Permeable Pavement

Description: Permeable pavements allow stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. Porous paving systems have several design variants. The four major categories are: 1) pervious concrete; 2) modular block systems; 3) porous asphalt and 4) grass and gravel pavers. All have a similar structure, consisting of a surface pavement layer, an underlying stone aggregate reservoir layer and a filter layer or fabric installed on the bottom. Porous asphalt shall not be used within the City of Franklin.

Variations: permeable interlocking pavers, concrete grid pavers, plastic reinforced grid pavers

Advantages/Benefits:

- Runoff volume reduction
- Can increase aesthetic value
- Provides water quality treatment

Disadvantages/Limitations:

- Cost
- Maintenance
- Limited to low traffic areas with limited structural loading
- Potential issues with handicap access
- Infiltration can be limited by underlying soil property
- Not effective on steep slopes

Applications:

- Best used in low traffic and low load bearing areas
- Parking lots (particularly overflow areas)
- Driveways (commercial)
- Sidewalks (outside the Right of Way)
- Emergency access roads, maintenance roads and trails, etc.

Manufacturer recommendations for installation shall supersede any requirement within the BMP manual

Selection Criteria:

LEVEL 1 – 45% Runoff Reduction Credit

LEVEL 2 – 95% Runoff Reduction Credit

Land Use Considerations:

[X] **Residential**

[X] **Commercial**

[X] **Industrial**

Maintenance:

- Turf pavers can require mowing, fertilization, and irrigation. Plowing is possible, but requires use of skids
- Sand, salt, and deicers shall not be applied
- Adjacent areas should be fully stabilized with vegetation to prevent sediment-laden runoff from clogging the surface
- A vacuum-type sweeper or high-pressure hosing (for porous concrete) should be used for cleaning

[H] **Maintenance Burden**
L = Low M = Moderate H = High

SECTION 1: DESCRIPTION

Permeable pavements are alternative paving surfaces that allow stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. Permeable pavements consist of a surface pavement layer, an underlying stone aggregate reservoir layer and a filter layer or fabric installed on the bottom (See **Figure 3.1** below).

The thickness of the reservoir layer is determined by both a structural and hydraulic design analysis. The reservoir layer serves to retain stormwater and supports the design traffic loads for the pavement. In low-infiltration soils, some of the filtered runoff is collected in an underdrain and returned to the storm drain system. If infiltration rates in the native soils permit, permeable pavement can be designed with a sump beneath the underdrain, to enable full infiltration of runoff. A combination of these methods can be used to infiltrate a portion of the filtered runoff.

Permeable pavement is typically designed to treat stormwater that falls on the actual pavement surface area, but it may also be used to accept run-on from small adjacent impervious areas, such as impermeable driving lanes or rooftops. However, careful sediment control is needed for any run-on areas to avoid clogging of the down-gradient permeable pavement. Permeable pavement has been used at commercial, institutional, and residential sites in spaces that are traditionally impervious. Permeable pavement promotes a high degree of runoff volume reduction and nutrient removal, and it can also reduce the effective impervious cover of a development site.

SECTION 2: PERFORMANCE

The overall runoff reduction of permeable pavement is shown in **Table 3.1**.

Table 3.1. Runoff Volume Reduction Provided by Permeable Pavement		
Stormwater Function	**Level 1 Design**	**Level 2 Design**
Runoff Volume Reduction (RR)	45%	95%

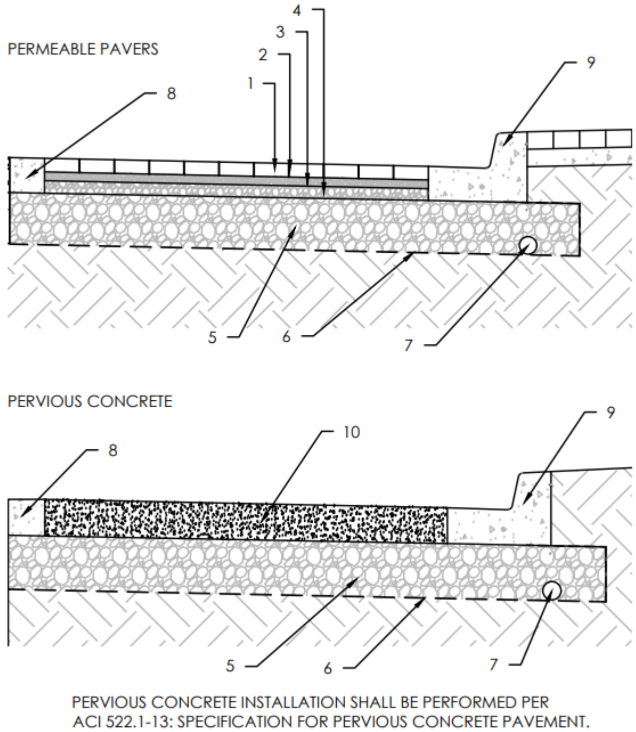
SECTION 3: DESIGN TABLE

The major design goal of permeable pavement is to maximize runoff reduction. To this end, designers may choose to use a baseline permeable pavement design (Level 1) or an enhanced design (Level 2) that maximizes runoff reduction. To qualify for Level 2, the design must meet all design criteria shown in the right hand column of **Table 3.2**.

Table 3.2. Permeable Pavement Design Criteria	
Level 1 Design	**Level 2 Design**
Sizing (Section 6.1): $Tv^1 = (1)(Rv)(A)\ 3630$	**Sizing (Section 6.1)**: $Tv^1 = (1.1)(Rv)(A)\ 3630$
Sub-soil Testing (**Section 6.2**): Testing is required. Min. infiltration rate > 0.5 inch/hour in order to remove the underdrain requirement.	**Sub-soil Testing** (**Section 6.2**): Testing is required. Min. infiltration rate > 0.5 inch/hour in order to remove the underdrain requirement.
Contributing Drainage Area (Section 5): Twice the permeable surface area.	**Contributing Drainage Area (Section 5)**: No additional contributing drainage area allowed.
Underdrain (**Section 6.8**) = PVC or Corrugated HDPE with clean-outs**.** Underdrains are required**.** (**Section 6.2**)	**Underdrain & Underground Storage Layer** (**Section 6.7**) = PVC or Corrugated HDPE with clean-outs, and a minimum 12-inch stone sump below the invert. Underdrains are required. (**Section 6.2**)
Long Term Maintenance Requirements (**Section 11**)	

1. A = Area in acres

SECTION 4: TYPICAL DETAILS



1	3 1/8" THICKNESS CONCRETE PAVERS 8,000 PSI STRENGTH
2	1/4" JOINTS NO. 8 STONE
3	2" BEDDING COURSE NO. 8 AGGREGATE
4	3" OPEN-GRADED BASE NO. 57 STONE
5	12" STONE SUBBASE NO. 2 STONE
6	GEOTEXTILE FILTER FABRIC U.S. FABRIC INC. 200 NON-WOVEN (ENVIRONMENTAL) (OR APPROVED EQUAL)
7	4" OR 6" P.V.C. UNDERDRAIN
8	RIBBON CURB (SEE C.O.F. STANDARD CURB DETAIL)
9	STANDARD C.O.F. CURB AS SPECIFIED ON PLANS
10	PERVIOUS CONCRETE PER ACI STANDARD

N.T.S.

Figure 3.1. Typical Detail of Concrete Pavers and Permeable Concrete

SECTION 5: PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

Since permeable pavement has a very high runoff reduction capability, it should always be considered as an alternative to conventional pavement. Permeable pavement is subject to the same feasibility constraints as most infiltration practices, as described below.

Contributing Drainage Area. Any external drainage area contributing runoff to permeable pavement should not exceed twice the surface area of the Level 1 permeable pavement and shall be as close to 100% impervious as possible. Level 2 designs shall only treat the rainfall that falls on its surface. Careful sediment source control and/or a pre-treatment strip or sump (e.g., stone or gravel) should be used to control sediment run-on to the permeable pavement section if there is any permeable run-on upgradient. It is recommended to not place permeable pavement under tree cover or near overhanging landscaping.

Available Space. A prime advantage of permeable pavement is that it does not require its surface area to be set aside solely for stormwater management and can still be utilized for vehicular or pedestrian. This can be important for tight sites and areas with high land costs where usable surface area is at a premium.

Pavement Subgrade Slope. The subgrade slope of a permeable pavement installation shall be as flat as possible (i.e., 0% longitudinal slope) to enable even distribution and infiltration of stormwater. However, a maximum longitudinal slope of 1% is permissible if an underdrain is employed. Lateral slopes should be 0%. The subgrade of the permeable pavement shall be an even slope both longitudinally and laterally to establish a level reservoir layer. Designers should consider using a terraced subgrade design for permeable pavement in sloped areas, especially when the local slope is several percent or greater. An overflow for larger design storms shall be provided. The surface slope shall be a maximum of 10% but is recommended to be less than 1%.

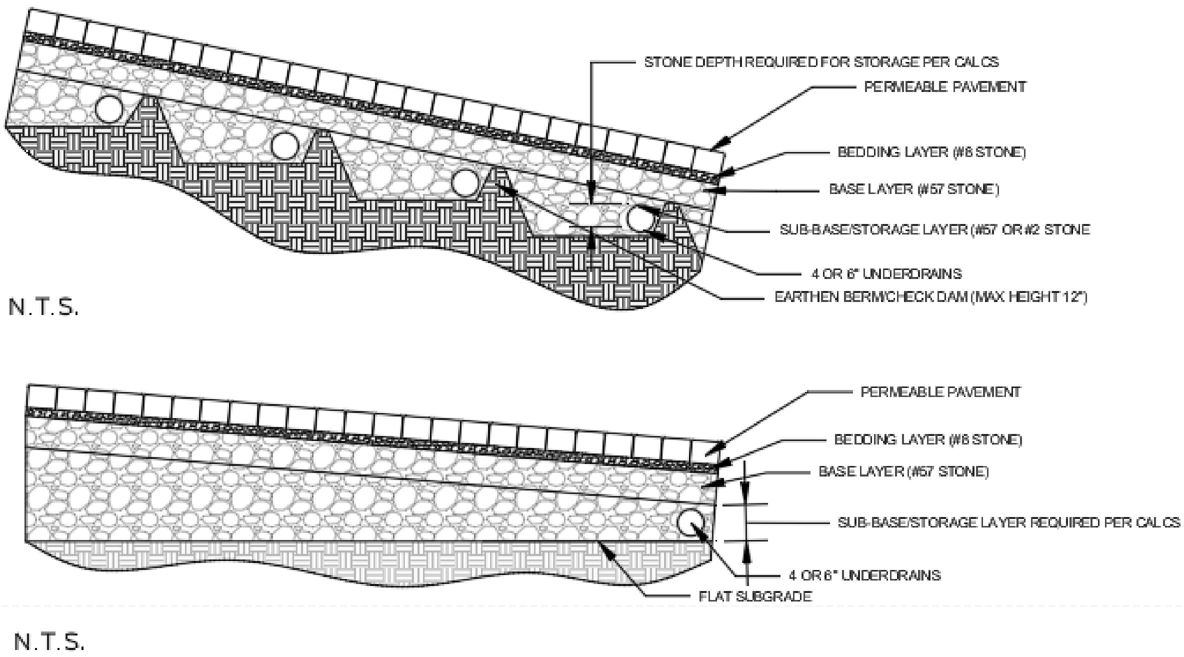


Figure 3.2. Typical Detail of Terraced and Flat Subgrade

Minimum Hydraulic Head. The elevation difference needed for permeable pavement to function properly is generally nominal, although 2 to 4 feet of head may be needed to drive flows through underdrains. Flat terrain may affect proper drainage permeable pavement designs, so underdrains shall have a minimum 0.5% slope.

Subsurface Constraints. A high groundwater table may cause runoff to pond at the bottom of the permeable pavement system. Therefore, a minimum vertical distance of 2 feet must be provided between the bottom of the subgrade of the permeable pavement and the seasonal high water table. The bottom subgrade of the permeable pavement system shall be above the bedrock/refusal depth provided with the geotechnical report.

Utilities. No utilities shall be located under the permeable pavement. All wet utilities shall be hydraulically disconnected to prevent a direct connection to the MS4.

Setbacks. Permeable pavement shall not be hydraulically connected to structure foundations, in order to avoid harmful seepage. It is not recommended to place permeable pavement immediately adjacent to structures. To avoid the risk of seepage, a licensed PE should be consulted to determine the appropriate setbacks necessary to prevent pavement infiltration from compromising structural foundations or pavement. At a minimum, small- and large-scale pavement applications shall be located a minimum horizontal distance of 100 feet from any water supply well, 50 feet from septic systems, and at least 5 feet down-gradient from dry or wet utility lines.

High Loading Situations. Permeable pavement is not intended to treat sites with high sediment, trash, or landscape debris loads, since such loads will cause the practice to clog and fail.

Limitations. Permeable pavement can be used as an alternative to most types of conventional pavement at residential, commercial and institutional developments; however, it is not currently approved for use in the Right of Way (ROW).

SECTION 6: DESIGN CRITERIA

6.1 SIZING OF PERMEABLE PAVEMENT

Structural Design. If permeable pavement will be used in a parking lot or other setting that involves vehicles, the pavement surface must be able to support the maximum anticipated traffic load. The structural design process will vary according to the type of pavement selected, and the manufacturer's specific recommendations shall be consulted. The thickness of the permeable pavement and reservoir layer must be sized to support structural loads and to temporarily store the design storm volume (e.g., the water quality, channel protection, and/or flood control volumes). On most new development and redevelopment sites, the structural support requirements will dictate the depth of the underlying stone reservoir.

The structural design of permeable pavements involves consideration of four main site elements:

- Total traffic;
- In-situ soil strength;
- Environmental elements; and
- Bedding and Reservoir layer design.

The resulting structural requirements may include, but are not limited to, the thickness of the pavement, filter, and reservoir layer. Designers should note that if the underlying soils have a low California Bearing Ratio (CBR) (less than 4%), they may need to be compacted to at least 95% of the Standard Proctor Density, which generally rules out their use for infiltration.

Designers should determine structural design requirements by consulting transportation design guidance sources, such as the following:

- TDOT Roadway Design Guidelines (latest edition);
- AASHTO Guide for Design of Pavement Structures (latest edition); and,
- AASHTO Supplement to the Guide for Design of Pavement Structures (latest edition).

Hydraulic Design. Permeable pavement is typically sized to store the complete water quality Treatment Volume (T_v) or another design storm volume in the reservoir layer. Modeling has shown that this simplified sizing rule approximates an 80% average rainfall volume removal for subsurface soil infiltration rates up to one inch per hour. More conservative values are given because both local and national experience has shown that clogging of the permeable material can be an issue, especially with larger contributing areas carrying significant soil materials onto the permeable surface.

The infiltration rate typically will be less than the flow rate through the pavement, so that some underground reservoir storage will usually be required. Designers should initially assume that there is no outflow through underdrains, using **Equation 3.1** to determine the depth of the reservoir layer, assuming runoff fully infiltrates into the underlying soil:

Equation 3.1. Depth of Reservoir Layer with no Underdrain

$$d_p = \frac{\{(d_c \times R) + P - \left({}^{i}/_{2} \times t_f\right)\}}{n}$$

Where:

d_p = The depth of the reservoir layer (ft.)

d_c = The depth of runoff from the contributing drainage area (not including the permeable paving surface)

		for the Treatment Volume (T_v/A_c), or other design storm (ft.)
R	=	A_c/A_p = The ratio of the contributing drainage area (A_c, not including the permeable paving surface) to the permeable pavement surface area (A_p) [NOTE: The maximum value for the Level 1 design is R = 2, (the external drainage area A_c is twice that of the permeable pavement area Ap; and for Level 2 design R = 0 (the drainage area is made up solely of permeable pavement A_p].
P	=	The rainfall depth for the Treatment Volume (Level 1 = 1 in.; Level 2 = 1.1 in.), or other design storm (ft.)
i	=	The field-verified infiltration rate for native soils (ft./day)
t_f	=	The time to fill the reservoir layer (day) – typically 2 hours or 0.083 day
n	=	The porosity for the reservoir layer (0.4)

The maximum allowable depth of the reservoir layer is constrained by the maximum allowable drain time, which is calculated using **Equation 3.2**.

Equation 3.2. Maximum Depth of Reservoir Layer

$$d_{p-max} = \frac{\left({}^{i}/_{2} \times t_d\right)}{n}$$

Where:

d_{p-max}	=	The maximum depth of the reservoir layer (ft.)
i	=	The field-verified infiltration rate for native soils (ft./day)
t_d	=	The maximum allowable time to drain the reservoir layer, typically 1 to 2 days
n	=	The porosity for the reservoir layer (0.4)

The following design assumptions apply to **Equations 3.1 and 3.2**:

- The contributing drainage area (A_c) should not contain pervious areas.
- For design purposes, the native soil infiltration rate (i) should be the field-tested soil infiltration rate divided by a factor of safety of 2. The minimum acceptable native soil infiltration rate is 0.5 inches/hr.
- The porosity (n) for No. 57 stone = 0.40
- Max. drain time for the reservoir layer should be not less than 24 or more than 48 hours.

If the depth of the reservoir layer is too great (i.e. d_p exceeds d_{p-max}), or the verified soil infiltration rate is less than 0.5 inches per hour, then the design method typically changes to account for underdrains. The storage volume in the pavements must account for the underlying infiltration rate and outflow through the underdrain. In this case, the design storm should be routed through the pavement to accurately determine the required reservoir depth. Alternatively, the designer may use **Equations 3.3 through 3.5** to approximate the depth of the reservoir layer for designs using underdrains.

Equation 3.3 can be used to approximate the outflow rate from the underdrain. The hydraulic conductivity, *k*, of gravel media is very high (~17,000 ft./day). However, the permeable pavement reservoir layer will drain increasingly slower as the storage volume decreases (i.e. the hydraulic head decreases). To account for this change, a conservative permeability coefficient of 100 ft./day can be used to approximate the average underdrain outflow rate.

Equation 3.3. Outflow through Underdrain

$$q_u = k \times m$$

Where:

q_u	=	Outflow through the underdrain (per outlet pipe, assumed 6-inch diameter)(ft./day)
k	=	Hydraulic conductivity for the reservoir layer (ft./day – assume 100 ft./day)
m	=	Underdrain pipe slope (ft./ft.)

Once the outflow rate through the underdrain has been approximated, **Equation 3.4** is used to determine the depth of the reservoir layer needed to store the design storm.

Equation 3.4. Depth of Reservoir Layer with Outflow through Underdrain

$$d_p = \frac{\{(d_c \times R) + P - \left(i/_2 \times t_f\right) - (q_u \times t_f)\}}{n}$$

Where:

d_p	=	Depth of the reservoir layer (ft.)
d_c	=	Depth of runoff from the contributing drainage area (not including the permeable pavement surface) for the Treatment Volume (Tv/A_c), or other design storm (ft.)
R	=	A_c/A_p = The ratio of the contributing drainage area (A_j (not including the permeable pavement surface) to the permeable pavement surface area (A_p)
P	=	The rainfall depth for the Treatment Volume (Level 1 = 1 inch; Level 2 = 1.1 inch), or other design storm (ft.)
i	=	The field-verified infiltration rate for the native soils (ft./day)
t_f	=	The time to fill the reservoir layer (day) – typically 2 hours or 0.083 day
n	=	The porosity for the reservoir layer (0.4)
q_u	=	Outflow through Underdrain (ft/day)

The maximum allowable depth of the reservoir layer is constrained by the maximum allowable drain time, which is calculated using **Equation 3.5**.

Equation 3.5. Maximum Depth of Reservoir Layer with Outflow through Underdrain

$$d_{p-max} = \frac{\{\left(i/_2 \times t_d\right) - (q_u \times t_d)\}}{n}$$

Where:

d_{p-max}	=	The maximum depth of the reservoir layer (ft.)
i	=	The field-verified infiltration rate for the native soils (ft./day)
n	=	The porosity for the reservoir layer (0.4)
t_d	=	The time to drain the reservoir layer (day – typically 1 to 2 days)
q_u	=	Outflow through Underdrain (ft/day)

If the depth of the reservoir layer is still too great (i.e. d_p exceeds d_{p-max}), the number of underdrains can be increased, which will increase the underdrain outflow rate.

Permeable pavement can also be designed to address, in whole or in part, the detention storage needed to comply with channel protection and/or flood control requirements. Permeable pavement shall have an underdrain if being used for detention storage. The designer can model various approaches by factoring in storage within the stone aggregate layer and any outlet structures used as part of the design. Routing calculations can also be used to provide a more accurate solution of the peak discharge and required storage volume.

Once runoff passes through the surface of the permeable pavement system, designers should calculate outflow pathways to handle subsurface flows. Subsurface flows can be regulated using underdrains, the volume of storage in the reservoir layer, and the bed slope of the reservoir layer.

6.2 SOIL INFILTRATION RATE TESTING

All permeable pavement systems shall have an underdrain. On-site soil infiltration rate testing procedures are outlined in **Appendix B**. The same frequency of soil borings must be taken to confirm the underlying soil properties at the depth where infiltration is designed to occur (i.e., to ensure that the depth to water table, depth to bedrock, or karst is defined).

Table 3.3. Required Infiltration Testing per Sq.Ft of pavement			
Impervious Area Treated	250 to 1,000 sq. ft.	1,000 to 10,000 sq. ft.	More than 10,000 sq. ft.
Required Soil Tests	Two per practice	Four per practice	Four + one per every additional 5000 ft^2

6.3 TYPE OF SURFACE PAVEMENT

Pervious concrete, permeable interlocking concrete pavers, concrete grid pavers, and plastic reinforced grid paver surfaces are permitted.

6.4 INTERNAL GEOMETRY AND DRAWDOWNS

- ***Elevated Underdrain.*** To promote greater runoff reduction for permeable pavement located on marginal soils, an elevated underdrain should be installed with a stone jacket that creates a 12 to 18 inch deep storage layer *below* the underdrain invert. The void storage in this layer can help qualify a site to achieve Level 2 design.
- ***Rapid Drawdown.*** When possible, permeable pavement should be designed so that the target runoff reduction volume stays in the reservoir layer for at least 36 hours before being discharged through an underdrain.
- ***Conservative Infiltration Rates.*** Designers should always decrease the measured infiltration rate by a factor of 2 during design, to approximate long term infiltration rates.

6.5 PRETREATMENT

Pretreatment for most permeable pavement applications is not necessary, since the surface acts as pretreatment to the reservoir layer below. For areas where there is a transition from conventional pavements to permeable pavement, a ribbon curb shall be installed between to two pavements to prevent settling and prevent fines from clogging the surface of the permeable pavement.

6.6 CONVEYANCE AND OVERFLOW

Permeable pavement designs should include methods to convey larger storms (e.g., 2-yr, 10-yr) to the storm drain system. The following is a list of methods that can be used to accomplish this:

- Place a perforated pipe horizontally near the top of the reservoir layer to pass excess flows after water has filled the base. The placement and/or design should be such that the incoming runoff is not captured (e.g., placing the perforations on the underside only).
- Increase the thickness of the top of the reservoir layer by as much as 6 inches (i.e., create freeboard). The design computations used to size the reservoir layer often assume that no freeboard is present.
- Create underground detention within the reservoir layer of the permeable pavement system. Reservoir storage may be augmented by plastic or concrete pipes, arch structures, etc. Corrugated metal is not permitted.
- Route excess flows to another detention or conveyance system that is designed for the management of extreme event flows.
- Set the storm drain inlets flush with the elevation of the permeable pavement surface to effectively convey excess stormwater runoff past the system (typically in remote areas). The design should also make allowances for relief of unacceptable ponding depths during larger rainfall events.

6.7 RESERVOIR LAYER

The thickness of the reservoir layer is determined by runoff storage needs, the infiltration rate of in situ soils, structural requirements of the pavement sub-base, depth to water table and bedrock, and frost depth conditions. A professional should be consulted regarding the suitability of the soil subgrade.

- The reservoir below the permeable pavement surface should be composed of clean, washed stone aggregate and sized for both the storm event to be treated and the structural requirements of the expected traffic loading.
- The storage layer may consist of clean washed No. 57 stone, although No. 2 stone is preferred because it provides additional storage and structural stability.

6.8 UNDERDRAINS

The use of underdrains is required for each permeable pavement system due to compaction needed for the Proctor Density Test. Each underdrain shall be installed at a minimum 0.5% slope located 20 feet or less from the next pipe (or equivalent corrugated HDPE may be used for smaller load-bearing applications). Perforated pipe installed for the full length of the permeable pavement cell, and non-perforated pipe, as needed, is used to connect with the storm drain system. T's and Y's shall be installed as needed, depending on the underdrain configuration. Extend cleanout pipes to the surface with vented caps or traffic rated lids at the Ts and Ys. Underdrains can also be used to manage extreme storm events to keep detained stormwater from backing up into the permeable pavement.

- An underdrain(s) shall have at least a 3 inch stone jacket around the underdrain.
- An underdrain(s) can also be installed and capped at a downstream structure as an option for future use if maintenance observations indicate a reduction in the soil permeability.

6.9 MAINTENANCE REDUCTION FEATURES

Maintenance is a crucial element to ensure the long-term performance of permeable pavement. The most frequently cited maintenance problem is surface clogging caused by organic matter and sediment, which can be reduced by the following measures:

- ***Protecting the Bottom of the Reservoir Layer.*** There are two options to protect the bottom of the reservoir layer from intrusion by underlying soils. The first method involves covering the bottom with nonwoven, polypropylene geotextile that is permeable, although some practitioners recommend avoiding the use of filter fabric since it may become a future plane of clogging within the system. Permeable filter fabric is still recommended to protect the excavated sides of the reservoir layer, in order to prevent soil piping. The second method is to form a barrier of choker stone and sand. In this case, underlying native soils should be separated from the reservoir base/subgrade layer by a thin 2 to 4 inch layer of clean, washed, choker stone (ASTM D 448 No. 8 stone) covered by a layer of 6 to 8 inches of course sand.

- *Observation Well.* An observation well, consisting of a well-anchored, perforated 4 to 6 inch (diameter) PVC pipe that extends vertically to the bottom of the reservoir layer, should be installed at the downstream end of all large-scale permeable pavement systems. The observation well should be fitted with a lockable cap or traffic rated lid installed flush with the ground surface (or under the pavers) to facilitate periodic inspection and maintenance. The observation well is used to observe the rate of drawdown within the reservoir layer following a storm event.
- *Overhead Landscaping.* Check the area of parking lots required to be in landscaping. Large-scale permeable pavement applications should be carefully planned to integrate this landscaping in a manner that maximizes runoff treatment and minimizes the risk that sediment, mulch, grass clippings, leaves, nuts, and fruits will inadvertently clog the paving surface.

SECTION 7: Material Specifications

Permeable pavement material specifications vary according to the specific pavement product selected. **Table 3.4** describes general material specifications for the component structures installed beneath the permeable pavement. **Table 3.4** provides specifications for general categories of permeable pavements. Designers should consult manufacturer's technical specifications for specific criteria and guidance.

Table 3.4. Material Specifications for Underneath the Pavement Surface

Material	Specification	Notes
Permeable Pavement System	Permeable Interlocking Concrete Pavers[1] Pervious Concrete[2] Reinforced Turf Systems[3] Reinforced Gravel Systems[4]	ASTM C936[1] ASTM C1688/C16188M & ACI 522[2] ASTM D638[3] ASTM D638[4]
Bedding Layer	#8 or #89 clean, washed stone	Meet TDOT Construction Specifications
Reservoir Layer	#57 or #2 clean, washed stone	Meet TDOT Construction Specifications. Depth is based on the pavement structural and hydraulic requirements.
Underdrain	4 to 6 inch diameter perforated HDPE or PVC pipe with 3/8-inch perforations at 6 inches on center;	(AASHTO M 252) Place perforated pipe at base of the reservoir layer at the lower end of the paver cell
Cleanout	6 inch SDR 35 PVC pipe with vented cap	Use traffic rated castings where required. Provide cleanouts at the upper end of the underdrain.
Filter Fabric/Sand Choker Layer	Filter Fabric (125 gpm/sq.ft.)[1] 2 to 4 inch layer of coarse sand[2]	AASHTO M288-06, ASTMD4491 & D4751[1] Meet TDOT Construction Specifications[2]
Impermeable Liner (if needed)	Use a thirty mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd.^{2} non-woven geotextile.	

[1] Specifications for Permeable Interlocking Concrete Pavers
[2] Specifcations for Pervious Concrete
[3] Specifications for Reinforced Turf Systems
[4] Specifications for Reinforced Gravel Systems

SECTION 8: SPECIAL CASE DESIGN ADAPTATIONS

The design adaptation described below permits permeable pavement to be used on a wider range of sites.

However, it is important not to force this practice onto marginal sites. Other runoff reduction practices are often preferred alternatives for difficult sites.

8.1 SHALLOW BEDROCK

Many parts of Franklin have shallow bedrock and groundwater, which can constrain the application of deeper paver areas. If bedrock or groundwater is encountered during subsurface testing for the construction of the bioretention area, the bottom sump elevation of the paver design shall be above the lowest bedrock/refusal or groundwater elevation encountered in subsurface testing. Bedrock removal should be limited to unexpected outcroppings and rises not encountered in subsurface testing.

Note that planned removal of bedrock is not desirable and should be utilized only when all other design possibilities have been exhausted. Where a hardship can be show and all other possibilities have been exhausted, a stormwater variance for bedrock removal may be granted on a case-by-case basis.

In cases where the reduced curve number method is to be utilized in stormwater quantity calculations, the bottom sump elevation shall be a minimum of 2 feet above existing bedrock elevations.

8.2 KARST

Karst regions are found in much of Middle Tennessee. Infiltrative practices, such as permeable pavement, shall not be used in any areas with high risk of sinkhole formations or in areas of know sinkholes.

8.3 SITE SPECIFIC LIMITATIONS

Some sites may have areas identified as site specific limitations to infiltration of stormwater runoff. Site specific limitations shall be determined by the City engineer and approved through the Stormwater variance process. Sites with brownfield permits are an example of site specific limitations. Site specific limitations cannot be self-imposed or be caused by requirements within the City Ordinance. It should be noted that the site specific limitation may only occupy a portion of the entire proposed use, and that some "clean" areas (such as rooftops) can be diverted away to another infiltration or runoff reduction practice. Development proposals should be carefully reviewed to determine if any future operation, on all or part of the site, will be designated as a potential site specific limitation. Based on this designation, infiltration may be restricted or prohibited.

SECTION 9: CONSTRUCTION

Experience has shown that proper installation is absolutely critical to the effective operation of a permeable pavement system.

9.1 NECESSARY EROSION & SEDIMENT CONTROLS

- All permeable pavement areas should be fully protected from sediment intrusion by silt fence or construction fencing, particularly if they are intended to infiltrate runoff.
- Permeable pavement areas should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment. Permeable pavement areas should be clearly marked on all construction documents and grading plans. To prevent soil compaction, heavy vehicular and foot traffic should be kept out of permeable pavement areas during and immediately after construction.
- During construction, care should be taken to avoid tracking sediments onto any permeable pavement surface to avoid clogging.

- Any area of the site intended ultimately to be a permeable pavement area should generally not be used as the site of a temporary sediment basin.
- Where locating a sediment basin on an area intended for permeable pavement is unavoidable, the invert of the sediment basin must be a minimum of 2 feet above the final design elevation of the bottom of the aggregate reservoir course.
- All sediment deposits in the excavated area should be carefully removed prior to installing the subbase, base and surface materials

9.2 PERMEABLE PAVEMENT CONSTRUCTION SEQUENCE

The following is a typical construction sequence to properly install permeable pavement:

Step 1. Construction of the permeable pavement shall only begin after the entire contributing drainage area has been stabilized. The proposed site should be checked for existing utilities prior to any excavation. Do not install the system in rain or snow, and do not install frozen bedding materials.

Step 2. As noted above, temporary EPSC measures are needed during installation to divert stormwater away from the permeable pavement area until it is completed. Special protection measures such as erosion control fabrics may be needed to protect vulnerable side slopes from erosion during the excavation process. The proposed permeable pavement area must be kept free from sediment during the entire construction process. Construction materials that are contaminated by sediments must be removed and replaced with clean materials.

Step 3. Where possible, excavators or backhoes should work from the sides to excavate the reservoir layer to its appropriate design depth and dimensions. For micro-scale and small-scale pavement applications, excavating equipment should have arms with adequate extension so they do not have to work inside the footprint of the permeable pavement area (to avoid compaction). Contractors can utilize a cell construction approach, whereby the proposed permeable pavement area is split into 500 to 1000 sq. ft. temporary cells with a 10 to 15 foot earth bridge in between, so that cells can be excavated from the side. Excavated material should be placed away from the open excavation so as to not jeopardize the stability of the side walls.

Step 4. The native soils along the bottom and sides of the permeable pavement system should be scarified or tilled to a depth of 3 to 4 inches prior to the placement of the filter layer or filter fabric. In large scale paving applications with weak soils, the soil subgrade may need to be compacted to 95% of the Standard Proctor Density to achieve the desired load-bearing capacity. (NOTE: This effectively eliminates the infiltration function of the installation, and it must be addressed during hydrologic design.)

Step 5. If filter fabric is to be installed on the bottom and the sides of the reservoir layer, the strips should overlap down-slope by a minimum of 2 feet, and be secured a minimum of 4 feet beyond the edge of the excavation. Where the filter layer extends beyond the edge of the pavement (to convey runoff to the reservoir layer), install an additional layer of filter fabric 1 foot below the surface to prevent sediments from entering into the reservoir layer. Excess filter fabric should not be trimmed until the site is fully stabilized.

Step 6. Provide a minimum of 2 inches of aggregate above and below the underdrains. The underdrains should slope down towards the outlet at a grade of 0.5% or steeper. The up-gradient end of underdrains in the reservoir layer should be capped. Where an underdrain pipe is connected to a structure, there shall be no perforations within 1 foot of the structure. Ensure that there are no perforations in clean-outs and observation wells within 1 foot of the surface.

Step 7. Moisten and spread 6-inch lifts of the appropriate clean, washed stone aggregate (usually No. 2 or No. 57 stone). Place at least 4 inches of additional aggregate above the underdrain, and then compact it using a vibratory roller in static mode until there is no visible movement of the aggregate. Do not crush the aggregate with the roller.

Step 8. Install the bedding layer. The thickness of the bedding layer is to be based on the block manufacturer's recommendation or that of a qualified professional.

Step 9. Paving materials shall be installed in accordance with manufacturer or industry specifications for the particular type of pavement.

9.3 CONSTRUCTION INSPECTION

Inspections before, during and after construction are needed to ensure that permeable pavement is built in accordance with these specifications. Use detailed inspection checklists that require sign-offs by qualified individuals at critical stages of construction, to ensure that the contractor's interpretation of the plan is consistent with the designer's intent.

Some common pitfalls can be avoided by careful construction supervision that focuses on the following key aspects of permeable pavement installation:

- Store materials in a protected area to keep them free from mud, dirt, and other foreign materials.
- The contributing drainage area should be stabilized prior to directing water to the permeable pavement area.
- Check the aggregate material to confirm that it is clean and washed, meets specifications and is installed to the correct depth.
- Check elevations (e.g., the invert of the underdrain, inverts for the inflow and outflow points, etc.) and the surface slope.
- Make sure the permeable pavement surface is even, runoff evenly spreads across it, and the storage bed drains within 48 hours.
- Inspect the structural integrity of the pavement surface, looking for signs of slumping, cracking, spalling or broken pavers. Replace or repair affected areas.
- Ensure that caps are placed on the upstream (but not the downstream) ends of the underdrains.
- Inspect the pretreatment structures (if applicable) to make sure they are properly installed and working effectively.
- The drawdown rate should be measured at the observation well for three (3) days following a storm event in excess of 0.5 inch in depth. If standing water is still observed in the well after three days, this is a clear sign that clogging is a problem.
- Once the final construction inspection has been completed, log the GPS coordinates for each facility and submit them to the City.

SECTION 10: AS-BUILT REQUIREMENTS

As-built and certification requirements can be found in **Appendix D**. Please reference the appendix as required components of the as-built differ from measure to measure.

SECTION 11: MAINTENANCE

11.1 MAINTENANCE DOCUMENT

Each BMP must have a City of Franklin Long Term Maintenance Plan (LTMP) Agreement submitted for approval and maintained and updated by the BMP owner. The LTMP Agreement must be completed and submitted to the City with the grading permit application. The LTMP Agreement is for the use of the BMP owner in performing routine inspections. The developer/owner is responsible for the cost of maintenance and annual inspections. The BMP owner must maintain and update the long term maintenance plan and agreement.

11.2 MAINTENANCE TASKS

It is difficult to prescribe the specific types or frequency of maintenance tasks that are needed to maintain the hydrologic function of permeable pavement systems over time. Most installations work reasonably well year after year with little or no maintenance, whereas some have problems right from the start.

One preventative maintenance task involves vacuum sweeping on a frequency consistent with the use and loadings encountered in the parking lot. Vacuum sweeping should be performed once or twice a year. This frequency should be adjusted according to the intensity of use and deposition rate on the permeable pavement surface. More frequent blowing, with a handheld or backpack blower, may also help prevent organic material from impacting the pavement. The contract for sweeping should specify that after vacuum sweeping is completed any joint material shall be replaced in interlocking paver systems.

11.3 MAINTENANCE INSPECTIONS

It is highly recommended that a spring maintenance inspection and cleanup be conducted at each permeable pavement site, particularly at large-scale applications.

Maintenance of permeable pavement is driven by annual inspections that evaluate the condition and performance of the practice. The following are suggested (at minimum) annual maintenance inspection points for permeable pavements:

- The drawdown rate should be measured at the observation well for three (3) days following a storm event in excess of 0.5 inch in depth. If standing water is still observed in the well after three days, this is a clear sign that clogging is a problem.
- Inspect the surface of the permeable pavement for evidence of sediment deposition, organic debris, staining or ponding that may indicate surface clogging. If any signs of clogging are noted, schedule a vacuum sweeper (no brooms or water spray) to remove deposited material. Then, test sections by pouring water from a five gallon bucket to ensure they work.
- Inspect the structural integrity of the pavement surface, looking for signs of surface deterioration, such as slumping, cracking, spalling or broken pavers. Replace or repair affected areas, as necessary.
- Check inlets, pretreatment cells and any flow diversion structures for sediment buildup and structural damage. Note if any sediment needs to be removed.
- Inspect the condition of the observation well and make sure it is still capped.
- Inspect any contributing drainage area for any controllable sources of sediment or erosion.

SECTION 12: COMMUNITY & ENVIRONMENTAL CONCERNS

Compliance with the Americans with Disabilities Act (ADA). Porous concrete and porous asphalt are generally considered to be ADA compliant. Interlocking concrete pavers are ADA compliant, if designers ensure that surface openings between pavers do not exceed 0.5 inch. However, some forms of interlocking pavers may not be suitable for handicapped parking spaces. Interlocking concrete pavers interspersed with other hardscape features (e.g., concrete walkways) *can* be used in creative designs to address ADA issues.

Underground Injection Control Permits. The Safe Drinking Water Act regulates the infiltration of stormwater in certain situations pursuant to the Underground Injection Control (UIC)

Program, which is administered either by the EPA or a delegated state groundwater protection agency. In general, the EPA (2008) has determined that permeable pavement installations are not classified as Class V injection wells, since they are always wider than they are deep.

Air and Runoff Temperature. Permeable pavement appears to have some value in reducing summer runoff temperatures, which can be important in watersheds with sensitive cold-water fish populations. The temperature reduction effect is greatest when runoff is infiltrated into the sub-base, but some cooling may also occur in the reservoir layer, when underdrains are used. ICPI (2008) notes that the use of certain reflective colors for interlocking concrete pavers can also help moderate surface parking lot temperatures.

Vehicle Safety. Permeable pavement is generally considered to be a safer surface than conventional pavement. Permeable pavement has less risk of hydroplaning, more rapid ice melt and better traction than conventional pavement.