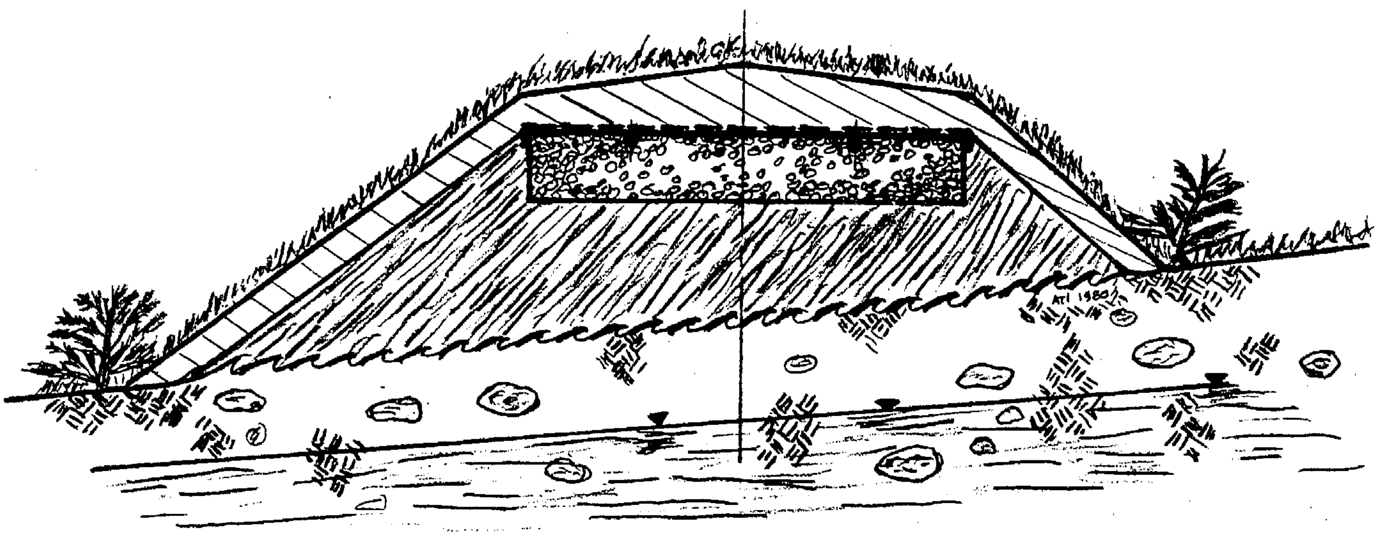
GUIDELINES FOR MOUND SYSTEMS



STATE WATER RESOURCES CONTROL BOARD

January 1980

GUIDELINES

FOR

MOUND SYSTEMS

STATE OF CALIFORNIA

STATE WATER RESOURCES CONTROL BOARD

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CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

GUIDELINES

FOR

MOUND SYSTEMS

I. INTRODUCTION

The State Water Resources Control Board (SWRCB) has prepared these guidelines for voluntary use by the Regional Boards, local health agencies and technical persons involved in the planning, design, construction or regulation of mound systems for residential wastewater treatment and disposal. All local agencies and technical persons are cautioned to consult the appropriate Regional Board prior to planning, designing or constructing any mound system. Regional Board approval of any such system may be required.

These systems, while more expensive than a conventional onsite wastewater system, enable onsite disposal in areas previously identified as unacceptable for onsite disposal due to shallow groundwater, bedrock, or areas with tight soils. The mound improves adsorption of effluent in areas having tight soils by utilizing a more permeable mound fill material to assist in the dispersion or uniform application of wastewater. Due to the mound elevated construction, wetter and tighter subsoils are not used for construction, thereby eliminating the problems with smearing and compaction. In soils with an inadequate depth to groundwater or bedrock, the mound fill material provides an adequate treatment media to ensure protection of groundwater quality.

Where site conditions are more severe than those allowed for mounds or where local regulation prevents subsurface percolation, an evapotranspiration (ET) system may be considered if climatological conditions are acceptable (see SWRCB Guidelines on ET Systems).

The mound disposal system is simple and can be subdivided into the following parts: (1) the mound body fill material; (2) the distribution bed; (3) the distribution manifold and laterals; and (4) the topsoil cover (see Figure 1). The various parts of the mound work together such that when effluent is delivered to the distribution bed through the pressurized distribution pipe manifold and laterals within this bed, moisture is uniformly distributed to the mound fill material. The mound fill material provides treatment and dispersion of the loaded effluent under an unsaturated condition from where it is uniformly distributed to the natural soil. The topsoil cover is usually a finer textured material than the fill and provides frost protection, sheds precipitation and provides moisture and support for the vegetative cover which grows on the topsoil.

The mounded treatment and disposal system was originally developed by the North Dakota Agricultural College in the late 1940's. This system was known as the NODAK system and was designed to overcome problems with slowly permeable soils or areas having high groundwater tables. Monitoring revealed that these systems were providing an inadequate treatment of percolated effluent and were contaminating shallow groundwater. Since that time, successful modifications have been developed which

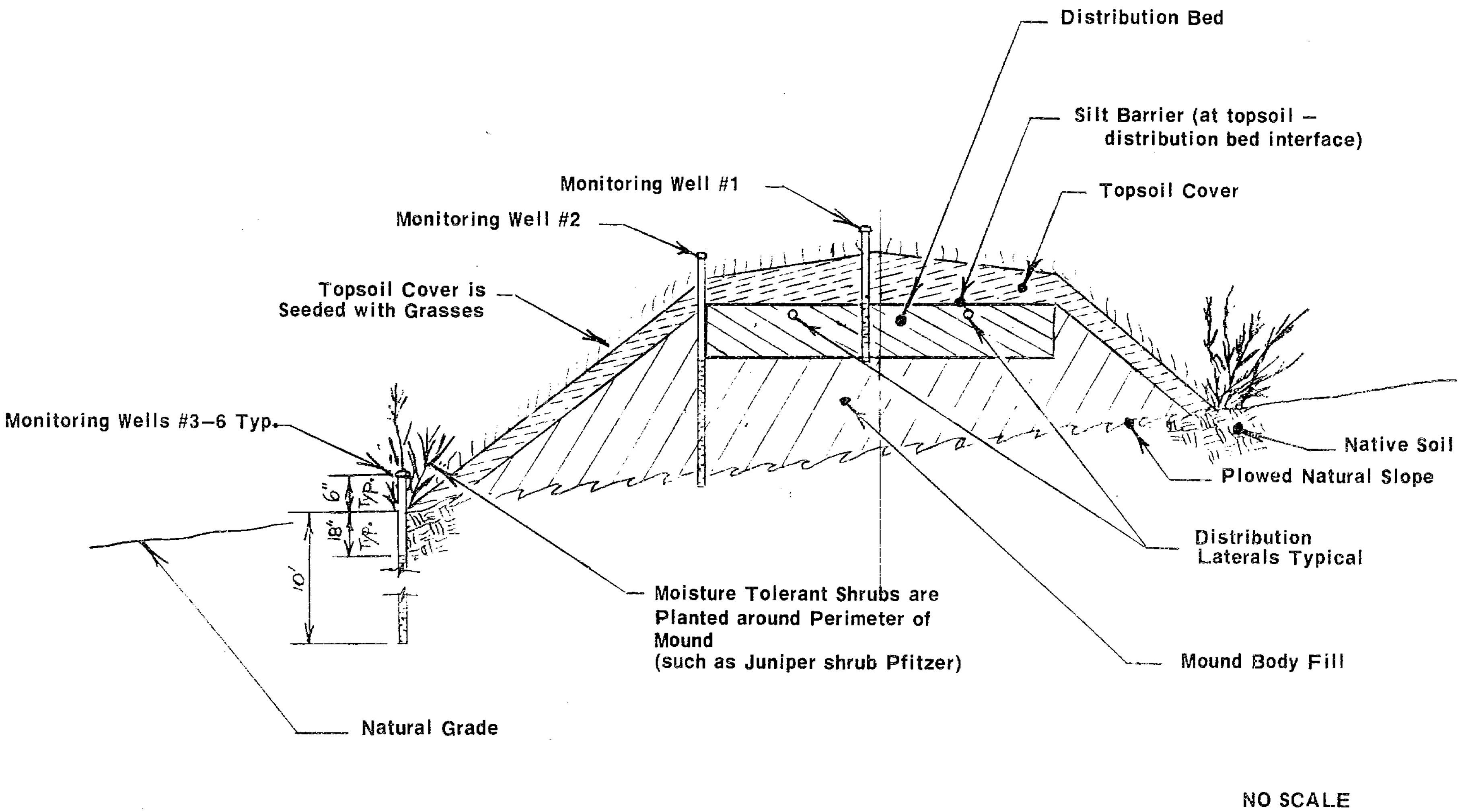

FIGURE 1. TYPICAL MOUND CROSS SECTION

Reference 1

enable the use of the mounded disposal system under a variety of conditions throughout the United States. However, actual installations remain limited. In California the present expansion of development into areas unacceptable for the conventional septic tank and leachfield system due to extremely rapid percolation, slow percolation, or high groundwater or bedrock, has caused a dramatic increase in requests to regulatory agencies for approval of mound systems. This demand has indicated that a general lack of information exists for planning, design, construction and operation of these systems. Therefore, all mounded systems should be considered experimental and should be monitored during initial operation until the appropriate regulatory agencies are convinced that local system designs are reliable. Since these systems require careful monitoring, the number of systems approved must not exceed the resources available for monitoring. Failure to provide adequate review of design, construction and monitoring can result in system failure with the possible construction of other inadequate units.

Approval may necessitate the satisfaction of specific regulatory requirements of the Regional Board such as:

- Notification of the Regional Board of the proposed project;
- Use of approved design criteria; and
- Identification of a responsible entity for system inspection, monitoring and maintenance.

These criteria are offered for voluntary use in an attempt to provide a rational planning, design, construction, and operation basis for these systems so that benefits typical of mound systems may be realized while providing protection of water quality and public health. The design criteria are derived from a review of literature coupled with the experiences of the State and Regional Water Quality Control Boards' staff. Criteria which appear stringent are so presented in order that critical aspects of the design are adequately controlled. Local experience may dictate more stringent criteria. The guidelines provide minimum standards unless otherwise noted. Local designers are encouraged to suggest alternate mound design approaches if equal performance can be demonstrated. Local regulatory agencies should, through a carefully documented monitoring program, verify whether local design modifications meet or exceed original expectations.

These guidelines address all essential aspects needed to understand mounded treatment/disposal systems. Included are discussions on design and construction techniques. The guidelines are presented in such a way that they may be incorporated directly into local regulations.

These guidelines address mounds for residential service. Commercial units can be designed using the same principles. Their design will necessitate different constraints in the sections on distribution systems, pump hydraulic specification and wet wells in addition to the section on treatment tanks. The sizing tables and figures contain values for larger systems and a section on commercial systems briefly addresses key modifications.

The basic mound design details are taken from work completed at the University of Wisconsin, Small Scale Waste Management Project 1976 (1) and as yet unpublished work modifying the above design reference by University of Wisconsin obtained by correspondence with Richard Otis and the EPA Municipal Environmental Research Laboratory in Cincinnati, Ohio (December 1979) (1A) in conjunction with material presented at a seminar sponsored by the State Board on mound systems in February 1979 (2). This basic design information is supplemented by other references as cited herein.

II. DEFINITIONS

Distribution Lateral - A pressurized PVC supply line with a series of holes drilled at a uniform spacing along the pipe invert. The distribution laterals uniformly distribute effluent over the area of the mound.

Distribution Manifold - A pressurized supply line receiving effluent from the wet well and supplying it to each distribution lateral.

Mound Body - The silty sand fill providing an unsaturated media for treating and dispersing effluent prior to the effluent encountering native soil.

Mound Distribution Bed - That portion of the mound filled with gravel and containing the distribution manifold and laterals. The gravel fill transports and uniformly distributes the effluent to the mound body from the distribution laterals.

III. DESIGN GUIDELINES

These design guidelines are divided into two areas:

General Design Guidelines

Notes on System Rehabilitation and Commercial Installations

The general design section will establish criteria for selecting the site, general design requirements, design methodology and will present the system components in their general design order. The section on system rehabilitation and commercial installations provide a brief discussion on rehabilitation methods and key design considerations for commercial systems.

A. General Design Guidelines

Engineered Design -

Mound systems shall be designed by a civil engineer, engineering geologist, or sanitarian licensed to practice in the State of California who is well versed concerning onsite system practices. All plans, design computations, layout sheets, reports and other engineering documents shall be signed by the designer (3).

Site -

Proper site selection necessitates the consideration of the following important parameters (1 & 1A):

Percolation - Percolation of the site shall not exceed 120 minutes per inch. Soil percolation tests are taken with a test hole bottom depth between 12 and 24 inches depneding upon site conditions (Table 1). All percolation tests should be in accord with the procedure discussed in the Appendix with the depth of test as noted for the specific design.

Slope - The site shall not have slopes steeper than 12 percent. The specific slope will vary depending upon other site conditions. Sloped sites are preferred over flat sites provided they are within the allowable limits (Table 1).

Topography - The crests of slopes, or convex contoured slopes are the most desirable locations for mound systems. Depressions, bases of slopes and concave slopes tend to concentrate effluent in one location and increase the probability for the effluent to surface. These locations shall therefore be avoided (Table 1 and Figure 2).

Soil Profile - The top soil horizon shall be well developed and undistrubed in its native state. The site shall be carefully investigated to verify the minimum depth to groundwater, pervious or fractured

TABLE 1

DESIGN CRITERIA[1/]

<table>
<tr><th>Design Parameter</th><th>Permeable Soil</th><th>Tight Soil</th></tr>
<tr><td>Percolation Rates, Minutes per inch[2/]</td><td>0-60</td><td>61-120</td></tr>
<tr><td>Percolation Test Hole Depth, Feet</td><td colspan="2">2[2/]</td></tr>
<tr><td>Topography -</td><td></td><td></td></tr>
<tr><td>The crest of slopes, or convex contoured slopes, are most desirable. Depressions, bases of slopes and concave slopes tend to concentrate percolated effluent and shall be avoided.</td><td></td><td></td></tr>
<tr><td>Allowable Slope, Percent</td><td>0-12</td><td>0-6</td></tr>
<tr><td>Soil Profile -</td><td></td><td></td></tr>
<tr><td>Soils should have a well developed and relatively undisturbed topsoil horizon. Sites shall be carefully investigated to identify textural changes which could affect water movement.</td><td></td><td></td></tr>
<tr><td>Minimum Depth to Seasonal Groundwater, or Pervious or Fractured Bedrock (from ground surface), Feet</td><td colspan="2">2</td></tr>
<tr><td>Minimum Depth to Impermeable Barrier (from ground surface), Feet</td><td colspan="2">3[3/]</td></tr>
<tr><td>Distribution Bed Geometry[4/]</td><td>Square</td><td>Rectangular</td></tr>
</table>

1/ For site conditions more limiting than those specified, special designs may be submitted for accommodating the specific constraint by the designer with special monitoring required. The design submittal, shall at a minimum, include the fundamental engineering criteria utilized and the applicable references and must satisfy the requirements of the appropriate regulatory agencies.

2/ Percolation tests should be performed in accord with Appendix A Recommendations for a Refined Percolation Test. The test hole depth shown shall be used unless water is encountered at two feet. In this case, the test is run at 20 inches. In shallow soils over pervious or fractured bedrock, the tests are run at one foot.

3/ This value should be considered an absolute minimum for tight soils and shall be increased to a depth of 5 feet in areas affected by soil freezing and/or flat sites (0-2%).

4/ The rectangular geometry, where major axis is extended as long as possible parallel to the slope contour, is preferred. The constraints on the distribution laterals and physical site layout shall dictate allowable length. For tight soils, the rectangular geometry is a necessity. For flat sites, the major axis should be normal to the prevailing winds where possible.

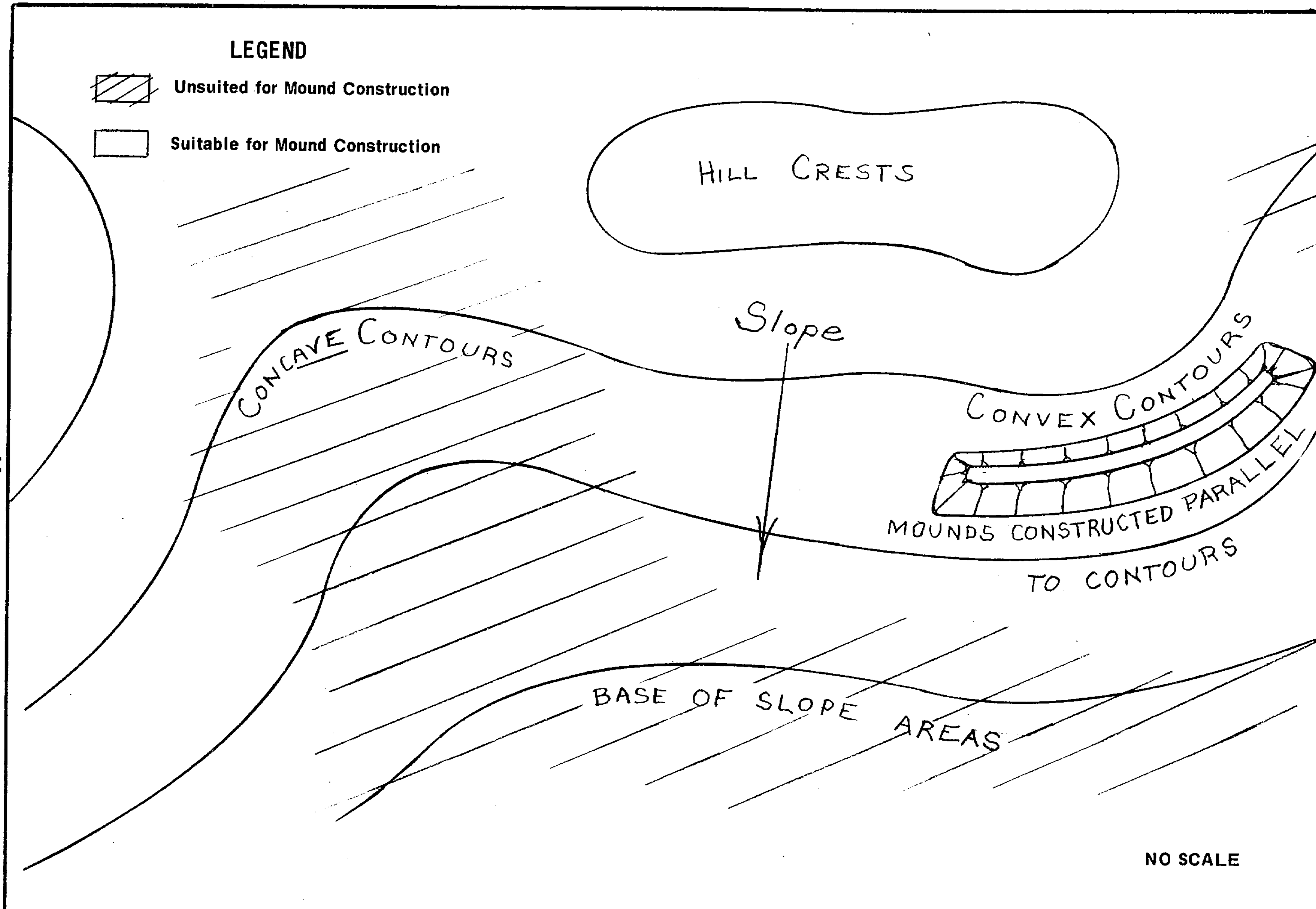

FIGURE 2. SUITABILITY OF SITE TOPOGRAPHY FOR MOUNDS

Reference 1A

bedrock and any impermeable layers which may be present. The specific limiting values are shown in Table 1. Some of these identifications may be made during the percolation test procedure (Appendix).

Exposure - Exposure of the system to the sun and wind is desirable. Therefore, the general site location shall be selected in an area as open as possible (4).

Horizontal Set Back Distance - Minimum horizontal separation between treatment/disposal facilities shall be as specified in Table 2 (1A, 3, 5, and 6). The values shown in Table 2 should be considered minimum. Local regulatory agencies may specify more stringent requirements based on local conditions.

Site Drainage - Site drainage shall be provided so that rainfall/runoff is directed away from or around the disposal site (1, 2, and 4). Systems shall not be constructed in areas subject to flooding.

TABLE 2

MINIMUM HORIZONTAL SETBACKS

Setbacks	Treatment Tank, feet	Mound System, feet
Structures	10	20 1/
Property lines	5	10
Water supply wells 2/	50	100
Streams, drainage ways and reservoirs	50	100
Private waterlines	5	10
Driveways and roads	5	5
Cuts or embankments	15	4H 3/
Swimming pools	10	15

1/ This distance shall be increased to 30 feet when system is located upslope of the structure.

2/ Sewerage facilities should be located as far as possible from wells but under no condition less than the distances shown. This criteria shall also be applied to future well locations.

3/ H is the height of the embankment. Therefore, the setback from the embankment is four times the height of the embankment.

Filled Sites - Mound systems shall not be constructed on fill material[1/]. This applies only to side slope fills and not to the excavation of native soils replaced with a fill of imported material prior to mound construction when required by the appropriate regulatory agency.

Design Flow -

System design shall be based on a flow rate of 75 gallons per capita per day or 150 gallons per bedroom--whichever is greater. The use of water-conserving fixtures is permitted but the local regulatory agency shall require this be noted on the property deed. Should a system based on hydraulic design using a water-conserving appliance fail, the replacement/repair system shall be based on design criteria not employing water-conserving fixtures. The designer shall certify the flow reduction allowance for all water-conservation fixtures employed (5 & 6).

Note: reserve areas for replacement systems shall be determined by designs based on full house flow without water-conservation fixtures (see Reserve Wastewater Disposal Areas).

1/ Percolating water into fill material can result in differential slope settlement and, in some cases, soil slippage. An exception to this requirement may be granted if the designer provides a thorough consideration of soil stability and maintains the minimum embankment setbacks.

Reserve Wastewater Disposal Areas -

Replacement areas for mound systems shall be provided to accommodate as a minimum a replacement system design based on 100 percent of the hydraulic loading irrespective of water-conservation allowances (5 & 7). The reserve shall be located as far as possible from adjacent irrigated areas. The design of the replacement system shall be based on a review of the original design criteria and assumptions with modifications, as necessary, to correct any original design errors.

The reserve area will be used at the time of failure of the original system to construct the repair system. The repair system design shall provide that the repair system be operated in parallel with the original system such that each would be simultaneously loaded[1/]. Disposal areas must be used exclusively for disposal of wastewater and not for corrals, playfields, parking lots, building sites or any other such use that would impair the system operation (5 & 8). The reserve area shall be recorded on the property deed.

Natural Soil Preparation -

Prior to placement of any mound construction materials, design shall specify that the soil surface is plowed at right angles to the slope of the site with the plowed soil thrown upslope. A disc shall not be used as this implement can break the soil into fine particles

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1/ This will preserve the organic mat which develops at the distribution bed base. The organic mat contributes to the mound treatment effectiveness. Its existence is desirable in this application in contrast with the conventional leachfield where it can contribute to system failure due to the restriction of the trench filtrative surface (3,5,8 & 9).

which can restrict the soil's percolation. Care shall be taken not to plow when the soil contains sufficient moisture to smear during plowing. This will severely limit the infiltration (1 & 2).

Distribution Bed -

The distribution area within a mound can either be bed, or a series of trenches--each trench containing a distribution lateral. Beds, however, are recommended for smaller systems serving individual residences since they are easier to construct. The recommended shape of the bed, however, depends on the specific permeability of the native soil and the slope of the site. Generally, a rectangular bed maximizing its long axis parallel to the contour of the slope is preferred to minimize the chance of seepage from the base of the mound. In tight soils, having percolation rates slower than 60 minutes per inch, this is especially important. In soils having percolation rates faster than 60 minutes per inch, the bed can be made square provided the water table is more than three feet below the natural soil surface.

The size of the distribution bed is based upon the percolation rate of the mound body fill material. For the material specified in the section on mound body fill, this rate shall be taken as 1.0 or 0.6 gal/square foot/day depending upon the type of fill (Table 3). To keep the costs of construction to a minimum, the use of local materials should be utilized in mound construction wherever possible. The required distribution bed area is simply the daily hydraulic load divided by the allowable daily surface loading rate of the

TABLE 3

MOUND BODY FILL MATERIALS[1/]

Fill Material	Characteristics	Design Infiltration Rates gal/day/sq.ft.
Silty Sand	o At least 25 percent by weight having grain sizes ranging between 2.0 and 0.25 mm; o Less than 35 percent by weight having grain sizes ranging between 0.25 and 0.05 mm; o At least 10 percent by weight but not more than 25 percent by weight should be clays, silts, or other fines with grain sizes smaller than 0.05 mm; this will provide adequate purification while providing adequate percolation.	1.0
Sandy Loam	5 to 15 percent clay content	0.6

1/ Personal Communique with Alvin L. Franks, Chief, Hydrologic Geotechnical Section, California State Water Resources Control Board, December 1979 and Reference 1A.

specific mound fill material (gal/square foot/day). The desired geometry is then specified depending upon site conditions (discussed above) and/or the constraints on the distribution system addressed in the next section.

The distribution bed is constructed in the silty sand fill of the mound body. The bed shall be constructed of 0.75 to 2.5 inch gravel placed to an overall depth of one foot. A hardness of 3 or greater on the "Moh's" scale is suggested. Such a rock can scratch a copper penny without leaving residual rock particles. Crushed limestone is unacceptable unless dolomitic. The rock should be washed free of fines prior to placement. Fines can clog the infiltrative surface interface between the distribution bed and mound body fill (1A).

The water is directed to the distribution bed by the distribution laterals placed within this bed. Nine inches of gravel lies under the distribution lateral invert and two inches are placed over the lateral crown.

Following construction of the distribution system in the distribution bed, the bed is overlain with 3 to 4 inches uncompacted straw or marsh hay or other protection from migrating fines. Polyproplylene filter fabric such as DuPont Typar (4 or 6 oz/sq yd) or equal, may prove effective in this application. The mound is then ready for its top soil cover (1 & 2).

Distribution System, Pump Hydraulic Specification and Wet Well -

Following the computation of the distribution bed area, coupled with the identification of the desired distribution bed geometry, the specific bed geometry will result from the design of the distribution system. Once the distribution system is designed, its hydraulic demand can be identified. The distribution system hydraulic demand will result in the sizing of the pump or dosing siphon required. Likewise, the wet well may be specified from the information resulting from the distribution system design.

These guidelines address a system sized to serve a residence. Commercial units may be constructed by providing a rigorous engineering analysis using the same design principles as discussed herein. Key elements are discussed in Section B. The sizing tables and figures are expanded to include values for designing larger systems.

Distribution Systems - Engineered pressure distribution systems have been shown to uniformly distribute effluent over the trench or bed area (Figure 3). Gravity distribution systems fail to provide this uniform distribution (8). Pressure distribution systems shall be specified for all mound designs.

A screen should be provided to remove solids in treatment tank effluent prior to entering the distribution system[1/]. The effluent screen is recommended for use following aerobic or anaerobic treatment tanks and should have openings sufficiently

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1/ Preliminary results from the Manila, California septic tank effluent pump pressure sewer project indicate that some solids having a specific gravity close to that of water find their way into the disposal system. These solids (mostly cigarette filters and lint) if not strained out of the treatment tank effluent can contribut to a premature clogging of the holes in a pressure distribution system or gravity tile system.

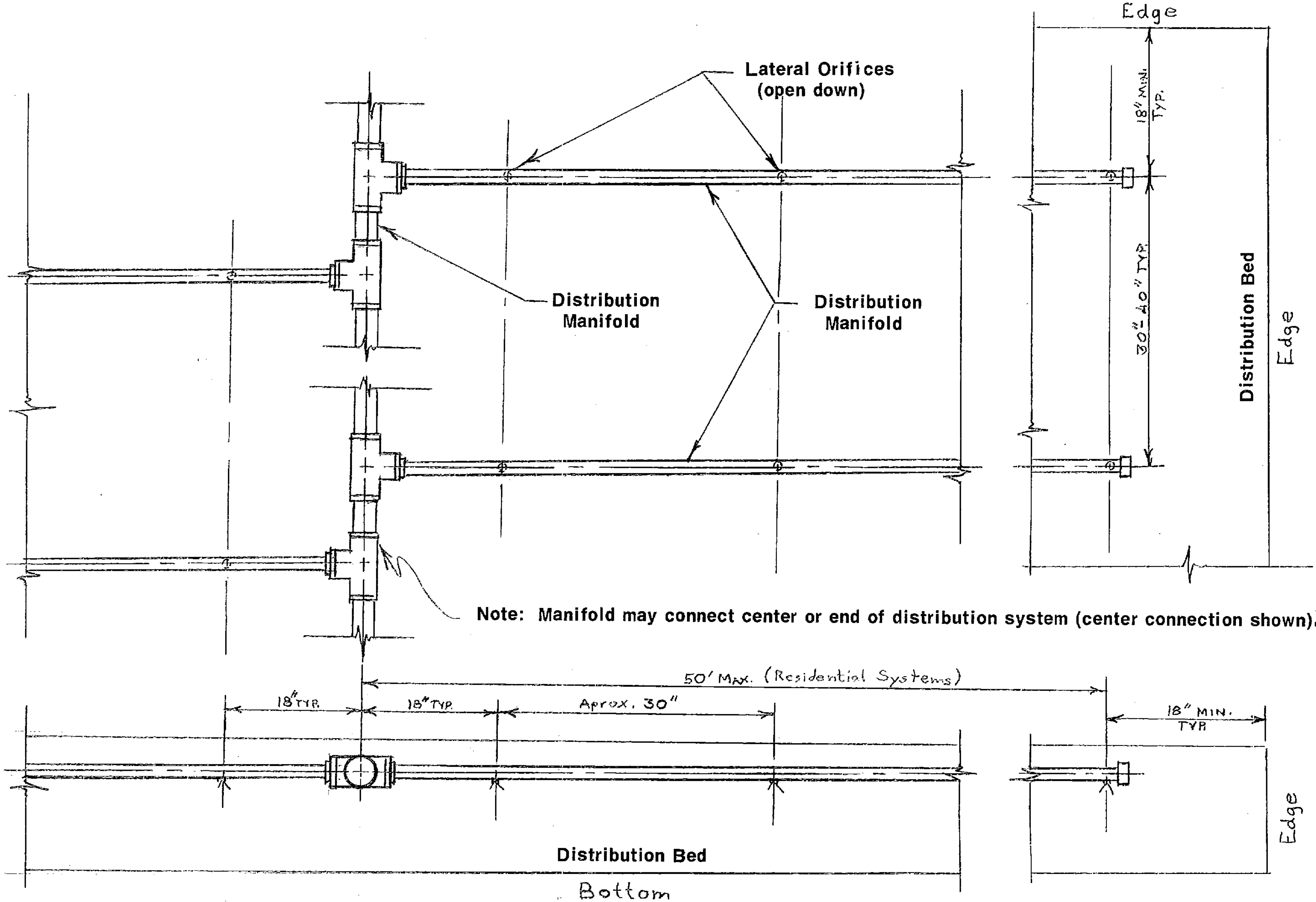

FIGURE 3. DISTRIBUTION SYSTEM DETAIL

Reference 1A

A.T.I. '79

small to remove 1/8 inch spheres. The solids removal in a septic tank is improved by specifying a two-compartment tank with adequate baffles (see section on Treatment Tank).

Pressure distribution depends upon the concept of providing a uniform flow of water over the distribution bed. To achieve even distribution, the volume of water passing from each hole in the distribution system must be uniform. This will necessitate the maintenance of a uniform pressure over the whole distribution system. This may be satisfactorily accomplished by balancing the head losses throughout the distribution system. Approximately 75 to 85 percent of the head loss should occur across the holes located in the distribution pipe. The balance of the head loss, 15 to 20 percent, will occur in the network delivering the fluid to each hole. The distribution laterals shall consist of polyvinyl chloride (PVC) plastic pipe with 1/4 inch holes drilled through the pipe invert approximately 30 inches on center. The distribution laterals connect to either a central or an end manifold which distributes the effluent to each lateral. The design of the distribution system necessitates head loss computations to balance the flow over the distribution bed. These guidelines offer tables and figures to assist with these computations.

The design routine for specifying a pressure distribution system for a mound shall be based upon the following constraints[1/]:

- The maximum lateral lengths shall not exceed 50 feet;
- The lateral diameter shall vary between 1 and 1-1/2 inches depending upon lateral length;
- The distribution lateral pipe shall have 1/4 inch holes drilled approximately 30 inches on center along its invert;
- The distribution laterals shall be spaced between 36 and 40 inches on center;
- The manifold line shall distribute effluent either to the center of the distribution bed laterals or to one end;
- Holes in distribution lateral shall start 18 inches from the intersection of the lateral with the distribution manifold;
- The distribution bed edge shall be 18 inches from the nearest distribution lateral centerline and shall end 18 inches from the last distribution lateral orifice.

Given these constraints, the design of the distribution system is then clear following a routine using the included charts and

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1/ The constraints identified are for residential systems. Larger systems may result in different constraints. Any variation from the above shall be supported by a rigorous hydraulic network analysis to ensure uniform distribution.

nomographs. The first task, having determined the required distribution bed area, is to identify the distribution bed geometry which is desired based upon the dictates of site conditions. This was addressed in the discussion on the distribution bed. The ideal bed geometry may necessitate some compromises due to the constraints identified above for the distribution laterals. Having identified the desired distribution bed geometry which satisfieds the distribution lateral constraints, one is then ready to proceed with the distribution lateral design.

The design of the pressure distribution system can be based on the following sequence:

1. Identify the number and length of the required laterals to cover the desired distribution bed geometry (if the specific distribution bed geometry has not been identified to accommodate the physical constraints placed on the distribution laterals, complete this operation before proceeding.

2. Having identified the number and length of the specific laterals, specify the lateral diameter from Table 4.

3. Compute the discharge flow of each lateral. The discharge flow of each lateral is dependent upon the specific head applied and length of the lateral since the hole size and spacing are fixed. As higher heads are applied, the effects of elevation changes distribution bed will become less significant. However,

TABLE 4

LATERAL PIPE SIZES FOR VARIOUS HOLE DIAMETERS, HOLE SPACINGS, AND LATERAL LENGTHS[1/]

Lateral Diameter, Inches[2/]

Hole Diameter, Inches	1/4						5/16						3/8						7/16						1/2					
Hole Spacing, Feet	2	3	4	5	6	7	2	3	4	5	6	7	2	3	4	5	6	7	2	3	4	5	6	7	2	3	4	5	6	7
Lateral Length, Feet																														
10	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1½"	1"	1"	1"	1"	1"
15	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1"	1¼"	1"	1"	1"	1"	1"	1¼"	1¼"	1"	1"	1"	1"	1½"	1½"	1½"	1"	1"	1"
20	1"	1"	1"	1"	1"	1"	1¼"	1"	1"	1"	1"	1"	1¼"	1¼"	1"	1"	1"	1"	1½"	1¼"	1¼"	1"	1"	1"	2"	1½"	1½"	1½"	1½"	1"
25	1¼"	1"	1"	1"	1"	1"	1¼"	1¼"	1"	1"	1"	1"	1½"	1¼"	1¼"	1¼"	1"	1"	2"	1½"	1¼"	1¼"	1¼"	1¼"	2"	2"	1½"	1½"	1½"	1½"
30	1¼"	1¼"	1"	1"	1"	1"	1½"	1¼"	1¼"	1¼"	1"	1"	2"	1½"	1½"	1¼"	1¼"	1¼"	2"	2"	1½"	1¼"	1¼"	1¼"	3"	2"	2"	1½"	1½"	1½"
35	1½"	1¼"	1¼"	1"	1"	1"	2"	1½"	1¼"	1¼"	1¼"	1"	2"	2"	1½"	1¼"	1¼"	1¼"	3"	2"	2"	1½"	1½"	1¼"	3"	3"	2"	2"	1½"	1½"
40	1½"	1¼"	1¼"	1¼"	1"	1"	2"	1½"	1½"	1¼"	1¼"	1¼"	3"	2"	1½"	1½"	1¼"	1¼"	3"	2"	2"	2"	1½"	1½"	3"	3"	2"	2"	2"	1½"
45	2"	1½"	1¼"	1¼"	1"	1"	2"	2"	1½"	1¼"	1¼"	1¼"	3"	2"	2"	1½"	1½"	1½"	3"	3"	2"	2"	2"	1½"	3"	3"	3"	2"	2"	2"
50	2"	1½"	1¼"	1¼"	1¼"	1¼"	3"	2"	2"	1½"	1½"	1¼"	3"	3"	2"	2"	2"	1½"	3"	3"	2"	2"	2"	1½"	3"	3"	3"	3"	2"	2"

1/ Reference 1A

2/ Computed for schedule 40 PVC plastic pipe only. The Hazen-Williams equation was used to compute headlosses through each pipe segment (Hazen-Williams C = 150). The orifice equation for sharp-edged orifices (discharge coefficient - 0.6) was used to compute the discharge rates through each orifice.

the required pump size will correspondingly increase. Thus, a saving in construction cost can increase the equipment cost. Typically, the head maintained over a pressure distribution system should be approximately two feet of water. The flow from each 1/4 inch hole in the distribution lateral may be identified from Table 5. The discharge flow of the lateral may then be computed by dividing the lateral length by the uniform spacing of the holes in the lateral invert (30 inches) and then multiplying this number times the flow rate given for the 1/4 inch holes at the specified head (taken from Table 5).

4. The next step is to specify the manifold size. This may be identified from Table 6 by knowing the number of laterals, the flow rate per lateral, the length of the manifold from the intersection of the first lateral to the last lateral, and the design specifications for either a central or an end manifold connection to the distribution laterals.

The system hydraulics may not be designed:

Pump and Hydraulic Specification - The following steps identify the order of design for the system hydraulic elements based on the foregoing discussion regarding the distribution system.

TABLE 5

DISCHARGE RATES FOR VARIOUS SIZED HOLES AT VARIOUS PRESSURES,1/

Gallons per Minute2/

Pressure, Feet of Water	Hole Diameter, inches				
	1/4	5/16	3/8	7/16	1/2
1	0.74	1.15	1.66	2.26	2.95
2	1.04	1.63	2.34	3.19	4.17
3	1.28	1.99	2.87	3.91	5.10
4	1.47	2.30	3.31	4.51	5.89
5	1.65	2.57	3.71	5.04	6.59

1/ Reference 1A.

2/ The orifice equation for sharp-edged orifices (discharge coefficient = 0.6) was used to compute the discharge rates through each orifice.

TABLE 6

MANIFOLD SIZES FOR VARIOUS MANIFOLD LENGTHS,
NUMBER OF LATERALS, AND LATERAL DISCHARGE RATES[1]

Manifold Diameter, Inches[2]

Manifold Length (ft): 5

Flow, Gallons per Minute per Lateral (For Laterals with Central Manifold / For Laterals with End Manifold)		
No. of Laterals (Central Manifold)	4	6
5 / 10	1"	1¼"
10 / 20	1¼"	1½"
15 / 30	1¼"	2"
20 / 40		
25 / 50	2"	3"
No. of Laterals (End Manifold)	2	3

Manifold Length (ft): 10

Flow, Gallons per Minute per Lateral (Central / End)				
No. of Laterals (Central Manifold)	4	6	8	10
5 / 10	1¼"		1½"	2"
10 / 20	1½"	2"		
15 / 30				
20 / 40		3"		
25 / 50				4"
No. of Laterals (End Manifold)	2	3	4	5

Manifold Length (ft): 15

Flow, Gallons per Minute per Lateral (Central / End)					
No. of Laterals (Central Manifold)	4	6	8	10	12
5 / 10	1¼"	1½"		2"	
10 / 20	2"				
15 / 30					
20 / 40			3"		
25 / 50				4"	
No. of Laterals (End Manifold)	2	3	4	5	6

Manifold Length (ft): 20

Flow, Gallons per Minute per Lateral (Central / End)					
No. of Laterals (Central Manifold)	6	8	10	12	14
5 / 10			2"		
10 / 20					
15 / 30					
20 / 40		3"			
25 / 50				4"	
No. of Laterals (End Manifold)	3	4	5	6	7

Manifold Length (ft): 25

Flow, Gallons per Minute per Lateral (Central / End)					
No. of Laterals (Central Manifold)	6	8	10	12	14
5 / 10	2"				
10 / 20		3"			
15 / 30					
20 / 40				4"	
25 / 50					
No. of Laterals (End Manifold)	3	4	5	6	7

Manifold Length (ft): 30

Flow, Gallons per Minute per Lateral (Central / End)					
No. of Laterals (Central Manifold)	6	8	10	12	14
5 / 10	2"				
10 / 20			3"		
15 / 30					
20 / 40			4"		
25 / 50				6"	
No. of Laterals (End Manifold)	3	4	5	6	7

Manifold Length (ft): 35

Flow, Gallons per Minute per Lateral (Central / End)						
No. of Laterals (Central Manifold)	6	8	10	12	14	16
5 / 10	2"					
10 / 20		3"				
15 / 30				4"		
20 / 40						
25 / 50					6"	
No. of Laterals (End Manifold)	3	4	5	6	7	8

Manifold Length (ft): 40

Flow, Gallons per Minute per Lateral (Central / End)							
No. of Laterals (Central Manifold)	6	8	10	12	14	16	18
5 / 10	2"						
10 / 20		3"					
15 / 30			4"				
20 / 40							
25 / 50					6"		
No. of Laterals (End Manifold)	3	4	5	6	7	8	9

Manifold Length (ft): 45

Flow, Gallons per Minute per Lateral (Central / End)								
No. of Laterals (Central Manifold)	6	8	10	12	14	16	18	20
5 / 10	2"							
10 / 20			3"					
15 / 30				4"				
20 / 40								
25 / 50						6"		
No. of Laterals (End Manifold)	3	4	5	6	7	8	9	10

Manifold Length (ft): 50

Flow, Gallons per Minute per Lateral (Central / End)									
No. of Laterals (Central Manifold)	6	8	10	12	14	16	18	20	22
5 / 10	2"								4"
10 / 20			3"						
15 / 30				4"					
20 / 40									
25 / 50							6"		
No. of Laterals (End Manifold)	3	4	5	6	7	8	9	10	11

1/ Reference 1A

2/ Computed for Schedule 40 PVC plastic pipe only . The Hazen-Williams equation was used to compute headlosses through each segment (Hazen-Williams C = 150). The maximum manifold length for a given lateral discharge rate and spacing was defined as that length at which the difference between the heads at the distal and supply ends of the manifold exceeded 10 percent of the head at the distal end.

1. The minimum dosage volume is computed based on the design assumption that the minimum dose is equal to ten times the volume contained in all laterals. This value may be obtained from the nomograph shown in Figure 4. By placing a straight edge from the lateral diameter through the lateral length, the lateral volume in gallons is read on the middle line. The second step involves placing the straight edge on the lateral volume across the line specifying the number of laterals and the dose volume in gallons is read on the far right side. If the daily system design flow is less than the minimum dose required, the wet well detention time shall be increased to assure the minimum dosage per pump cycle.

2. The required pump flow rate may be identified simply by multiplying the number of laterals times the flow rate per lateral computed in Step 3 of the pressure distribution system design sequence.

3. Finally, the minimum total dynamic head (TDH) of the pump shall be determined by adding the heads and head losses of the following items:

   o Elevation difference between the wet well pump low water cut-off and the invert of the distribution system laterals.

   o Friction loss over the delivery pipe and manifold lengths based on the design pump flow rate (Table 7).

   o Friction loss of the PVC fittings (Tables 7 & 8).

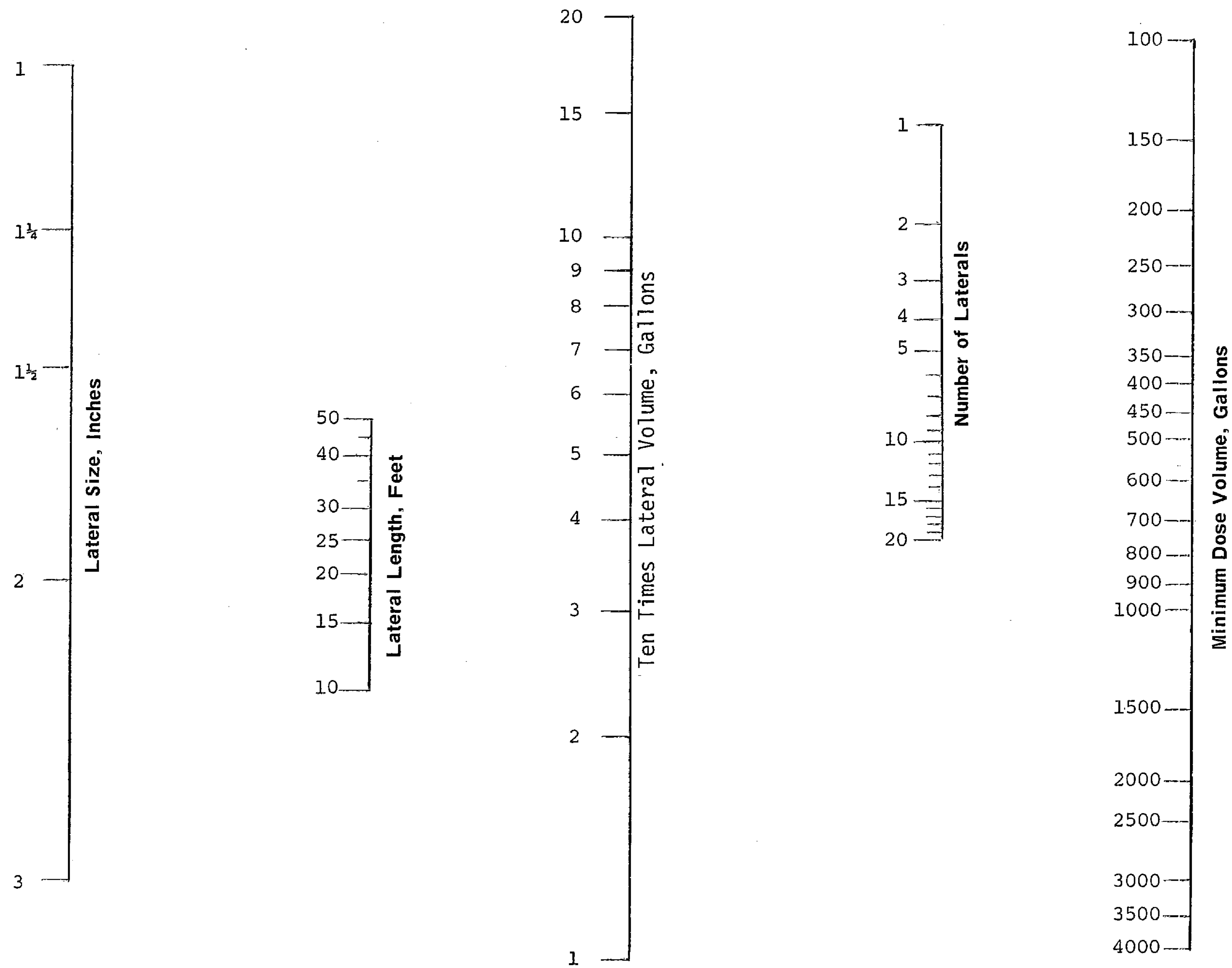


FIGURE 4. NOMOGRAPH FOR DETERMINING THE MINIMUM DOSE VOLUME GIVEN LATERAL SIZE, LATERAL LENGTH AND NUMBER OF LATERALS

Reference 1A

TABLE 7

PIPE FRICTION LOSSES[1/]

Feet per 100 Feet[2/]

Flow, gpm	1	1-1/4	1-1/2	2	3	4	6	8	10	Flow, gpm
	Pipe Diameter, Inches									
1	0.07									1
2	0.28	0.07								2
3	0.60	0.16	0.07							3
4	1.01	0.25	0.12							4
5	1.52	0.39	0.18							5
6	2.14	0.55	0.25	0.07						6
7	2.89	0.76	0.36	0.10						7
8	3.63	0.97	0.46	0.14						8
9	4.57	1.21	0.58	0.17						9
10	5.50	1.46	0.70	0.21						10
11		1.77	0.84	0.25						11
12		2.09	1.01	0.30						12
13		2.42	1.17	0.35						13
14		2.74	1.33	0.39						14
15		3.06	1.45	0.44	0.07					15
16		3.49	1.65	0.50	0.08					16
17		3.93	1.86	0.56	0.09					17
18		4.37	2.07	0.62	0.10					18
19		4.81	2.28	0.68	0.11					19
20		5.23	2.46	0.74	0.12					20
25			3.75	1.10	0.16					25
30			5.22	1.54	0.23					30
35				2.05	0.30	0.07				35
40				2.62	0.39	0.09				40
45				3.27	0.48	0.12				45
50				3.98	0.58	0.16				50
60					0.81	0.21				60
70					1.08	0.28				70
80					1.38	0.37				80
90					1.73	0.46				90
100					2.09	0.55	0.07			100
125						0.85	0.12			125
150						1.17	0.16			150
175						1.56	0.21			175
200							0.28	0.07		200
250							0.41	0.11		250
300							0.58	0.16		300
350							0.78	0.20	0.07	350
400							0.99	0.26	0.09	400
450							1.22	0.32	0.11	450
500								0.38	0.14	500
600								0.54	0.18	600
700								0.72	0.24	700
800									0.32	800
900									0.38	900
1000									0.46	1000

1/ Reference 1A.

2/ Computed for Schedule 40 plastic pipe only. The Hazen-Williams equation was used to compute headlosses (Hazen-Williams C = 150).

TABLE 8

EQUIVALENT LENGTH IN PIPE DIAMETERS (L/D) FOR VALVES AND FITTINGS[1/]

Gate Valves	Wedge disk or plug disk		Fully open	13
			Three-quarters open	35
			One-half open	160
			One-quarter open	900
Check Valves	Conventional swing	0.5[2/]	Fully open	135
	Clearway swing	0.5[2/]	Fully open	50
	Globe-lift or stop:	2.0[2/]	Fully open	
	stem perpendicular to run			400
	Y pattern			160
	Angle-lift or stop	2.0[2/]	Fully open	175
	In-line ball	2.5 vertical and 0.25 horizontal [2/]	Fully open	150
Cocks	Straight-through	Rectangular plug port area equal to 100% of pipe area	Fully open	18
	Three-way	Rectangular plug port area equal to 80% of pipe area (fully open)	Flow straight through	44
			Flow through branch	140
Fittings	90^o standard elbow			30
	45^o standard elbow			16
	90^o long radius elbow			20
	90^o street elbow			50
	45^o street elbow			26
	Square-corner elbow			57
	Standard T	With flow through run		20
		With flow through branch		60
	Close-pattern return bend			50

1/ Source: Karassik, Igor J., et al., editors, Pump Handbook, McGraw Hill Publisher, 1st Edition, C 1976.

2/ Minimum calculated pressure drop (lb/in^2) across valve to provide sufficient flow to lift disk fully.

o The desired surplus head over the distribution system (typically two feet of water to provide uniform lateral flow).

The pump is selected from the manufacturer's performance curves of total dynamic head (TDH) versus flow, usually in gallons per minute. The pump selected shall be a submersible centrifugal suited to pumping septic tank effleunt. The pump is identified from the manufacturer's performance curves such that it will deliver the design flow while maintaining the minimum TDH plus 10 - 15 percent to compensate for pump aging. Care should be taken to check that the pump will be operating in an efficient region of its performance curve at its design point. The use of diaphragm switches should be avoided for control of the pump since these units have been found to corrode in the presence of wastewater. Mercury and reed switches have been noted to work satisfactorily (2).

A dosing siphon may be used provided supply the required quanity of water at the specified head deducting the pipe losses in the same manner as the specification for the centrifugal pump. Again, the specific dosing siphon would be selected from equipment specifications provided by the manufacturer.

Wet Well - The wet well is a storage tank accumulating effluent from a treatment tank (commonly a septic tank). A pump in the wet well pumps accumulated effleunt to the mound distribution system (Figure 5).

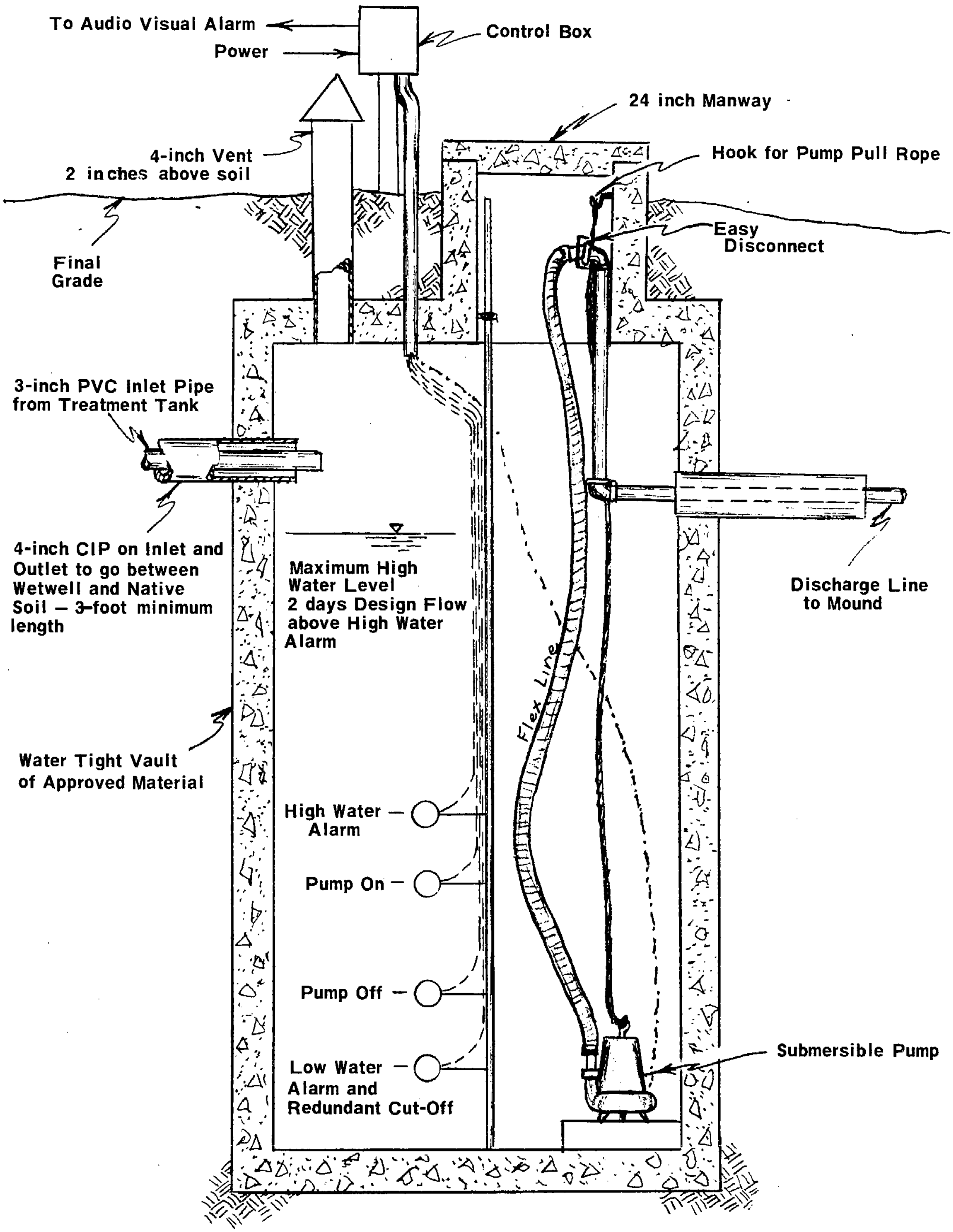


FIGURE 5. TYPICAL WET WELL

Reference 1

A.T.I. 1979

The design of the wet well requires a predesign of the distribution system. As a minimum, the wet well shall be designed to dose the volume contained in the distribution laterals. This may be determined from the nomograph in Figure 4 (1A). When the daily design flow rate exceeds this quantity, the wet well shall be designed to dose one day's hydraulic loading (one pump cycle daily). If the design flow is less, the wet well is sized to dose the minimum computed dosage (Figure 4) and the system will be dosed less than once daily. The pump specified above is located within the wet well and shall be fitted with a high level on and low level off controller with a high and low level alarm (both light and horn) (3). This will alert the owner should the system fail to activate at high on or continue to pump below off conditions. A redundant low level cutoff switch shall be provided in conjunction with the low level alarm to prevent the effluent pump from continuing to operate at the low level condition. The wet well shall accommodate 48 hours of emergency storage following mechanical failure.

Mechanical Systems Maintenance Agreement -

As a condition of use, the appropriate regulatory agency shall require the homeowner to provide a signed maintenance agreement to ensure 48 hours replacement or repair of faulty mechanical components (3 & 6).

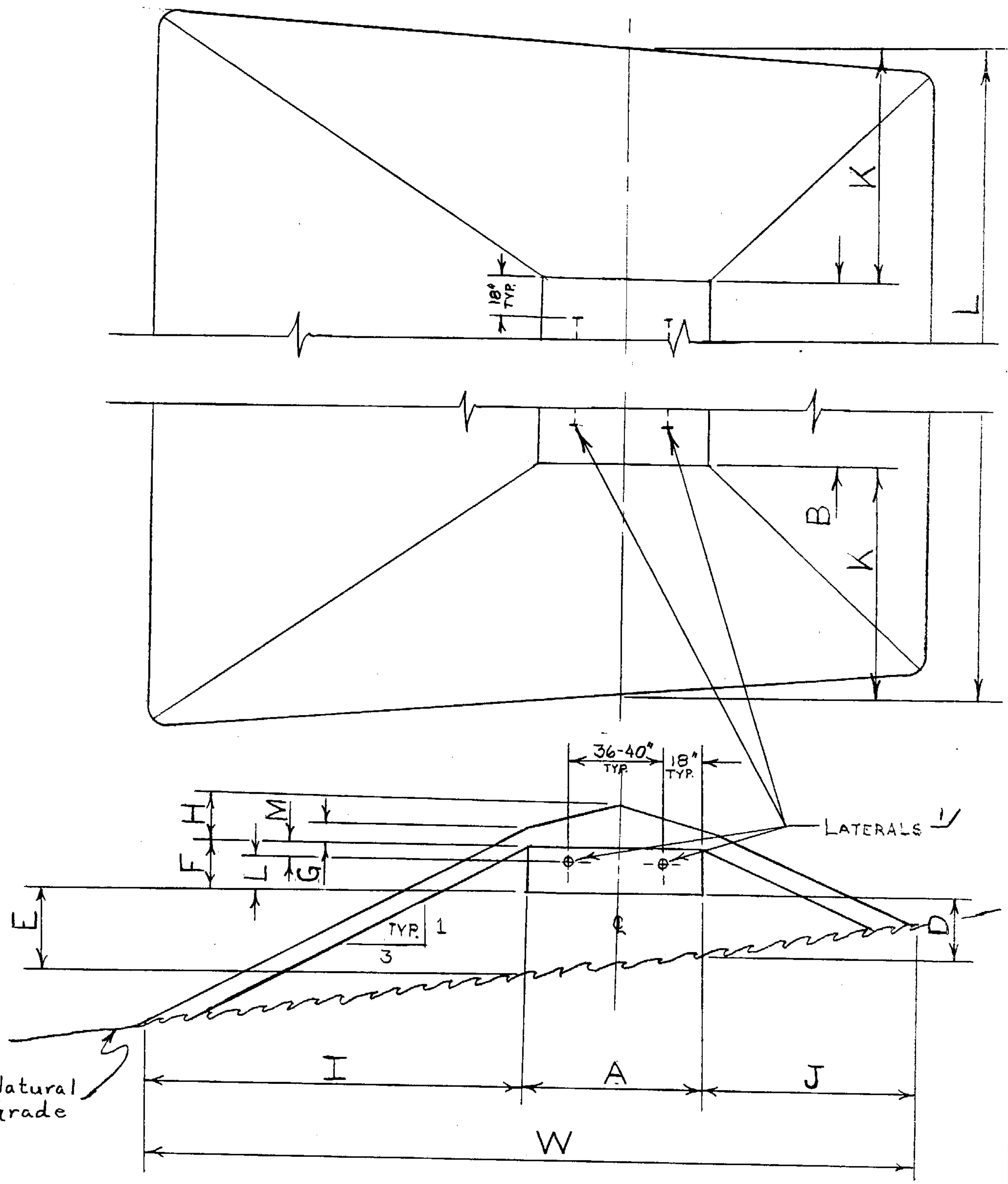
Mound Body -

The design of the mound body fill area is dependent upon the size and geometry of the distribution bed. The permeability of the soil and slope of the site affect the size of the distribution bed and, consequently, the configuration of the mound body fill material. The mound component dimensions are shown in profile and plan in Figure 6. The dimensional constraints are identified in Table 9. These constraints are necessary to ensure the maintenance of minimum slopes and distances to provide adequate treatment and effluent dispersion within the mound body under varying site conditions.

A major design computation for the mound is that of the mound body basal area. This value is based on site percolation rates. These rates are correlated with the design infiltration rate in Table 10 (1A).

As with the required area for the distribution bed, the mound body basal area is the design site infiltration rate selected above divided into the design system daily loading rate.

The next step is to arrange the mound body base configuration in relation to the distribution bed final geometry previously specified (1A). On a level site, the length by width (dimensions L x W on Figure 6) shall be selected to provide the required basal area. The distribution bed shall be centered over the mound basal area (dimensions I, J, and K on Figure 6, shall be equal). The side slopes shall not be steeper than 3:1. This check shall be made as it could necessitate increasing



1/ The number of laterals varies with design.

FIGURE 6. MOUND PLAN AND PROFILE DIMENSIONS

Reference 1A
ATI 1979

TABLE 9

MOUND DIMENSIONAL CRITERIA

Profile	Permeable Soil		Tight Soil
Minimum Mound Body Fill Depth Below Distribution Bed (D)[1], Inches	24[2]		12
Minimum Mound Body Fill Depth Below Distribution Bed at its Down Slope Edge (E), Inches	24[3]		12[3]
Distribution Bed Depth Under Distribution Lateral (1), Inches		9	
Total Distribution Bed Depth (F), Inches		12	
Topsoil Cover Depth at Edge of Distribution Bed (G), Inches		6[4]	
Topsoil Cover Depth at Center of Distribution Bed (H), Inches		12[4]	
Maximum Steepness of Side Slopes, Horizontal:Vertical		3:1	
Plan			
Minimum Up Slope Length (J), Feet[5]	10.5		7.5
Minimum Side Slope Length (K), Feet[5]	10.5		7.5
Minimum Down Slope Length (I), Feet[5]	10.5		7.5
Maximum Distribution Bed Length (B), Feet[6]		106	

1/ Letters refer to dimensions shown on Figure 6.

2/ This distance shall be increased to 36 inches for sites having percolation rates faster than 10 minutes per inch.

3/ This dimension will change dependent upon slope of natural grade to maintain a level distribution bed plane. Value shall be 36 inches for sites having percolation rates faster than 10 minutes per inch.

4/ Erosion protection shall be provided such that Distribution Bed is not exposed. In climates subject to soil freezing this depth shall be increased 6 additional inches.

5/ This assumes maintenance of the 3:1 minimum side slope in areas not subject to soil freezing on flat sites. Sloped site values will be greater except for the up slope length.

6/ Distribution laterals are limited to 50 feet maximum. Therefore, a distribution bed with central distribution manifold is limited to 106 feet while an end manifold limits the bed to 53 feet. (The extra 3 feet allows 1½ feet of distribution bed extension beyond the first and last holes in the distribution lateral.)

TABLE 10

NATIVE SOIL PERCOLATION AND DESIGN INFILTRATION RATES

Natural Soil Texture	Soil Percolation Rate * minutes/inch	Design Infiltration Rate gal./sq.ft./day
Sand, Sandy Loam	0-30	1.25
Loams, Silt Loam	31-45	0.70
Silt Loams, Silty Clay Loams	46-60	0.50
Clay Loams, Clay	60-120	0.25

* **Percolation tests** should be performed in accord with Appendix A Recommendation for a Refined Percolation Test. The test hole depths shall be as shown in Table 1.

the basal area length and width. On sloping terrain, only the area below and downslope from the distribution bed is considered in determining the mound basal infiltrative area. (Infiltrative area is equal to B x (A+I) on Figure 6). Since dimensions B and A are determined from the specified distribution bed geometry, dimension I is adjusted to provide sufficient mound basal infiltrative area. The minimum fill depth is dependent upon the specific site conditions and is shown in Table 9. Following the specification of the mound body dimensions, Table 9 shall be consulted to ensure that the design meets the dimensional constraints. Any dimensions not satisfying the constraints shall be modified to conform. The mound body is recommended to be constructed with fill materials generally meeting the specifications shown in Table 3.

To keep the costs of construction to a minimum, local materials should be used in mound construction wherever possible. Care should be taken to preserve the grain distribution shown, as this specification is important to ensure proper effluent treatment and dispersion. Variations may be granted if the designer can substantiate the use of different material to the satisfaction of the appropriate regulatory agencies. The design variation may require special monitoring to confirm the design. Following field confirmation, the modification may be allowed on a general basis.

Mound Cover -

The distribution bed is covered with a silt barrier. DuPont Typar in the 4-6 oz./yd. weight range, or equal, may be adequate for this purpose. The distribution bed and mound body are then overlain with a topsoil mound covering. The cover provides protection of the inner mound from freezing and provides a cover to shed most incident precipitation. In addition, the mound cover wicks some water up to the roots of grasses planted on its surface. This provides additional disposal of effluent by evapotranspiration.

The topsoil cover shall have a minimum thickness of 12 inches in the center of the mound. This shall be tapered to 6 inches over the edge of the distribution bed. The soil maintains the minimal 6-inch cover over the mound body side slopes to the toe of the fill (1 & 1A). These depths are subject to change, depending upon climate (Table 9 & Figure 6).

Landscaping -

Grasses and shrubs shall be planted on the mound and around its perimeter. Shrubs shall be confined to the mound perimeter so their long roots will not obstruct the distribution laterals (1). Grasses planted on the topsoil cover will prevent cover erosion and, in conjunction with shrubs, will improve evapotranspiration of effluent from the system. The grass types and combinations will vary based on climate and whether the mound is to be mowed. The selected vegetation shall be tolerant to salts and wide variations in moisture. An excellent source of information regarding local vegetation suitable for this application could be the local Agricultural Commissioner or Resource Conservation District. Moisture tolerant shrubs should be placed around the toe and sides of the mound as this area will be moist most of the year. If local shrubs are not specified, the juniper shrub pfitzer is recommended (10).

Monitoring Wells -

The following discussion is derived from the mound system monitoring well specifications of the California North Coast Regional Water Quality Control Board. The following shall be considered as a suggested monitoring program which will allow for a thorough evaluation of the mound water quality. The specific number of well locations and depths as well as parameters and sampling frequency should be specified individually for each installation based on local need. An important point to remember is that the wells will only monitor saturated soil conditions. If it is desired to monitor unsaturated soil moisture, it will be necessary to construct an impervious PVC film horizontal stop at the proper depth to intercept and direct downward migrating water to a collection and sampling sump.

a. The mound shall be constructed with six monitoring wells as follows:

-No. 1 shall be located at the center of the mound, extending from 6 inches above the mound surface to the bottom of the gravel distribution bed.

-No. 2 shall be located within the mound's deepest silty sand fill extending from 6 inches above the mound surface to 6-inches into the native soil. In a mound placed on a sloping site, this well will monitor any water migrating down slope.

-Nos. 3, 4, 5, and 6 shall be located respectively midway along each of the four sides of the mound, at the toe of the slope, extending from 6 inches above ground surface to a depth of 10 feet.

b. All monitoring wells shall be constructed of 3 or 4 inch plastic pipe (or equivalent), equipped with a removable cap and sealed at the soil surface to prevent infiltration of surface water. All wells shall be perforated beginning at a depth of 18-inches below grade and extending to the bottom of the pipe. All wells shall be clearly identified.

c. The monitoring wells are used to monitor groundwater levels and bacterial concentrations (total and fecal coliform). The monitoring should be part of a local program which will allow only that number of systems to be implemented as monitoring resources permit. A suggested monitoring frequency would be as follows: The groundwater level should be monitored one day following each storm dropping more than one inch of rainfall or monitored every two weeks during the snow melt period (generally March through May). Well Nos. 3, 4, 5 and 6 shall be sampled alternately every two months.

Treatment Tank -

The designer shall specify a two-compartment septic tank having a minimun capacity of 1200 gallons with the addition of 250 gallons for every bedroom over four. The first chamber shall have a volume of approximately two-thirds of the total tank volume. The tank shall be of water-tight construction and be fabricated from concrete, fiberglass or other material approved by the designer and shall be fitted with approved inlet and outlet baffles. The tank shall be fitted with covered access ports flush with the ground. These covers shall be removable to provide access to the tank covers located over the inlet and outlet baffles. The provision of these entry ways enables ease of tank inspection and pumping as required. A local public onsite wastewater management district or, if not available, the homeowner should inspect the tank once every two years and should have the tank pumped when the sludge or scum layer is a foot or more in thickness. The use of an aerobic treatment system must meet the requirements of the local agency or Regional Board. No literature has yet demonstrated that an aerobic system functions superior to the septic tank in terms of overall system performance for subsurface disposal in spite of the higher capital and operation and maintenance costs (4, 5, 6, 8 & 11).

The above discussion addresses a treatment tank designed for residential application. The design of a commercial unit shall be sized to handle the specific flow and biological loadings which can vary widely. The discussion of commercial treatment tanks is outside the scope of this presentation.

Deed Record -

The local regulatory agency shall specify that the following be recorded on the property deed as a condition of permission to construct the system:

- o Treatment tank location
- o Wet well location
- o Mound location
- o Reserve area location
- o Any special allowances such as water conserving fixtures
- o Requirement for a mechanical component maintenance agreement.

The first four items shall be shown on a property plot. The recordation will provide the homeowner knowledge of the system, its location and will note that the reserve area shall be expressly reserved permanently for installation of additional wastewater disposal facilities in the event of failure of the original area (3). The homeowner will also be aware of special design allowances and any required mechanical maintenance agreements. When the property is sold, the new owner will be informed of the wastewater system through the recordation process.

B. Notes on Mound System Rehabilitation and Commercial Installations

Sufficient research has been conducted on mound systems to predictably design, construct and operate these systems in the field. When properly designed and constructed, the mound disposal field should require no maintenance and operate for an extended period of time. Should an existing system fail due to inadequate design or overloading, perhaps due to expansion of the residence it serves, some procedures are available to rehabilitate the system. A situation such as poor siting, however, may require an abandonment of the failing system.

While these guidelines concentrate on the design of systems to serve residences, commercial installations may be designed using the same principles. Some elements of commercial design however differ from those of residential design. This section will also address these points.

Rehabilitation -

Failure of the mound system may occur in four ways:

1. The system may fail due to inadequate siting.

2. The bottom of the distribution bed may clog at its interface with the mound body fill.

3. Clogging of the mound basal area interface with the native soil.

4. Clogging of the distribution network.

Usually all but the first of these failure cases can be corrected. If the failure results from poor siting, the mound system may have to be abandoned. If the site conditions are acceptable, numbers two and three of the failure modes may be rectified by constructing a duplicate mound design adjacent to the failing system. This was discussed earlier in the text under "Reserve Areas". It may be possible to rehabilitate the failing system by a specific operation on the system, such as unclogging the distribution lateral. These methods are discussed below.

1. In the second failure case where the bottom of the distribution bed becomes clogged, the cause of the bed clogging must first be determined. Should the cause be related to poor treatment tank maintenance with a consequence of solids carryover, hydrogen peroxide may be used to oxidize the offending clogging mat. The hydrogen peroxide may be applied directly to the bed or through the distribution system. It is stressed that hydrogen peroxide is a very strong oxident and should be handled only by persons familiar with the procedure.

   Should the clogging be due to system overloading or unusual wastewater characteristics, the best method would be to construct additional mound facilities to handle the surplus wastewaters. These may be handled by constructing a separate mound as discussed in the section on "Reserve Area" or it may be accommodated by extending the existing mound provided the distribution laterals allow for this construction.

2. In the third case where clogging occurs in the interface between the mound body fill and the natural soil, seepage will be noted at the base of the mound. The mitigation of this problem can be

accommodated by constructing a duplicate mound facility as discussed in "Reserve Areas" or likewise may necessitate extending the existing mound provided the distribution system can accommodate this modification. The system addition should extend the mound parallel to the slope of the site.

3. In the fourth failure mode, the distribution pipe clogs. This should not occur if the screen is placed following the treatment tank. Once the screen is installed, the problem may be corrected by excavating the ends of the distribution laterals and attempt to flush the materials from the line. Should this be impossible, the lines may be rodded. This failure case is identifiable by unusually long pump cycles.

Commercial Installations -

The same basic mound design principles may be used for commercial installations as with residential units. The first consideration should be the system hydraulic loading. Commercial units will usually serve larger numbers of people but, flow contribution per capita will be reduced from that used in residential design. The specific design flow rates should be developed on a case-by-case basis. This value will vary widely depending on the commercial installation served. Systems serving multiple residences may be sized according to the criteria identified in the guidelines provided the service is limited to five homes or less.

When treating commercial wastewaters, a prime consideration must be the specific wastewater character. This must be evaluated on a case-by-case basis and proper pretreatment shall be provided should this character differ from that of domestic wastewater.

Design modifications are necessary for commercial installations on sloping sites. Most systems are sufficiently large such that the distribution bed widths may require that considerable fill be placed between the distribution bed and the sloping native soil. This mound body fill should be restricted to 4 or 5 feet maximum to prevent undue settlement of the distribution bed. A long bed broken into several short systems should be built end to end parallel to the slope contour to accommodate the required bed area for preventing an accumulation of effluent in the downslope areas.

The construction of multiple distribution systems in commercial units will enable added flexibility to the system. While the guidelines do not recommend the resting of distribution systems, the duplicate systems will provide flexibility for pump maintenance or other unforeseen emergencies necessitating a shutdown of a portion of the bed. The balance of the unit can remain in service, thus preventing a complete shutdown of the individual system.

In summary, commercial units differ from residential units in that they require a hydraulic load determination based on the specific case involved. In cases where the wastewater chacteristics differ from residential wastewater, pretreatment should be used to condition the influent. Commercial systems often require large distribution systems which lend themselves to the provision of modular distribution units each fitted with its own pump. The modular configuration enhances the systems flexibility in the event of an unforeseen emergency. The best distribution system configurations are constructed parallel to the slope contour, as opposed to downslope in a parallel configuration.

IV. DESIGN EXAMPLE

Given a residence with three bedrooms and four persons living in the dwelling. The proposed site has the following characteristics:

- o Slope: 4 percent
- o Twenty-inch deep percolation rate (average of four tests) 95 min/inch,
- o Depth to seasonally high water table 26 inches,
- o No bedrock or other impermeable layers,
- o Soil not subject to freezing.

Design Step	Process
1	Review the site conditions to assure that the site is adequate per Table 1. This site has the following:

- o Percolation rate between 61-120 min/inch,
- o Topography contour at site is not concave (convex is preferred to straight),
- o Slope is between 0 and 6 percent,
- o Soil profile has a well developed topsoil with no abrupt textural changes in top five feet,
- o Seasonal groundwater is more than two feet deep,
- o The restriction on depth to impermeable strata is not applicable.

2	Specify distribution bed geometry: rectangular with major axis parallel to slope contour. This is because the system is constructed in tight soil.
3	Select the mound body fill material. The local area has a silty sand available. This material has an allowable design infiltration rate of 1.0 gallons per square foot per day (Table 3).
4	Determine the daily design flow rate. There are two cases, pick the greatest:

a. number of bedrooms (3) x 150 gallons per bedroom per day = 450 gallons per day;

Design Step	Process
	b. four persons live in the house x 75 gallons per person per day = 300 gallons per day.
	The design hydraulic loading is 450 gallons per day.
5	Determine the distribution bed area by dividing the hydraulic loading (from step 4, this is 450 gallons per day) by the mound body fill infiltration rate (from step 3, this is 1.0 gallons per square foot per day), hence:
	450 gallons per day/1.0 gallon per square foot per day = 450 square feet.
6	Determine the Distribution Bed Geometry - Since the site has tight soil (percolation rate slower than 60 minutes per inch), a rectangular bed is a necessity. It is desirable to extend the major axis of the rectangle as far as possible along the contour of the site. Due to the 50-foot limitation on distribution laterals, the bed could be 106 feet long maximum. For the sake of this example, we shall assume that 85 feet for the bed plus room for the mound side slopes is physically available on the site. Therefore, the bed width is equal to the area of the distribution bed (from step 5) divided by the selected length (85 feet), hence:

Design Step | Process

450 square feet/85 feet = 5.3 feet.

Let the bed width be 6 feet to accommodate two distribution laterals on 3 foot centers with 1.5 feet on each side. This falls within the allowable lateral spacing ranging from 36 - 40 inches.

The bed dimensions are therefore 85 feet x 6 feet.

7 Mound Dimensions[1/]

a. Mound Profile

- o Minimum mound body fill below distribution bed (D) for tight soil (Table 9): 1 foot.

- o Minimum mound body fill below distribution bed at its downslope edge (E) slope 4 percent:

  1 foot + (0.04 vertical feet per horizontal feet x 6 foot distribution bed width) = 1 + 0.24 = 1.24 feet.

  This is approximate. The distribution bed level bottom will control in practice.

- o Distribution bed depth under distribution lateral (L) (Table 9) 9 inches

1/ All letters in parentheses refer to dimensions shown on Figure 6.

Design Step	Process

o Total distribution bed depth (F)
(Table 9) 12 inches

o Topsoil cover depth at edge of distribution bed (G)
(Table 9) 6 inches

o Topsoil cover depth at center of the distribution
bed (H) (Table 9) 12 inches

b. Mound Plan

o Upslope length (J)

This may be computed as follows:
(Mound body fill depth at upslope edge (D) + distribution bed depth (F) + depth of topsoil cover over edge of distribution bed (G)) x 3 to maintain a slope of 3 horizontal units to each vertical unit. Therefore:

$$(1 + 1 + 0.5)\ 3 = \underline{7.5 \text{ feet}}$$

This value will be slightly shorter due to the rising slope.

o Side slope length at mound centerline (K).

This may be computed by determining the average mound body fill depth: (The upslope depth (D)

Design Step	Process

plus downslope depth (E))/2 and then adding the total depth of the distribution bed (F) + depth of top soil cover at mound center (H). This result is multiplied by 3 to provide the minimum 3:1 side slopes.

[(1 + 1.24) / 2] + 1 + 1. This result x 3 = 3.12 x 3 = 9.36 feet

This value will decrease upslope and increase downslope.

- Downslope length (I): This value is determined from the area required for the mound basal area. The mound basal area is determined from site percolation tests and Table 10. For a percolation rate of 95 minutes per inch, the design infiltration rate is 0.25 gallons per square foot per day. Therefore, the required mound basal area for percolation is the design daily flow rate divided by the basal infiltration rate.

  Hence:

  450 gallons per day/0.25 gallons per square foot per day = 1800 square feet of mound base infiltration area.

Design Step	Process
	Since the site is sloped, this area must be provided by the soil directly under and down slope of the distribution bed.
	Dimensions [(I) + (A)] x (B)
	The downslope length (I) may be computed by dividing the basal percolative area by the distribution bed length (B) and then subtracting the distribution bed width (A). Hence:
	(I) = (1800 square feet/85 feet) - 6 feet = 15.2 feet
	This value must be checked to see that it does not result in a slope steeper than 3:1.
	The downslope distance to maintain a 3:1 slope may be computed by adding the mound body fill depth at the downslope edge of the distribution bed (E) to the total depth of distribution bed (F) in addition to the top soil cover depth at the edge of the distribution bed (G). This result is multiplied by 3 to compute the horizontal extension. Hence:
	[1.24 + 1 + 0.5] x 3 = 8.22 feet.

Design Step | Process

This value will actually be longer due to the slope of the site.

A comparison of the length dictated by hydraulic considerations exceeds the minimum length required to maintain 3:1 slopes. Therefore, the hydraulic consideration dictates the downslope length. Hence:

(I) = 15.2 feet

In the field application this length will be increased due to the slope of the site.

- Total mound length (L) is the length of the distribution bed (B) + each of the two side slope lengths (K). Hence:

  L = 85 + [2 x (9.4)] = 103.8 feet.

  This dimension will be shorter at the up slope edge and longer at the downslope edge.

- Total mound width (W) = the upslope length (J) + the distribution bed width (A) + the downslope length (I). Hence:

  W = 7.5 + 6 + 15.2 = 28.7 feet

Design Step	Process
8	Effluent Distribution System

The effluent distribution system must be designed to apply effluent uniformly over the distribution bed having a length of 85 feet and a width of 6 feet.

Since the maximum single lateral length is limited to 50 feet, use a central manifold. There will be two parallel laterals in each half of the distribution bed joining a common central manifold. Each will be spaced 3 feet on center and will be 1.5 feet from the edge of the distribution bed (See Step 6). Since the distribution bed is 85 feet long, half of this length (42.5 feet). Each lateral shall have a total length 1.5 feet shorter than this bed length to position the end lateral orifice 1.5 feet from the end of the bed. Therefore, each lateral shall be 41 feet long. The first lateral orifice shall be 1.5 feet from the distribution manifold. Therefore, the length of perforated lateral is 39.5 feet. The lateral orifices shall be 1/4 inch holes approximately 30 inches on center along the lateral invert. Space the lateral orifices as close to this value as possible to provide uniform spacing within the 39.5 foot perforated lateral length. Use 17 holes, 29.6 inches on center.

Design Step	Process

Now specify the size of the laterals. We will use four laterals joined by a central manifold. Each lateral is 41 feet long with 1/4 inch performations spaced 29.6 inches on center. From Table 4, either a 1-1/4 or 1-1/2 inch diameter lateral is acceptable. Select the larger: 1-1/2 size. Compute the required flow to supply each lateral. A head of 2 feet of water should be maintained over the distribution system. According to Table 5, a 1/4 inch hole will discharge 1.04 gallons per minute. The total flow per lateral may now be computed by multiplying this discharge rate by the number of holes in each lateral. Hence:

1.04 x 17 = 17.7 gallons per minute per lateral.

Now we will size the central manifold line from Table 6, by knowing the flow per lateral, the number of laterals, the length of the manifold which is defined as the length of pipe required to connect all laterals from the intersection of the first lateral to the last and whether a central or end manifold is used. In our example, the two parallel laterals are 3 feet apart, so use the minimum table manifold length of 5 feet. Table 6 indicates a 2 inch PVC manifold will be adequate.

Design Step	Process
9	Pump and Hydraulic Specifications and Wet Well

The pump must provide a minimum dosage equal to the volume contained in the laterals. Figure 4 can be used to identify the volume of the laterals knowing the lateral size (1-1/2 inches), length (41 feet), and number (4). Figure 4 indicates the minimum dose to be 150 gallons. This is less than the dose required for one cycle per day. Therefore, provide a wet well with sufficient size to dose 450 gallons, once per day. If the required minimum dose exceeded the daily flow, the wet well would dose the minimum required volume less often than once per day.

o The required pump flow rate is the lateral supply rate times the number of laterals. Simply:

17.7 (4) = 70.8 gpm Say: 70 gallons per minute.

o Finally the pump total dynamic head (TDH) must be identified. TDH is computed by adding the following:

The elevation difference between the wet well pump low water cut-off and the invert of the distribution laterals (Assume this is 10 feet, for example): 10

Design Step	Process	
	Friction loss over the delivery pipe from Table 7, 3 inch PVC pipe at 70 gpm. (3 inch was selected over 2 inch as the 2 inch line had excessive head losses for the given flows). Assume a length of 100 feet. This length has a head loss of 1.08 feet per 100 feet from Table 7.	1.08
	Friction loss of fittings, Table 7 and 8. Assume our system has the following: two 90^{o} elbows with an equivalent length of 5 feet of 3 inch pipe each x 2 = 10 feet. Two 45^{o} elbows with an equivalent length of 2.6 feet of 3 inch pipe each x 2 = 5.3 feet. Total equivalent length 15.3 feet. From Table 7 the fitting head loss is:	
	(15.3/100) 1.08	0.2 *
	The desired head over the distribution system	2.0
	Total Dynamic Head	13.3 ft. water

For pump specification, add 15 percent to this value to account for pump aging. Therefore:

* In systems having few fittings, this computation may be omitted.

Design Step | Process

13.3 + (13.3 x 0.15) = 15.3

Say: 16 feet of water TDH

Pump Specification

Select a submersible centrifugal pump for septic tank effluent with a TDH of 16 feet of water at a flow of 70 gallons per minute.

Check the manufacturers information such that the selected pump is operating efficiently at this design point.

- Wet Well

The wet well is simply a reservoir containing 450 gallons (one day's flow) between the pump on and off point. A low water redundant cut-off and alarm shall turn the pump off prior to exposing the pump motor. The high water alarm shall sound if the pump fails to turn on at the 450 gallon point (Figure 5). The wet well receives water from the treatment tank. The total surplus volume of the treatment tank and wet well shall be 900 gallons (48 hours storage) over the high water alarm point without surfacing effluent.

Design Step	Process
	o Treatment Tank A two-compartment septic tank having a 1200 gallon total capacity with access ports at the ground level shall be provided. The tank shall be of concrete or fiberglass and shall be fitted with inlet and outlet baffles. The effluent line shall be filled with a screen which can remove 1/8-inch spheres prior to the wet well.

Following design specifications, the construction shall follow closely the procedures noted in the next section.

V. CONSTRUCTION TECHNIQUES

The designer shall inspect the system at critical construction points and submit a written certification that the system was installed in exact accordance with design. The written certification shall be signed by the designer (3).

The construction techniques employed for a mounded system are quite important. This is especially true for the equipment used. The following steps provide a discussion of the recommended practice for constructing a mound (1 & 2).

1. Stake out the location of the designed mound such that its distribution laterals will be generally parallel to the elevation contours of the site.

2. Measure the natural soil elevation under the future mound bed and note the highest natural soil elevation. Note this on a remote bench mark for controlling bed bottom elevation within the mound fill.

3. Trench and place the influent line from the wet well to the mound site. This will avoid compaction of the mound site following plowing. This line should be placed either below the frost line or sloped such that it drains back to the wet well when the pump is off in areas subject to freezing.

4. Plowing the site is the first critical construction task. The plowing should be done only when the soil moisture content is sufficiently low. The soil shall not be disced as the operation can break the soil into fine particles leading to a restriction in the soil's surface percolation capacity. If the soil 6 inches or more under the surface can be rolled into a rope or can be easily molded, the soil is too wet. If plowed in this condition, the soil's natural infiltration rate will be substantially reduced thereby increasing the chance of system failure. Plowing should immediately precede construction. If after plowing the soil becomes wet, construction should be postponed.

Plowing shall be parallel with the elevation contours. The soil shall be plowed to a depth of 7 or 8 inches and the soil shall be thrown upslope. A plow as wide as possible should be used to minimize site compaction.

5. Extend the inlet pipe to a height above the future distribution bed.

6. Stockpile the fill sand around the perimeter of the plowed area taking care to keep the truck wheels off the plowed surface.

7. Using a crawler tractor with a blade and a minimum of 6 inches of sand under the tracks to minimize compaction of the plowed surface, distribute the sand over the mound. The sand is placed to the same elevation as the top of the gravel distribution bed. The sides of the mound are shaped to the proper slope (three horizontal to one vertical is the steepest).

8. The blade of the crawler tractor is used to place the bed bottom to the proper elevation within the mound body fill. Great care is taken to make sure the distribution bed bottom is level. This will require careful hand work.

9. With a crawler tractor fitted with a dump bucket, place the gravel in the excavated bed. The bed excavation is approached by traveling up the sand fill slopes, filling them from the sides. The distribution bed is filled to the top with 12 inches of gravel.

10. Within the distribution bed, place a 3 inch deep furrow with a shovel for the distribution lateral. For testing, temporarily connect the distribution laterals with holes up to the distribution manifold pipe which is connected to the inlet line. Place clear water in the wet well and test the pump, controls and distribution system, checking for uniform streams of water from each hole. Clean out and enlarge those holes with impaired flow until all streams are uniform. Rotate the laterals so the holes are downward into the gravel and cement them to the manifold. Cover the line with 2 inches of gravel taking care that the laterals are level and the manifold slopes back to the inlet line so the system can drain to the wet well if necessary.

11. Markers are placed at the end of each lateral for future location of the lateral.

12. Place six 3 or 4 inch diameter plastic (or equivalent) observation wells. Well No. 1 shall be located at the center of the mound, extending from 6 inches above the mound surface to the bottom of the gravel distribution bed. Well No. 2 shall be located within the mound's silty sand fill along the downslope edge extending from 6 inches above the mound surface and 6 inches into the native soil. Well Nos. 4, 5, and 6 shall be located respectively midway along each of the four sides of the mound, at the toe of the slope, extending from 6 inches above the ground surface to a depth of 10 feet. All wells shall be fitted with a removable cap and sealed at the soil surface to prevent infiltration of surface water. The

wells shall be perforated beginning at a depth of 18 inches below grade and extending to the bottom of the well. All wells shall be clearly identified. This monitoring layout is considered maximal. The specific number of the wells may be reduced and their locations modified at the direction of the local approving authority.

13. Material is placed over the distribution bed to prevent migration of fines from the cover soil into the bed. This could be 4 inches of uncompacted straw or marsh hay. Other materials may be allowed with the proper justification of the designer. Polypropylene filter fabric such as DuPont Typar (4 or 6 oz./sq. yd.) or equal may prove effective in this application.

14. Reshape the mound surface. Take care not to drive over the distribution bed surface because the distribution system could be damaged.

15. Place a minimum of 1 foot of top soil over the top of the mound and taper this to 6 inches over the sloped sides.

16. Landscape the mound with grasses and the periphery with shrubs.

VI. OPERATION AND MAINTENANCE

The homeowner of a mechanized system shall have a signed maintenance or replacement agreement stipulating procedures to ensure maintenance, repair, or replacement of critical items within the 48-hour period following failure.

The following tips and suggestions are reproduced with modifications for mound systems from the Homeowners and Users Guide for Onsite Wastewater Disposal Systems prepared by the Stinson Beach County Water District (12). They are intended to increase the useful life of the treatment system. Their applicability and effectiveness will vary with each home.

Minimize the Liquid Load

The less wastewater you produce, the less wastewater there will be to dispose. The following suggestions will help to reduce the liquid load:

- Repair leaky fixtures. Check your toilet by dropping food dye in the tank and see if it shows up in the bowl without flushing.
- Wash clothes only when you have a full load. Avoid doing several loads in one day.
- Take short showers instead of baths. Don't turn the shower on all the way and turn off the water while lathering.
- Use a water-saving device in your toilet tank and don't flush unnecessarily.
- Don't let water run while washing teeth, hands, vegetables, dishes, etc. Use a stoppered basin.
- Provide adequate drainage around the mound disposal area to divert runoff from higher ground.

- Many other ways of conserving water exist. Be alert for other water-saving ideas.

Minimize the Solids Load

A good rule is: don't use your septic system for anything that can be disposed of some other way. The less material you put into your septic tank, the less often it will need pumping.

- Avoid using a garbage disposal unit. Compost scraps or throw them out with the trash.

- Collect grease in a container near the sink rather than pouring it down the drain.

- Minimize the discharge of paper products. Nondegradable items, such as disposable diapers, sanitary napkins, kleenex, and paper towels are especially harmful. Don't throw cigarette butts down the toilet.

- Only three things should go into the septic tank: human wastes, toilet paper, and water from toilets, bathing fixtures, laundry and kitchen sinks.

Ordinary use of household chemicals won't hurt the bacteria in your system but don't use excessive amounts. Also, don't use your tank to get rid of oils, paint thinner, or other poisonous liquids.

Septic Tank Additives

Chemicals, bacteria, enzymes, etc., do not help solids breakdown in the tank and will not reduce the need for pumping.

Keep Heavy Vehicles Off Your System

Underground pipes and soil porosity can be damaged by driving over them repeatedly. Never drive over the disposal area. This area should be walked on only to attend the planted vegetation. This vegetation normally does not need to be irrigated.

If Your System Fails

If your mound system has failed, provisions should have been made for supplementing the original bed with a new one of equal or greater size. A qualified person shall design all failed system repairs. Mound systems shall be repaired with a system of equal or greater size constructed adjacent to the original with their inlet lines in parallel so that each unit is loaded simultaneously.

Operation and Inspection of Mound Systems

Check your system inspection pipes regularly. Standing water near the elevation of the natural soil surface may be an indication of trouble. These inspections are best made during the rainy season of the year. Your septic tank, mound system, and effluent screen should be inspected at least once every two years. If these items are not routinely inspected by a wastewater agency, you should inspect your system. To inspect the tank, remove the manhole cover at the inlet end. The best practice is to check both scum and sludge levels, but the following simplified procedure works well in most cases. Use a shovel to push the scum layer away from the side of the tank so that you can estimate its thickness.

If the thickness of the scum layer is a foot or more, arrange to have your tank pumped immediately. Replace the manhole cover and wash off the shovel and your hands as a sanitary precaution. If the tank is not pumped, solids can carry over to the disposal bed and affect proper bed operation. A general inspection of the mound including the removal, cleaning, and reinstallation of the effluent screen to protect the mound system is a recommended annual task.

Aerobic Systems

The same basic tips are applicable to aerobic systems. The solids accumulation rate in these units may be more rapid than a septic tank and therefore they need to be inspected more frequently. The designer or manufacturer should provide a required inspection and pumping schedule. Due to increased initial operation and maintenance costs of these systems over the septic tank, coupled with a lack of information indicating the superiority of the overall treatment and disposal process, aerobic treatment systems are not considered to have any overall advantage over septic tanks for use with mound systems. They have a definite disadvantage in that they are more vulnerable to homeowner neglect.

VII. MONITORING REQUIREMENTS

Mounded disposal systems are experimental systems in California. Implementation approval should not be granted for these systems until a monitoring program is developed which is acceptable to both the local health agency and the Regional Water Quality Control Board. A primary need is the monitoring of effluent quality under the bed fill in the natural soil prior to the effluent encountering groundwater. Another important factor is the monitoring of the system's ability to dispose of effluent in the soil without surfacing or causing a plumbing backup.

Each mound installation should be monitored until the local agency and the Regional Board are satisfied that each design will result in an acceptable system.

Most important, the number of experimental installations authorized should not exceed the resources available for adequate monitoring and follow-up evaluation of each system.

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APPENDIX

APPENDIX

RECOMMENDATIONS FOR A REFINED PERCOLATION TEST

Introduction

The percolation test procedure was originally developed in 1926 by Mr. Henry Ryon, an engineer with the New York State Engineer's Office. The results of his work remain essentially unchanged in the general percolation test procedure used as the basis of subsoil disposal system designs today. The standard for percolation tests is contained in the U.S. Public Health Services Manual of Septic Tank Practices (USPHS Manual)[1/]. The soil percolation test can give variable results due to changes in site conditions, innate variation in the reproducibility of the test, and differences in the test specifications and procedures.

A promising alternative to the percolation test procedure involves an analysis of soil type and texture. This procedure will continue to be refined as the practice continues to be advanced. A soil examination should take place even when a percolation test is used for system designs. As the percolation test pit is excavated, the soil type should be identified, taking care to note texture, the presence of any soil mottling due to previous high groundwater levels, and the existence of any impervious layers. This investigation is an important part of any site investigation for a subsoil disposal system. This appendix, while acknowledging the innate shortcomings of the percolation test,

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1/ U. S. Department of Health, Education, and Welfare, Public Health Service, Manual of Septic Tank Practice, U. S. Government Printing Office, 1967 edition. The USPHS Manual has undergone one revision and four reprintings since its first printing in 1957.

will establish a rationale and make a recommendation for a refined percolation test to eliminate the differences resulting from the varying test specifications and procedures.

Research (1, 2, 3, 4, & 5) has shown that percolation test results can be affected by the following variables:

- The method used in digging the test hole,
- The diameter, or size, of the test hole,
- Silting of the hole during the test,
- The height of water during the test
- The equipment and methods used to obtain readings.

Refining and standardization of the percolation test methods, while not necessarily resulting in more conservative results, will result in more constant results indicative of improved practice. The USPHS Manual allows for hole size variations from 4-12 inches, having either a square or circular cross section. Measurements are taken with a batter board and measuring stick, and percolation rates are measured during varying liquid levels in the hole. The USPHS Manual does not address specific methods for excavating the test hole, or the effects of sidewall siltation, during the test. Much of the procedural wording is casual in the USPHS Manual. To obtain more reproducible results in the same soil, the test procedure needs to be standardized beyond the procedures identified in the USPHS Manual.

Field Practices which Introduce Variation in Percolation Test Results

The following discussion addresses various field practices which have resulted in percolation test variations.

Power augers can compact the sidewalls of a test hole. Studies with power augers have shown approximately 85 percent of the soil is removed from percolation test holes, with 15 percent being compacted into the walls (2 & 4). Test results indicate the percolation rates may decrease 10-100 fold due to sidewall compaction. Sidewall compaction, even with the proper surface scraping to remove soil smearing due to the digging equipment can significantly effect test results (1 & 2).

The test hole diameter can cause percolation test results to vary widely (1, 2, & 3). This is due to the varying ratio of hole percolation area to volume of water (small diameter holes yield faster percolation rates). This is especially true of holes dug with shovels. Frequently, unless great care is exercised, the lower walls of these excavations can taper in toward the center of the hole.

Experience has indicated that the siltation of test hole due to unstable sidewall caving during the test can cause a decrease in the percolation rate observed in some soils. Another effect of this problem is the filling of the hole which destroys the bottom of the hole as a water depth measurement datum, while elevating the general test depth (1, 2, & 3).

Winneberger (1) found that variations in hydraulic head caused changes in the percolation rate with deep water test depths yielding the faster percolation rates. This will result in a varying percolation rate depending upon the elevation of the test water at the time the reading is taken.

The use of a batter board and measuring tape, or stick, can likewise introduce errors (1). These may be due to depressing the batter board when taking a reading (the batter board may be laying on dry grass or other unstable surface), mistaking when the measuring stick, or tape, touches the water surface due to ripples in the water surface caused by falling soil particles not the measuring stick, or holding the measuring stick out of plumb. All of these results can amount to errors with a variation of 1/8 of an inch or more. This seemingly small amount of error can become significant when measuring tight soils with percolation rates in the vicinity of 60 minutes per inch.

Rationale for the Components of a Refined Standard Percolation Test Procedure

Below is the rationale to support selection of specific refinements in percolation test procedures. The refinements are discussed under the major topics of test hole excavation, hole diameter, sidwall and bottom protection, water height, and water height measurement.

Digging the percolation test hole:

The test section (bottom 8-12 inches) of the test hole should be dug by a manual auger. Power augers may be used to reach the test section depth, but must not be allowed to continue beyond this depth. An auger will maintain a uniform hole cross-section geometry throughout the test section. The use of a hand auger will enable a careful examination of soil characteristics, especially in the test section. Sidewall soil compaction caused by power augers will be avoided.

Diameter or size of test hole:

Literature varies on the recommended size of the test hole. Ryon's original test hole was one foot square. Winneberger and the San Francisco Regional Board Guidelines recommend a hole 12 inches square or 14 inches in diameter (1 & 3). The USPHS Manual of Septic Tank Practice allows a hole 4-12 inches in diameter, or one foot square. The draft EPA Manual for On-Site Wastewater Treatment and Disposal Systems (5) recommends a hole 6-9 inches in diameter. Caltrans recommends a 6-inch diameter hole (2). A review of local and regional; regulatyory agencies indicates that practices vary.

Ryon's original hole was 12 inches square and had a 6-inch test depth (6). The various procedures for converting percolation test results to soil absorption system size trace their origins to Ryon's original percolation test procedures. Since this work forms the cornerstone of today's design procedures, it is important that any recommended percolation test provide results commensurate with Ryon's test procedure.

An additional consideration for standardization is to select a geometry minmizing excavation energy while providing a sufficient cross-section for effective side wall sacrification, final side wall inspection and the placement of a side wall gravel pack when required.

The excavation of a 12-inch square hole require great care to maintain a uniform cross-section over the bottom 6 inches of depth and requires the excavation of a considerable quantity of soil especially at a 3 or 4-foot test depth.

A 6-inch diameter hole can effectively meet the uniformity requirements with test depths to 4 feet while minimizing excavation energy and providing effective side wall access. The 6-inch diameter hole is used by several counties and regional regulatory agencies, Caltrans (2), and falls within the range of the USPHS Manual and the EPA draft manual (5). Six inches is also a standard hand auger diameter.

The use of the 6-inch diameter hole requires adjustment of resultant percolation values to those representative of Ryon's 12-inch square test hole.

The following routine derives a correction factor, F, based on surface area to volume ratios which is multiplied by the results (minutes/inch) of the 6-inch diameter test to result in a value (minutes/ inch) representative of Ryon's 12-inch square standard hole:

Percolation surface areas (6-inches deep)

6 inch diameter hole = 141 square inches

12 inch square hole = 432 square inches

Volume of hole (6-inches deep)

6 inch diameter hole = 170 cubic inches

12 inch square hole = 864 cubic inches

Surface area to volume ratio

6 inch diameter hole 0.83

12 inch square hole 0.50

Factor (F) to adjust the results of the 6-inch diameter hole to the 12-inch square hole: 0.83/0.50 = 1.66

F = 1.66

When multiplied by the resultant time for the 6 inch diameter hole test depth to drop 1 inch, the result will be adjusted to the result from Ryon's standard 12 inch square hole. Results are reported in minutes/inch.

Sidewall and bottom protection:

While not mentioned in the USPHS Manual, other literature recommends the protection of sidewalls for those soils whose sidewalls cave in during testing (1, 2, 3, & 5). The most common form of protection is use of a perforated pipe with an external gravel pack (1, 2, & 3). All references use 2 inches of pea gravel at the base of the hole to prevent bottom scouring when adding water. An excellent method for retaining the side wall gravel pack is the use of 1/8 inch mesh galvanized hardware cloth rolled into a 4 inch diameter cylinder having sufficient length for the test. This simplifies the adjustment computations of the test hole liquid volume by not requiring the consideration of the gravel retainer displacement in addition to the gravel. The use of pipe requires consideration of its volume in deriving the test volume adjustment. Hardware cloth is economical and is readily available. It requires no shop work to apply it to this use.

The use, when required, of gravel side wall protection necessitates the use of a correction factor, C, to allow the volume reduction of the test water due to the gravel volume. The factor is based on the gravel percent voids (volume of gravel voids/total volume of gravel) and many be derived as follows:

Volume of unobstructed 6 inch diameter hole (6 inch deep):

$\pi r^2 h = 3.14\ (3)^2\ (6) = 170$ cubic inches

Liquid volume of 6-inch hole (6 inch deep) with 1 inch wide pea gravel annular fill:

Volume of 4-inch diameter hole (6 inch deep) +
Liquid volume of the 1 inch wide annular pea gravel wall =
$3.14(2)^2(6)$ + (percent voids/100) x $[3.14(3)^2(6) = 3.14(2)^2(6)]$ =
75 + (percent voids/100) x (170 - 75) =
75 + 95 (percent voids/100) = 75 + 0.95 (percent voids)

The correction Factor C is therefore the unobstructed volume/the liquid volume of the hole with the pea gravel side wall protection.

Hence:

C = 170/[75 + 0.95 (percent voids)]

This factor is multiplied by the resultant time for the test water to drop 1 inch. The result is equivalent to the result obtained with the 6-inch diameter hole without the pea gravel sidewall protection.

Height of water during the test:

The test procedure should minimize the water fluctuation enabling a more consistent percolation rate. The USPHS Manual and several local and regional procedures allow the test depth to vary over 4 to 6 inches or more during the test. Several procedures recommend minimizing percolation variation (1, 3, 5, & 6).

Ryon's original work measured the time required for 6 inch deep water surface to drop 1 inch. From this practice, the percolation test units of minutes per inch were derived. This procedure has two advantages.

1. The variation in head is restricted to 1 inch prior to readjusting the hole test depth.

2. The test procedure remains unchanged for rapid or slow percolating soils.

The test continues until three consecutive times for a 1 inch drop vary by less than 10 percent (1,3 & 6). This method has been selected for the refined percolation test procedure and will minimize the impact of test water depth variations on resultant percolation rate values. Since the water depth is 6 inches in both the refined percolation test procedure and Ryon's original procedure, the variations from Ryon's work due to head variation are eliminated.

Another method minimizing test depth fluctuations (5) takes measurements over 30 minutes or 10 minutes (depending upon soil infiltration capacity) and requires refilling the hole to a 6 inch depth (over the bottom gravel layer) prior to taking the next reading the same period (30 or 10 minutes) later. The test continues until the extremes of three measurements vary by less than 10 percent.

Measurement equipment and methods:

There are numerous simi-automatic techniques that can be used to monitor hole water level more accurately than the common batter board and tape measure method. One low-cost example from the literature (1) is presented below. Refer to Figure A 1 for a sketch. This method minimizes equipment complexities, and eliminates the errors discussed above.

The entire apparatus is mounted on a 1/2-inch diameter steel stake, 18 inches long, fitted with a sharpened end, which is driven into the soil adjacent to the test hole. A laboratory clamp is fastened to the steel rod and may be adjusted vertically, as required. The other end of the clamp has a thumb screw for extending another gripping clamp over the center of the test hole. This clamp can be procured from any laboratory supply house.

A 1/2-inch diameter acrylic tube 18 inches long is fastened in vertical position in the gripping clamp over the hole center. A 2-inch diameter spherical or cylindrical float (a float can be fashioned from a 300 ml polyethylene bottle) is used to monitor the water level. The float is weighted with sufficient sand to ballast it for floating half submerged with the weight of a rigid 1/8-inch diameter wire above it. The 1/8-inch diameter stiff steel or brass

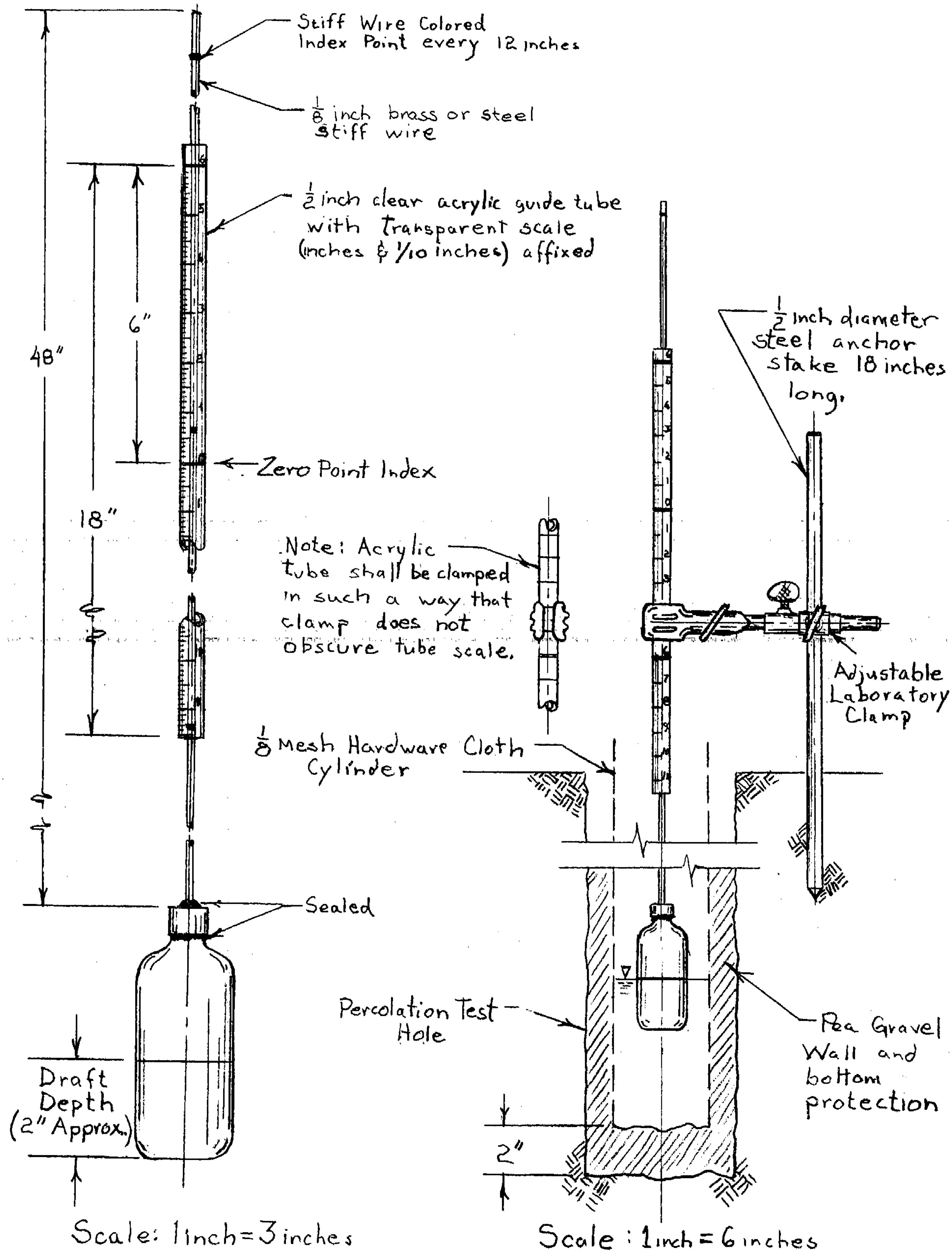

FIGURE A1. FLOAT GAGE AND PERCOLATION TEST ASSEMBLY

Reference: 1 ATI 1979

wire is fastened at the top of the float. The bottle's cap and all construction joints are sealed. The depth (draft) from the bottom of the float to its water line when floating in vertical position with the wire above, shall be carefully noted and recorded. The rod should be about 48 inches long and fitted with an index girdle every 12 inches along its length.

Each index should be a different color to easily distinguish them apart. Colored tape can work well for this application. The index wire extends through the center hole of the 1/2-inch acrylic tube. The acrylic tube is fitted with a permanently attached plastic index tape with the scale starting in the upper 1/4-inch of the tube's length and continuing to its bottom. The scale should be calibrated in inches and tenths. (SCALAFIX is one brand sold through laboratory supply houses). If this cannot be procurred, an appropriate scale may be etched on the acrylic tube and blackened with shoe polish. The laboratory clamp is then rased up and down along the steel stake with the float at the bottom of the hole on the gravel. The scale tube is adjusted until a convenient index on the wire corresponds to a point 6 inches minus the draft of the float lower than the zero index on the scale fastened to the plastic tube. The hole is filled gently with water for presoak until the wire index indicates approximately 6 inches above the zero point on the acrylic tube scale (water in hole: 12 inches above gravel). Presoak continues for four hours. The water level is maintained at 12 inches for this period. The next day, water is added or bailed from the hole thereby adjusting the scale to its zero point (6 inches of water over the gravel layer). A stopwatch is used to monitor time during the test. The hole is refilled with water to the zero point after every reading detecting a 1 inch drop in water level.

Refined Percolation Test Procedure

The following is a recommended refined standard test procedure employing the methods discussed above. If followed carefully, it will reduce the variability of results common to the percolation test procedure described in the USPHS Manual.

1. Dig a test hole 6 inches in diameter to the desired depth, depending upon site conditions, using a hand auger[1/]. Examine and record the soil type and texture every 6 inches over the depth of the hole. Special note shall be made of abrupt changes in soil type or the existence of any impermeable layers. The presence of soil mottling shall be noted thereby identifying a previously high groundwater condition. The test hole side walls shall be scraped with a garden fork or a exposed nail point to remove any smearing effects of the digging equipment to a depth 12 inches above the base of the hole. Remove all loose earth.

1/ Power machinery may dig to within 12 inches of the hole bottom with the final 12 inches completed with a hand auger.

2. Prepare a cylindrical silt barrier form 4 inches in diameter and at least 24 inches long from 1/8-inch gird hardware cloth. Procure sufficient pea gravel to cover the bottom of the hole to a depth of 2 inches and fill the 1-inch annular space between the hardware cloth cylinder and hole sidewall to a minimum depth of 12 inches. Prior to placing pea gravel, determine the percent voids by placing the gravel in a vessel of known volume. Add water until the water level coincides with the level of gravel in the vessel. Pour off the water and determine its volume. The percent void is simply: (volume of water/volume of gravel) x 100. This value is used to adjust the percolation results to compensate for the volume displaced by the gravel in the annular space. Place the gravel over the hole bottom; place the pea gravel uniformly in the annular space between the hardware cloth and walls of the hole.

   The use of the hardware cloth and pea gravel annular silt barrier may be eliminated in soils having stable side walls. In these cases, one will eliminate the use of the gravel void correction factor as discussed below. The 2-inch thick gravel base shall be placed in the bottom of all test holes. Special care shall be taken to prevent erosion of the unprotected hole side walls when applying water for the tests not using the gravel packed side walls.

3. Install the float guage (See Measurement Equipment and Methods in the previous section for a discussion on the float guage and its use). Presoak the test hole one day before the test for 4 hours by maintaining the water level at a depth of 12 inches above the base of the hole. An

automatic valve is acceptable for regulating the 12-inch depth for the required 4-hour period(2). This will cause swelling of the clay minerals enabling a more realistic test result.

In sandy soils having a low clay content (the water drains from the hole in less than 10 minutes) the 4-hour presoak may be eliminated.

4. Perform the test the next day following the presoak. There are two cases:

   a. Water remains in the hole following presoak:

      If water remains in the hole, adjust it to 6 inches above the pea gravel bottom (8 inches above the soil bottom of the hole) by bailing any excess water over this level or adding if under 6 inches(5).

   b. The hole contains no water following presoak:

      If the hole contains no water, fill it to the 6 inch level.

5. Using a stopwatch, determine the time for the water to drop 1 inch using the float guage used during presoaking. Depth changes may be precisely determined with this guage. Similar arrangements such as hook guages and various calibrated floats are also acceptable. These methods provide resolution to the nearest 1/16 inch. Following each timed 1 inch drop in water level, the hole is readjusted to the original depth 6 inches above the gravel bottom with water. The process is repeated until each time varies by no more than 10 percent.

6. Percolation Value Standarization

The percolation rate is adjusted by two factors: C and F. The factor C adjusts for the presence of pea gravel side wall protection and the factor F adjusts the rate to Ryon's standard 12-inch square hole size.

If the side wall protection was used, the rate is adjusted as follows:

Standard percolation value (minutes/inch) =

Test percolation value (minutes/inch) x C x F

where:

C = 170/[75 + 0.95 (percent voids in gravel)]

F = 1.66

If the side wall protection is not used, the rate may be adjusted as follows:

Standard percolation value (minutes/inch) =

Test percolation value (minutes/inch) x F

where:

F = 1.66

The following example illustrates the adjustment of a test percolation value to a standard percolation value.

Example:

Assume final fime for a 1 inch drop was 25 minutes after getting less than 10 percent variation in the final three time readings (test percolation value).

The gravel percentage of voids is obtained by filling a 500 ml container with gravel. Water is added until its surface corresponds with the surface of the gravel at the 500 ml mark. All of the water is decanted into a graduate cylinder. The volume is 225 ml. Hence, the percentage of voids is simply

(225 ml/500 ml) x 100 = 45

The test percolation value is adjusted to allow for the gravel packed side walls (C) and the adjustment to Ryon's original test role size results (F). Therefore:

C = 170/[75 + 0.95 (percent voids)] =

170/[75 + 0.95 (45)] = 1.44

F = 1.66 for a 6-inch diameter percolation hole

Standard percolation value =

25 minutes/inch (C)(F) = 25 (1.44) (1.66) = <u>60 minutes per inch</u>

This value is then used in the design.

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FOR

MOUND SYSTEMS

STATE OF CALIFORNIA

STATE WATER RESOURCES CONTROL BOARD

Alan T. Ingham

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