Chapter 8 – Infiltration Trench

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8.1 Overview of Practice

Infiltration trenches are shallow trenches equipped with an underground reservoir comprised of coarse stone aggregate. The void space created by the aggregate provides storage for surface runoff that has been diverted into the trench. This runoff then infiltrates into the surrounding soil, through the bottom and sides of the trench.

Infiltration trenches act primarily as water quality BMPs; however, when equipped with underground piping, the temporary storage volume of the trench may be increased to a volume that provides peak runoff rate reduction for the one and two year return frequency storms. Peak rate control of the 10-year and greater storm events is typically beyond the capacity of an infiltration practice.

8.2 Site Constraints and Siting of the Facility

The designer must consider a number of site constraints in addition to the contributing drainage area's impervious cover when an infiltration trench is proposed. These constraints are discussed as follows.

8.2.1 Minimum Drainage Area

The minimum drainage area contributing to an infiltration trench is not restricted. Infiltration trenches are particularly well suited to small drainage areas.

8.2.2 Maximum Drainage Area

The maximum drainage area to a single infiltration trench should be restricted to no more than five acres. Multiple trenches may be employed to receive runoff from larger drainage areas; however, when considering required trench maintenance, the implementation of multiple infiltration trenches is often undesirable.

8.2.3 Site Slopes

Infiltration trenches are suitable for installation on sites exhibiting slopes generally less than 20 percent. Infiltration trenches should be located a minimum of 50 feet away from any slope steeper than 15 percent. When site slopes exceed 20 percent, alternative BMP measures should be considered.

8.2.4 Site Soils

The soil infiltration rate is a critical design element of an infiltration trench. When such a facility is proposed, *a subsurface analysis and permeability test is required*. The required subsurface analysis should investigate soil characteristics to a depth of no less than three feet below the proposed bottom of the stone trench. Data from the subsurface investigation should be provided to the Materials Division early in the project planning stages to evaluate the feasibility of such a facility on native site soils.

The soil's infiltration rate should be measured when the soil is in a saturated condition. Soil infiltration rates which are deemed acceptable for infiltration trenches range between *0.52 and 8.27 inches per hour* (DCR, 1999, Et Seq.). Infiltration rates falling within this range are typically exhibited by soils categorized as loam, sandy loam, and loamy sand.

Soils exhibiting a clay content of greater than 30 percent are unacceptable for infiltration facilities. Similarly, soils exhibiting extremely high infiltration rates, such as sand, should also be avoided. Table 8.1 presents typical infiltration rates observed for a variety of soil types. This table is provided as a reference only, and does not replace the need for a detailed site soil survey.

Texture Class	Effective Water Capacity (C_w) (inch per inch)	Minimum Infiltration Rate (*f*) (inch per hour)	Hydrologic Soil Grouping
Sand	0.35	8.27	A
Loamy Sand	0.31	2.41	A
Sandy Loam	0.25	1.02	B
Loam	0.19	0.52	B
Silt Loam	0.17	0.27	C
Sandy Clay Loam	0.14	0.17	C
Clay Loam	0.14	0.09	D
Silty Clay Loam	0.11	0.06	D
Sandy Clay	0.09	0.05	D
Silty Clay	0.09	0.04	D
Clay	0.08	0.02	D

Table 8.1. Hydrologic Soil Properties Classified by Soil Texture
Source: (Virginia Stormwater Management Handbook, 1999)

8.2.5 Depth to Water Table

Infiltration trenches should not be installed on sites with a high groundwater table. Inadequate separation between the trench bottom and the surface of the water table may result in contamination of the water table. This potential contamination arises from the inability of the soil surrounding the trench to filter pollutants prior to their entrance into the water table. Additionally, a high water table can flood an infiltration trench and render it inoperable during periods of high precipitation and/or runoff. A separation distance of no less than two feet is required between the bottom of an infiltration trench and the surface of the *seasonally* high water table. Unique site conditions may arise which require an even greater separation distance. The separation distance provided should allow the trench to empty completely within a maximum of 48 hours following a runoff producing event.

8.2.6 Separation Distances

Infiltration trenches should be located at least 20 feet down-slope and at least 100 feet up-slope from building foundations. Infiltration trenches should not be located within 100 feet of any water supply well. Local health officials should be consulted when the implementation of an infiltration trench is proposed within the vicinity of a septic drainfield.

8.2.7 Bedrock

A minimum of two feet of separation is required between the bottom of an infiltration trench and bedrock, with four feet or greater recommended.

8.2.8 Placement on Fill Material

Infiltration trenches should not be constructed on or nearby fill sections due to the possibility of creating an unstable subgrade. Fill areas are vulnerable to slope failure along the interface of the in-situ and fill material. The likelihood of this type of failure is increased when the fill material is frequently saturated, as anticipated when an infiltration BMP is proposed.

8.2.9 Karst

The concentration of runoff into an infiltration trench may result in the formation of flow channels. Such channels may lead to collapse in karst areas, and therefore the implementation of infiltration trenches in known karst areas should be avoided.

8.2.10 Existing Utilities

Infiltration trenches can often be constructed over existing easements, provided permission to construct the strip over these easements is obtained from the utility owner *prior* to design of the strip.

8.2.11 Wetlands

When the construction of an infiltration trench is planned in the vicinity of known wetlands, the designer must coordinate with the appropriate local, state, and federal agencies to identify wetlands boundaries, their protected status, and the feasibility of BMP implementation in their vicinity.

8.3 General Design Guidelines

The following presents a collection of design issues to be considered when designing an infiltration trench for improvement of water quality.

8.3.1 Design Infiltration Rate

To provide a factor of safety, and to account for the decline in performance as the facility ages, the soil infiltration rate upon which a trench design is founded should be one-half the infiltration rate obtained from the geotechnical analysis.

8.3.2 Maximum Storage Time

Infiltration trenches should be designed to empty within 48 hours following a runoff producing event.

8.3.3 Trench Sizing

Generally, the trench's total depth ranges from 2 to 10 feet. The surface area of the trench is that area which, when multiplied by the trench depth and the aggregate porosity, provides the computed treatment volume. Trench widths greater than 8 feet require large excavation equipment rather than smaller trenching equipment. When treatment volumes require a width greater than 8 feet, an infiltration basin or other BMP should be considered.

8.3.4 Runoff Pretreatment

Infiltration trenches *must* be preceded by a pretreatment facility. Roadways and parking lots often produce runoff with high levels of sediment, grease, and oil. These pollutants can potentially clog the pore space in the trench, thus rendering its infiltration and pollutant removal performance ineffective. Suitable pretreatment practices include vegetated buffer strips, sediment forebays, and proprietary water quality inlets.

All infiltration trenches that receive surface runoff as sheet flow should be equipped with a vegetated buffer strip at least 20-feet wide (see *Chapter Seven – Vegetated Filter Strip)*.

8.3.5 Aggregate Material

The infiltration trench material should be comprised of clean aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches. Aggregate meeting this specification should be VDOT No. 1 Open-graded Coarse Aggregate or its equivalent as recommended by the Materials Division.

An 8-inch deep sand layer must be installed at the bottom of the trench. This material should be VDOT Fine Aggregate, Grading A or B, or equivalent as approved by the Materials Division.

8.3.6 Observation Well

An observation well is recommended at an interval of every 50 feet along the entire trench length. Observation wells provide a means by which dewatering times can be observed to ensure that the trench is emptying within the maximum allowable time of 48 hours. Generally, the observation well is constructed of 4 or 6 inch perforated PVC pipe, configured as shown in Figure 8.1

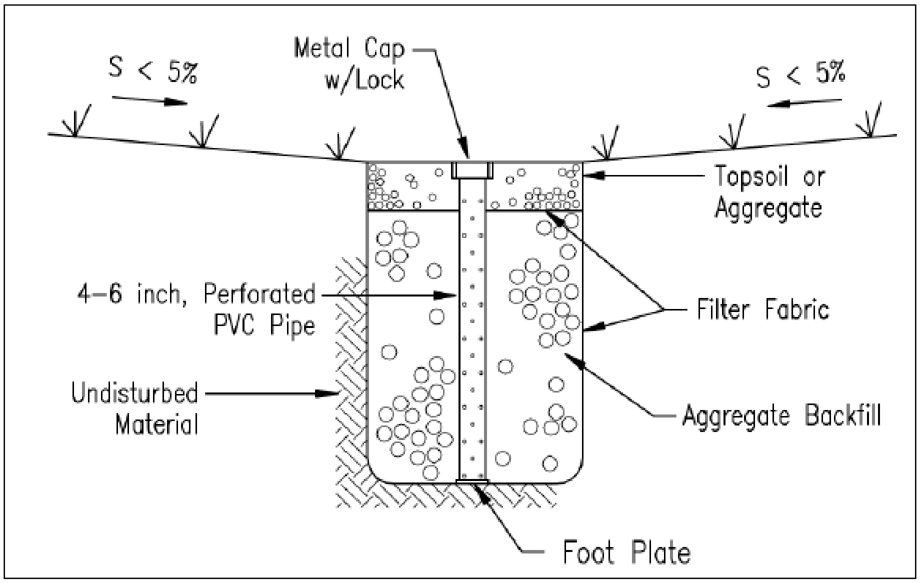

Figure 8.1. Infiltration Trench Observation Well Configuration
(Virginia Stormwater Management Handbook, 1999, Et seq.)

8.3.7 Filter Fabric

The trench aggregate material should be surrounded with filter fabric as shown in Figure 8.2. The filter fabric should be a material approved by the Materials Division. Filter fabric should *not* be placed on the trench bottom. When the trench is constructed as a "surface trench" with no soil overlay, a separate piece of filter fabric should be used as the top layer. This enables replacement of the upper filter fabric upon its eventual clogging.

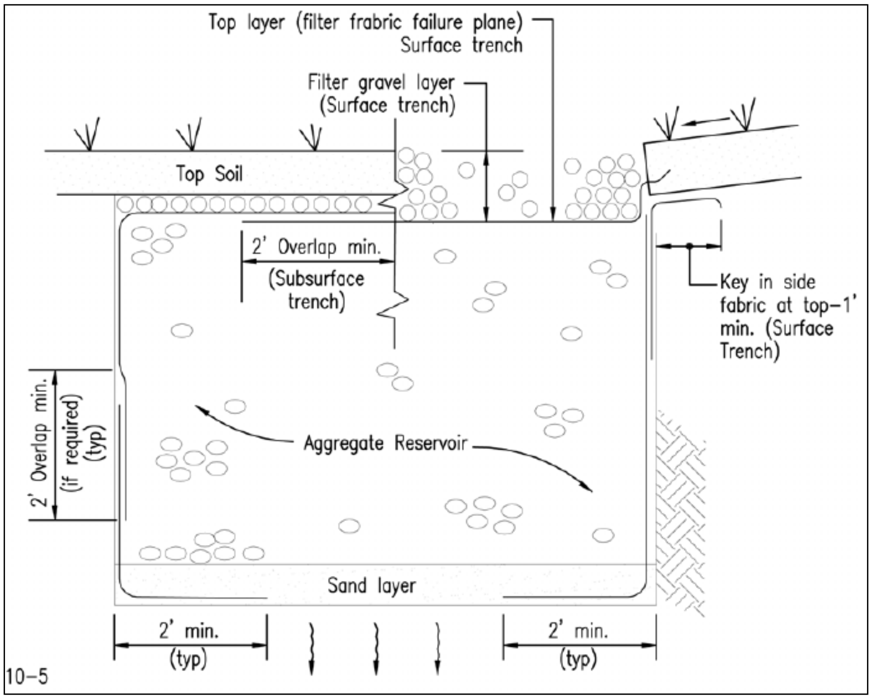

Figure 8.2. Infiltration Trench Filter Fabric Installation
(Virginia Stormwater Management Handbook, 1999, Et seq.)

8.4 Design Process

This section presents the design process applicable to infiltration trenches serving as water quality BMPs. The pre and post-development runoff characteristics are intended to replicate stormwater management needs routinely encountered during linear development projects. The hydrologic calculations and assumptions presented in this section serve only as input data for the detailed BMP design steps. Full hydrologic discussion is beyond the scope of this report, and the user is referred to Chapter 4 of the Virginia Stormwater Management Handbook (DCR, 1999, Et Seq.) for expanded hydrologic methodology.

The infiltration trench design will meet the technology-based water quality requirements arising from the construction of approximately 2,000 linear feet of roadway in Halifax County. Topography is such that runoff from the road is collected in VDOT CG-6 curb and gutter and conveyed to curb inlets along the road. The runoff is then discharged into sediment forebays from which it then enters onto the surface of the proposed trench, which is located in the median of the divided roadway. The total project site, including right-of-way and all permanent easements, consists of 6.2 acres. Pre and post-development hydrologic characteristics are summarized below in Table 8.2. Approximately 300 linear feet is available for construction of the trench. Geotechnical investigations reveal the site's saturated soil infiltration rate to be 2.3 inches per hour. The project site does not exhibit a high or seasonally high groundwater table.

	Pre-Development	Post-Development
Project Area (acres)	6.2	6.2
Land Cover	Unimproved Grass Cover	3.4 acres impervious cover
Impervious Percentage	0	54.8

Table 8.2. Hydrologic Characteristics of Example Project Site

Step 1. Compute the Required Water Quality Volume

The project site's water quality volume is a function of the developed impervious area. This basic water quality volume is computed as follows:

$$WQV = \frac{IA \times \frac{1}{2} in}{12 \frac{in}{ft}}$$

IA= Impervious Area (ft^2)

The project site in this example has a total drainage area of 6.2 acres. The total impervious area within the site is 3.4 acres. Therefore, the water quality volume is computed as follows:

$$WQV = \frac{3.4ac \times \frac{1}{2} in \times \frac{43{,}560\, ft^2}{ac}}{12 \frac{in}{ft}} = 6{,}171\, ft^3$$

The impervious cover within the project site is less than 67 percent of the total project site. Therefore, in accordance with Table 1.1, the infiltration trench will be sized to treat the computed water quality volume of 6,171 ft^3.

Step 2. Compute the Design Infiltration Rate

Per DCR guidelines, the design infiltration rate, f_d, is computed as one-half the infiltration rate obtained from the required geotechnical analysis. For the given site conditions, the infiltration rate is computed as:

$$f_d = 0.5 f = (0.5)\left(2.3 \frac{in}{hr}\right) = 1.15 \frac{in}{hr}$$

Step 3. Compute the Maximum Allowable Trench Depth

The trench must be designed such that it is completely empty within a maximum of 48 hours following a runoff producing event. To ensure compliance with this requirement, we will compute the maximum allowable trench depth by the following equation:

$$d_{\max} = \frac{f_d \times T_{\max}}{V_r}$$

d_{max} = maximum allowable trench depth (ft)
f_d = design infiltration rate (in/hr)
T_{max} = maximum allowable drain time (48 hours)
V_r = void ratio of the stone trench (0.40 for VDOT No. 1 Coarse-graded Aggregate)

The maximum allowable trench depth is therefore computed as:

$$d_{\max} = \frac{\left(1.15 \frac{in}{hr}\right)\left(\frac{1\, ft}{12 in}\right)(48 hrs)}{0.40} = 11.5\, ft$$

Step 4. Compute the Minimum Allowable Trench Bottom Area

Employing the principles of Darcy's Law, and assuming one-dimensional flow through the bottom of the trench, we can compute the minimum allowable surface area of the trench by the following equation:

$$SA_{\min} = \frac{WQV}{(f_d)(T_{\max})}$$

SA_{min} = minimum trench bottom surface area (ft^2)
WQV = treatment volume (ft^3)
f_d = design infiltration rate (in/hr)
T_{max} = maximum allowable drain time (48 hours)

The minimum allowable trench surface area is computed as follows:

$$SA_{\min} = \frac{6{,}171\,ft^3}{\left(1.15\dfrac{in}{hr}\right)\left(\dfrac{1\,ft}{12in}\right)(48hr)} = 1{,}342\,ft^2$$

Step 5. Size the Trench Based on Site-Specific Parameters

The example trench is to be located in the median of a divided highway. Per the problem statement, approximately 300 linear feet are available for construction of the trench. This entire length will be utilized in an effort to minimize the trench depth.

The maximum desirable trench width is 8 feet. Employing this maximum width with the available 300 foot length results in a trench bottom surface area computed as follows:

$$SA = (300\,ft)(8\,ft) = 2{,}400\,ft^2$$

This value is greater than the minimum value (computed previously as 1,342 ft^2), and is therefore considered acceptable.

Next, the trench depth must be computed. The volume of storage provided in the void space of the trench aggregate must provide the computed treatment volume. Therefore, the minimum trench depth is computed by the following equation, with variables as previously defined.

$$d = \frac{WQ_V}{(V_r)(SA)}$$

The trench depth is then computed as:

$$d = \frac{6{,}171\,ft^3}{(0.4)(2{,}400\,ft^2)} = 6.43\,ft$$

The computed trench depth is less than the maximum value (computed previously as 11.5 ft), and is therefore considered acceptable.

A summary of the trench parameters are provided in Table 8.3.

Length	300 ft
Width	8 ft
Depth	6.5 ft
Storage Volume	6,240 ft^3

Table 8.3. Summary of Trench Dimensions

Step 6. Alternative Trench Sizing Procedure

The addition of a large perforated pipe(s) within the trench can greatly increase the trench storage capacity. This increased storage capacity can be used to reduce the overall dimensions of the trench, or, keeping the trench size fixed, provide a greater overall infiltration volume. The following steps illustrate the procedure for decreasing the trench depth by providing perforated corrugated metal pipes within the trench. The demonstrated methodology can also be adapted to resize the trench length and/or depth.

In this example, we will consider placement of two 36-inch perforated corrugated metal pipes within the trench. Assuming the pipes extend the full length of the trench, we can compute the total volume provided by the pipes as follows:

$$V_{Pipe} = L \times \pi \times r^2$$

$$V_{Pipe} = \left[300 \times \pi \times 1.5^2\right] \times 2Pipes = 4{,}242\,ft^3$$

The volume provided by the stone aggregate to be replaced by the pipes is computed as:

$$V_{Stone} = 4{,}242\,ft^3 \times 0.4 = 1{,}696.8\,ft^3$$

Therefore, the net "gain" in storage volume by replacing the aggregate with the pipes is computed as:

$$V_{Net} = 4{,}242\,ft^3 - 1{,}696.8\,ft^3 = 2{,}545.2\,ft^3$$

The reduction in trench depth can then be computed as a function of the net gain in storage volume and the trench's length and width:

$$D_{\mathrm{Re}\,duction} = \frac{2{,}545.2\,ft^3}{300\,ft \times 8\,ft \times 0.4} = 2.65\,ft$$

The new trench depth is computed as:

$$D = 6.43\,ft - 2.65\,ft = 3.8\,ft$$

The overall volume provided by the re-sized trench is then computed as:

$$V_{Trench} = 300\,ft \times 8\,ft \times 3.8\,ft \times 0.4 = 3{,}648\,ft^3$$

This volume is then added to the net gain in volume provided by the two 36-inch diameter pipes:

$$V_{Total} = 3{,}648\,ft^3 + 2{,}545\,ft^3 = 6{,}193\,ft^3$$

A schematic illustration of the re-sized trench is shown in Figure 8.3.

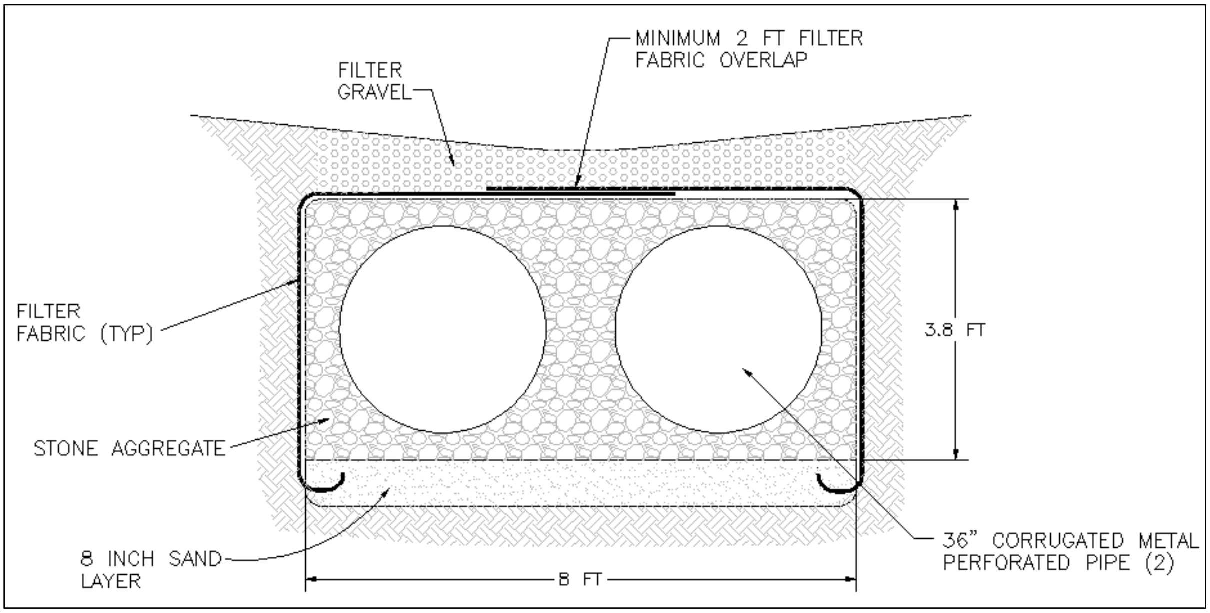

Figure 8.3. Infiltration Trench Equipped with Perforated Pipes

Step 7. Provide Provision for Overflow

Infiltration trenches serve primarily as water quality BMPs. Typically, it is impractical to size the trench to accommodate a volume of runoff beyond that which must be captured for water quality purposes. Therefore, provisions must be provided for runoff conveyance when the capacity of the trench is exceeded. Because of the small drainage area served by an infiltration trench, an emergency spillway is typically not required; however, a non-erosive channel or storm sewer system must be located at the downstream end of the trench. The channel or sewer should carry excess flows to an adequate receiving channel as defined by Regulation MS-19 in the Virginia Erosion and Sediment Control Handbook, (DCR, 1992, Et seq.). Existing natural channels conveying pre-development flows may be considered receiving channels if they satisfactorily meet the standards outlined in the VESCH MS-19. Unless unique site conditions mandate otherwise, receiving channels should be analyzed for overtopping during conveyance of the 10-year runoff producing event and for erosive potential under the 2-year event.

When a storm sewer or other conduit is used to convey excess runoff, the invert must be located at an elevation that is not below the surface of the infiltration trench's aggregate storage volume. *Only the volume of storage provided below the invert of the bypass pipe can be considered infiltration (treatment) volume.* A typical bypass configuration is shown below in Figure 8.4.

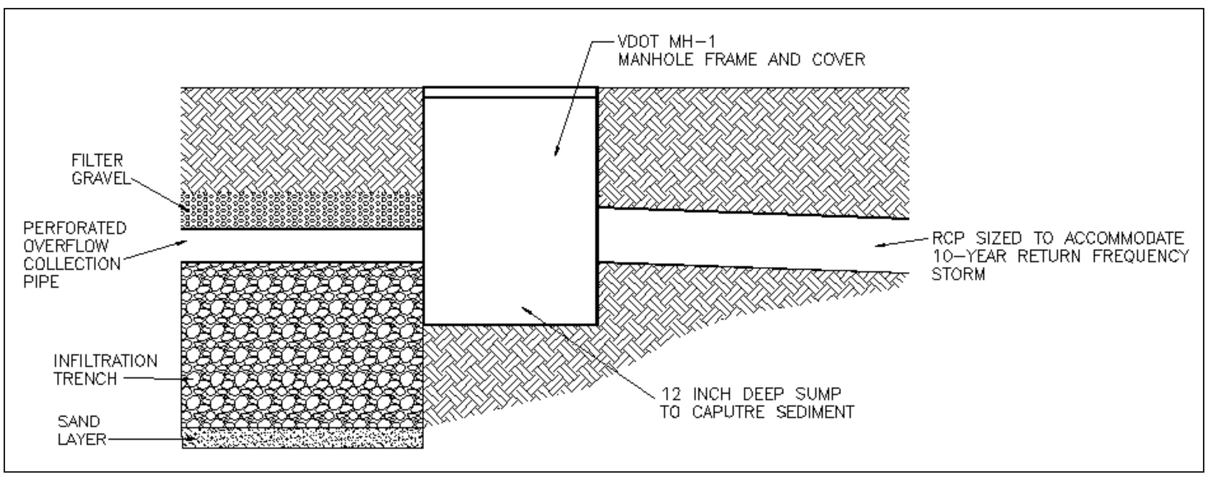

Figure 8.4. Infiltration Trench Section Equipped with RCP Overflow Pipe

Step 8. Landscaping

Trenches that are not designed to function as a surface trench (as shown in Figure 8.2) must exhibit a dense vegetative cover before any stormwater runoff is directed to the facility. Careful attention must be given to the types of vegetation selected for the trench surface. The vegetative species must be selected based on their inundation tolerance and the anticipated frequency and depth of inundation. The designer is referred to the Virginia Erosion and Sediment Control Handbook (DCR, 1992, Et seq.) for recommendations of specific vegetative species based on the facility's geographic location. Generally, low-growing stoloniferous grasses are good candidates for infiltration facilities as they permit long intervals between mowing, thus minimizing the frequency of traffic on the surface of the facility.

Maintenance of the facility's vegetative cover is essential to the long-term performance of the facility. A dense vegetative stand enhances infiltration, minimizes surface erosion, and deters invasive and detrimental vegetative species. Any bare spots on the surface of the facility should be re-seeded immediately.

The use of fertilizers should be minimized and avoided completely if practically possible. Excessive use of fertilizers on highly permeable soil may lead to groundwater contamination. Reference the Virginia Erosion and Sediment Control Handbook (DCR, 1992, Et seq.) for recommendations on appropriate fertilizer types and minimum effective application rates.