selecting the number of laterals, calculating the system flow rate and dose volume, sizing the force main, sizing the pump based on total dynamic head and flow rate, and sizing the pump chamber.

A 5/16 inch diameter perforation and 24 inch (2ft) perforation spacing are recommended and are used in the examples that follow. Varying perforation size to ¼ inch, and the spacing between perforations can be employed to optimize performance. Perforation spacing on laterals of two to four feet is ideal and should provide adequate distribution of effluent to all portions of the bed. It should be noted that design of distribution networks is an iterative process. For example the use of a two (2) foot hole spacing is a starting point for calculations. Having a fractional number of holes requires adjustments to be made to hole spacing and/or number of holes in a design.

4.2 END AND CENTER FEED DISTRIBUTION NETWORKS

End Feed Network:

If the length along the contour of the absorption bed is less than 51 feet, an end feed distribution system as shown in Figure 4 can be used. In an end feed network, the length of the lateral, from force main to distal end, is equal to the bed length minus ½ the perforation spacing, minus the distance from the bed end to the force main (usually 1 ft.).

End Feed Lateral Length =
Bed Length – (½ Perforation Spacing + 1 ft.)

Center Feed Network:
It is recommended that systems with absorption beds longer than 51 ft. have a central force main distribution connection.

Length of Lateral from Force main

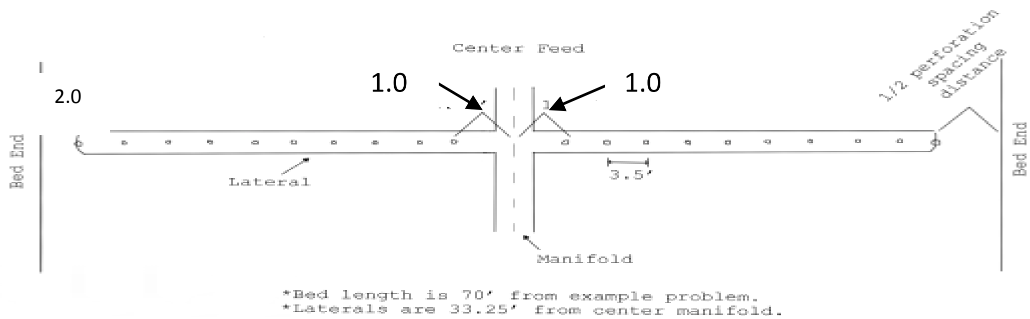
Prior to a final determination of lateral length, determine whether a center or end feed network will be employed. Once this is done, the number of holes per lateral and hole spacing are calculated as is the final lateral length network as shown in Figure 4.2. A central fed network allows for the use of smaller lateral diameters and consequently smaller dose volumes when beds longer than 51 ft. are specified. The length of the laterals in a center feed network is equal to ½ the bed length minus ½ the perforation spacing.

Center Feed Lateral Length = ½ Bed Length – ½ Perforation Spacing

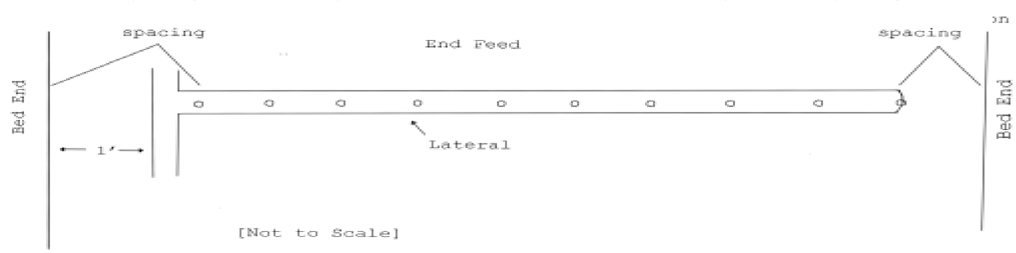
Example

Length of Absorption bed = 57 feet

Fifty seven (57) feet is greater than 51 feet, therefore a center feed distribution network is used. A 2 ft perforation spacing can be used.



If hole spacing causes first perforation to be in the manifold adjust hole spacing to 3"



Where force main is 1' from the bed end and calculations yield the hole spacing to be 2' a slight adjustment can be made to the 1st hole

FIGURE 4 – PERFORATION SPACING AND LATERAL LENGTH DIAGRAMS

EXAMPLE

$$\text{Lateral Length} = (0.5 \times 57 \text{ ft.}) - (0.5 \times 2 \text{ ft.})$$
$$= 28.5 \text{ ft.} - 1.0 \text{ ft.}$$
$$= 27.25 \text{ ft.}$$

Note: The distribution lateral ends at the last perforation which is drilled in the protected turn-up as shown in Figure 5.

4.2.1 Number of Perforations Per Lateral

The number of perforations per lateral from the force main connection to the distal end can be calculated using the following equations:

1. *End Feed* = bed length divided by spacing between perforations.
2. *Center Feed* = 0.5 × bed length divided by spacing between perforations.

Note: To avoid fractional numbers of perforations, it will usually be necessary to modify the perforation spacing from the recommended 2 ft. If a fractional number of perforations is calculated using the above formula with a 2 ft. spacing, the nearest whole number of perforations can be chosen. The final perforation spacing can then be determined according to the equation in the following section.

Example

Center Feed Force main

Bed Length	=	57 ft.
Perf. Spacing	=	2 ft.
0.5 × 57 ft. / 2 ft.	=	14.25 perforations

Choose 14 perforations

For center feed distribution networks choose an even number so that each lateral has equal numbers of perforations opposite the force main connection
Note: Once adjustments to the number of perforations is made the spacing must likewise be adjusted.

4.2.2 Spacing Between Perforations

Perforation spacing is determined according to the following equations.

3. *End Feed* = bed length divided by number of perforations per lateral.
4. *Center Feed* = 0.5 × bed length divided by number of perforations per lateral.

The distance between the end of the bed and the last perforation is ½ the perforation spacing. To calculate the distance between the force main and the first perforation, use the following formulas and refer to Figure 6:

1. *Center Feed* = 0.5 × perforation spacing
2. *End Feed* = (0.5 × perforation spacing) – 1 ft.*

* 1 ft. is the distance from the force main to the end of the bed. This distance

allows the force main to be surrounded by gravel and to be covered by non woven geotextile fabric, providing for its protection during placement of cap and topsoil.

Note: Employing perforation spacing's of approximately 2 ft. on laterals spaced two to four feet apart (if additional laterals are needed) should provide adequate distribution of effluent to all portions of the absorption bed.

4.2.3 Diameter of Perforations in Laterals

Experience in Maryland and other states indicate that proper diameter perforation is best for avoiding clogging. Two choices for hole diameter apply under specific conditions. When utilizing a Best available technology (BAT) unit or other advanced pretreatment unit, ¼ inch diameter perforation may be used with a three foot discharge head.

In systems where a BAT unit or other advanced pretreatment unit is not utilized a two compartment septic tank or two septic tanks in series must be installed with an effluent filter on the discharge outlet. In these cases, a 5/16 inch diameter perforation may be used with at least two foot discharge head.

4.2.4 Diameter of Laterals

Using a ¼ inch perforation diameter and 24-inch spacing between perforations, lateral diameter is a direct function of lateral length. The following lateral diameters apply:

TABLE 4.1
SELECTION OF LATERAL DIAMETERS FOR 1/4-INCH DIAMETER PERFORATION AND 24-INCH SPACING

Lateral Length (L) (ft.)	Lateral Diameter (in.)
L Less than 23	1
L to 26	1¼
L between 26 and 31	1½
L between 31 and 50	2

Note: The charts in Figure 6 show how the interrelated factors of perforation diameter, perforation spacing and lateral length affect the lateral's diameter. This figure must be used with ¼ inch or 5/16 inch perforations and/or when spacings other than 2 ft. between perforations are used. Table 4.1 can only be used to determine lateral diameter when employing ¼ inch perforations spaced 2 ft. apart. For other configurations Figure 6 must be utilized.

Example

The individual lateral length is 27.25 feet. Since 27.5 is less than 31 but greater than 26, both the chart and Figure 4.4 indicate that a minimum 1½ inch diameter lateral be used with ¼ inch perforations spaced 2 feet apart.

4.2.5 Spacing and Number of Laterals

Laterals must be spaced so that effluent is applied uniformly to the absorption area. Laterals should be placed in the center of the effective bed if site has 0 % slope, otherwise the lateral row should be placed 2 feet from upslope of bed edge.

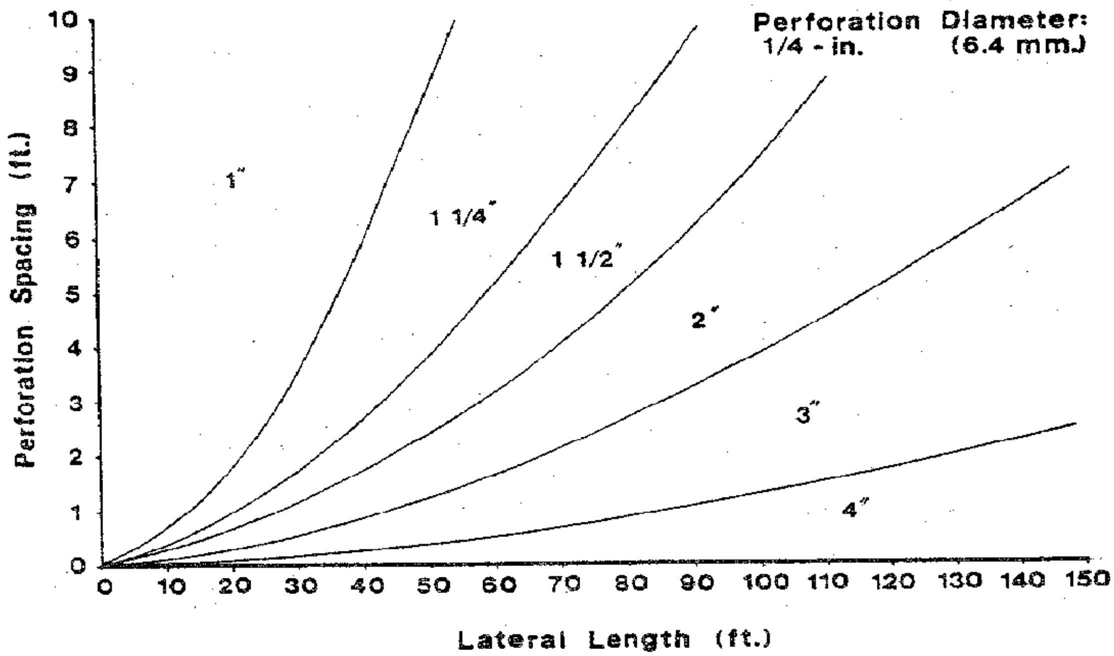
4.2.6 Last Perforation in Each Lateral

To provide an outlet for air trapped in the distribution system during the pumping cycle, and to promote rapid draining of the laterals upon pump shut off, the last perforation in each lateral should be located at the elevation of the crown of the pipe in a turn-up as shown in Figure 7.

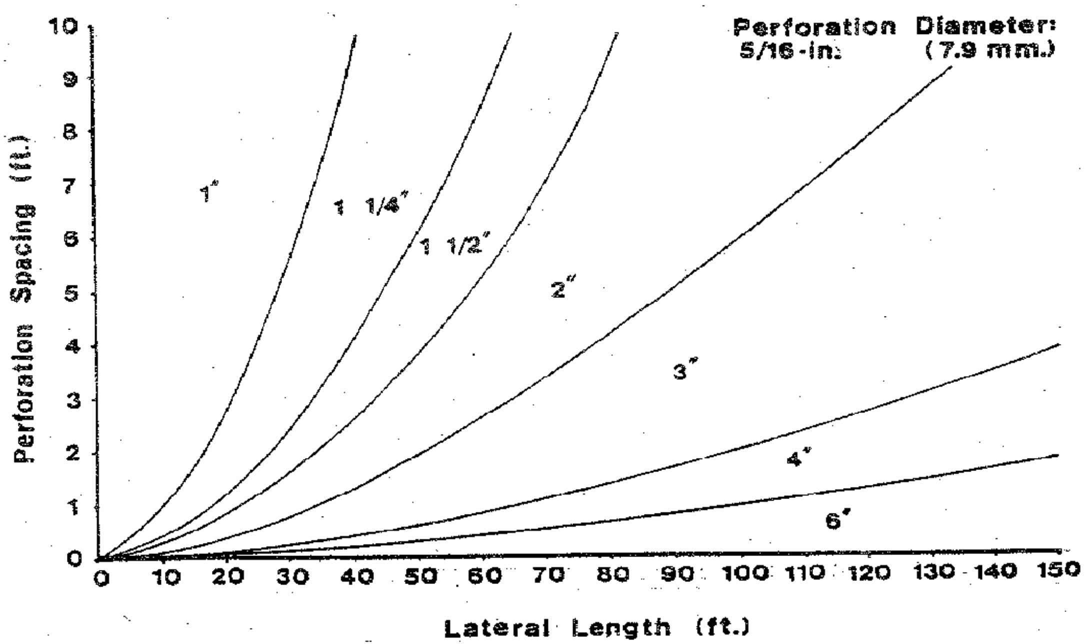
4.2.7 Diameter of Force Main

The force main can be from two to three inches in diameter.

Figure 6 - Perforations Spacing as a Function of Perforation Diameter, Lateral Diameter and Lateral Length

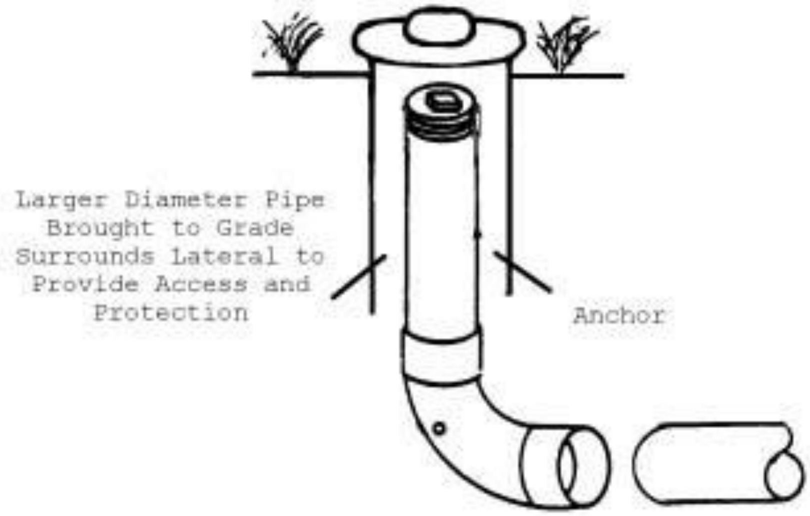


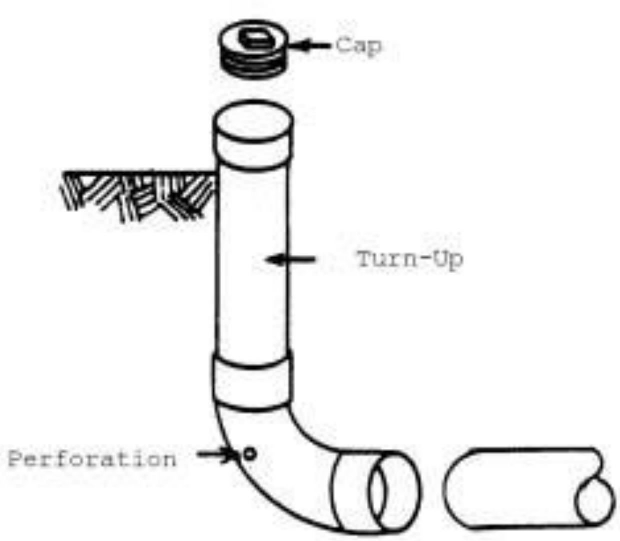
Minimum Lateral Diameter for Plastic Pipe (C_h = 150) Versus Perforation Spacing and Lateral Length for 1/4 in. Diameter Perforations (Otis, 1981)



Minimum Lateral Diameter for Plastic Pipe (C_h = 150) Versus Perforation Spacing and Lateral Length for 5/16 in. Diameter Perforations (Otis, 1981)

FIGURE 7 – ALTERNATIVES FOR PLACEMENT OF THE END PERFORATION IN A DISTRIBUTION LATERAL





Turn-Up Placement

Required for use on all laterals in at-grade systems

TABLE 4.2 PIPELINE SIZE AND VOLUME

A. Actual Inside Diameter (Inches)

Nominal Pipe size (inches)	Outside Diameter (inches)	PVC Flexible Pressure Pipe				PVC Rigid Pipe	
		SDR32.5	SDR26	SDR21	SDR17	Sch. 40	Sch. 80
1	1.315		1.195	1.189	1.161	1.049	0.957
1¼	1.660	1.54	1.532	1.502	1.464	1.380	1.278
1½	1.90	1.78	1.754	1.72	1.676	1.610	1.50
2	2.375	2.229	2.193	2.149	2.095	2.067	1.939
2½	2.875	2.699	2.655	2.601	2.537	2.469	2.323
3	3.50	3.284	3.23	3.166	3.088	3.068	2.90
3½	4.0	3.754	3.692	3.62	3.53	3.548	3.364
4	4.50	4.224	4.154	4.072	3.97	4.026	3.826
5	5.563	5.221	5.135	5.033	4.909	5.047	4.813
6	6.625	6.217	6.115	5.993	5.845	6.065	5.761
8	8.625	8.095	7.961	7.805	7.609	7.981	7.625

B. Volume Per 100 Feet (Gallons)

Nominal Pipe size (inches)	PVC Flexible Pressure Pipe				PVC Rigid Pipe	
	SDR32.5	SDR26	SDR21	SDR17	Sch. 40	Sch. 80
1		5.8	5.8	5.5	4.5	3.7
1¼	9.7	9.6	9.2	8.7	7.8	6.7
1½	12.9	12.6	12.1	11.5	10.6	9.2
2	20.3	19.6	18.8	17.9	17.4	15.3
2½	29.7	28.8	27.6	26.3	24.9	22.0
3	44.0	42.6	40.9	38.9	38.4	34.3
3½	57.5	55.6	53.5	50.8	51.4	46.2
4	72.8	70.4	67.7	64.3	66.1	59.7
5	111	108	103	98.3	104	94.5
6	158	153	147	139	150	135
8	267	259	249	236	260	237

Notes: "SDR" means standard dimension ratio and is the ratio of outside pipe diameter to wall thickness. Source: Modified from ASTM Standards D-1785, D-2241, D-2729, and F-405.

4.3 DESIGN PROCEDURE FOR THE PUMPING SYSTEM

For the example problem, assume the difference in elevation between the pump inlet and the highest part of the distribution network is eight feet, and the length of the force main is 60 feet.

4.3.1 Dose

The minimum dose must be (the volume of the force main and manifold)+ (5 × volume of the laterals). Pipe volume can be calculated using Table 4.2.

Example

Length of force main and manifold = 66 feet of two-inch diameter pipe

Length of laterals = 54.5 feet of 1½ inch pipe.

66 feet × 17.4 gallons/100 feet = 11.48 gallons

54.5 feet × 10.6 gallons/100 feet = 5.7 gallons

(5 × 5.7 gallons) + 11.48 gallons = 39.98 gallons

4.3.2 Pumping Chamber

A typical pump chamber detail is given in Figure 8.

a. *Watertight* – Circumstances may dicate the pumping chamber getting installed into the water table for many at-grade systems. In a poorly sealed pumping chamber, when the effluent level is pumped down, the difference in the hydraulic pressure gradient between the inside and outside of the chamber will likely cause infiltration of groundwater into the pumping chamber. To reduce the probability of infiltration, the pumping chamber should be installed as close to the ground surface as possible with all seams located above the high water table. All tanks must be certified for water tightness, preferably after the installation of manhole risers which should terminate a minimum of six inches above grade. Manufactures shall certify that tanks are watertight; however the approving authority may require a vacuum test or water pressure test to confirm water tightness. Many cases of infiltration have been attributed to manhole risers as well as the tanks themselves.

Installation of an event counter and/or elapsed time meter on the pumping system make possible future evaluations of the tank's water - tightness.

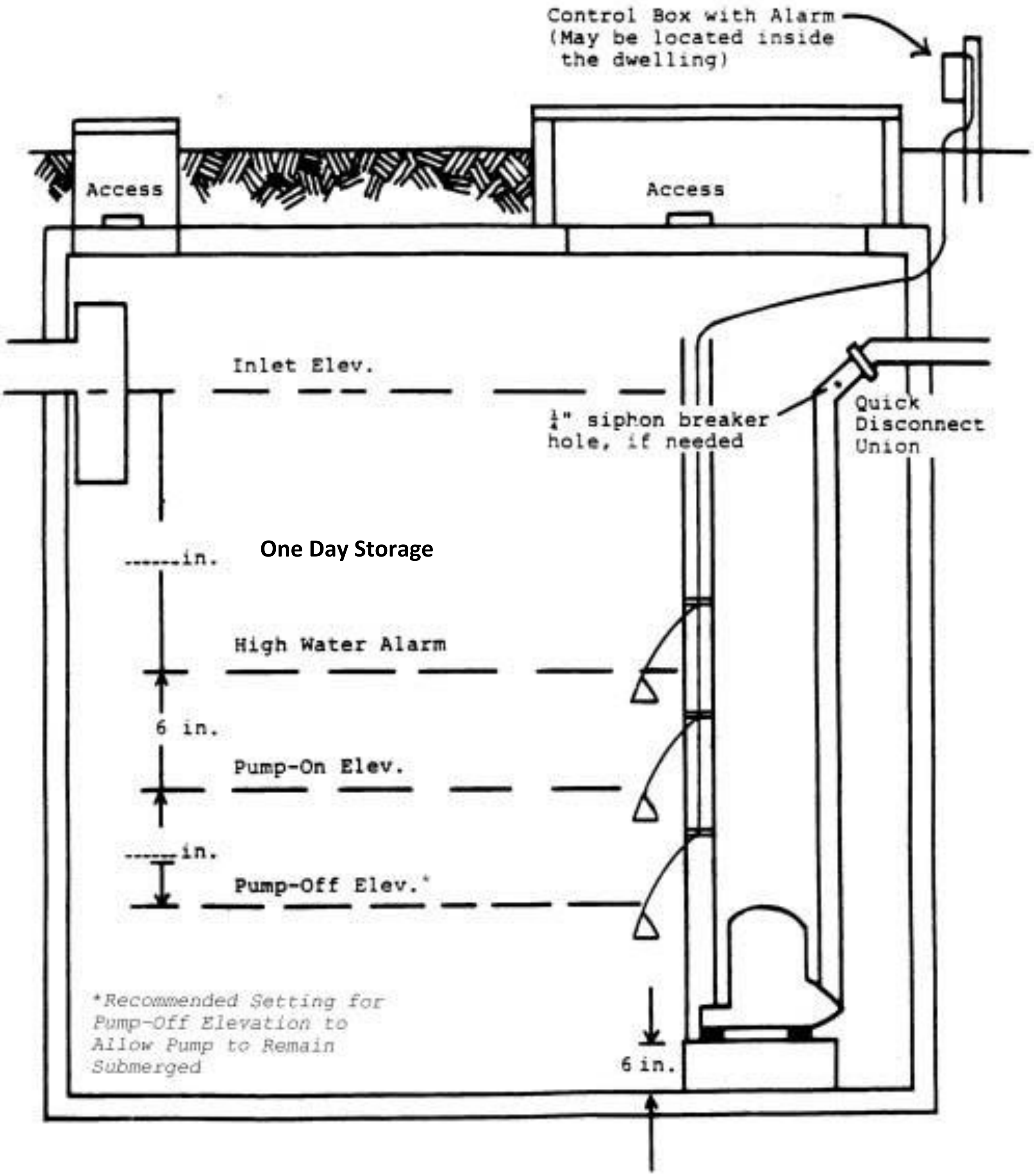
b. *Sizing the pump chamber* – The pump chamber must have the capacity to accommodate a pump positioned on a six-inch riser, one dose volume, and one day's design flow storage capacity above the high water alarm.

Example

One Day Storage Capacity	=	450 gallons
Dose	=	75 gallons
Total	=	525 gallons

The pumping chamber normally would need to have a 525-gallon capacity between the pump chamber inlet and the pump off float. Additional capacity in the pump chamber above the inlet can be included as long as the level is not higher than the elevation of the septic tank inlet invert.

Note: The pump must be located on a six-inch riser. Settings of floats in equal volume pump chambers will vary as pump chambers' dimensions change.



It is recommended that a gate valve for controlling discharge head and/or to shut of flows back into the pump chamber be installed after the disconnect union.

FIGURE 8 – TYPICAL PUMP CHAMBER DETAIL

4.3.3 Sizing the Pump

The pump must be capable of delivering the necessary flow (gpm) at the calculated design head (feet).

a. *Flow* – The number of perforations in the system times the discharge rate per perforation is equal to the flow. The discharge rate for a 1/4- inch perforation with three feet of head is 1.28 gpm. The discharge rate for a 5/16 inch perforation with two feet of head is 1.63 gpm.

Example

In our problem we have two laterals with fourteen 1/4 inch perforations per lateral.

14×2 laterals = 28 perforations

Flow = 28×1.28 gpm = 35.84 gpm

b. *Design Head* – Static head (feet) plus friction head (feet) plus 3 ft. of head at distal end of laterals equals the design head.

1. *Static Head* (feet) – The relative elevation of the highest component of the distribution system minus the relative elevation of the pump off float switch.

Example

Relative elevation of pump off float is 124 feet. Relative elevation of manifold is 132 feet. Static head = 132 feet – 124 feet = 8 feet.

2. *Friction Head* (feet) – The head loss due to friction in the pipe between the pumping chamber and the laterals. All fittings, such as 90 degree bends, disconnect unions, and valves, contribute to friction head loss. Fittings' contributions to friction loss can be calculated in equivalent length of pipe by using **Table 4.3**. For example, a two-inch quick disconnect union or coupling adds 2 feet of equivalent length of two inch pipe to the actual length of the actual length of two inch pipe in the

system. Once the total equivalent length of pipe is determined, (equivalent length of pipe from fittings plus actual length), the friction head can be calculated. Friction loss (feet) per 100 feet of pipe for a given flow can be found in Table 4.4.

TABLE 4.3
ALLOWANCE IN EQUIVALENT LENGTH OF PIPE FOR FRICTION LOSS IN VALVES AND THREADED FITTINGS (ASA A40.8-1955)

Diameter of Fitting	90 Deg. Standard Ell	45 Deg. Standard Ell	90 Deg. Side Tee	Coupling or Str. Run of Tee	Gate Valve	Globe Valve	Angle Valve
Inches	Feet	Feet	Feet	Feet	Feet	Feet	Feet
3/8	1	0.6	1.5	0.3	0.2	8	4
1/2	2	1.2	3	0.6	0.4	15	8
3/4	2.5	1.5	4	0.8	0.5	20	12
1	3	1.8	5	0.9	0.6	25	15
1 1/4	4	2.4	6	1.2	0.8	35	18
1 1/2	5	3	7	1.5	1.0	45	22
2	7	4	10	2	1.3	55	28
2 1/2	8	5	12	2.5	1.6	65	34
3	10	6	15	3	2	80	40
3 1/2	12	7	18	3.6	2.4	100	50
4	14	8	21	4	2.7	125	55
5	17	10	25	5	3.3	140	70
6	20	12	30	6	4	165	80

TABLE 4.4
FRICTION LOSS IN SCHEDULE 40 PLASTIC PIPE, C = 150 (ft / 100 ft)

	Pipe Diameter (In.)								
Flow gpm	**1**	**1-¼**	**1-½**	**2**	**3**	**4**	**6**	**8**	**10**
1	0.07								
2	0.28	0.07							
3	0.60	0.16	0.07						
4	1.01	0.25	0.12						
5	1.52	0.39	0.18						
6	2.14	0.55	0.25	0.07					
7	2.89	0.76	0.36	0.10					
8	3.63	0.97	0.46	0.14					
9	4.57	1.21	0.58	0.17					
10	5.50	1.46	0.70	0.21					
11		1.77	0.84	0.25					
12		2.09	1.01	0.30					
13		2.42	1.17	0.35					
14		2.74	1.33	0.39					
15		3.06	1.45	0.44	0.07				
16		3.49	1.65	0.50	0.08				
17		3.93	1.86	0.56	0.09				
18		4.37	2.07	0.62	0.10				
19		4.81	2.28	0.68	0.11				
20		5.23	2.46	0.74	0.12				
25			3.75	1.10	0.16				
30			5.22	1.54	0.23				
35				2.05	0.30	0.07			
40				2.62	0.39	0.09			
45				3.27	0.48	0.12			
50				3.98	0.58	0.16			
60					0.81	0.21			
70					1.08	0.28			
80					1.38	0.37			
90					1.73	0.46			
100					2.09	0.55	0.07		
150						1.17	0.16		
200							0.28	0.07	
250							0.41	0.11	
300							0.58	0.16	
350							0.78	0.20	0.07
400							0.99	0.26	0.09
450							1.22	0.32	0.11
500								0.38	0.14
600								0.54	0.18
700								0.72	0.24
800									0.32
900									0.38
1000									0.46

Source: EPA Design Manual

Example

We have 66 feet of two-inch diameter pipe from the pump to the laterals. Let us say the fittings add on 11 equivalent feet of pipe. The friction loss then must be calculated for 91 feet (66 + 25) of two-inch diameter pipe at 35.84 gpm. From Table 4.4 we know that, at 100 gpm in a three-inch pipe, friction loss would be 2.09 feet per 100-foot length.

100 foot length	=	2.09 foot friction loss
$0.91 \times$ 100 foot length	=	$0.91 \times$ 2.09 foot friction loss
91 foot length	=	1.90 foot friction loss

Or: 91 ft of pipe X 2.09 ft of friction loss per 100 ft of pipe = 1.90 ft of friction loss

3. *Discharge Head at Distal End of Laterals* = 3 feet

Design Head (Total Dynamic Head)
= 8 feet (static) + 1.90 feet (friction) + 3 feet (distal end head)
= 12.90 feet.

A pump is needed that can deliver 35.84 gpm at 12.90 feet of head. Using the pump curve given in Figure 9 – Effluent Pump Curves, the pump needed would be the WP03 , 1/3 horsepower.

An equation for calculating horsepower is:

$$\frac{\text{Flow} \times \text{Total Dynamic Head} \times \text{Specific Gravity}}{3960 \times \text{efficiency}}$$

(specific gravity of H_2O at $68^{o}F$ is 1)

For example, use 0.4 for efficiency, as this is common for effluent pumps.

$$\frac{97.8 \times 11.90 \times 1}{3960 \times 0.4} = 0.735 \text{ horsepower}$$

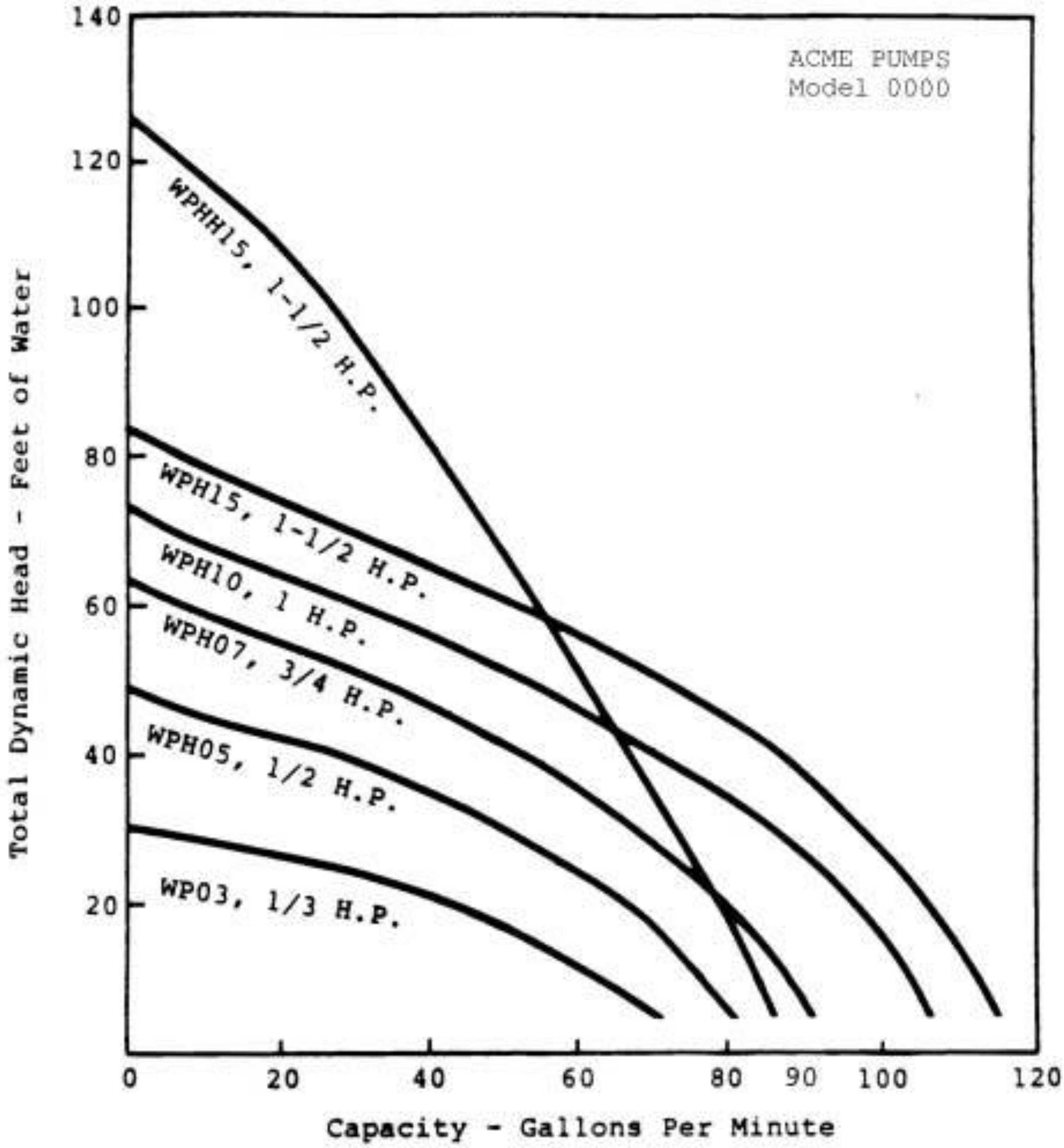


FIGURE 9 – EXAMPLE EFFLUENT PUMP CURVES

4.3.4 Adjustment of Float Switches in the Pumping Chamber

The volume between the pump-on float and the pump-off float must equal the dose. The volume between the high water alarm float and the pump chamber inlet should equal the volume of one day's design flow. The equation to calculate the distance between the pump-on float and pump-off float is:

$d = \underline{(D) \times 231} / A$

Where:

d	=	distance in inches between pump-on and pump-off floats
231	=	cubic inches per gallon
D	=	dose in gallons
A	=	cross-sectional area of the pumping chamber interior (in.^{2})

To calculate the distance between the high water alarm switch and the pump chamber inlet use:

$r = \underline{(R) \times 231} / A$

Where:

r	=	distance in inches between pump chamber inlet and high water alarm
R	=	one day's flow (reserve capacity) in gallons
231	=	cubic inches per gallon
A	=	cross-sectional area of the pumping chamber interior (in.^{2})

4.3.5 Float Attachment

Floats should be attached to a dedicated float tree that can be removed from the pump pit independent of the pump. Floats should not be hung from the discharge piping. Floats attached to trees with inappropriate straps that are prone to fatigue and failure in the pump pit environment can result in floats becoming detached and premature pump failure. Drilling through a dummy pipe and knotting the float wire on each side of the pipe provides a fail-safe attachment.

4.3.6 Wiring

A control panel should always be used. This provides for greater safety since it is not necessary for the entire electrical current energizing the pump to be fed through the floats. It also provides for easier troubleshooting of the system, allows emergency operation capability in the event of float failure, and allows for the use of timed dosing to enhance system's treatment and hydraulic performance. The high-level alarm float must be wired on a circuit separate from the pumping system.

SECTION FIVE

CONSTRUCTION PROCEDURES

5.1 GENERAL

Proper construction is extremely important if the at grade is to function as designed. Installation of an at-grade system is prohibited when soils are frozen or if the soil is wet. Construction of the atgrade should NOT occur if the soil is wet. Compaction and puddling of the soil in the location of the at grade system, any replacement areas and within 25 ft downslope must be avoided. Soil is too wet for construction of the at-grade system if a sample, taken anywhere within the uppermost eight inches, when rolled between the hands forms a wire. If the sample crumbles, the soil is dry enough for construction to proceed. Approval of soil moisture and site conditions must be obtained from the local Approving Authority prior to beginning construction.

5.2 EQUIPMENT

The following equipment is required:

1. A small track machine (low ground pressure) for placing and spreading the aggregate, and topsoil.
2. A cordless drill for drilling holes in the pipe on-site. A sharp drill bit of a specified size is required.
3. A chisel plow, chisel plow attachment or moldboard plow for plowing the soil within the perimeter of the at grade. Other scarification equipment (preferably on tracks) may be used but must be approved in advance by the inspector. A rototiller is prohibited.
4. A rod and level for determining bed elevations, slope on pipes, outlet elevation of septic tank or BAT unit, slope of site, etc.

5.3 MATERIALS

The following specifications are required:

1. Aggregate shall be clean aggregate free off fines and between ¾ and 2 inches in diameter. Washed river gravel is preferred. Aggregate is to be inspected and approved by the inspector.
2. If a BAT unit is not required a two compartment tank or two tanks in series with an effluent filter installed in the outlet of the second compartment - with proper access provided is required.
3. Nonwoven geotextile fabric must be used.
4. Topsoil shall be of good quality, and free of debris such as rocks and trash. A silt loam or other medium textured soil is recommended. A clay cap is not recommended.

5.4 TANK INSTALLATION AND SITE PREPARATION

Locate, fence or rope-off the entire sewage disposal area to prevent damage to the area during other construction activity on the site. Vehicular traffic over the disposal area and directly downslope of the disposal area is prohibited to avoid soil compaction.

Install BAT unit or compartmented septic tanks if allowed and pumping chamber(s) and pump as shown on the approved design plan and drawings. Access risers should terminate 6 inches above finished grade. Call for inspection.

Verify the stake out per the approved design or stake out the initial system and recovery area perimeters in their proper orientation on contour based on field verified grade shots. This orientation should match the approved design. Reference stakes offset from the at-grade corner stakes are recommended. Locate the upslope edge of the absorption bed within the at grade system and determine the ground elevation at the highest location. Reference this elevation to a benchmark for future use. This is necessary to determine the elevation of the top of the absorption bed as well as the topsoil elevation. Call for inspection.

Excess vegetation should be cut and removed carefully. Trees should be cut at ground level and stumps left in place.

Determine the location where the force main from the pumping chamber will connect to the distribution network manifold within the at-grade.

Install the force main from the pumping chamber to the proper location within the at grade. (preferably connecting the force main to the laterals from the upslope side of the bed) Pipe should be laid with uniform slope back to the pump chamber so that it drains after dosing. Cut and stub off pipe one foot below existing grade within the proposed perimeter of the initial system. Backfill trench and compact to prevent seepage along the trench. If it is not possible to connect the force main from the uslope side of the gravel bed, the force main could be installed from the end of the mound but elevated and placed along the upper edge of the gravel bed beside the laterals. Connecting the force main from the downslope side of the mound should be avoided. Call for inspection.

Once soil conditions are approved by the inspector, plow or properly scarify the soil following the contour to a depth of eight inches within the entire perimeter of the at-grade. The plowed area should be at least the total length and width of the system. Chisel plows or chisel plow attachments are preferred or extender teeth mounted on a tracked excavator bucket are satisfactory. Plowing should be done along the contour, throwing soil upslope when using a two bottom or larger Moldboard plow leaving the dead furrow at the bottom. In wooded areas with stumps, roughening the surface to a depth of six inches with a ripper tooth placed on a backhoe may be satisfactory. The normal teeth on a backhoe are not satisfactory and must not be used. However, all work must be done from the upslope or sides of the system. Rototilling may not be used. After plowing, all foot and vehicular traffic shall be kept off the plowed area. Call for inspection.

5.5 AGGREGATE PLACEMENT AND DISTRIBUTION NETWORK

Relocate and extend the force main at least one foot above the ground surface. Temporarily cap or otherwise cover the pipe opening to prevent anything from entering the pipe.

Working from the upslope side, carefully place the clean aggregate in the designated bed area to a minimum depth of six inches. Level the aggregate to a minimum depth of six inches under the pipe. Avoid all foot and vehicular traffic on the plowed area at all times. Minimize the soil disturbance beneath and downslope of the absorption area.

Place the designated number of observation ports at the toe of the gravel at the locations shown on the approved plan. Ideally three ports should be used. The ports should be Schedule 40 PVC or equivalent, must be anchored and placed so the ponded effluent at the downslope edge of the gravel may be observed in the ports. Ports should extend at least twelve inches above finish grade.

Place the three observation ports at the toe of the gravel at the designated locations. The ports must be placed so the ponded effluent at the downslope edge of the gravel may be observed in the ports. Stabilize the observation ports.

Uncap the force main terminus. The distribution network is assembled in place using PVC primer and glue. The laterals should be laid level with the holes directed downward except the first and last hole in each lateral. The lateral turn ups should be sleeved in either a larger diameter pipe or turf box for protection and access. Call for inspection. Test the pumping chamber and distribution network with clean water.

Place additional aggregate to a depth of at least two (2”) inches over the crown of the laterals. Place the non-woven geotextile fabric over the gravel bed. Extend it to no more than 1 ft over the edge of the gravel.

5.6 COVER MATERIAL

Place a minimum of twelve inches of good quality topsoil such as a loam or silt loam over the entire bed surface and taper it to a distance of at least five feet in all directions from the gravel bed. Finish grading around the system to divert surface water away. Call for inspection.

5.7 VEGETATION

Fertilize, lime, seed and mulch the entire surface of the at grade system immediately after construction to control erosion. Grass mixtures adapted to the area should be used. Consult the county extension agent or Soil Conservation District for recommendations.

Irrigate the seeded mound sufficiently to establish grass growth in a timely manner. Call for final inspection.

Several of the necessary inspections can be combined to save the installer time.

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AT GRADE MOUND PRE-CONSTRUCTION CHECK LIST

1. Absorption bed length (ft) = _______________
2. Total Absorption bed width (ft) = _______________
   Effective width of bed (ft)=__________(downslope of lateral)

3. Side slope setback = _______________
4. Upslope setback = _______________
5. Downslope setback = _______________
6. Total mound width (ft) = _______________
7. Total mound length (ft) = _______________
8. Minimum depth of Gravel below lateral=________________
9. Depth of gravel over lateral=______________
10. Center feed or end feed force main/manifold = _______________(Circle One)
11. Length of laterals = _______________
12. Number of rows of laterals = _______________(Normally only one row of laterals)
13. Total length of lateral pipe required for system = _______________
14. Space between laterals (if applicable)= _______________
15. Lateral diameter = _______________
16. Perforation diameter = 5/16 or ¼ inch (Circle one)
17. Perforation spacing = _______________
18. Number of perforation per lateral = _______________
19. Space between first perforation and manifold = _______________
20. Reducers – type and number required = _______________
21. Diameter of force main = _______________
22. Diameter of manifold=_________________
23. Total length of force main = _______________
24. Minimum flow or discharge rate for system (g.p.m.) = _______________
25. Total dynamic head (TDH) = _______________
26. Minimum Dose (gal.) = _______________

AT-GRADE SEWAGE DISPOSAL SYSTEM
INSPECTION CHECKLIST

I. Site Preparation

Date: ______________

A. MDE Certified Installer Name ________________________

B. MDE Certified Installer Present ________________________

C. Mound & gravel bed properly staked out ______________

D. No compaction by heavy equipment: ___________

1. Within perimeter ___________
2. Downslope from mound by 25 ft ___________
3. Within sewage disposal area ___________

E. Vegetation/Boulders cut and removed ___________

F. Trees, if present, cut off at ground level stumps left in place ___________

G. Soil moisture level low enough to permit construction and not frozen ___________

H. Soil plowed or scarified to suitable depth and perpendicular to slope ___________

I. Location of BAT unit/septic tank(s) and pumping ___________
station properly staked out ___________

II. Construction

A. BAT units or Septic Tank(s) Date: ___________

1. Number of tanks ___________
2. Tank type and construction meet specification (i.e., top-seam, baffled, etc.) ___________
3. Capacity requirements met ___________
4. Proper installation ___________
(level, turned proper direction) ___________
5. Inlet and outlet pipes at proper elevations and sealed at tank ___________
6. Baffles/filters properly installed ___________________

7. Tank watertightness checked ______________
    a. Certified by Supplier ______________
    b. Weep hole sealed if present ______________
    c. 24-hour leakage test conducted if necessary ______________
    d. Proper vacuum test conducted ______________
    e. Riser to tank lid watertight ______________

B. Pump Chamber Date: ______________

1. Dimensions meet specifications ______________
2. Six-inch block present under pump ______________
3. Control panel meets specifications ______________
4. Event counter/elapsed time meter/
   flow meter installed, if required ______________
5. Proper float elevations (on/off /alarm) ______________
6. Quick disconnect/siphon hole present
   (if required) ______________
7. Proper elevation of influent pipe ______________
8. Pipes through tank walls sealed ______________
9. Valves meet specifications ______________
10. Tank joints above seasonal high water level ______________
11. Manhole Access provided and ______________
    above finished grade ______________
12. One-day design flow storage capacity above ______________
    high level alarm ______________
13. Force main diameter as specified ______________
14. High water alarm on separate circuit ______________
15. Riser to lid watertight

C. Absorption Area Date: ______________

1. Gravel meets specifications ______________
2. Gravel brought to proper elevation ______________
   Prior to placement of distribution
   system ______________
3. Gravel covers entire basal area ______________
4. Absorption bed at the proper dimensions ______________

5. Absorption bed or trenches level ____________
6. Six-inches of suitable gravel between soil and distribution pipe ____________

D. Distribution System Date: ____________

1. Pressure fittings used at joints ____________
2. Fittings adequately bonded ____________
3. Proper diameter of manifold ____________
4. Proper diameter of lateral piping ____________
5. Proper diameter of lateral perforations ______________
6. Proper spacing of lateral perforations ____________________
7. Perforations oriented downward ____________
8. End perforation suitable (sleeved on turnup radius) ________
9. Two-inch gravel to cover laterals ______________
10. Distribution system checked under Pressure for leakage _____________________

E. Final Placement of Fill and Topsoil Date: ____________

1. Acceptable geotextile fabric covers entire gravel layer ____________
2. Tapered cap present:
   A. Twelve-inches depth at center ____________
   B. Extends five feet from edges of gravel bed ______________________
3. Cover:
   A. Acceptable quality ____________
   B. Present and graded ____________
   C. Seeded/Sod ____________
   D. Mulched, if applicable ____________
4. Sides no steeper than 3:1 slope ____________

F.

G. Monitoring Appurtenances Date: ____________

1. Observation ports:
   A. Proper location and number ________________
   B. Installed to proper depth _________________
   C. Anchored ______________
2. Lateral turn-ups in place (if required) ________

H. <u>Site Drainage</u> (if required) Date: ____________

1. Surface water diversion ____________
2. Curtain drain ____________
3. Vertical drain ____________

III. Pumping System Test Date: ____________

A. Pump-on switch is operational ____________

B. Pump-off switch is operational ____________

C. High level alarm switch is operational ____________

D. Volume of drawdown corresponds with specified dose ______________

E. System achieves specified pressure ____________

IV. Comments:

Table 1

Perforation Discharge Rates in Gallons per Minute vs. Perforation Diameter and In-Line Pressure (adapted from Otis, 1981)

In-Line Pressure (ft)	Perforation Diameter (inches)							
	1/8	**1/4**	**5/16**	**3/8**	**7/16**	**1/2**	**9/16**	**5/8**
	gpm							
1.0	0.18	0.74	1.15	1.66	2.26	2.95	3.73	4.60
1.5	0.22	0.90	1.41	2.03	2.76	3.61	4.57	5.64
2.0	0.26	1.04	1.63	2.34	3.19	4.17	5.27	6.51
2.5	0.29	1.17	1.82	2.62	3.57	4.66	5.90	7.28
3.0	0.32	1.28	1.99	2.87	3.91	5.10	6.46	7.97
3.5	0.34	1.38	2.15	3.10	4.22	5.51	6.98	8.61
4.0	0.37	1.47	2.30	3.31	4.51	5.89	7.46	9.21
4.5	0.39	1.56	2.44	3.52	4.79	6.25	7.91	9.77
5.0	0.41	1.65	2.57	3.71	5.04	6.59	8.34	10.29

The typical orifice diameter would not exceed 5/16”, the larger diameters are shown for comparison only.

Table 2

Maximum Manifold Length (ft) For Various Manifold Diameters Given the Lateral Discharge Rate and Lateral Spacing (from: Otis, 1981)

Lateral Discharge Rate	Manifold Diameter = 1¼"	Manifold Diameter = 1 ½"	Manifold Diameter = 2"	Manifold Diameter = 3"	Manifold Diameter = 4"	Manifold Diameter = 5"
End Manifold / Center Manifold	Lateral Spacing (ft)	Lateral Spacing (ft)	Lateral Spacing (ft)	Lateral Spacing (ft)	Lateral Spacing (ft)	Lateral Spacing (ft)
	2 4 6 8 10	2 4 6 8 10	2 4 6 8 10	2 4 6 8 10	2 4 6 8 10	2 4 6 8 10
10 / 5	4 8 6 8 10	10 8 12 16 20	12 16 24 24 30	26 40 48 56 70	42 64 84 96 110	84 134 174 200 240
20 / 10	4 4 6	4 4 6 8 10	6 8 12 16 20	16 24 30 32 40	26 40 54 64 70	54 84 106 128 150
30 / 15	2	2 4 6	4 8 6 8 10	12 16 24 24 30	20 26 36 48 60	42 64 84 96 110
40 / 20			4 4 6 8 10	10 12 18 16 20	16 24 30 32 40	34 52 66 80 90
50 / 25			2 4 6 8	8 12 12 16 20	14 20 24 32 40	30 44 60 72 80
60 / 30			2 4	8 12 18 16 20	12 16 24 24 30	26 40 48 64 70
70 / 35			2	6 8 12 8 10	10 16 18 24 30	24 36 48 56 60
80 / 40			2	6 8 6 8 10	10 12 18 16 20	22 32 42 46 60
90 / 45			2	4 8 6 8 10	8 12 18 16 20	20 28 42 46 50
100 / 50				4 4 6 8 10	8 12 12 16 20	18 28 36 40 50
110 / 55				4 4 6 8 10	8 12 12 16 20	16 24 36 40 40
120 / 60				4 4 6 8 10	6 8 12 16 10	16 24 30 32 40
130 / 65				4 4 6 8 10	6 8 12 16 10	14 24 30 32 40
140 / 70				2 4 6 8	6 8 12 8 10	14 20 24 32 40
150 / 75				2 4 6	6 8 12 8 10	14 20 24 32 30
160 / 80				2 4 6	6 8 6 8 10	12 20 24 32 30
170 / 85				2 4 6	4 8 6 8 10	12 20 24 24 30
180 / 90				2 4	4 8 6 8 10	12 16 24 24 30
190 / 95				2 4	4 8 6 8 10	12 16 18 24 30
200 / 100				2 4	4 4 6 8 10	10 16 18 24 30