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(54) **DRAIN FIELD SYSTEMS AND METHODS FOR IMPLEMENTING SAME**

(75) Inventors: **Carl D. Ring**, Oakland, TN (US); **Dennis Koerner**, Oakland, TN (US)

Correspondence Address:
SUGHRUE MION, PLLC
2100 PENNSYLVANIA AVENUE, N.W.
SUITE 800
WASHINGTON, DC 20037 (US)

(73) Assignee: **Ring Industrial Group, L.P.**

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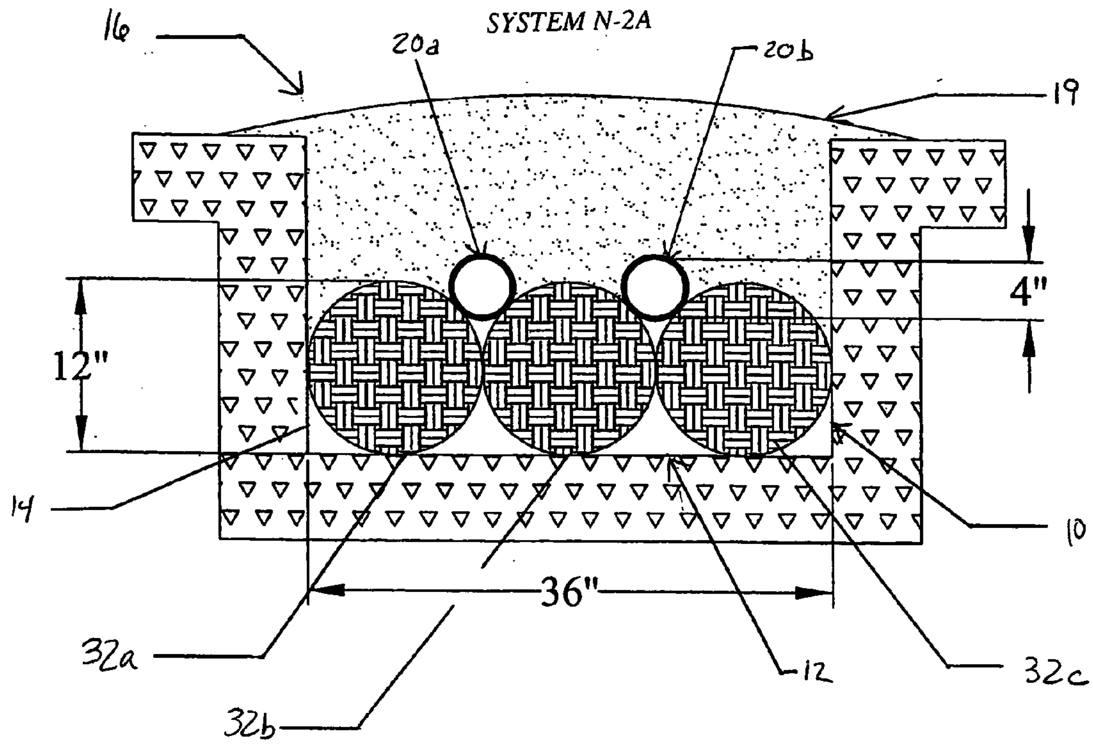
(57) **ABSTRACT**

A drain field system including a trench having two sidewalls and a floor, one or more perforated drainage pipes, and one or more contained aggregate bundles placed in the vicinity of the drainage pipe. In one application, a system includes two aggregate bundles disposed on the floor of a trench with a drainage pipe placed between the two bundles on the trench floor. In another application, a drainage pipe is placed on top of two contained aggregate bundles that have been placed side by side in a trench.



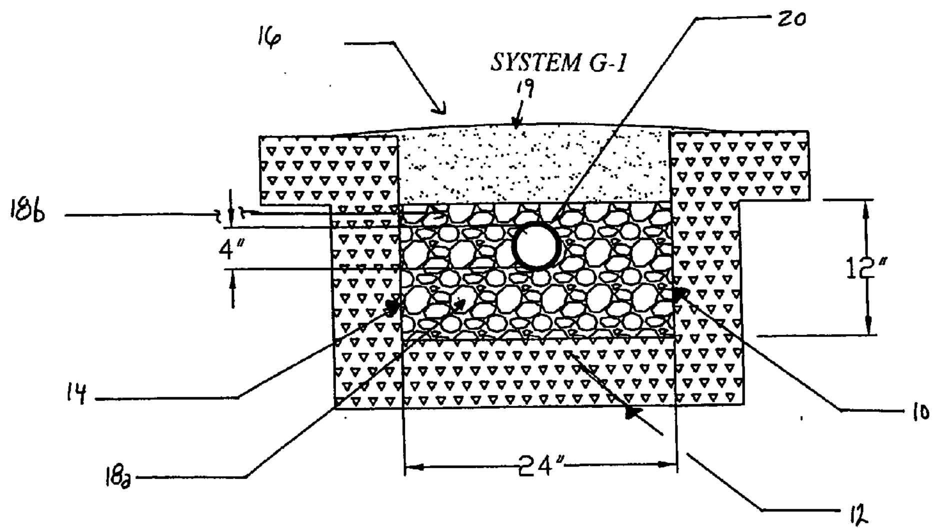


FIGURE 1A

RELATED ART

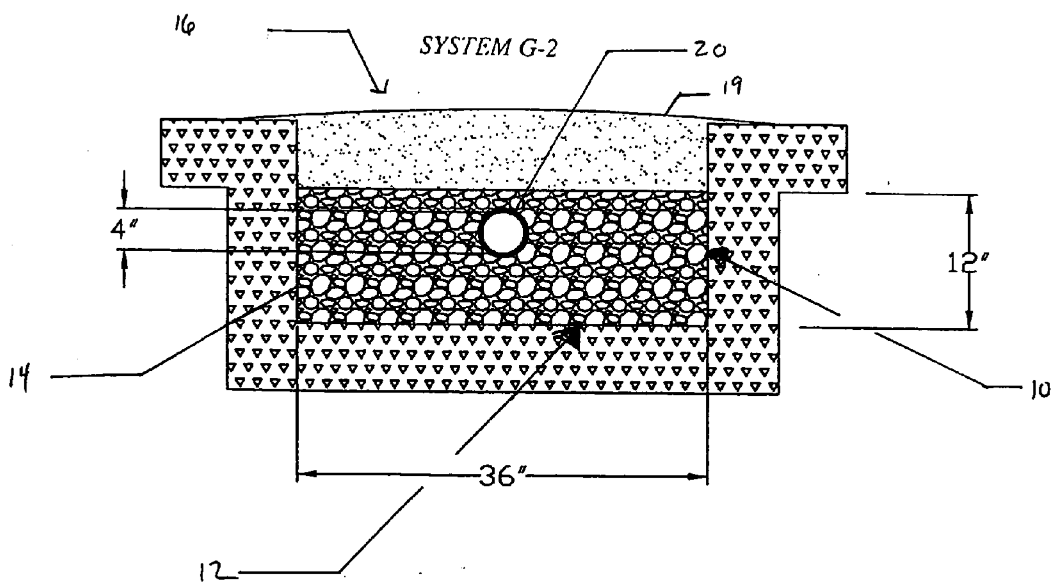


FIGURE 1B

RELATED ART

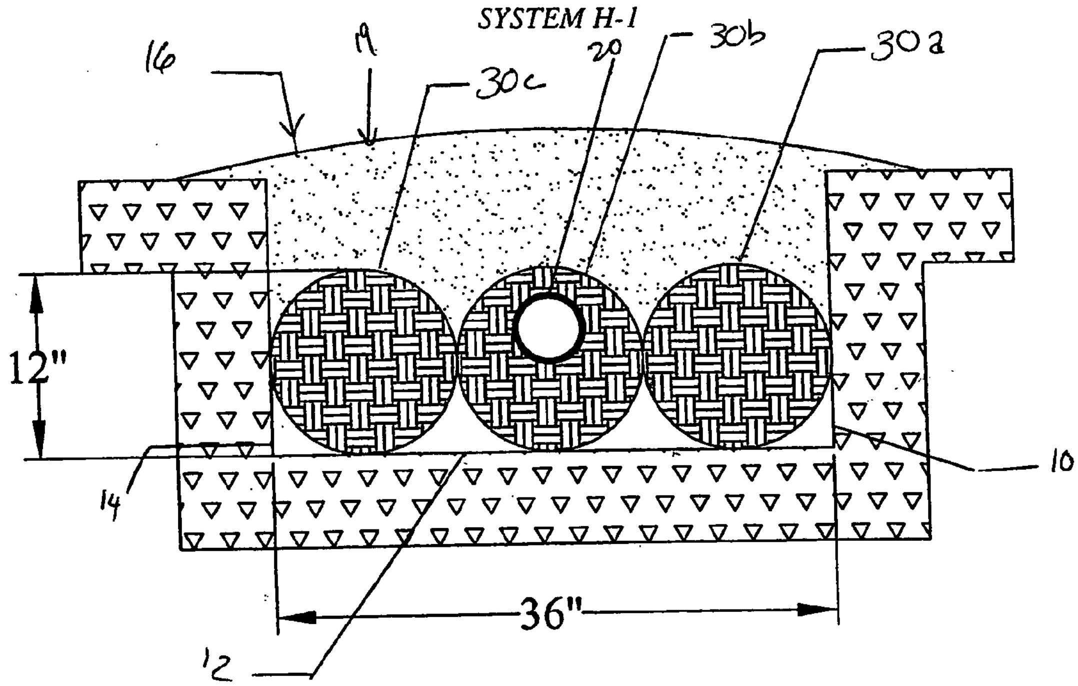


FIGURE 2A
RELATED ART

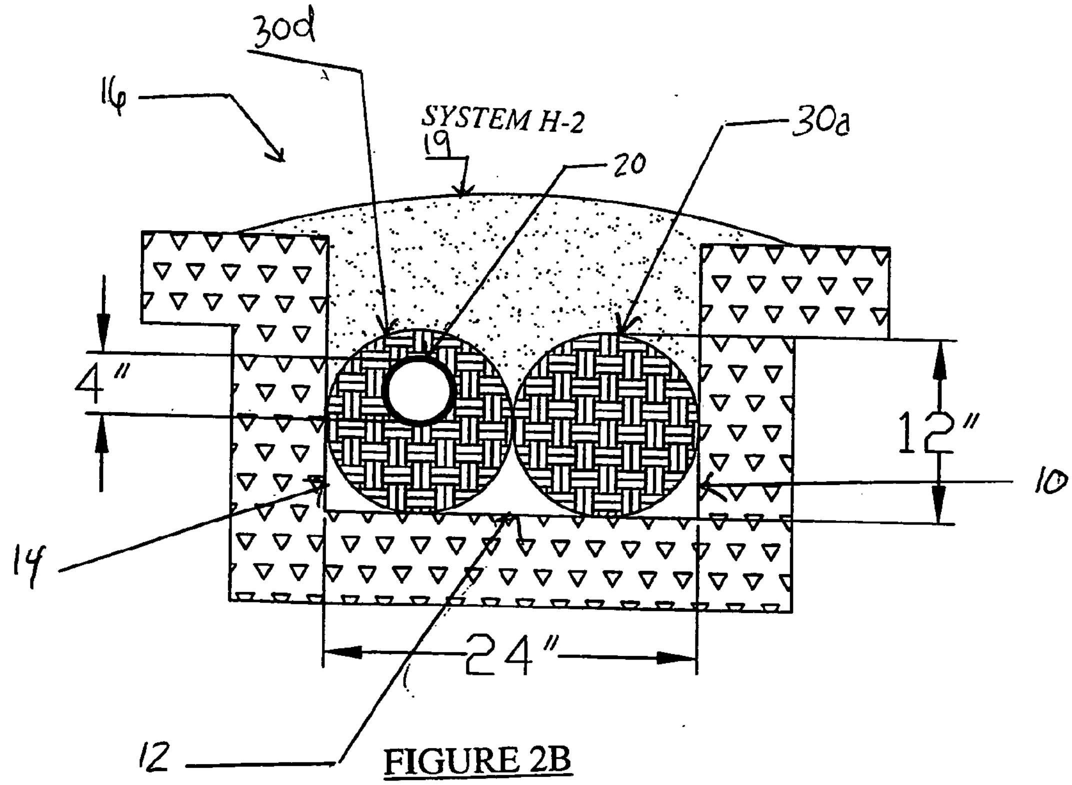


FIGURE 2B
RELATED ART

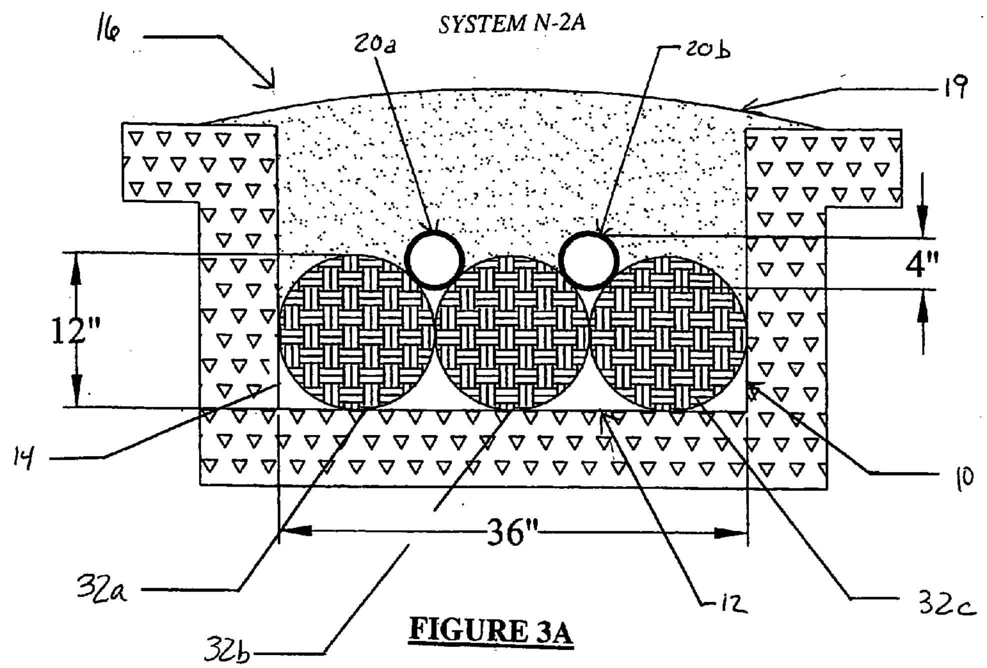


FIGURE 3A

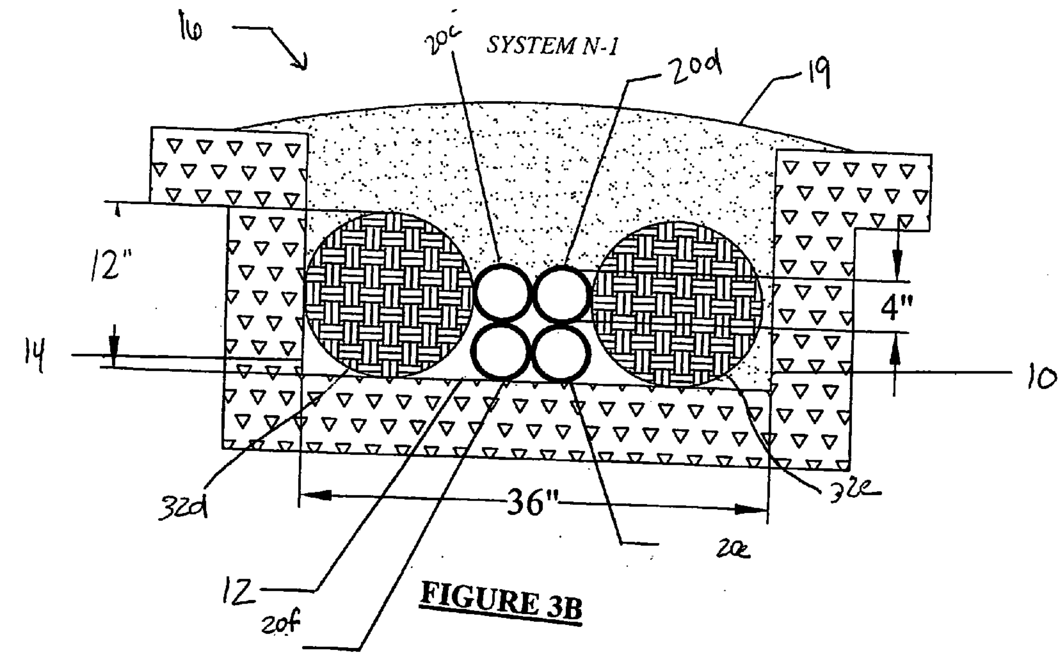


FIGURE 3B

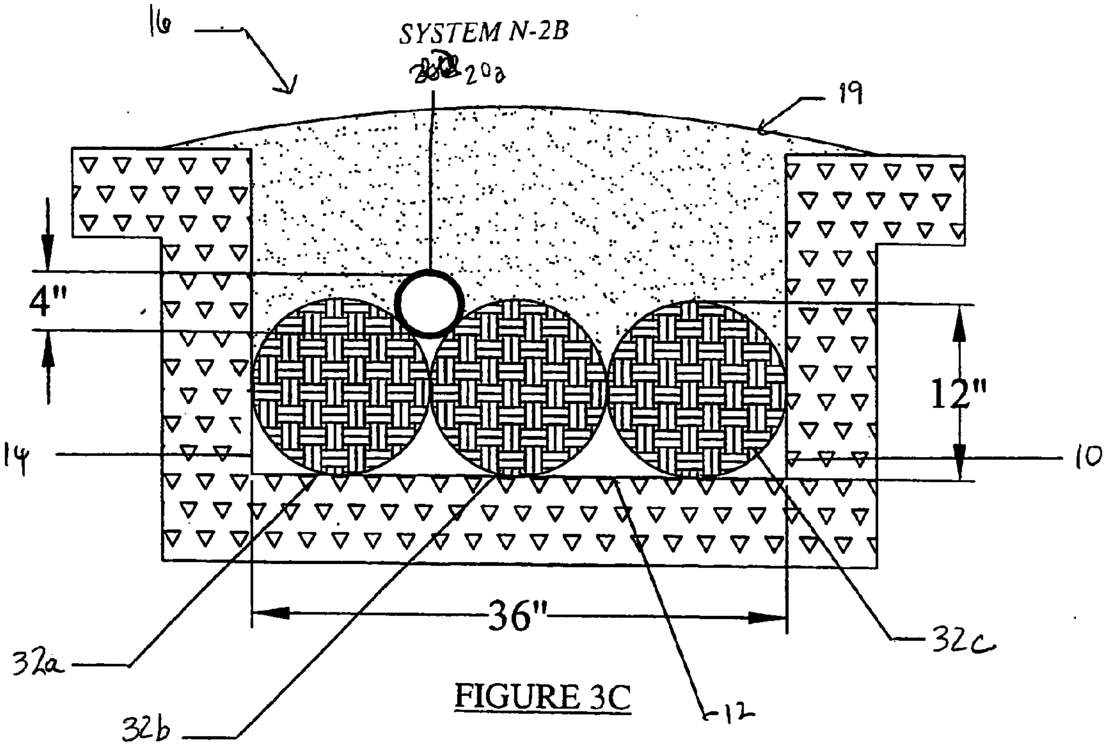


FIGURE 3C

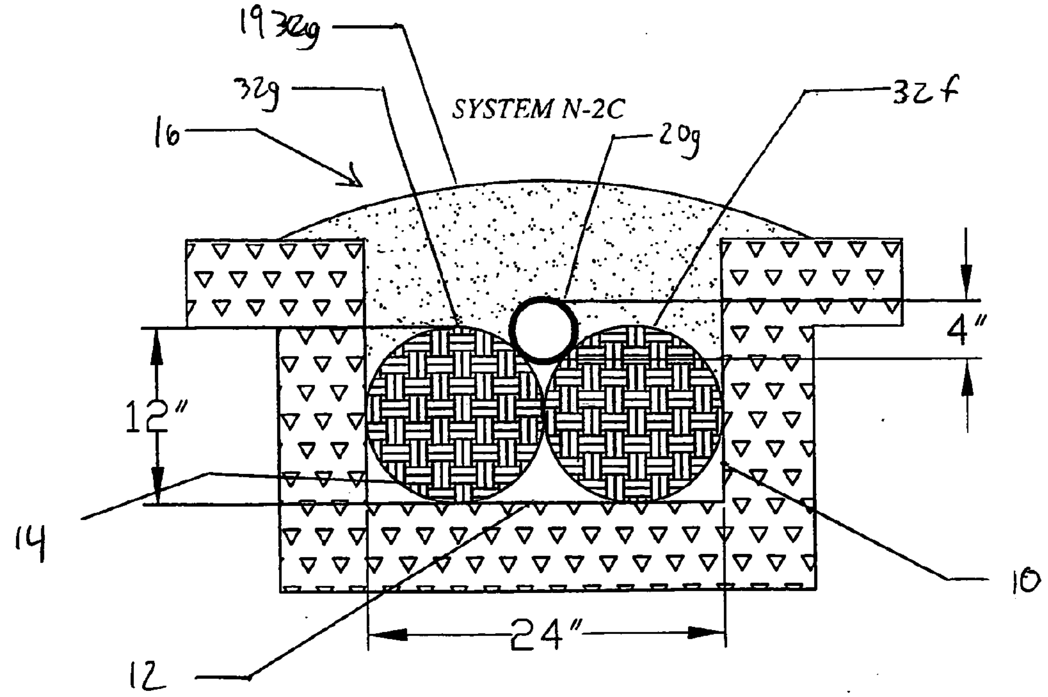


FIGURE 3D

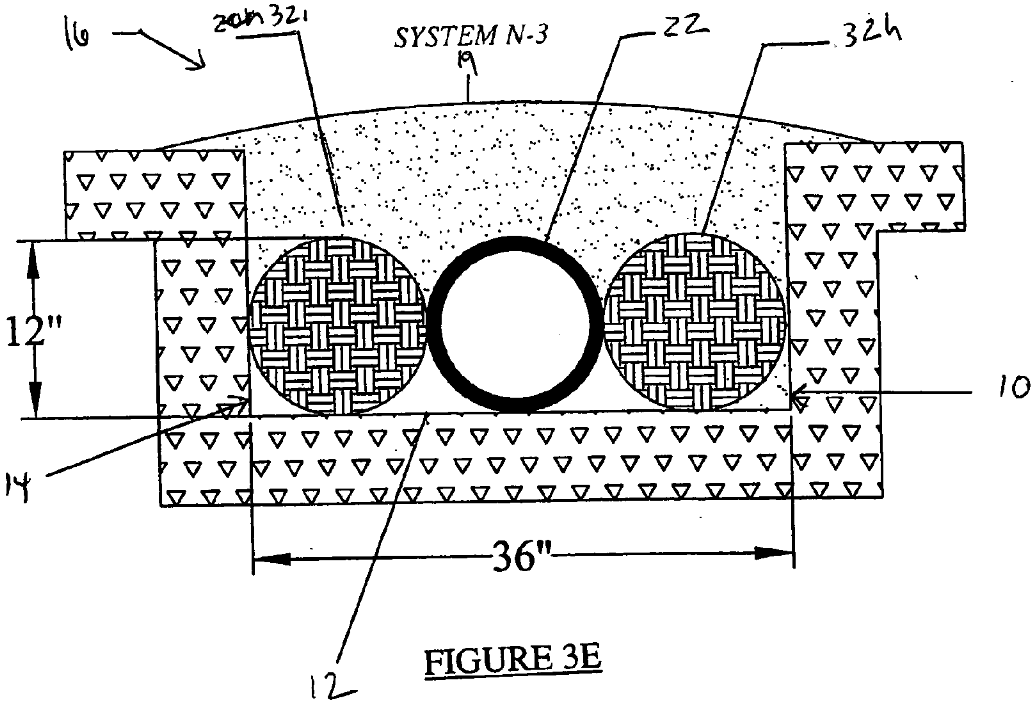


FIGURE 3E

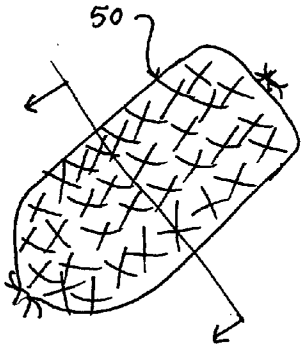


FIG. 4A

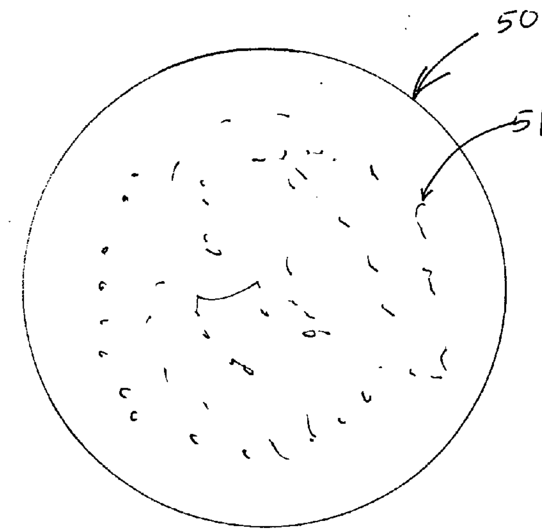


FIG. 4B

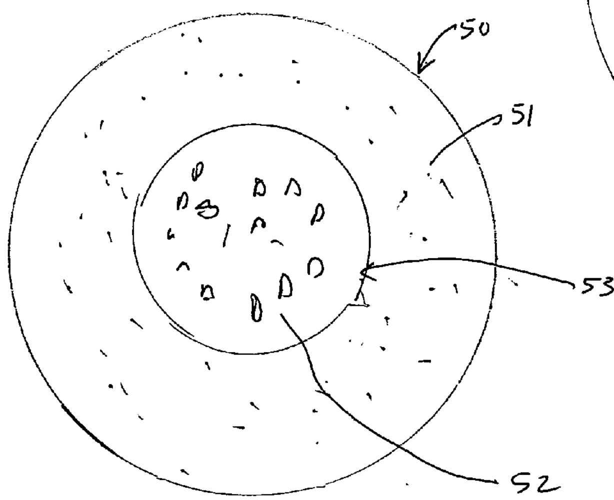


FIG. 4C

DRAIN FIELD SYSTEMS AND METHODS FOR IMPLEMENTING SAME

FIELD OF THE INVENTION

[0001] This invention relates to drain field systems in which preassembled aggregate bundles are arranged together with drainage pipes in trenches used in fields, including fields used for exfiltration or infiltration applications, and methods employing the same.

BACKGROUND OF THE INVENTION

[0002] Gravel-based drain field systems are one of the oldest and most prevalent types of liquid drainage systems. Gravel-based drain fields are constructed by placing a layer of gravel **18***a* in an excavation or trench **16** as shown, for example, in **FIGS. 1A-1B**. A drainage pipe **20**, e.g., a 4-inch diameter pipe, made from any number of well-known materials, including polyvinyl chloride (PVC) or high density polyethylene (HDPE), and containing distribution holes or perforations, is then placed on top of the gravel **18***a*. The perforated drainage pipe **20** is then covered with additional gravel **18***b*. Finally, soil or other suitable backfill **19** is placed on top of the gravel **18***b*. The popularity of gravel-based drain field systems can be attributed to their characteristics. For example, gravel-based drain field systems, such as those shown in **FIGS. 1A-1B**, have the following characteristics:

[0003] the gravel provides for underground void volume to contain and convey liquid surge events;

[0004] the gravel surrounding the drain pipe prevents soil intrusion into the void spaces due to the tortuosity of the void space path;

[0005] the gravel provides for excellent structural integrity and support of the surrounding soil as compared to non-aggregate systems, thereby insuring a relatively long useful life for the system;

[0006] liquids flow through the gravel both horizontally and vertically, insuring that both the trench sidewalls and the trench bottom are used as effective infiltrative and exfiltrative surface areas, whereas other alternative drainage systems may rely primarily on the trench bottom area only or have a limited hydraulic head which results in reduced flow through the sidewall portion of the system;

[0007] in exfiltration applications, the gravel displaces some of the volume in the trench so that each dosing event will cause a higher hydraulic pressure which in turn increases the wetted perimeter of the trench, and increases the infiltrative surface area, thereby promoting faster absorption of the media-contained liquid into the surrounding soil; and

[0008] gravel-based drainage systems typically have a higher soil interface to volume ratio than other non aggregate type drain field products such as a pipe, a multi-pipe bundle or a chamber system due to the lower porosity of the gravel. This increased soil interface to volume ratio is desirable for distribution of liquids containing organic matter such as septic tank effluent as systems having such a higher ratio allows for faster absorption of liquid over an extended period of time due to reduced rates of microbial growth in the soil.

[0009] Despite their popularity, gravel-based drain field systems suffer from significant limitations. For example, gravel systems are relatively heavy and require significant labor to be properly placed in a trench. Due to its weight, shipping heavy gravel to an installation site can be a daunting undertaking, particularly in remote locations or in locations where heavy vehicle travel is difficult. Also, due to its weight, placement of gravel in a trench requires either heavy machinery or difficult and time consuming manual labor. The heavy weight of the gravel when placed into the trench can also embed into the soil and cause compaction of the soil at the trench bottom. This compaction or embedment of the gravel into the soil at the trench bottom reduces the ability of the system to exfiltrate the effluent into the soil at the trench bottom by restricting the area of undisturbed soil available for exfiltration. Another limitation of the gravel is that it contains fines that can significantly reduce the flow rate of effluent into the soil. Even cleaned, screened, and washed gravel contains small quantities of fines. Over time, these fines settle to the bottom of the trench and increase the flow resistance of the effluent into the surrounding soils, thereby reducing the effectiveness of the system. In addition, gravel can be an expensive material and its use results in damage to the environments and in some areas, depletion of a limited resource.

[0010] The limitations of a gravel drainage system are well known and have been addressed in the marketplace with range of alternative products including chambers, pipe systems and lightweight aggregate systems. In U.S. Pat. No. 5,015,123 to Houck et al. (the '123 patent), the disclosure of which is hereby incorporated by reference, certain improvements to the design of the gravel-based drain field systems were disclosed. The '123 patent disclosed a preassembled unit for a sewage nitrification fields made of loose, lightweight plastic aggregate material enveloped and bound by a plastic sleeve with a horizontal conduit or perforated drainage pipe located within the plastic sleeve. See, for example, the abstract and **FIG. 2** of the '123 patent. These preassembled units allow for relatively easy installation in comparison to gravel drain field systems, while providing savings in machinery and labor costs related to delivery and installation.

[0011] Additional benefits provided by the use of the '123 patent include greater void volume per unit of trench foot and improved performance due to the absence of fines and no embedment of the lightweight plastic aggregate material or compaction of the soil at the trench bottom.

[0012] The disclosure of the '123 patent, however, is limited to drain field systems containing a perforated drainage pipe located entirely within the plastic sleeve, i.e., entirely within the aggregate bundle as shown in **FIG. 2** of the '123 patent. This design, while an improvement over gravel drain field systems, has significant performance limitations associated with it. For example, systems designed in accordance with the '123 patent's disclosure have less ability to store liquid below the pipe invert during peak wastewater flows and require additional drainfield to match the volume storage capacity of gravel-based drain field systems as required by state and municipal onsite rules and regulations. Systems consistent with the '123 patent's disclosure utilize only the trench perimeter below the pipe invert for the dispersal of organics, and it is this area where trench clogging materials often accumulate. This relatively small area available for the dispersal of organics and the accumulations of clogging materials shortens the life and diminishes the performance of drainfield systems. An increase in the area available for organic growth would substantially increases the life of the drainfield system by spreading the organics and the clogging material over a larger area.

[0013] An additional limitation of the '123 patent disclosure is the ability to place the conduit pipe and subsequent void channel in a desired location. For example, typically in a French drain used to dewater a foundation, the drainage pipe is placed on the bottom of the trench and in direct contact with the soil. Subsequently the gravel is placed on top of the pipe. In a septic effluent dispersal system the drain pipe is placed towards the top of the gravel in the trench. In the '123 patent, placement of the pipe to extreme top or the extreme bottom of the aggregate is prevented because the pipe is contained inside of the aggregate. The '123 patent cannot be used to place the pipe in direct contact with a soil surface associated with the trench.

[0014] Accordingly, a need existed in drain field technology for a drain field system having improved performance, namely, increased void volume per trench foot, increased void volume below the pipe invert, increased hydraulic gradient, increased wetted soil perimeter, increased media area for attached microbial growth, increased soil interface area for dispersal of organic materials, prevention or reduction of soil intrusion, and increased soil interface area to volume ratios.

SUMMARY OF THE INVENTION

[0015] In view of the limitations of conventional drain field systems, Applicant invented and discloses herein novel and non-obvious drain field systems and methods for implementing the same to overcome the limitations of gravel and '123 patented drain field systems disclosed in the '123 patent. The systems and related methods disclosed herein relate to a drain field system wherein the efficiency and effectiveness of the system is significantly improved by precise location of volume (in the form of aggregate bundles) relative to perforated drainage pipes. The location of volume relative to the drainage pipes and the trench infiltrative area has a dramatic effect on critical performance measures and regulatory acceptance of drain field systems.

[0016] The systems and related methods disclosed herein include a one or more preassembled drainage line members consisting of bundles of contained light-weight aggregate placed in the vicinity of one or more perforated drainage pipes. These preassembled bundles of contained aggregate can be of a size or length as needed for the particular application. This system represents a substantial improvement over gravel-based systems and systems as disclosed in the '123 patent in that it allows for:

[0017] increased void volume per trench foot;

[0018] increased void volume below the pipe invert;

[0019] increased hydraulic gradient;

[0020] increased wetted soil perimeter;

[0021] increased media area for attached microbial growth;

[0022] prevention or reduction of soil intrusion; and

[0023] increased soil interface area to volume ratios.

[0024] Increased dispersal of organic materials

[0025] While the enhancement of these important performance measures results in an improved drainage field system and broader regulatory acceptance, the system remains cost effective both in terms of material and labor costs. As those of skill in the art would readily appreciate, these performance measures are highly desirable in drainage field systems. The drainage industry has experienced a long felt, yet unmet need for such cost-effective drainage field systems having these improved performance measures. These improved performance measures are not, however, at the expense of other important properties of gravel and disclosed in the '123 patent (e.g., structural integrity, high resistance to soil intrusion and maximum exposure to air for treatment of liquids containing organic materials).

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Further details of the invention will now be described, by way of a non-limiting example, with reference to preferred embodiments of the invention depicted in the attached drawings in which:

[0027] **FIGS. 1A and 1B** are cross-sectional views of conventional gravel-based drain field systems.

[0028] **FIGS. 2A and 2B** are cross section view of conventional drain field systems wherein the perforated drainage pipe is located completely inside an aggregate bundle.

[0029] **FIGS. 3A-3E** are cross-sectional views of drain field systems in accordance with the present invention.

[0030] **FIGS. 4A-4C** illustrate exemplary embodiments of aggregate bundles which may be may utilized to create volume in the drain field systems in accordance with the present invention.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0031] The systems and related methods disclosed herein employ one or more contained aggregate bundles to effectively place volume in the vicinity of a drainage pipe having holes therein to allow drainage material to exit or enter the pipe, as needed depending on the application. As shown in **FIG. 4A**-B, these aggregate bundles can be made using porous sleeve **50**, such as a nylon netting or mesh that is filled with an aggregation of discrete, water impervious, crush resistant lightweight elements **51**. For example, the aggregation can be expanded polystyrene, Styrofoam or any number of other materials, including materials used in crush-resistant packing. Alternatively, as shown in **FIG. 4C**, the aggregate bundle can have multiple aggregate regions. For example, the aggregate bundle illustrated in **FIG. 4C** has an annular ring **51** with a first aggregate material, and a region containing a second aggregate material **52**. Depending on the necessary properties of the drain field system, one or more aggregate bundles is placed near a drainage pipe. The aggregate bundles in conjunction with the drainage pipe, when placed in an excavation or trench, create the drain field system.

[0032] One example of a drainage field system according to the present invention is shown in **FIG. 3A**. In this system, indicated as system N-2A, three 12-inch diameter bundles **32***a*, **32***b* and **32***c* are placed side by side on the bottom **12** of a 3-foot wide trench **16**. Two 4-inch diameter pipes **20***a* and **20***b* are then placed on top of the three aggregate bundles **32***a*, **33***b* and **32***c* as shown in **FIG. 3A**. Soil or other suitable backfill material **19** is then placed on top of the aggregate bundles **32***a*, **32***b* and **32***c* and pipes **20***a* and **20***b*. Other exemplary systems consistent with the present invention are shown in **FIGS. 3B-3E** and indicated as systems N-**1**, N-2B, N-2C, and N-**3**. While these exemplary embodiments are provided to help explain the present invention, the present invention is not limited to these exemplary embodiments.

[**0033**] Also to help better explain the present invention by way of comparison, a discussion is provided of the gravel systems shown in **FIGS. 1A-1B**, which are indicated as systems G-**1** and G-**2**, and drain field systems disclosed in the '123 patent wherein a perforated drainage pipe is disposed within a contained aggregate bundle shown in **FIGS. 2A-2B** and indicated as systems H-**1** and H-2.

[**0034**] As discussed above, gravel-based drain field systems are limited by their structure and materials, thereby hindering the creation of efficient drain field systems. As demonstrated in more detail below, the systems disclosed in the '123 patent are limited in comparison with the drainage systems of the present invention. For example, the gravel-based systems and the systems disclosed in the '123 patent have inferior void volume per trench foot, inferior void volume below the pipe invert, less hydraulic head potential, less total wetted soil perimeter below the pipe invert, less media surface area for attached microbial growth, and smaller soil interface area to volume ratios.

A. Gravel-Based Drain Field Systems

[**0035**] **FIG. 1A** illustrates a gravel drainage system (hereinafter, system G**1**), including a 4-inch diameter pipe **20** in 24-inch by 12-inch trench **16** filled with gravel **18***a* and **18***b*. To calculate various performance measures, it is necessary to know the relative dimensions of the drain field system and several calculated properties, for example, total void volume and trench area. A total void volume and trench area can be calculated according to equations 1-9, below:

VOID VOLUME CALCULATION

$$\text{Void coefficient in gravel given at 40\%} \quad [1]$$

$$O.D.\ \text{of}\ 4''\ \text{pipe} = 4.625\ \text{in} \quad [2]$$

$$\text{Void volume of pipe per linear foot} = 3.14 * \left(\frac{2.3125\ \text{in}}{12\ \text{in/ft}}\right)^2 * 1\ \text{ft} = 0.117\ \text{ft}^3 \quad [3]$$

$$\text{Void volume in gravel} = \left[\left(\frac{24\ \text{in}}{12\ \text{in/ft}} * \frac{12\ \text{in}}{12\ \text{in/ft}}\right) - \left(3.14\left(\frac{2.3125\ \text{in}}{12\ \text{in/ft}}\right)^2\right)\right] * .40 * 1\ \text{ft} = 0.753\ \text{ft}^3 \quad [4]$$

$$\text{Total void volume} - 0.117 + 0.753 = .870\ \text{ft}^3/\text{ft} \quad [5]$$

$$\text{Gallons per ft} = .870 \times 7.48 = 6.51\ \text{gallons per linear foot} \quad [6]$$

Projected Trench Area

Side (2 sidewalls)=2*12=2.0 ft^2/ft [7]

Bottom=24=2.0 ft^2/ft [8]

Total Projected Trench Area=4.0 ft^2/ft [9]

[**0036**] The void coefficient for gravel is based on the February 2002, *USEPA Onsite Wastewater Treatment Systems Manual*, Chapter 4, Section 4.3, which states that "the porous medium maintains the structure of the excavation, exposes the applied wastewater to more infiltrative surface, and provides storage space for the wastewater within its void fractions (interstitial spaces, typically 30 to 40 percent of the volume) during peak flows with gravity systems."

[**0037**] **FIG. 1B** illustrates a gravel-based drain field system (hereinafter, system G**2**), including a 4-inch diameter pipe **20** disposed in 36-inch by 12-inch trench **16** filled with gravel **18***a* and **18***b*. For system G-**2**, a total void volume and trench area can be calculated according to equations 10-18, below.

Void Volume Calculation

Void Coefficient in Gravel given at 40% [10]

O.D. of 4" pipe=4.625 in [11]

$$\text{Void volume of pipe per linear ft.} = 3.14 * \left(\frac{2.3125\text{in}}{12\text{in/ft}}\right)^2 * 1\text{ft} = 0.117\text{ft}^3 \quad [12]$$

$$\text{Void volume in gravel} = \left[\left(\frac{36\text{in}}{12\text{in/ft}} * \frac{12\text{in}}{12\text{in/ft}}\right) - \left(3.14\left(\frac{2.3125\text{in}}{12\text{in/ft}}\right)^2\right)\right] * .40 * 1\text{ft} = 1.153\text{ft}^3 \quad [13]$$

Total void volume=**0.117+1.153=1.27** ft^3/ft **[14]**

Gallons per ft=1.27×7.48=9.50 gallons per linear ft [15]

Projected Trench Area

Sides=2*12 inches=2.0 ft^2/ft [16]

Bottom=36 inches=3.0 ft^2/ft [17]

Total Projected Trench Area=5.0 ft^2/ft [18]

[**0038**] As will be demonstrated in TABLES 1-7, below, the gravel-based drain field systems are inferior to the systems of the present invention when measured by such performance factors as void volume per trench foot, void volume below the pipe invert, hydraulic gradient, wetted soil perimeter below the pipe invert, media area for attached microbial growth, ability to prevent or reduce of soil intrusion, and soil interface area to volume ratios.

B. Conventional Drain Field Systems with Aggregate Bundles Containing a Perforated Drainage Pipe

[**0039**] **FIG. 2A** illustrates a cross-section of a drain field system disclosed in the '123 patent (hereinafter, system H-**1**) wherein a perforated drainage pipe **20** is located entirely within an aggregate bundle **30***b*. Two aggregate bundles **30***a* and **30***c* are disposed on either side of aggregate bundle **30***b*. All three aggregate bundles **30***a*, **30***b* and **30***c* rest on the floor **12** of trench **16**. Aggregate bundles **30***c* and **30***a* are in contact with the sidewalls **14** and **10** of the trench **16**, respectively. Aggregate bundle **30***b* is on contact with aggregate bundles **30**_c_ and **30**_a_ on either side. The void volume and trench area for this system can be calculated according to equations 19-32, below.

[0040] The void coefficient in the aggregate is based upon testing of EZflow™ beads under ASTM standards C29-91a and C127-88 by Law Engineering, project No. 50161-8-2142-01-831. The void coefficient of the EZflow™ bead under no load conditions was an average of 57.4%.

VOID VOLUME

$$\text{Void coefficient in aggregate given at } 57.4\% \quad [19]$$

$$O.D.\ \text{of } 4'' \text{ pipe} = 4.625 \text{ in} \quad [20]$$

$$\text{Void volume per linear foot} = 3.14 * \left(\frac{2.3125 \text{ in}}{12 \text{ in/ft}}\right)^2 * 1 \text{ ft} = 0.117 \text{ ft}^3 \quad [21]$$

$$O.D.\ \text{of center cylinder} = 12.5\text{in} \quad [22]$$

$$\text{Void volume in aggregate of center cylinder} = \left(3.14 * \left(\frac{6.25 \text{ in}}{12 \text{ in/ft}}\right)^2 - 3.14 * \left(\frac{2.3125 \text{ in}}{12 \text{ in/ft}}\right)^2\right) * .574 = .422 \text{ ft}^3 \quad [23]$$

$$O.D.\ \text{of outside cylinders} = 12 \text{ in} \quad [24]$$

$$\text{Void volume in outside cylinders} = 2 * 3.14\left(\frac{6 \text{ in}}{12 \text{ in/ft}}\right)^2 * .574 = .901 \text{ ft}^3 \quad [25]$$

$$\text{Void volume at bottom between cylinders} = \left[\left(\frac{24 \text{ in}}{12 \text{ in/ft}} * \frac{6 \text{ in}}{12 \text{ in/ft}}\right) - \left(3.14\left(\frac{6 \text{ in}}{12 \text{ in/ft}}\right)^2\right)\right] = 0.215 \text{ ft}^3 \quad [26]$$

$$\text{Void volume at outside bottom corners } \left(\frac{1}{2} \text{ of void volume between cylinders}\right) = 0.215/2 = 0.108 \text{ ft}^3 \quad [27]$$

$$\text{Total void volume} = 0.117 + 0.422 + 0.901 + 0.215 + 0.108 = 1.763 \text{ ft}^3/\text{ft} \quad [28]$$

$$\text{Gallons per foot} = 1.763 \times 7.48 = 13.2 \text{ gallons per linear ft} \quad [29]$$

Projected Trench Area

Sides (2 Sidewalls)=2*12 in=2.0 ft^2/ft [30]

Bottom=36 inches=3.0 ft^2/ft [31]

Total Projected Trench Area=5.0 ft^2/ft [32]

[0041] **FIG. 2B** illustrates a cross-section of a drain field system disclosed in the '123 patent (hereinafter, system H-**2**) wherein a perforated drainage pipe **20** is located within an aggregate bundle **30**_d_. A second aggregate bundle **30**_a_ is disposed next to aggregate bundle **30**_d_. Both aggregate bundles rest on the bottom surface **12** of the trench **16** and are in contact with the respective sidewalls **14** and **10** of trench **16**. The void volume and trench area for this system can be calculated according to equations 33-46, below.

VOID VOULME CALCULATION

$$\text{Void coefficient in aggregate given at } 57.4\% \quad [33]$$

-continued

$$O.D.\ \text{of } 4'' \text{pipe} = 4.625 \text{ inches} \quad [34]$$

$$\text{Void volume per linear ft.} = 3.14 * \left(\frac{2.3125 \text{ in}}{12 \text{ in/ft}}\right)^2 * 1\text{ft} = 0.117 \text{ ft}^2 \quad [35]$$

$$O.D.\ \text{of cylinder with pipe} = 12.5 \text{ in} \quad [36]$$

$$\text{Void volume in aggregate of cylinder} = \left(3.14 * \left(\frac{6.25 \text{ in}}{12 \text{ in/ft}}\right)^2 - 3.14 * \left(\frac{2.3125 \text{ in}}{12 \text{ in/ft}}\right)^2\right) * .574 = 0.422 \text{ ft}^2 \quad [37]$$

$$O.D.\ \text{of cylinder without pipe} = 12 \text{ in} \quad [38]$$

$$\text{Void volume in aggregate of cylinder} = 3.14\left(\frac{6 \text{ in}}{12 \text{ in/ft}}\right)^2 * .574 = 0.451 \text{ ft}^3/\text{ft} \quad [39]$$

$$\text{Void volume at bottom between cylinders} = \left[\left(\frac{12 \text{ in}}{12 \text{ in/ft}} * \frac{6 \text{ in}}{12 \text{ in/ft}}\right) - \left(3.14\left(\frac{6 \text{ in}}{12 \text{ in/ft}}\right)^2 * \frac{1}{2}\right)\right] = 0.108 \text{ ft}^2 \quad [40]$$

$$\text{Void volume at outside bottom corners (same as void volume between cylinders)} = 0.108 \text{ ft}^2 \quad [41]$$

$$\text{Total void volume} = 0.117 + 0.422 + 0.451 + 0.108 + 0.108 = 1.2 \text{ ft}^3/\text{ft} \quad [42]$$

$$\text{Gallons per ft} = 1.2 \times 7.48 = 9.02 \text{ gallons per linear ft} \quad [43]$$

Projected Trench Area

Sides (2 sidewalls)=2*12 inches=2.0 ft^2/ft [44]

Bottom=24 inches=2.0 ft^2/ft [45]

Total Projected Trench Area=4.0 ft^2/ft [46]

C. Exemplary Embodiments of the Present Invention

[0042] **FIG. 3A** illustrates yet another exemplary embodiment of a drainage system (hereinafter, RING system N-**2**A) in accordance with the present invention. In system N-**2**A, a first perforated drainage pipe **20**_a_ is disposed between and on top of a first aggregate bundle **32**_a_ and a second aggregate bundle **32**_b_. A second drainage pipe **20**_b_ is disposed between and on top of a second aggregate bundle **32**_b_ and a third aggregate bundle **32**_c_. All three aggregate bundles rest on the floor **12** of trench **16**. For this system, a void volume and a projected trench area can be calculated according to equations 47-58, below.

Void Volume

Void coefficient in aggregate given at 57.4% [47]

O.D. of 4" Pipe—4.625 in [48]

$$\text{Void Volume per linear ft.} = 2 * 3.14 * \left(\frac{2.3125 \text{ in}}{12 \text{ in/ft}}\right)^2 * 1\text{ft} = 0.233 \text{ ft}^3 \quad [49]$$

$$O.D.\ \text{of Aggregate Bundles} = 12 \text{ in} \quad [50]$$

-continued

Void Volume in Aggregate Bundles = [51]

$$3*3.14*\left(\frac{6.00\text{ in}}{12\text{ in/ft}}\right)^2*0.574=1.352\text{ ft}^3$$

Void Volume Between Aggregate Bundles & Pipes= **0.035** ft^3 (Determined by CAD Software). **[52]**

Void Volume at Bottom=0.323 ft^3 [53]

Total Void Volume=0.233+1.352+0.035+0.323=1.943 ft^3/ft [54]

Gallons per Trench Foot=1.943×7.48=14.53 [55]

Projected Trench Area

Sides (2 Sidewalls)=2*12 in=**2.0** ft^2/ft [56]

Bottom=**36** in =**3.0** ft^2/ft [57]

Total Projected Trench Area=5.0 ft^2/ft [58]

[0043] **FIG. 3B** illustrates still another exemplary embodiment of a drainage system (hereinafter, system N-**1**) consistent with the present invention. In system N-**1**, four 4-inch diameter drainage pipes **20***c*, **20***d*, **20***e* and **20***f* are stacked between two aggregate bundles **32***d* and **32***e*. Drainage pipes **20***e* and **20***f* are located on the trench floor **12** and drainage pipes **20***c* and **20***d* are stacked on top of drainage pipes **20***f* and **20***e*, respectively. In system N-**1**, a void volume and a projected trench area can be calculated according to equations 59-71, below.

Void Volume

Void coefficient in aggregate given at 57.4% [59]

O.D. of 4" Pipe=4.625 inches [60]

$$\text{Void Volume per linear ft.}=4*3.14*\left(\frac{2.3125\text{ in}}{12\text{in/ft}}\right)^2*1\text{ft}=0.467\text{ft}^3 \quad [61]$$

$$O.D.\text{ of Aggregate Bundles}=13\text{ in} \quad [62]$$

Void Volume in Aggregate Bundles = [63]

$$2*3.14*\left(\frac{6.50\text{ in}}{12\text{ in/ft}}\right)^2*0.574=1.058\text{ ft}^3$$

Void Volume Between Aggregate Bundles & Pipe= **0.170** ft^3 (As Determined by CAD Software). **[64]**

Void Volume at Bottom Corner=0.063 ft^3 [65]

Void Volume Between 4-inch Pipes=6*0.008=0.048 ft^3 [66]

Total Void Volume=0.467+1.058+0.170+0.063+0.048=1.806 ft^3/ft [67]

Gallons per Trench Foot=1.806×7.48=13.51 [68]

Projected Trench Area

Sides (2 sidewalls)=2*13 in=2.167 ft^2/ft [69]

Bottom=**36** in=3.0 ft^2/ft [70]

Total Projected Trench Area=5.17 ft^2/ft [71]

[0044] **FIG. 3C** illustrates one exemplary embodiment of a drainage system (hereinafter, system N-**2**B) in accordance with the present invention. In system N-**2**B, a 4-inch diameter perforated drainage pipe **20***a* is disposed between and on top of two aggregate bundles **32***a* and **32***b*. A third aggregate bundle **32***c* is disposed to one side of aggregate bundle **32***b*. All three aggregate bundles **32***a*, **32***b*, and **32***c* rest on the floor **12** of the trench **16** For this system, a void volume and a projected trench area can be calculated according to equations 72-83, below.

Void Volume

Void Coefficient in Aggregate given at 57.4% [72]

O.D. of 4" Pipe=4.625 inches [73]

$$\text{Void Volume per linear ft.}=3.14*\left(\frac{2.3125\text{ in}}{12\text{in/ft}}\right)^2*1\text{ft}=0.117\text{ ft}^3 \quad [74]$$

$$O.D.\text{ of Aggregate Bundles}=12\text{ in} \quad [75]$$

Void Volume in Aggregate Bundles = [76]

$$3*3.14*\left(\frac{6.00\text{ in}}{12\text{ in/ft}}\right)^2*0.574=1.352\text{ft}^3$$

Void Volume Between Aggregate Bundles & Pipes= **0.018** ft^3 (As Determined by CAD Software). **[77]**

Void Volume at Bottom=0.323 ft^2 [78]

Total Void Volume=0.117+1.352+0.018+0.323=1.810 ft^3/ft [79]

Gallons per Trench Foot=1.810×7.48=13.54 [80]

Projected Trench Area

Sides (2 sidewalls)=2*12 in=2.0 ft^2/ft [81]

Bottom=36 inches=3.0 ft^2/ft [82]

Total Projected Trench Area=5.0 ft^2/ft [83]

[0045] **FIG. 3D** illustrates another exemplary embodiment of a drain filed system (hereinafter, system N-**2**-C) in accordance with the present invention. In system N-**2**C, a 4-inch diameter pipe **20***g* is disposed between and on top of two aggregate bundles **32***g* and **32***f*. For this system, a void volume and a projected trench area can be calculated according to equations 84-95, below.

Void Volume

Void Coefficient in Aggregate given at 57.4% [84]

O.D. of 4" pipe=4.625 in [85]

$$\text{Void Volume per linear ft.}=3.14*\left(\frac{2.3125\text{ in}}{12\text{ in/ft}}\right)^2*1\text{ft}=0.117\text{ ft}^3 \quad [86]$$

$$O.D.\text{ of Aggregate Bundles}=12\text{ in} \quad [87]$$

Void Volume in Aggregate Bundles = [88]

$$2*3.14*\left(\frac{6.00\text{ in}}{12\text{ in/ft}}\right)^2*0.574=0.902\text{ ft}^3$$

Void Volume Between Aggregate Bundles & Pipes= **0.018** ft^3. (As Determined by CAD Software). **[89]**

Void Volume at Bottom=0.216 ft^3. [90]

Total Void Volume=0.117+0.902+0.018+0.216=1.253 ft^3/ft [91]

Gallons per Trench Foot=1.253×7.48=9.37 [92]

Projected Trench Area

Sides=2 Sidewalls=2*12 inches=2.0 ft^2/ft [93]

Bottom=24 inches=2.0 ft^2/ft [94]

Total Projected Trench Area=4.0 ft^2/ft [95]

[0046] **FIG. 3E** illustrates one exemplary embodiment of a drain field system (hereinafter, system N-**3**) in accordance with the present invention. In system N-**3**, a 12-inch diameter pipe **22** is disposed between two aggregate bundles **32***h* and **32***i*. In this system, the perforated drainage pipe **22** has substantially the same outside diameter as the aggregate bundles **32***h* and **32***i*. For this system, a void volume and a projected trench area can be calculated according to equations 96-104, below.

Void Volume Calculation

Void Coefficient in Aggregate given at 57.4% [96]

O.D. of 10" pipe=12" [96]

$$\text{Void volume of pipe per linear ft} = 3.14*\left(\frac{5.50\text{ in}}{12\text{ in/ft}}\right)^2*1\text{ft} = 0.660\text{ ft}^3 \quad [97]$$

$$\text{Void volume in aggregate bundles} = 2*3.14*\left(\frac{6.00\text{ in}}{12\text{ in/ft}}\right)^2*0.574 = 0.902\text{ ft}^3 \quad [98]$$

$$\text{Void volume at between bundles} = 6*\left[\left(\frac{6.0\text{ in}}{12\text{ in/ft}}*\frac{6.0\text{ in}}{12\text{ in/ft}}\right)-\left(3.14\left(\frac{6.0\text{ in}}{12\text{ in/ft}}\right)^2*\frac{1}{4}\right)\right] = 0.322\text{ ft}^3 \quad [99]$$

Total void volume=**0.660+0.902+0.321=1.883** ft^3/ft**[100]**

Gallons per ft=1.883×7.48=14.08 gallons per linear ft [101]

Projected Trench Area

Sides (2 sidewalls)=2*12 in=2.0 ft^2/ft [102]

Bottom=36 inches=3.0 ft^2/ft [103]

Total Projected Trench Area=5.0 ft^2/ft [104]

[0047] As can be seen from the above equations and as will be described in greater detail below by reference to the exemplary embodiments of the present invention (in comparison to comparably-sized gravel drain field systems), key performance measures for drain field systems in accordance with the present invention are greatly improved.

1. Increased Void Volume Per Trench Foot

[0048] Void volume per trench foot is one measure of drain field performance relied upon by those of skill in the art to determine the efficiency of a drain field system. Gravel-based drainage systems, such as systems G-**1** or G-**2**, have void volume per trench foot equal to approximately 6 gallons per trench foot in a two foot wide trench and 9 gallons per foot in a 3 foot wide trench. Storage volume (i.e., void volume) is needed to accommodate peak flows into the drainfield and to temporarily store the liquid that accumulates during the peak flow, allowing time for the liquid to infiltrate into the soil. Storage volume per trench foot requirements are sometimes imposed by some state and municipal onsite rules and regulations.

[0049] This low void volume per trench foot values of the gravel-based drain field systems are a result of the lower porosity of the aggregate. While systems as disclosed in the '123 patent, such as systems H-**1** and H-**2**, result in an increased void volume per trench foot ratio, this measure still is significantly less than that of the exemplary embodiments of the present invention, namely systems N-**1**, N-**2**B, N-**2**C, and N-**3**.

[0050] Gravel aggregate void volumes can typically be in the range of 30-40% with a commonly accepted average of 35%. A table of void volume per trench foot for the above described exemplary embodiments of the present invention and comparable gravel drain field systems is shown below:

TABLE 1

SYSTEM	VOLUME (gal.)/TRENCH FOOT
	3-foot Trench Width
N-2A	14.53
N-3	14.08
N-2B	13.54
N-1	13.51
H-1	13.20
G-2	9.50
	2-foot Trench Width
N-2C	9.37
H-2	9.02
G-1	6.51

[0051] As shown in TABLE 1, the exemplary embodiments of the present invention result in a greater void volume per trench foot than conventional systems. For example, system N-**2**A results in a 52.9% increase over a comparable gravel-based drain field system, system G-**2**. In comparison to system H-**1**, system N-**1** results in a 2.3% increase over system H-**1** whereas system N-**2**A results in a 10.0% increase in comparison to the same system. Void volume per trench foot ratios obtained in systems N-**1**, N-**2**A-C and N-**3** could not be achieved in a conventional system wherein the drainage pipes are completely contained within an aggregate bundle as in systems H-**1** and H-**2**, for example. In a system having dimensionally similar measurements to gravel trenches, preferred embodiments consistent with the present invention provide a percent increase in volume per trench foot of at least 10%. A 10% increase represents a substantial improvement over volumes per trench foot achieved using gravel-based systems and systems as disclosed in the '123 patent.

2. Increased Volume Below the Pipe Invert

[0052] When used in septic applications, some state environmental regulations determine system size based on volume below the pipe invert. In accordance with many state and municipal onsite rules and regulations, the more storage volume below the invert allows for a shorter installed trench length. This shorter trench length allows for system installation on smaller lot sizes, which in turn saves the homeowner and the installer time and money. Placing the pipe outside of the aggregate bundles as in systems N-**2**A, N-**2**B, and N-**2**C dramatically increases volume below the pipe invert in comparison to comparable conventional systems. For example, for a 3-foot wide trench, system N-**2**A results in an increase of 49.4% increase in volume below the pipe invert over system H-**1** and a 147.66% increase over system G-**2**. In a system having dimensionally similar measurements to gravel trenches, preferred embodiments consistent with the present invention provide a percent increase in volume below the pipe invert of at least 25%. A 25%

increase represents a substantial improvement over volumes below the pipe invert achieved using gravel-based systems and systems as disclosed in the '123 patent.

TABLE 2

SYSTEM	VOLUME (Gal) BELOW THE PIPE INVERT
	3-foot Trench Width
N-2A	11.12
N-2B	10.98
H-1	7.35
G-2	4.49
	2-foot Trench Width
N-2C	7.49
H-2	4.87
G-1	2.99

3. Increased Pressure Head With Increased Volume

[0053] Placing drainage pipes in the vicinity of aggregate bundles as disclosed herein, as opposed to in a gravel-filled trench or inside aggregate bundles results in increasing volume and pressure head, the pressure head being defined as the water level above the soil and below the invert of the drainage pipe. In a septic drainfield, the presence of an aggregate displaces a volume of liquid to a greater height, while utilizing more surface area, than non-aggregate systems with the same quantity of liquid introduced into the drainfield. The height of the displaced liquid creates a pressure head, which, because of the pressure, forces the liquid into the surrounding soil at a greater rate.

[0054] TABLE 3, below, illustrates the increase in pressure head for systems in accordance with the present invention in comparison to comparable gravel-based drain field systems and systems disclosed in the '123 patent.

TABLE 3

SYSTEM	PRESSURE HEAD (in.)
	3-foot Trench Width
N-2A	8.0
N-2B	8.0
H-1	6.0
G-2	6.0
	2-foot Trench Width
N-2C	8.0
H-2	6.0
G-1	6.0

[0055] In the examples given above, the pressure head below the invert for a 3-foot wide system increases for systems N-**2**A and N-**2**B 33% over the pressure head for either system H-**1** or G-**2**. Similar results are obtained for a 2-foot wide trench.

4. Increased Wetted Soil Perimeter Below the Pipe Invert

[0056] Another key metric for evaluating the performance of a drain field system is the wetted soil perimeter below the pipe invert. In drainfields systems, an increased wetted soil perimeter below the pipe invert is desirable as it allows for a larger area for the dispersal of organics, and less trench clogging material per unit area. This increase in the area available for organic growth increases the life of the drainfield system substantially by spreading the organics and the clogging material over a larger area, and lessens the organic loading rate per unit area. Gravel-based drain field systems and systems as disclosed in the '123 patent have a reduced wetted soil perimeter in comparison to comparable systems embodying the present invention. By locating drainage pipe(s) on the top of aggregate bundles, the wetted soil perimeter below the pipe invert is increased, resulting in enhanced drainage characteristics.

[0057] For example, as shown in TABLE 4, for a 3-foot wide trench, systems H-**1** and G-**2** have a wetted soil perimeter below the pipe invert of 4 feet, whereas systems N-**2**A and N-**2**B each have a wetted soil perimeter below the pipe invert of 4.33 feet, an 8.25% increase over the conventional systems. For a 2-foot wide trench, system N-**2**C results in an 11.0% increase over the wetted soil perimeter below the pipe invert for comparable conventional systems H-**2** and G-**1**. This substantial increase in wetted soil perimeter below the pipe invert greatly enhances drainage characteristics of drain field systems.

TABLE 4

SYSTEM	WETTED SOIL PERIMETER BELOW THE PIPE INVERT (ft)
	3-foot Trench Width
N-2A	4.33
N-2B	4.33
H-1	4.00
G-2	4.00
	2-foot Trench Width
N-2C	3.33
H-2	3.00
G-1	3.00

5. Increased Media Surface Area for Attached Microbial Growth

[0058] Placement of liquid distribution pipes on the top of contained aggregate bundles allows for the use of the media as an attachment site for bacteria (which treat liquids containing organic matter) to grow. As shown below in TABLE 5, for a 3-foot wide and a 2-foot wide trench, the increase in media surface area below the pipe invert per trench foot is increase by 20% and 25% respectively. This substantial increase significantly improves that ability of bacteria to grow, thereby having a parallel impact on the ability of those bacteria to treat liquids containing organic matter.

TABLE 5

SYSTEM	MEDIA SURFACE AREA (ft^2) BELOW THE PIPE INVERT PER TRENCH FOOT
	3-foot Trench Width
N-2A	60
N-2B	60
H-1	50
	2-foot Trench Width
N-2C	40
H-2	32

6. Prevention or Reduction of Soil Intrusion into High-Volume Systems

[0059] Drainage products such as pipes, multiple pipes or chamber systems require protection from soil intrusion into the system's open space. This protection is generally provided in one of two ways: a pipe system has a fabric or geo-textile wrap used to cover system openings, and chamber systems employ a louver with an angle of repose and/or fabric. Placement of aggregate bundles alongside pipes eliminates the need for a geo-textile wrap, thereby reducing material and labor costs. Placement of aggregate bundles alongside a chamber system side wall also greatly improves the chamber system's resistance to soil intrusion.

7. Improved Oxygen Diffusivity for High-Volume Systems

[0060] High volume systems such as pipe system or chamber system provide relatively little open exposure of liquid to the soil. This is especially true for sidewalls. Open exposure is important in biologically-active systems, e.g., septic drainfields, where oxygen is used to treat organic matter, and is related to soil content area. Use of systems embodying the present invention in conjunction with a pipe system allows for an increase in volume and an increase in soil exposure at the sidewall and surface interface areas.

TABLE 6

SYSTEM	VOLUME BELOW INVERT (gal/ft)	SOIL EXPOSURE (ft)
G-1	2.99	3.00
H-2	4.87	3.00
N-2C	7.49	3.33
G-2	4.49	4.00
H-1	7.35	4.00
N-2A	11.12	4.33
N-2B	10.98	4.33

8. Volume Placement

[0061] The use of contained aggregate bundles in a drain field system as disclosed herein enables volume to be easily and efficiently added at the desired location within the drain field. In drain field systems, volume per se does not necessarily enhance the performance of the system—the volume must be appropriately located. For example, in conventional system H-**1**, to add volume under the invert of pipe **20**, a larger aggregate bundle can be used or an additional aggregate bundle can be used. A larger aggregate bundler results in wasted material as the aggregate above the pipe not efficiently used and is, therefore, wasted. An additional aggregate bundle results in additional and unneeded material and labor costs. However, as illustrated in FIGS. **3**B-D, exemplary embodiments of the present invention allow for efficient utilization of volume by allowing for volume placement where it is most effective—under the pipe invert—without creating excessive wasted volume above the pipe invert and without the use of multiple contained aggregate bundles.

9. Increased Soil Interface to Volume Ratio for High-Volume Systems

[0062] Gravel-based drain field systems and systems as disclosed in the '123 patent typically have a higher soil interface area per unit volume ratio than non aggregate type drain field products such as a pipe, multiple pipe or chamber systems. This higher soil interface area to volume ratio is due to the lower porosity of the aggregate. Gravel volumes can be typically in the range of 25 to 50% with a commonly accepted average of 35%. A table of soil interface area to volume ratios for various drainage systems is given below.

TABLE 7

SYSTEM	WIDTH (ft)	SOIL INTERFACE AREA TO VOLUME RATIO
N-2A	3	2.907
N-3	3	2.817
N-2B	3	2.710
H-1	3	2.640
N-2C	2	2.343
H-2	2	2.255
G-2	3	1.901
G-1	2	1.628

[0063] As evident from TABLE 7. the drain field systems in accordance with the present invention have significantly better soil interface area to volume ratios over the conventional systems. Higher soil interface area to volume ratios, such as those provided by the systems of the present invention, are desirable as they allow a drainfield system to be sized and installed with a higher organic loading rate per trench foot, and thus a trench length reduction compared to conventional gravel-based systems. This is because systems consistent with the invention disclosed herein utilize the higher soil interface area and the increased pressure head to move the liquid out of the drainfield and into the soil at a faster rate. The use of a higher soil interface area increases the lifespan of the system per trench foot installed. The system also contains enough storage capacity to handle peak flows when sized at a higher organic loading rate.

[0064] The above description of exemplary embodiments has been given by way of example. From the disclosure given, those skilled in the art will not only understand the present invention and its attendant advantages, but will also find apparent various changes and modifications to the structures and methods disclosed. It is sought, therefore, to cover all such changes and modifications as fall within the spirit and scope of the invention, as defined by the appended claims, and equivalents thereof.

What is claimed is:

1. A drain field system comprising,

a trench having a first sidewall, a second sidewall, and a floor;

at least one perforated drainage pipe; and

at least one contained aggregate bundle,

wherein the at least one perforated drainage is pipe placed in the vicinity of and outside of the at least one aggregate bundle.

2. The drain field system according to claim 1,

wherein a first one of the at least one contained aggregate bundle is disposed on the floor of the trench and is in contact with the first sidewall of the trench,

wherein a second one of the at least one contained aggregate bundle is disposed on the floor of the trench and is in contact with the first one of the at least one contained aggregate bundle, and

wherein a first one of the at least one perforated drainage pipe is disposed on the first and second ones of the at least one contained aggregate bundle at a location above the point where the second one of the at least one contained aggregate bundle is in contact with the first one of the at least one contained aggregate bundle.

3. The drain field system according to claim 2, wherein the second one of the at least one aggregate bundle is in contact with the second sidewall of the trench.

4. The drain field system according to claim 2, wherein a third one of the at least one contained aggregate bundle is disposed on the floor of the trench and is in contact with the second one of the at least one contained aggregate bundles.

5. The drain field system according to claim 4, wherein the third one of the at least one contained aggregate bundle is in contact with the second sidewall of the trench.

6. The drain field system according to claim 5, wherein a second one of the at least one perforated drainage pipe is disposed on the second and third ones of the at least one contained aggregate bundle at a location above the point where the third one of the at least one contained aggregate bundle is in contact with the second one of the at least one contained aggregate bundle.

7. The drain field system according to claim 1,

wherein a first one of the at least one contained aggregate bundle is disposed on the floor of the trench, and

wherein a first one of the at least one perforated drainage pipe is located on the floor of the trench and is in contact with the first one of the at least one contained aggregate bundle.

8. The drain field system according to claim 7, wherein the first one of the at least one contained aggregate bundle is in contact with the first sidewall of the trench.

9. The drain field system according to claim 8, wherein a second one of the at least one contained aggregate bundle is disposed on the floor of the trench and is in contact with the first one of the at least one perforated drainage pipe.

10. The drain field system according to claim 9, wherein the second one of the at least one contained aggregate bundle is in contact with the second sidewall of the trench.

11. The drain field system according to claim 10, wherein the first one of the at least one perforated drainage pipe has approximately the same diameter as the first and second ones of the at least one contained aggregate bundle.

12. The drain field system according to claim 7, wherein a second one of the at least one perforated drainage pipe is disposed on the floor of the trench and is in contact with the first one of the at least one drainage pipe.

13. The drain field system according to clam **12**, wherein a second one of the at least one contained aggregate bundle is disposed on the floor of the trench and is on contact with the second one of the at least one perforated drainage pipe.

14. The drain field system according to claim 13,

wherein a third one of the at least one perforated drainage pipe is disposed above and in contact with the first one of the at least one perforated drainage pipe, and is in contact with the first one of the at least one contained aggregate bundle, and

wherein a fourth one of the at least one perforated drainage pipe is disposed above and in contact with the second one of the at least one perforated drainage pipe, and is in contact with the second one of the at least one contained aggregate bundle.

15. The drain field system according to claim 1, wherein each of the at least one contained aggregate bundles comprises:

a plurality of lightweight aggregates; and

a porous sleeve.

16. The drain field system according to claim 15, wherein the plurality of lightweight aggregate is comprised of at least one of expanded polystyrene and Styrofoam.

17. The drain field system according to claim 16, wherein the plurality of lightweight aggregates comprise a first annular area containing a first aggregate material and a second circular area within the first annular area containing a second aggregate material.

18. The drain field system according to claim 17, wherein the first aggregate material is expanded polystyrene and the second aggregate material is rubber chips.

19. The drain field system according to claim 1, wherein drainfields having dimensionally similar characteristics to conventional gravel trenches provide a percent increase in volume per trench foot of at least 5%.

20. The drain field system according to claim 1, wherein drainfields having dimensionally similar characteristics to conventional gravel trenches provide a percent increase in volume below the pipe invert of at least 5%.

21. A method of installing a drain field comprising:

excavating a trench,

placing at least one contained aggregate bundle on the floor of the trench, and

placing at least one perforated drainage pipe on top of the at least one contained aggregate bundle.

22. The method according to claim 21, wherein:

a first one of said at least one contained aggregate bundle is placed on the floor of the trench in proximity to a first sidewall of the trench,

a second one of said at least one contained aggregate bundle is placed on the floor of the trench in proximity to a second sidewall of the trench,

the first and second ones of said at least one contained aggregate bundle contact one another

a first one of the at least one perforated drainage pipe is placed on top of and in between the first and second ones of said contained aggregate bundles.

23. The method according to claim 21, wherein:

a first one of said at least one contained aggregate bundle is placed on the floor of the trench in proximity to a first sidewall of the trench,

a second one of said at least one contained aggregate bundle is placed on the floor of the trench in proximity to a second sidewall of the trench,

a first one of the at least one perforated drainage pipe is placed on the floor of the trench between the first and second ones of said at least one contained aggregate bundle.

24. A method of installing and operating a drain field, the method comprising:

placing at least one contained aggregate bundle in a trench;

placing at least one perforated drainage pipe over the at least one contained aggregate bundle;

running organic matter through the perforated drainage pipe to allow the organic matter to penetrate the at least one contained aggregate bundle,

wherein the contained aggregate bundle is used to disperse organic material over the aggregate, and

wherein aggregate contained in the at least one contained aggregate bundle is used to provide surface area for attached microbial growth and subsequent treatment and breakdown of the organic material.

25. The method according to claim 24 wherein the perforated drainage pipe is placed in direct contact with a soil interface of the trench.

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