

City of Grand Rapids Michigan

Green Infrastructure Standards

2018

## **SPECIAL SPECIFICATIONS FOR STORMWATER MANAGEMENT**

Bioretention - Comprehensive  
Bioretention  
Aggregates for Stormwater Management  
Bioretention Soil  
Geosynthetics  
Planting  
Underdrains  
Porous Asphalt Pavement  
Pervious Concrete Pavement  
Permeable Interlocking Unit Pavers Pavement

## **SUPPLEMENT TO STANDARD DRAWINGS**

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## **SUPPLEMENT TO STANDARD DRAWINGS – CON'T**

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- G/51 Stormwater Facility Underdrain Pipe Risers in Permeable Pavement
- G/52 Stormwater Facility Underdrain Pipe Risers in Bioretention
- G/53 Stormwater Facility Underdrain Bedding and Catch Basin Connection
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- G/55 Exfiltration Trench
- G/56 Stormwater Facility Anti-Seep Collar

### **Check Dam Series**

- G/60 Concrete Check Dam
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- G/70 Tree Planting
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City of Grand Rapids Michigan

Green Infrastructure  
Special Specifications

## BIORETENTION - COMPREHENSIVE

NOTE TO SPECIFIER. Delete this text before publishing with construction documents.

The bioretention specification section is an all-inclusive standard specification for constructing any type of bioretention system. This specification section may be used as a standard by itself or the individual specification sections may be used. Use one or the other, but not both.

When a project includes both porous pavement type practices and bioretention use the individual specification sections instead of this all-inclusive bioretention. The reason being is that there will be duplication on aggregates, geotextile, underdrains, etc.

### A. DESCRIPTION

This work consists of providing all labor, equipment and materials necessary for preparing the subsoil and constructing the bioretention system as indicated on the Drawings, or as directed by the Engineer.

The work shall be in accordance with *Divisions 4, 18, 22 and 23 of the City of Grand Rapids Standard Construction Specifications*, except as specified herein.

### References

The following specifications and standards of the organizations and documents listed in this paragraph form a part of the specification to the extent required by the references thereto. In the event that the requirements of the following referenced standards and specification conflict with this specification section the requirements of this specification shall prevail. In the event that the requirements of any of the following referenced standards and specifications conflict with each other the more stringent requirement shall prevail or as determined by the Engineer.

1. American Association of State Highway and Transportation Officials (AASHTO): cited section numbers:
  1. AASHTO M288-06(2011) Standard Specification for Geotextile Specification for Highway Applications
  2. AASHTO T-99 Standard Method of Test for Moisture-Density Relations of Soils
  3. AASHTO M 278 Standard Specification for Class PS46 Poly(Vinyl Chloride) (PVC) Pipe
2. American Joint Committee on Horticultural Nomenclature (AJCHN): Standardized Plant Names.
3. American National Standards Institute (ANSI) cited section numbers:
  1. ANSI Z60.1 American Standard for Nursery Stock, most current edition.
  2. ANSI A 300 – Standard Practices for Tree, Shrub and other Woody Plant Maintenance, most current edition and parts.
4. American Society of Testing Materials (ASTM) cited section numbers.
  1. ASTM D4972 Standard Test Method for pH of Soils
  2. ASTM D5268 Standard Specification for Topsoil Used for Landscaping Purposes
  3. ASTM D698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort
  4. ASTM F1815 Standard Test Methods for Saturated Hydraulic Conductivity, Water Retention, Porosity, and Bulk Density
  5. ASTM D1785 Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120
  6. ASTM D2729 Standard Specification for Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings
  7. ASTM D3034 Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings
  8. ASTM D3212 Standard Specification for Joints to Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals
  9. ASTM D3350 Standard Specification for Polyethylene Plastics Pipe and Fittings Materials

5. Standard Methods for the Examination of Water and Wastewater (SMEWW): 2540B: Total Solids Dried at 103-105 degrees Celsius
6. Soil Science Society of America (SSSA) Methods of Soil Analysis (<http://www.soils.org/>).
7. Test Methods from the Examination of Composting and Compost (TMECC) cited section numbers.
8. U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), 2003. National Soil Survey Handbook, title 430-VI. Available Online.

## **B. MATERIALS**

The Contractor will furnish certification by the Manufacturer, Supplier or Independent Testing Agency stating that the compost, topsoil, aggregates, geosynthetics or other materials as required by the Engineer conform to the required specifications. Engineer will determine the material sampling rates required. Samples shall be obtained from source location no earlier than 90 days prior to the beginning of construction.

### **Aggregates**

Aggregate materials shall conform to the specifications in *section 902 of the Michigan Department of Transportation Standard Specifications for Construction*. Recycled crushed concrete is not allowed. All aggregates shall be washed, sufficient to remove dust and other coatings and shall be free from clay balls, organic matter and other deleterious substances. Washed material that does not match the consistency of the approved material sample is subject to rejection and washing at Contractor's expense until requirements are met. If washing is to be completed on site, Contractor and/or supplier shall provide all resources and materials and cleanup required for washing the aggregate and completing the work in a method acceptable to the Engineer.

### **Bioretention Soil**

Bioretention soil shall be provided according to the soil mix identified on the construction drawings and the specifications provided below.

Final mix shall meet the following requirements:

- pH between 6.0 and 7.5
- Organic matter content: 2 to 10 percent, percent loss on ignition by dry weight
- Soluble salt concentration: Maximum of 2 dS/m (mmho/cm)

**NOTE TO SPECIFIER:** The following table lists the possible mixes that could be used for bioretention facilities. Choose the appropriate mix for the project and delete references to all other mixtures.

Soil Mix A is the standard mix that has been specified in Grand Rapids. This mix is best used in situations where water discharging from the practice connects back to a combined sewer due to the high levels of nutrients that will leach from the compost.

Soil Mix B is a more expensive mix that is best used near sensitive water bodies or in high profile areas where high quality plant material will be used.

Soil Mix C is designed for the reuse of onsite topsoil with high levels of clay. It contains very low amounts of nitrogen, which will limit weed growth and allow native vegetation to establish with lower maintenance inputs. It is best used on sites that are not located in high profile areas since standard native plant mixes for bioretention requiring low maintenance tend to look 'weedy' to most people.

Soil Mix D should be specified for swales that will be vegetated with turf grass only. The profile will consist of sand or aggregate as a storage layer, a layer of geotextile and finally topsoil.

Soil Mix E is designed for tree pits in commercial areas, tree trenches under suspended pavement or as backfill in soil cell systems like SilvaCell.

Structural Soil is a proprietary mix that can be compacted to 95% under pavements and will still support root growth.

Type	Composition
Soil Mix A	A well-blended, homogenous mixture of: <ul style="list-style-type: none"> <li>• 50 to 60% Coarse Sand</li> <li>• 20 to 30% Topsoil</li> <li>• 20 to 30% Compost</li> </ul>
Soil Mix B	A mixture of coarse sand, compost and unscreened topsoil in proportions to meet the following: <ul style="list-style-type: none"> <li>• Silt plus clay (combined): 25 to 40 percent, by dry weight</li> <li>• Total sand: 60 to 75 percent, by dry weight</li> <li>• Total coarse and medium sand: minimum of 55 percent of total sand, by dry weight</li> <li>• Fine gravel less than 5 millimeters: up to 12 percent by dry weight (calculated separately from sand/silt/ clay total)</li> <li>• Saturated hydraulic conductivity: 1 to 8 inches per hour</li> <li>• ASTM F1815 at 85 percent compaction, Standard Proctor ASTM D698</li> <li>• Phosphorus between 12 and 30 parts per million (ppm)</li> </ul> <p>Suggested mix ratio ranges, by volume, are:</p> <ul style="list-style-type: none"> <li>• Coarse sand: 50 to 65%</li> <li>• Unscreened topsoil: 25 to 35%</li> <li>• Compost: 10 to 15%</li> </ul> <p>Lightly mix the Bioretention Soil using a front end loader to preserve topsoil peds as much as possible. Topsoil peds 2 inches in diameter or larger should be visible in the finished stockpile. Do not over mix or screen the material.</p>
Soil Mix C	Unscreened topsoil salvaged from site amended with woodchips: <ul style="list-style-type: none"> <li>• Woodchips shall be aged at least 3 weeks and shall not contain roots, soil, seeds or wood chipped from black walnut</li> </ul>
Soil Mix D	Topsoil compacted to 85% compaction per Standard Proctor ASTM D698
Soil Mix E	A mixture of unscreened topsoil, coarse sand, and compost in proportions to meet the following: <ul style="list-style-type: none"> <li>• Coarse sand: 30 to 40%</li> <li>• Unscreened topsoil: 50 to 60%</li> <li>• Compost: 10%</li> </ul> <p>Mix the sand and compost together and then add to the topsoil. Mix with a loader bucket to loosely incorporate the topsoil into the sand/compost mix. Do not over mix or screen the material. Topsoil peds 2 inches in diameter or larger should be visible in the finished stockpile.</p>
Structural Soil	Structural Soil shall be "CU Soil" as manufactured by Amereq, Inc. New York City, NY, or approved equal.

Mix shall be free of stones, stumps, roots or other similar objects larger than 2 inches, excluding mulch and soil peds. The material shall be loose and friable. No other materials or substances that may be harmful to plant growth or prove a hindrance to the planting or maintenance operations shall be mixed or dumped within the bioretention area. It shall have no visible free water.

**Compost**

Compost must be mature, stabilized, humus-like, dark brown or black compost derived from the aerobic decomposition of yard clippings or other compostable materials as defined in 1995 PA 451, Part 115 Solid Waste Management, and federal and state laws. Compost must be capable of supporting plant growth; free of objectionable odor, plastic, glass, metal, or other physical contaminants; not contain viable weed seeds, or other plant parts capable of reproducing; and must not produce visible free water or dust during

handling. Compost shall not resemble the raw material from which it was derived or over 5% sand, silt, clay or rock material by dry weight.

The compost shall meet the following criteria:

Parameter	Range	Testing Method
pH	5.5-7.0	TMECC 4.11A
Soluble Salt Concentration	< 10dS/m (mmhos/cm)	TMECC 4.10-A
Moisture	30-60% wet weight basis	SMEWW 2540B
Organic Matter	30-65% dry weight basis	TMECC 5.07-A
Particle Size	98% passing 3/4" screen or smaller	TMECC 2.02-B
Stability (Carbon Dioxide evolution rate)	> 80% relative to positive control	TMECC 5.08-B
Maturity (Seed emergence and seedling vigor)	> 80% relative to positive control	TMECC 5.05-A
Physical contaminants (man-made inerts)	< 1% dry weight basis	TMECC 3.08-A
Chemical contaminants	Meet or exceed US EPA Class A standard, 40 CFR § 503.13, Tables 1 and 3 levels:	
Arsenic	< 41ppm	TMECC 4.06-AS
Cadmium	< 39 ppm	TMECC 4.06-CD
Copper	< 1,500 ppm	TMECC 4.05-CU
Lead	< 300 ppm	TMECC 4.06-PB
Mercury	< 17 ppm	TMECC 4.06-HG
Molybdenum	< 75 ppm	TMECC 4.05-MO
Nickel	< 420 ppm	TMECC 4.06-NI
Selenium	< 100 ppm	TMECC 4.06-SE
Zinc	< 2,800 ppm	TMECC 4.06-ZN
Biological contaminants (pathogens)	Meet or exceed US EPA Class A standard, 40 CFR § 503.32(a) levels:	
Fecal coliform	< 1,000 MPN per gram, dry weight basis	TMECC 7.01
Salmonella	< 3 MPN per 4 grams, dry weight basis	TMECC 7.02

#### Coarse Sand

Coarse sand, ASTM C-33 Fine Aggregate, with a Fines Modulus Index between 2.8 and 3.2. Coarse Sand shall be clean, sharp, mineral sand and shall be washed to remove silt and clay particles. Provide the following particle size distribution:

Sieve Size	Percent Passing
3/8 inch	100%
#4	95 to 100%
#8	80 to 100%
#16	50 to 85%
#30	25 to 60%
#50	5 to 30%
#100	0 to 10%
#200	<3%

#### Topsoil

Sandy loam, loamy sand, loam texture or sandy clay loam according to USDA textural triangle. Topsoil shall be unscreened and shall be free of subsoil, stones or other materials 2 inches or larger in diameter in any direction and free of extraneous materials harmful to plant growth, with a pH range of 5.5 to 7.5. The soil chemistry should be suitable for growing plants and the soluble salt level should be less than 2 dS/m (mmho/cm). Existing onsite topsoil may be reused only if it meets the above requirements, or if otherwise specified.

All imported topsoil shall be tested for metals hazardous to human health including at a minimum, arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. Topsoil containing metals with concentrations above MDEQ Part 201 Residential Direct Contact Generic Cleanup Criteria shall not be accepted.

**Soil Cells**

Pre-engineered modular structures designed to hold up pavement and to be filled with soil to support tree roots and treat storm water, with the goal of protecting soil within the cells from compaction from the loads on the overlying pavement. Soil Cells shall be manufactured by DeepRoot Green Infrastructure, LLC., San Francisco CA; GreenBlue, Woodstock ON, or approved equal.

**Geotextile**

Geotextile shall meet AASHTO M288-06(2011), for Class 2 strength property requirements and Subsurface Drainage requirements as shown below.

<b>Parameter</b>	<b>Value</b>	<b>Test Method</b>
Grab strength (min)	700 N (150 lbs)	ASTM D 4632
Tear strength (min)	250 N (50 lbs)	ASTM D 4533
Puncture strength (min)	1375 N (300 lbs)	ASTM D 6241
Permittivity (min)	0.5 per second	ASTM D 4491
Apparent opening size (max)	0.215 mm (70 US Std. Sieve)	ASTM D 4751

**Underdrain and Cleanout**

All materials shall meet the requirements set forth in *Section 909 of the Michigan Department of Transportation (MDOT) Standard Specifications* and *Division 18 of the City of Grand Rapids Standard Construction Specifications*.

*Underdrain*

Underdrain shall be Schedule 40 or SDR 35 smooth wall PVC pipe as specified on Plans. Underdrains within the bioretention areas shall be perforated with 3/8-inch perforations. Use solid sections of non-perforated PVC piping with watertight joints when underdrain is located outside of bioretention areas, connects to a drainage structure, or daylights to grade.

Underdrain shall be HDPE along curves, as indicated on Plans.

*Fittings and Caps*

All fittings and connections shall be compatible with the underdrain materials used to prevent pipe separation. End caps shall be threaded PVC with 2-inch square lug in non-paved areas and lockable flush mounted caps rated for HS-20 loading in paved areas as shown on Plans.

*Cleanout*

Cleanouts shall be constructed with vertical non-perforated schedule 40 PVC pipe as shown on Plans. Extend cleanout to the surface and cap with a watertight removable cap.

*Valves*

Gate valve: Shall be manual slide valve, PVC plastic body and hubs with 304 stainless steel shaft and paddle (4-inch or 6-inch) and die cast aluminum handle, Valterra or approved equal as shown on Plans.

**Root Barrier**

Root barrier shall prevent root penetration. The material shall be impermeable and ribbed with a thickness of 1mm to 2mm.

**Permeable Tree Well Paving**

Permeable pavement placed over tree trench in the opening around the tree with the goal of providing a hard surface that infiltrates water and allows air transfer. The pavement must be suitable for heavy pedestrian traffic, ADA compliant, slip resistant, UV stable and capable of passing a minimum of 50 gallons per minute per square foot. Allowable resin based products include the following or approved equal:

Product	CIP or Precast	Color
Xeripave® ( <a href="http://www.xeripave.com">www.xeripave.com</a> )	Precast	
Porous Pave Inc. ( <a href="http://www.porouspaveinc.com">www.porouspaveinc.com</a> )	Cast in place	
Filterpave Glass Series ( <a href="http://filterpave.net/">http://filterpave.net/</a> )	Cast in place	
Filterpave Stone Series ( <a href="http://filterpave.net/">http://filterpave.net/</a> )	Cast in place	

**Delivery, Storage and Handling**

Material shall not be handled or hauled when it is wet or frozen. Soil shall be hauled only when the moisture content is between 60% and 100% of optimum moisture content as determined by AASHTO T-99 for all planting soils. Stockpiles shall be covered during wet weather. The Soil Supplier is responsible for meeting these requirements until the soil is delivered to the site. Soil which is delivered that exceeds the allowable maximum moisture content shall be replaced with new soil that meets the requirements.

Contractor shall store and handle packaged materials in strict compliance with manufacturer's instructions and recommendations. Protect all materials from weather, damage, injury and theft.

All flexible pipe shall be stored on flat surface so that barrel is evenly supported. Pipe shall not be stored in piles higher than 4 feet. If pipe is to be stored for over 1 month, it shall be covered with opaque material so that it is protected from sun's ray and bells shall be inverted in alternate rows so they are not supporting direct load. Deflection of pipe shall not exceed 5 percent. Follow manufacturer's instructions in storing and handling pipe during periods of extreme temperatures.

**C. CONSTRUCTION**

**Pre-Installation Examination and Preparation**

Coordinate activities with other project contractors so that there is no soil disturbance from traffic or other construction activities subsequent to bioretention construction. The Contractor shall examine previous work, related work, and conditions under which this work is to be performed and shall notify the Engineer in writing of all deficiencies and conditions detrimental to the proper completion of this work. The Contractor shall not place any planting soil until all work in adjacent areas is complete and approved by the Engineer.

**Excavation**

Excavate bioretention surfaces as indicated on the grading and landscape Drawings, using light earth-moving equipment or by excavating from the perimeter of the excavated area. Appropriate equipment includes wide track or marsh track equipment, or light equipment with turf-type tires. No heavy equipment will be allowed on the bottom of the bioretention. Remove excavated materials from the site.

**Subgrade**

No heavy equipment shall pass over the subsoils (subgrade) after they have been loosened. If the Contractor plans to utilize such areas for any use of heavy equipment, this work should be carried out prior to beginning the process of loosening soils or filling in that area.

Placement of material will not be allowed if any portion of the bioretention area is excessively wet, saturated, or has been subjected to more than ½ inch of precipitation within 48 hours prior to the proposed construction activities. The Engineer shall have final authority to determine if excessively wet or saturated conditions exist.

Prior to placing any aggregate, soil or any drainage materials beneath the bioretention area the entire subgrade shall be loosened using a soil ripper or subsoiler to break up the native soil to a minimum 12-inch depth. Remove ponded water at the bottom of the excavation before tilling or ripping. Soil shall be friable before tilling.

After the subgrade soils have been loosened and inspected, remove stones and debris 6 inches or greater and dispose of off the project site. Do not bury large stones or debris. Confirm that the subgrade is at the proper elevation as shown on the drawings.

Upon completion of sub-grade work, the Engineer shall be notified and shall inspect the sub-grade before the Contractor continues installation. Owner or City Engineer shall have the option to perform infiltration

testing on the subgrade to verify minimum infiltration rates, at the Contractor's expense where specified on the contract documents. Infiltration shall be measured through Double-Ring Infiltrometer field testing in accordance with *Appendix E of the 2008 Edition of the Michigan LID Manual*.

Any accumulation of debris or sediment which takes place after approval of sub-grade and prior to placement of aggregate shall be removed prior to aggregate base installation continuing at no extra cost.

### **Geotextile**

Material shall be cut and fit to the dimensions shown on the plans with adequate lap lengths, a minimal number of seams, and with excess materials removed and disposed of properly. Clean and straight cuts are required to the line and grade of the plans. The graded surface shall be smooth and free of deleterious materials such as sharp objects or large protruding rocks that could cause the geotextile to tear.

Geotextiles shall be placed on the prepared surface parallel to the longest side of the practice. Place geotextile in a manner that minimizes folds and creases. Successive sheets of geotextile shall be overlapped a minimum of 1 foot with the up-flow sheet overlapping the down flow sheet.

Securing pins or staples for geotextile fabric shall have a minimum length of 10 inches and shall be designed to securely hold the geotextile fabric in place during construction. Waterproofing membrane shall be held in place by backfilling or other means without puncturing the material. Other methods of pinning can also be used as allowed by the Engineer.

Waterproofing membrane shall be glued continuously at seams in accordance with all manufacturers' recommendations including any required overlap. Folds shall also be secured and pulled taught.

### ***Protection of Geotextiles***

Construction traffic on exposed geosynthetic materials is strictly prohibited. After beginning work, coordinate activities with other work so that there is no disturbance or damage from traffic or other construction activities subsequent to placement. Any damaged geotextile, geogrid, or waterproofing membrane shall be repaired or replaced immediately upon discovery of the damage, to the satisfaction of the Engineer, at the Contractor's expense.

### **Aggregate**

Provide and place aggregate with a uniform gradation, free of contamination and segregation. Do not rut or distort the subbase material or aggregate base during spreading. Compact the aggregate layers to a uniform thickness, no greater than 12 inches. Compact each layer of aggregate to at least 95 percent of the maximum unit weight. Where the aggregate course is constructed in more than one-layer, complete grading, and then clean previously constructed layers of loose and foreign matter prior to placing subsequent layers.

### **Underdrain**

Place underdrains to the line and grade as shown on Plans or established by the Engineer. Perforated pipes shall be placed with perforations pointing down. Pipe shall be placed with the bell end up grade. Pipe sections shall be joined with appropriate couplings. The ends of underdrain pipe shall be plugged at the upstream ends as directed by the Engineer.

Underdrains are to be tapped to existing storm water structures and pipes as shown on Plans. Connections shall meet the requirements set forth in *GR Standard Specification 18.03*, and on Plans.

Do not wrap underdrain with geotextile fabric or pipe sock unless directed by the Engineer.

At the close of each day's work, the open ends of the pipe shall be satisfactorily protected against the entrance of water, earth or rubbish. If there is as much as ¼ inch or more of silt or earth deposited in pipe, the Contractor shall clean out and remove such deposits at no cost to the Owner.

### ***Cleanouts***

Connect riser to underdrain pipe using approved fittings as shown on Plans. In non-paved areas set caps 6 inches above final grade. In paved areas, encase flush mounted caps in concrete as shown on Plans.

### *Valves*

Gate valve to be located per the plans and as directed by the Engineer within an accessible catch basin or overflow riser and upstream of proposed sewer field connection yet downstream of perforated underdrain pipe. The incoming non-perforated PVC pipe shall extend into the catch basin or overflow riser a sufficient distance to allow for connection of the valve as well as sufficient operation of the valve handle but not more than a distance of 8 inches. Valves may also be placed within valve boxes as per plans and specifications and as directed by the Engineer. Catch basins, overflow risers and/or valve boxes must have sufficient depth to allow for the height of the valve when in its fully open position plus at least 3 inches at the top.

### **Bioretention Soil**

When bioretention soil is installed directly on top of subsoil, apply an initial lift of 3 to 4 inches and till into subsoil with one pass to create a gradation zone.

*Soil Mix A.* Place bioretention soil mix in 18-inch maximum lifts. Avoid compaction with heavy equipment. The soil may be compacted with water by saturating each soil layer lift. Apply water by spraying or sprinkling in a manner to avoid separation of the bioretention soil mixture components.

*Soil Mix B.* Install soil mix in approximately 12 to 16-inch lifts to the required depths. Compact each lift of the soil mix so that the pressure reading of a cone penetrometer is between 100 and 200 pounds per square inch (psi) with a volumetric soil moisture between 12 and 20 percent. Scarify the surface of each lift with the teeth of a back hoe or similar equipment prior to installing additional lifts.

*Soil Mix C.* Place 2 inches of woodchips over the subgrade at the bottom elevation of the bioretention area and place the first 2 inches of topsoil over the woodchip layer. Rototill with one pass to create a gradation zone. Apply the remainder of the topsoil in 18-inch maximum lifts. Apply 2 inches of woodchips to surface of topsoil and till with one pass only to incorporate. Do not over-till so as to preserve the natural clumps and peds in the soil. Water compact the soil by spraying or sprinkling in a manner to avoid any scour or erosion.

*Soil Mix D.* Place 6 inches of topsoil and compact so that the pressure reading of a cone penetrometer is between 100 and 200 pounds per square inch (psi) with a volumetric soil moisture between 12 and 20 percent.

*Soil Mix E.* Install soil mix in approximately 12 to 16-inch lifts to the required depths, or as directed per manufacturer's requirements. Walk through the placed planting soil to remove air pockets and settle the soil. Do not compact greater than 80 percent of maximum dry density in accordance with ASTM D698, Standard Proctor Method.

*Structural Soil.* Install and compact Structural Soil in accordance with the manufacturer's requirements.

Where possible place large trees first and fill Bioretention Soil around the root ball.

Phase work such that equipment to deliver or grade soil does not have to operate over previously installed Bioretention Soil. Work in rows of lifts the width of the extension of the bucket on the loader. Install all lifts in one row before proceeding to the next. Work out from the furthest part of each bed from the soil delivery point to the edge of each bed area.

Where travel over installed soil is unavoidable, limit paths of traffic to reduce the impact of compaction in Bioretention Soil. Each time equipment passes over the installed soil it shall reverse out of the area along the same path with the teeth of the bucket dropped to scarify the soil. In the event that soil becomes over compacted, remove and replace the soil at no additional cost to the Owner.

The depths and grades shown on the drawings are the final grades after settlement and shrinkage. The Contractor shall install the Bioretention Soil at a higher level to anticipate this reduction of Planting Soil volume. Where settling occurs, before final acceptance or during the warranty period, remove finish surfacing, backfill with additional approved soil, and restore any disturbed areas to a condition acceptable to the Owner.

Planting of the vegetation and mulching must be conducted immediately following final grading. Refer to the specification for planting for further requirements.

**Soil Cells**

Install soil cells in accordance with manufacturer's requirements.

**Root Barrier**

Root barriers shall be installed per manufacturer's specifications and recommendations. Install with vertical root directing ribs facing inwards towards trees or plants.

**Permeable Tree Well Paving**

Install permeable pavement in accordance with manufacturer's recommendations.

**D. MEASUREMENT AND PAYMENT**

The completed work, as described, shall be paid for at the contract unit price for the following contract item (pay item):

<b>Contract Item (Pay Item)</b>	<b>Pay Unit</b>
Bioretention, _____	Cubic Yard

Measurement for **Bioretention**, \_\_\_\_\_ will be measured in cubic yards complete as measured in place and includes all labor, equipment and materials necessary to complete the work as described.

## BIORETENTION

NOTE TO SPECIFIER. Delete this text before publishing with construction documents.

This bioretention specification assume individual specification sections are included in the construction documents for individual components that make up the bioretention. This specification section is used to define the method of payment.

When a project includes both porous pavement type practices and bioretention use the individual specification sections instead of this all-inclusive bioretention. The reason being is that there will be duplication on aggregates, geotextile, underdrains, etc.

### A. DESCRIPTION

This work consists of providing all labor, equipment and materials necessary for preparing the subsoil and constructing the bioretention system as indicated on the Drawings, or as directed by the Engineer.

The work shall be in accordance with *Divisions 4, 18, 22 and 23 of the City of Grand Rapids Standard Construction Specifications*, and the following specification sections:

- Aggregates for Stormwater Management
- Bioretention Soil
- Check Dams for Stormwater Facilities
- Geosynthetics
- Underdrains

### B. MATERIALS

Refer to the referenced specification section for material requirements.

### C. CONSTRUCTION

Refer to the referenced specification sections for the construction requirements beyond subgrade preparation.

#### **Pre-Installation Examination and Preparation**

Coordinate activities with other project contractors so that there is no soil disturbance from traffic or other construction activities subsequent to bioretention construction. The Contractor shall examine previous work, related work, and conditions under which this work is to be performed and shall notify the Engineer in writing of all deficiencies and conditions detrimental to the proper completion of this work. The Contractor shall not place any planting soil until all work in adjacent areas is complete and approved by the Engineer.

#### **Excavation**

Excavation and sub-grade preparation to the lines and grades shown on the Contract Documents. Excavate using light earth-moving equipment or by excavating from the perimeter of the excavated area. Appropriate equipment includes wide track or marsh track equipment, or light equipment with turf-type tires. No heavy equipment will be allowed on the bottom of the intended infiltration area. Remove excavated materials from the site.

#### **Subgrade**

No heavy equipment shall pass over the subsoils (subgrade) after they have been loosened. If the Contractor plans to utilize such areas for any use of heavy equipment, this work should be carried out prior to beginning the process of loosening soils or filling in that area.

Placement of material will not be allowed if any portion of the bioretention area is excessively wet, saturated, or has been subjected to more than ½ inch of precipitation within 48 hours prior to the proposed construction

activities. The Engineer shall have final authority to determine if excessively wet or saturated conditions exist.

Prior to placing any aggregate, soil or any drainage materials beneath the infiltration area the entire subgrade shall be loosened using a soil ripper or subsoiler to break up the native soil to a minimum 12-inch depth. Remove ponded water at the bottom of the excavation before tilling or ripping. Soil shall be friable before tilling.

After the subgrade soils have been loosened and inspected, remove stones and debris 6 inches or greater and dispose of off the project site. Do not bury large stones or debris. Confirm that the subgrade is at the proper elevation as shown on the drawings.

Upon completion of sub-grade work, the Engineer shall be notified and shall inspect the sub-grade before the Contractor continues installation. Owner or City Engineer shall have the option to perform infiltration testing on the subgrade to verify minimum infiltration rates, at the Contractor's expense where specified on the contract documents. Infiltration shall be measured through Double-Ring Infiltrometer field testing in accordance with *Appendix E of the 2008 Edition of the Michigan LID Manual*.

Any accumulation of debris or sediment which takes place after approval of sub-grade and prior to placement of aggregate shall be removed prior to aggregate base installation continuing at no extra cost.

**D. MEASUREMENT AND PAYMENT**

The completed work, as described, shall be paid for at the contract unit price for the following contract items (pay items). The price shall be payment in full for furnishing all labor, equipment and material, for furnishing and placing aggregates for stormwater management, bioretention soil, geosynthetics, underdrains and cleanouts, root barriers, structural soil cells, and riprap, and for any necessary grading, excavation and backfill when not paid for separately, and for performing the work complete.

<b>Contract Item (Pay Item)</b>	<b>Pay Unit</b>
Bioretention, _____	Square Feet
Linear Bioretention, _____	Linear Feet
Bioretention Planter, _____	Square Feet
Bioretention Bulbout, _____	Square Feet
Tree Trench, _____	Linear Feet
Tree Trench, _____	Square Feet

NOTE TO SPECIFIER. Delete this text before publishing with construction documents.  
 Measurement and payment for curb and gutter around the perimeter of the bioretention should be separate.  
 Measurement and payment for furnishing, installing and maintenance of vegetation should be separate.

# AGGREGATES FOR STORMWATER MANAGEMENT

## A. DESCRIPTION

This item shall consist of constructing aggregate base courses for permeable pavements and bioretention facilities to the specified depths on a prepared foundation conforming to the lines, grades and cross sections shown in the contract documents. Base courses may include reservoir layer, storage layer, choker layer, filter layer, and other layers included in the Contract Documents. Except as herein stated, the requirements for control of materials, submittals, sampling, and testing items specified under *Division 3* found in *Section 105 of the Michigan Department of Transportation (MDOT) Standard Specifications* that are not described in sections below, are applicable to this specification.

## B. MATERIALS

The Contractor will furnish certification by the Manufacturer, Supplier or Independent Testing Agency stating that the compost, topsoil, aggregates, geosynthetics or other materials as required by the Engineer conform to the required specifications. Engineer will determine the material sampling rates required. The Contractor will submit the shipping list (packing slip) for plant material.

### Aggregates

Aggregate materials shall conform to the specifications in *section 902 of the Michigan Department of Transportation Standard Specifications for Construction*. Recycled crushed concrete is not allowed. All aggregates shall be washed, sufficient to remove dust and other coatings and shall be free from clay balls, organic matter and other deleterious substances. Washed material that does not match the consistency of the approved material sample is subject to rejection and washing at Contractor's expense until requirements are met. If washing is to be completed on site, Contractor and/or supplier shall provide all resources and materials and cleanup required for washing the aggregate and completing the work in a method acceptable to the Engineer.

## C. CONSTRUCTION

### Aggregate

Provide and place aggregate with a uniform gradation, free of contamination and segregation. Do not rut or distort the subbase material or aggregate base during spreading. Compact the aggregate layers to a uniform thickness, no greater than 12 inches. Compact each layer of aggregate to at least 95 percent of the maximum unit weight. Where the aggregate course is constructed in more than one-layer, complete grading, and then clean previously constructed layers of loose and foreign matter prior to placing subsequent layers. Aggregate base that does not meet grade, contains segregated or degraded material, or has suboptimal water content is subject to rejection and correction by the Contractor at no cost to the Owner.

### Hauling Aggregates for Stormwater Management

Trucks meeting the same cleanliness requirements of the washed materials shall be used during hauling. Trucks used to haul other materials shall be inspected and cleaned prior hauling the washed material.

### Limitations on Placing

Do not install aggregate base course when rainfall or other weather conditions will detrimentally affect the quality of the work.

### Protection

Prevent sediment from washing into the aggregate at all times during and after construction. Sediment accumulation into the aggregate base course shall be removed immediately by cleaning or replacement of the aggregate by the Contractor at no cost to the owner.

## D. MEASUREMENT AND PAYMENT

The work specified in this section shall be included in the price bid for bioretention and porous pavements and no additional payment will be made therefor.

# BIORETENTION SOIL

## A. DESCRIPTION

This work consists of providing all labor, equipment and materials necessary for furnishing and placing the bioretention soil as indicated on the Drawings, or as directed by the Engineer.

The work shall be in accordance with *Divisions 4, 18, 22 and 23 of the City of Grand Rapids Standard Construction Specifications*, except as specified herein.

### References

The following specifications and standards of the organizations and documents listed in this paragraph form a part of the specification to the extent required by the references thereto. In the event that the requirements of the following referenced standards and specification conflict with this specification section the requirements of this specification shall prevail. In the event that the requirements of any of the following referenced standards and specifications conflict with each other the more stringent requirement shall prevail or as determined by the Engineer.

1. American Association of State Highway and Transportation Officials (AASHTO): cited section numbers:
  1. AASHTO T-99 Standard Method of Test for Moisture-Density Relations of Soils
2. American Society of Testing Materials (ASTM) cited section numbers.
  1. ASTM D4972 Standard Test Method for pH of Soils
  2. ASTM D5268 Standard Specification for Topsoil Used for Landscaping Purposes
  3. ASTM D698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort
  4. ASTM F1815 Standard Test Methods for Saturated Hydraulic Conductivity, Water Retention, Porosity, and Bulk Density
3. Standard Methods for the Examination of Water and Wastewater (SMEWW): 2540B: Total Solids Dried at 103-105 degrees Celsius
4. Soil Science Society of America (SSSA) Methods of Soil Analysis (<http://www.soils.org/>).
5. Test Methods from the Examination of Composting and Compost (TMECC) cited section numbers.
6. U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), 2003. National Soil Survey Handbook, title 430-VI. Available Online.

## B. MATERIALS

The Contractor will furnish certification by the Manufacturer, Supplier or Independent Testing Agency stating that the compost, topsoil, aggregates, or other materials as required by the Engineer conform to the required specifications. Engineer will determine the material sampling rates required. Samples for testing shall be obtained from source location no earlier than 90 days prior to the beginning of construction.

Bioretention soil shall be provided according to the soil mix identified on the construction drawings and the specifications provided below.

Final mix shall meet the following requirements:

- pH between 6.0 and 7.5
- Organic matter content: 2 to 10 percent, percent loss on ignition by dry weight
- Soluble salt concentration: Maximum of 2 dS/m (mmho/cm)

- NOTE TO SPECIFIER: The following table lists the possible mixes that could be used for bioretention facilities. Choose the appropriate mix for the project and delete references to all other mixtures.
- Soil Mix A is the standard mix that has been specified in Grand Rapids. This mix is best used in situations where water discharging from the practice connects back to a combined sewer due to the elevated levels of nutrients that will leach from the compost.

- Soil Mix B is a more expensive mix that is best used near sensitive water bodies or in high profile areas where high quality plant material will be used.
- Soil Mix C is designed for the reuse of onsite topsoil with prominent levels of clay. It contains very low amounts of nitrogen, which will limit weed growth and allow native vegetation to establish with lower maintenance inputs. It is best used on sites that are not located in high profile areas since standard native plant mixes for bioretention requiring minimal maintenance tend to look ‘weedy’ to most people.
- Soil Mix D should be specified for swales that will be vegetated with turf grass only. The profile will consist of sand or aggregate as a storage layer, a layer of geotextile and finally topsoil.
- Soil Mix E is designed for tree pits in commercial areas, tree trenches under suspended pavement or as backfill in soil cell systems like Silva Cell.
- Structural Soil is a proprietary mix that can be compacted to 95% under pavements and will still support root growth.

Type	Composition
Soil Mix A	A well-blended, homogenous mixture of: <ul style="list-style-type: none"> <li>• 50 to 60% Coarse Sand</li> <li>• 20 to 30% Topsoil</li> <li>• 20 to 30% Compost</li> </ul>
Soil Mix B	A mixture of coarse sand, compost and unscreened topsoil in proportions to meet the following: <ul style="list-style-type: none"> <li>• Silt plus clay (combined): 25 to 40 percent, by dry weight</li> <li>• Total sand: 60 to 75 percent, by dry weight</li> <li>• Total coarse and medium sand: minimum of 55 percent of total sand, by dry weight</li> <li>• Fine gravel less than 5 millimeters: up to 12 percent by dry weight (calculated separately from sand/silt/ clay total)</li> <li>• Saturated hydraulic conductivity: 1 to 8 inches per hour</li> <li>• ASTM F1815 at 85 percent compaction, Standard Proctor ASTM D698</li> <li>• Phosphorus between 12 and 30 parts per million (ppm)</li> </ul> <p>Suggested mix ratio ranges, by volume, are:</p> <ul style="list-style-type: none"> <li>• Coarse sand: 50 to 65%</li> <li>• Unscreened topsoil: 25 to 35%</li> <li>• Compost: 10 to 15%</li> </ul> <p>Lightly mix the Bioretention Soil using a front-end loader to preserve topsoil peds as much as possible. Topsoil peds 2 inches in diameter or larger should be visible in the finished stockpile. Do not over mix or screen the material.</p>
Soil Mix C	Unscreened topsoil salvaged from site amended with woodchips: Woodchips shall be aged at least 3 weeks and shall not contain roots, soil, seeds or wood chipped from black walnut
Soil Mix D	Topsoil compacted to 85% compaction per Standard Proctor ASTM D698
Soil Mix E	A mixture of unscreened topsoil, coarse sand, and compost in proportions to meet the following: <ul style="list-style-type: none"> <li>• Coarse sand: 30 to 40%</li> <li>• Unscreened topsoil: 50 to 60%</li> <li>• Compost: 10%</li> </ul> <p>Mix the sand and compost together and then add to the topsoil. Mix with a loader bucket to loosely incorporate the topsoil into the sand/compost mix. Do not over mix or screen the</p>

	material. Topsoil peds 2 inches in diameter or larger should be visible in the finished stockpile.
Structural Soil	Structural Soil shall be "CU Soil" as manufactured by Amereq, Inc. New York City, NY, or approved equal.

Mix shall be free of stones, stumps, roots or other similar objects larger than 2 inches, excluding mulch and soil peds. The material shall be loose and friable. No other materials or substances that may be harmful to plant growth or prove a hindrance to the planting or maintenance operations shall be mixed or dumped within the bioretention area. It shall have no visible free water.

### **Compost**

Compost must be mature, stabilized, humus-like, dark brown or black compost derived from the aerobic decomposition of yard clippings or other compostable materials as defined in 1995 PA 451, Part 115 Solid Waste Management, and federal and state laws. Compost must be capable of supporting plant growth; free of objectionable odor, plastic, glass, metal, or other physical contaminants; not contain viable weed seeds, or other plant parts capable of reproducing; and must not produce visible free water or dust during handling. Compost shall not resemble the raw material from which it was derived or over 5% sand, silt, clay or rock material by dry weight.

The compost shall meet the following criteria:

<b>Parameter</b>	<b>Range</b>	<b>Testing Method</b>
pH	5.5-7.0	TMECC 4.11A
Soluble Salt Concentration	< 10dS/m (mmhos/cm)	TMECC 4.10-A
Moisture	30-60% wet weight basis	SMEWW 2540B
Organic Matter	30-65% dry weight basis	TMECC 5.07-A
Particle Size	98% passing 3/4" screen or smaller	TMECC 2.02-B
Stability (Carbon Dioxide evolution rate)	> 80% relative to positive control	TMECC 5.08-B
Maturity (Seed emergence and seedling vigor)	> 80% relative to positive control	TMECC 5.05-A
Physical contaminants (man-made inert)	< 1% dry weight basis	TMECC 3.08-A
Chemical contaminants	Meet or exceed US EPA Class A standard, 40 CFR § 503.13, Tables 1 and 3 levels:	
Arsenic	< 41ppm	TMECC 4.06-AS
Cadmium	< 39 ppm	TMECC 4.06-CD
Copper	< 1,500 ppm	TMECC 4.05-CU
Lead	< 300 ppm	TMECC 4.06-PB
Mercury	< 17 ppm	TMECC 4.06-HG
Molybdenum	< 75 ppm	TMECC 4.05-MO
Nickel	< 420 ppm	TMECC 4.06-NI
Selenium	< 100 ppm	TMECC 4.06-SE
Zinc	< 2,800 ppm	TMECC 4.06-ZN
Biological contaminants (pathogens)	Meet or exceed US EPA Class A standard, 40 CFR § 503.32(a) levels:	
Fecal coliform	< 1,000 MPN per gram, dry weight basis	TMECC 7.01
Salmonella	< 3 MPN per 4 grams, dry weight basis	TMECC 7.02

### **Coarse Sand**

Coarse sand, ASTM C-33 Fine Aggregate, with a Fines Modulus Index between 2.8 and 3.2. Coarse Sand shall be clean, sharp, mineral sand and shall be washed to remove silt and clay particles. Provide the following particle size distribution:

Sieve Size	Percent Passing
3/8 inch	100%
#4	95 to 100%
#8	80 to 100%
#16	50 to 85%
#30	25 to 60%
#50	5 to 30%
#100	0 to 10%
#200	<3%

**Topsoil**

Sandy loam, loamy sand, loam texture or sandy clay loam according to USDA textural triangle. Topsoil shall be unscreened and shall be free of subsoil, stones or other materials 2 inches or larger in diameter in any direction and free of extraneous materials harmful to plant growth, with a pH range of 5.5 to 7.5. The soil chemistry should be suitable for growing plants and the soluble salt level should be less than 2 dS/m (mmho/cm). Existing onsite topsoil may be reused only if it meets the above requirements, or if otherwise specified.

All imported topsoil shall be tested for metals hazardous to human health including at a minimum, arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. Topsoil containing metals with concentrations above MDEQ Part 201 Residential Direct Contact Generic Cleanup Criteria shall not be accepted.

**Delivery, Storage and Handling**

Material shall not be handled or hauled when it is wet or frozen. Soil shall be hauled only when the moisture content is between 60% and 100% of optimum moisture content as determined by AASHTO T-99 for all planting soils. Stockpiles shall be covered during wet weather. The Soil Supplier is responsible for meeting these requirements until the soil is delivered to the site. Soil which is delivered that exceeds the allowable maximum moisture content shall be replaced with new soil that meets the requirements.

Contractor shall store and handle packaged materials in strict compliance with manufacturer's instructions and recommendations. Protect all materials from weather, damage, injury and theft.

**C. CONSTRUCTION**

When bioretention soil is installed directly on top of subsoil, apply an initial lift of 3 to 4 inches and till into subsoil with one pass to create a gradation zone.

*Soil Mix A.* Place bioretention soil mix in 18-inch maximum lifts. Avoid compaction with heavy equipment. The soil may be compacted with water by saturating each soil layer lift. Apply water by spraying or sprinkling in a manner to avoid separation of the bioretention soil mixture components.

*Soil Mix B.* Install soil mix in approximately 12 to 16-inch lifts to the required depths. Compact each lift of the soil mix so that the pressure reading of a cone penetrometer is between 100 and 200 pounds per square inch (psi) with a volumetric soil moisture between 12 and 20 percent. Scarify the surface of each lift with the teeth of a back hoe or similar equipment prior to installing additional lifts.

*Soil Mix C.* Place 2 inches of woodchips over the subgrade at the bottom elevation of the bioretention area and place the first 2 inches of topsoil over the woodchip layer. Rototill with one pass to create a gradation zone. Apply the remainder of the topsoil in 18-inch maximum lifts. Apply 2 inches of woodchips to surface of topsoil and till with one pass only to incorporate. Do not over-till so as to preserve the natural clumps and peds in the soil. Water compact the soil by spraying or sprinkling in a manner to avoid any scour or erosion.

*Soil Mix D.* Place 6 inches of topsoil and compact so that the pressure reading of a cone penetrometer is between 100 and 200 pounds per square inch (psi) with a volumetric soil moisture between 12 and 20 percent.

*Soil Mix E.* Install soil mix in approximately 12 to 16-inch lifts to the required depths, or as directed per manufacturer's requirements. Walk through the placed planting soil to remove air pockets and settle the soil. Do not compact greater than 80 percent of maximum dry density in accordance with ASTM D698, Standard Proctor Method.

*Structural Soil.* Install and compact Structural Soil in accordance with the manufacturer's requirements.

Where possible place large trees first and fill Bioretention Soil around the root ball.

Phase work such that equipment to deliver or grade soil does not have to operate over previously installed Bioretention Soil. Work in rows of lifts the width of the extension of the bucket on the loader. Install all lifts in one row before proceeding to the next. Work out from the furthest part of each bed from the soil delivery point to the edge of each bed area.

Where travel over installed soil is unavoidable, limit paths of traffic to reduce the impact of compaction in Bioretention Soil. Each time equipment passes over the installed soil it shall reverse out of the area along the same path with the teeth of the bucket dropped to scarify the soil. In the event that soil becomes over compacted, remove and replace the soil at no additional cost to the Owner.

The depths and grades shown on the drawings are the final grades after settlement and shrinkage. The Contractor shall install the Bioretention Soil at a higher level to anticipate this reduction of Planting Soil volume. Where settling occurs, before final acceptance or during the warranty period, remove finish surfacing, backfill with additional approved soil, and restore any disturbed areas to a condition acceptable to the Owner.

Planting of the vegetation and mulching must be conducted immediately following final grading. Refer to the specification for planting for further requirements.

#### **D. MEASUREMENT AND PAYMENT**

The work specified in this section shall be included in the price bid for bioretention and additional payment will be made therefor.

# GEOSYNTHETICS

## A. DESCRIPTION

This work consists of supplying and installing various geosynthetics for use in stormwater management, including the following:

Geotextile, Class 2: a geotextile fabric for use in applications where there is little to average risk of damage during construction due to construction equipment or dumped aggregates, including use on the sides of stormwater management facilities.

Waterproofing Membrane: material that is used to prevent infiltration and contain stormwater within the facility by lining the sides and bottom.

Except as herein stated, the requirements specified by *MDOT Standard Specifications* are applicable to this specification.

## B. MATERIALS

### Geotextile

Geotextile shall meet AASHTO M288-06(2011), for Class 2 strength property requirements and Subsurface Drainage requirements as shown below.

Parameter	Value	Test Method
Grab strength (min)	700 N (150 lbs.)	ASTM D 4632
Tear strength (min)	250 N (50 lbs.)	ASTM D 4533
Puncture strength (min)	1375 N (300 lbs.)	ASTM D 6241
Permittivity (min)	0.5 per second	ASTM D 4491
Apparent opening size (max)	0.215 mm (70 US Std. Sieve)	ASTM D 4751

### Waterproofing Membrane

Waterproofing Membrane: shall have a thickness of 30 mil and conform to the following requirements.

Test Property	Test Method	Specifications Limits
Thickness	D5199	+/-5%
Specific Gravity (min.)	D 792	1.20
100% Modulus (psi, min.) (lb. force/in width, min.)	D 882	1000 30
Tensile (psi, min.) (lb. force/in width, min.)	D 882	2300 73
Elongation at Break (% , min.)	D 882	380
Graves Tear (lb./in., min.) (lb. force/in. width, min.)	D 1004	325 8
Resistance to Soil Burial (% change, max.)	G 160	
Break Strength		5
Elongation		20
Modulus at 100%		20
Low Temperature Impact (Pass/F)	D 1790	-20
Dimensional Stability (% change/max.)	D 1204 (212/F/15 min.)	3
Water Extraction (% , Max. Loss)	D 1239	0.15
Volatile Loss (% , max.)	D 1203	0.70
Hydrostatic Resistance (psi, min.)	D 751	100

## **C. CONSTRUCTION**

### **Delivery, Storage and Handling**

Deliver, store and handle packaged materials in strict compliance with all manufacturer's instructions and recommendations. Minimize exposure to ultraviolet (UV) degradation by keeping geotextile materials out of direct sunlight at all times. Protect all materials from weather, damage, injury and theft.

### **Placement**

Material shall be cut and fit to the dimensions shown on the plans with adequate lap lengths, a minimal number of seams, and with excess materials removed and disposed of properly. Clean and straight cuts are required to the line and grade of the plans. The graded surface shall be smooth and free of deleterious materials such as sharp objects or large protruding rocks that could cause the geotextile to tear.

Geotextiles shall be placed on the prepared surface parallel to the longest side of the practice. Place geotextile in a manner that minimizes folds and creases. Successive sheets of geotextile shall be overlapped a minimum of 1 foot with the up-flow sheet overlapping the down flow sheet.

Securing pins or staples for geotextile fabric shall have a minimum length of 10 inches and shall be designed to securely hold the geotextile fabric in place during construction. Waterproofing membrane shall be held in place by backfilling or other means without puncturing the material. Other methods of pinning can also be used as allowed by the Engineer.

Waterproofing membrane shall be glued continuously at seams in accordance with all manufacturers' recommendations including any required overlap. Folds shall also be secured and pulled taught.

### **Protection**

Construction traffic on exposed geosynthetic materials is strictly prohibited. After beginning work, coordinate activities with other work so that there is no disturbance or damage from traffic or other construction activities subsequent to placement. Any damaged geotextile, geogrid, or waterproofing membrane shall be repaired or replaced immediately upon discovery of the damage, to the satisfaction of the Engineer, at the Contractor's expense.

## **D. MEASUREMENT AND PAYMENT**

The work specified in this section shall be included in the price bid for bioretention and porous pavements and no additional payment will be made therefor.

# PLANTING

## A. DESCRIPTION

This work consists of providing all labor, equipment, materials, transportation, and services necessary for furnishing, delivery, and installation of plants and mulch as indicated on the Drawings, or as directed by the Engineer.

The work shall be in accordance with *Divisions 4, 18, 22 and 23 of the City of Grand Rapids Standard Construction Specifications*, except as specified herein.

### References

The following specifications and standards of the organizations and documents listed in this paragraph form a part of the specification to the extent required by the references thereto. In the event that the requirements of the following referenced standards and specification conflict with this specification section the requirements of this specification shall prevail. In the event that the requirements of any of the following referenced standards and specifications conflict with each other the more stringent requirement shall prevail or as determined by the Engineer.

1. American Joint Committee on Horticultural Nomenclature (AJCHN): Standardized Plant Names.
2. American National Standards Institute (ANSI) cited section numbers:
  1. ANSI Z60.1 American Standard for Nursery Stock, most current edition.
  2. ANSI A 300 – Standard Practices for Tree, Shrub and other Woody Plant Maintenance, most current edition and parts.

### Warranty and Maintenance Period

*Plant Warranty:* All plant material installed, with the exception of annual cover crops, shall be warrantied against failures including death, unsatisfactory growth, and structural failures including plantings falling or blowing over. Contractor shall not be responsible for damage by others.

The warranty period shall begin immediately following Substantial Completion and extend as follows:

1. Trees and Shrubs: 12 months
2. Ground Covers and Perennials: 12 months

*Replacements:* Remove plant material found to be dead or in unhealthy condition during warranty period and replace with new. Make replacements during the planting period following the end of the warranty period. Furnish and plant replacements which comply with this Section. Replace plants which are in doubtful condition at end of warranty period unless, in the opinion of the Engineer, it is satisfactory to extend warranty period for a full growing season.

*Initial Maintenance Period:* The contract requires an establishment period beginning immediately after plants are installed and shall extend through the following three full growing seasons. A growing season is the months of June, July, and August.

### Planting Restrictions

Proceed with planting only when the existing and forecasted weather conditions permit planting to be performed when beneficial and optimum results may be obtained. Do not install plant material during periods of temperature extremes when atmospheric temperature may drop below 36°F or rise above 90°F. In the event that the Contractor requests planting outside the dates of the planting seasons, approval of the request does not change the requirements of the warranty.

1. Spring Planting: April 15 – June 1
2. Fall Planting: October 1 – First hard frost, as defined by temperatures falling below 28° F

## B. MATERIALS

### Plant Material

Furnish nursery-grown plants true to genus, species, variety, cultivar, stem form, shearing, and other features indicated in the Planting Schedule as shown on Drawings and complying with ANSI Z60.1 for sizes, grades and ball or container sizes. Provide well-shaped, fully branched, vigorous stock, densely foliated when in leaf, and reasonably free of die-back, disease, insects, eggs, bores, and larvae. Plants shall be in a well-hydrated and healthy state at time of delivery. Do not use plants harvested from the wild, from native stands, from an established landscape planting, or not grown in a nursery unless otherwise indicated. Plant material may be substituted due to lack of availability only after approval from the Engineer. Contact the Engineer immediately if a particular species is unavailable

**NOTE TO SPECIFIER:** The current American Nursery and Landscape Association's "American Standards for Nursery Stock (ANSI Z60.1)" does not adequately address standards for quality. Simply stating that plant material shall comply with ANSI Z60.1 only implies that plant material shall be "in good living condition, and typical in habit for the species".

It is never required for any specification to accept all products available from an industry. The specifier has a choice of what to accept as long as they can verify that products meeting the specifications are available. On projects where plant quality is of extreme importance **paragraphs A thru D** from the appendix can be added for the plant material that will be used on the project.

Label at least one plant of each variety, size, and caliper with a securely attached, waterproof tag bearing legible designation of common name and full scientific name, including genus and species. Include nomenclature for hybrid, variety, or cultivar, if applicable for the plant as shown on Plans.

Shipped product shall be accompanied by a packing slip that clearly lists shipped species by scientific and common name, the number of each species, and the total number of boxes shipped

#### **Mulch**

All mulch shall be triple-shredded hardwood bark mulch aged a minimum of six weeks and not longer than twelve months. Mulch shall be free from deleterious materials including trash, stones, seeds or other plant propagules and suitable as a top dressing of trees and shrubs, passing through a #3 sieve and sized between 3/8"-1/2", dark tan and brown in uniform natural color (not dyed). Shredded former wood products are not allowed (ex., wood pallets).

#### **Tree Staking and Guying Material**

Tree guying shall be flat woven polypropylene material, 3/4 inch wide, and 900-pound break strength. Stakes shall be lodge pole stakes free of knots and of diameters and lengths appropriate to the size of the plant as required to adequately support the plant.

### **C. CONSTRUCTION**

Prior to construction, Contractor shall provide 1-gallon sample of mulch to the Engineer for approval.

Do not dump or store mulch near structures, utilities, walkways, or on existing turf areas or plants. Provide erosion control measures to prevent erosion or displacement of mulch.

**NOTE TO SPECIFIER:** It is important to inspect the plant material before installation, because once the Contractor has it installed, it become very difficult to reject plants based on quality determinations until the end of the warranty period.

When large quantities of plants are specified it can become difficult to locate replacement material on short notice, especially in the fall planting period, so early verification of quality is important. Insert **Paragraph E** from the appendix to require the Contractor to submit representative photographs of the plant material from the source nursery.

When high quality plant material is desired, simple visual inspection can be done when the plants are delivered to the site, but before planting. Insert **Paragraph F** to require visual inspection of the plant material by the Engineer before installation begins.

Deliver plants after preparations for planting have been completed and install immediately. Store delivered plants in a staging area that protects plants from drying winds and direct sunlight. Water plant material sufficiently to maintain root moisture throughout the planting operation.

**NOTE TO SPECIFIER:** Since bioretention soils will begin to self-compact immediately following installation, it is extremely important to coordinate the timing of soil preparation and planting so that root growth can be initiated as soon as possible. If acceptable plant material cannot be located by the Contractor, or if the completion of soil installation falls outside of a specified planting window, insert **Paragraph G** to require an annual cover crop to be planted in order to maintain soil porosity until permanent plants can be installed.

**NOTE TO SPECIFIER:** On smaller projects, it may be acceptable to request all plant material be staked prior to planting, or to request a small area to be staked to ensure Contractor understands the correct spacing and layout of plant material for the project. Adjust paragraph below as necessary.

Stake locations of all trees and shrubs. Obtain the Engineer's acceptance of layout before excavating or planting. Make minor adjustments as required.

Apply antidesiccant to trees and shrubs using power spray to provide an adequate film over plants, branches, stems, twigs, and foliage to protect during digging, handling, and transportation. If deciduous shrubs are moved in full leaf, spray with antidesiccant at nursery before moving and again two weeks after planting. Wrap shrubs with burlap fabric over branches, stems, twigs and foliage to protect from wind and other damage during digging, handling, and transportation.

#### *Excavation for Trees and Shrubs*

Planting Pits and Trenches: Excavate circular planting pits with sides sloping inward at a 45-degree angle. Excavations with vertical sides are not acceptable. Trim perimeter of bottom leaving center area of bottom raised slightly to support root ball and assist in drainage away from center. Do not further disturb base. Ensure that root ball will sit on undisturbed base soil to prevent settling. Scarify sides of planting pit smeared or smoothed during excavation.

Excavate approximately three times as wide as ball diameter for balled and burlapped and container-grown stock. Do not excavate deeper than depth of the root ball, measured from the root flare to the bottom of the root ball. If area under the plant was initially dug too deep, add soil to raise it to the correct level and thoroughly tamp the added soil to prevent settling.

Planting Pits in Bioretention Planting Areas: Soils within the bioretention planting areas have only been water compacted. Compact the area under the plant by thoroughly tamping to provide a stable base for the tree or shrub to prevent settling. Add soil and compact as necessary to ensure the root flare will be at or above adjacent grades after planting.

#### *Tree and Shrub Planting – Balled and Burlapped.*

Before planting verify that root flare is visible at top of root ball according to ANSI Z60.1. If root flare is not visible, remove soil in a level manner from the root ball to where the top-most root emerges from the trunk. After soil removal to expose the root flare, verify that root ball still meets size requirements. Remove stem girdling roots and kinked roots. Remove injured roots by cutting cleanly; do not break.

Set balled and burlapped stock plumb and in center of planting pit or trench with root flare 1 inch above adjacent finish grades. Use soil removed from planting hole for backfill.

After placing some backfill around root ball to stabilize plant, carefully cut and remove burlap, rope, and wire baskets from tops of root balls and from sides, but do not remove from under root balls. Remove pallets, if any, before setting. Do not use planting stock if root ball is cracked or broken before or during planting operation.

Backfill around root ball in layers, tamping to settle soil and eliminate voids and air pockets. When planting pit is filled, water thoroughly and replace any backfill that has settled. Repeat watering until no more water is absorbed.

#### *Tree and Shrub Planting – Container Grown Stock*

Before planting verify that root flare is visible at top of root ball according to ANSI Z60.1. If root flare is not visible, remove soil in a level manner from the root ball to where the top-most root emerges from the trunk. After soil removal to expose the root flare, verify that root ball still meets size requirements. Remove stem girdling roots and kinked roots. Remove injured roots by cutting cleanly; do not break.

Set container grown stock plumb and in center of planting pit or trench with root flare 1 inch above adjacent finish grades. Use soil removed from planting hole for backfill. Carefully remove root ball from container without damaging root ball or plant.

Backfill around root ball in layers, tamping to settle soil and eliminate voids and air pockets. When planting pit is filled, water thoroughly and replace any backfill that has settled. Repeat watering until no more water is absorbed.

When planting on slopes, set the plant so the root flare on the uphill side is flush with the surrounding soil on the slope; the edge of the root ball on the downhill side will be above the surrounding soil. Apply enough soil to cover the downhill side of the root ball.

#### *Tree and Shrub Pruning*

Remove only injured, dying or dead branches from trees and shrubs. Do not prune to shape plants. Do not apply pruning paint to wounds.

#### *Staking and Guying*

Do not stake or guy trees unless specifically required by the Plans or in the event that the Contractor feels that staking is the only alternative way to keep particular trees plumb. All staking must be approved by the Engineer. Guying shall be tied in such a manner as to create a minimum 12-inch loop to prevent girdling. Stakes shall be driven to a sufficient depth to hold the tree rigid. Trees that are guyed shall have their guys and stakes removed after one full growing season.

#### *Ground Cover and Perennial Planting*

Set out and space ground cover and perennials as indicated with triangular spacing. In planting areas where more than one species is listed, plant species randomly and not in large groupings of the same species, or as directed by the Engineer. Use soil removed from planting hole for backfill. Dig holes large enough to allow spreading of roots.

For rooted cutting plants supplied in flats, plant each in a manner that will minimally disturb the root system but to a depth not less than two nodes.

Work soil around roots to eliminate air pockets and leave a slight saucer indentation around plants to hold water. Water thoroughly after planting, taking care not to cover plant crowns with wet soil. Protect plants from hot sun and wind; remove protection if plants show evidence of recovery from transplanting shock.

#### *Planting Area Mulching*

Mulch backfilled surfaces around all plants and in all bioretention areas as shown on Plans and in planting details to the specified depth. Place mulch only after all plant material has been installed, including plugs.

#### **Cleanup and Protection**

During planting, keep adjacent paving and construction clean and work area in an orderly condition.

Protect plants from damage due to landscape operations and operations of other contractors and trades. Maintain protection during installation and maintenance period. Treat, repair, or replace damaged plantings.

After installation and before Substantial Completion, remove nursery tags, nursery stakes, tie tape, labels, wire, burlap, nursery applied tree wrap, and other debris from plant material, planting areas, and Project site.

**Bioretention Maintenance**

In addition to the watering-in required at the time of planting, maintain plantings at least 5 times during each of the three growing seasons of the establishment period. Bioretention maintenance includes pruning, cultivating, watering, weeding, fertilizing, mulching, restoring planting saucers, resetting to proper grades or vertical position, removal of trash and debris, and performing other operations as required to establish healthy, viable plantings. The Engineer may add or subtract watering as conditions warrant. Notify the Engineer at least 3 days before each watering.

Maintain the bioretention during each of the following periods.

- 3. From June 1 to June 15,
- 4. From June 23 to July 7,
- 5. From July 15 to July 29,
- 6. From August 4 to August 18, and
- 7. From September 5 to September 19.

**D. MEASUREMENT AND PAYMENT**

The completed work, as described, shall be paid for at the contract unit price for the following contract item (pay item):

<b>Contract Item (Pay Item)</b>	<b>Pay Unit</b>
(Botanical Name), (Size) .....	Each
(Botanical Name), (Size) .....	Flat
Mulch, ___ inch .....	Square Yard
Bioretention Maintenance, First Season .....	Lump Sum
Bioretention Maintenance, Second Season .....	Lump Sum
Bioretention Maintenance, Third Season .....	Lump Sum

**Plants.** Measurement for each specific variety of plant listed above shall be each, for each plant installed as measured in the field, or by flat for plugs as measured in the field. Payment shall include the installation of the plan in accordance with the details and spacing as indicated on the Drawings, excavation and backfill of the planting hole, watering, and all necessary materials, labor, and equipment required to complete the work. Payment for the Planting will not be made until the plant has been planted, watered in, braced or guyed when necessary, and mulched. No additional payment will be made for replacement plants.

Measurement and payment for **Mulch, \_\_\_ inch** shall be on the basis of square yards. Payment for **Mulch, \_\_\_ inch** shall include all transportation, storage and placement of materials as indicated on the Drawings and as required by the Engineer, and all other materials, labor and equipment required to complete the work.

During the first season 20 percent of the lump sum price **Bioretention Maintenance, First Season** will be paid at the completion of each of the five maintenance operations. Payment for **Bioretention Maintenance, First Season** includes the cost of the watering, cultivating, trash and debris removal and all other work required for satisfactory growth and development of the plants. Proof of documentation of all work performed will be required at time of payment.

During the second season 20 percent of the lump sum price **Bioretention Maintenance, Second Season** will be paid at the completion of each of the five maintenance operations. Payment for **Bioretention Maintenance, Second Season** includes the cost of the watering, cultivating, trash and debris removal and all other work required for satisfactory growth and development of the plants. Proof of documentation of all work performed will be required at time of payment.

During the third season 20 percent of the lump sum price **Bioretention Maintenance, Third Season** will be paid at the completion of each of the five maintenance operations. Payment for **Bioretention Maintenance, Third Season** includes the cost of the watering, cultivating, trash and debris removal and all other work required for satisfactory growth and development of the plants. Proof of documentation of all work performed will be required at time of payment.

Supplemental bioretention maintenance, in addition to the 15 operations required, will be paid at 20 percent of the associated lump sum contract unit price. The City will reduce the relevant lump sum contract unit price by 2 percent for each deleted bioretention maintenance operation.

## **Planting Specification Appendix**

This section contains additional language that may be added to the Planting Specification under special circumstances. Refer to the specification for directions on where to add the following paragraphs.

### **Paragraph A**

#### *Balled and Burlapped Stock - Trees*

Plant roots shall be normal to the plant type specified, reasonably free of scrapes, broken or split wood. A minimum of three structural roots reasonably distributed around the trunk (not clustered on one side) shall be found in each plant. Root distribution shall be uniform throughout the root ball. Plants with structural roots on only one side of the trunk (J roots) shall be rejected. The root collar shall be within the upper 2 inches of the soil and the root system shall be reasonably free of stem girdling roots over the root collar or kinked roots from nursery production practices. At time of delivery, the root ball shall be moist throughout. Roots shall not show signs of excess oil moisture condition as indicated by stunted, discolored, distorted, or dead roots.

The form and density of the crown shall be typical for a young specimen of the species or cultivar pruned to one central or dominant leader. The tip of the leader must be intact and its terminal bud must be the highest part of the tree. Crown specifications do not apply to multi-stem, clump, contorted, or weeping cultivars. The size, color and appearance of leaves shall be typical for the time of year and stage of growth of the species or cultivar. Trees shall not show signs of prolonged moisture stress or over watering as indicated by wilted, shriveled, or dead leaves. Shoot growth throughout the crown should be appropriate for the age and size of the species or cultivar. Main branches shall be distributed along the central leader, not clustered together. They shall form a balanced crown appropriate for the cultivar or species. Branch diameter shall be no larger than two thirds (one-half is preferred) the diameter of the central leader measured 1 inch above the branch union. The trunk shall be relatively straight, vertical, and free of wounds that penetrate to the wood (property made pruning cuts are acceptable and are not considered wounds), sunburned areas, conks, wood cracks, sap leakage, signs of boring insects, galls, cankers, girdling ties, or lesions (mechanical injury). Trees with damaged, crooked, or multiple leaders; tight vertical branches where bark is squeezed between two branches or between branch and trunk ("included bark"); crossing trunks; cut-off limbs more than ¾" in diameter; or with stem girdling roots are unacceptable.

### **Paragraph B**

#### *Balled and Burlapped or Container Stock – Shrubs*

Plants shall be well-shaped, well-branched and well-foliated with healthy, vigorous leaves of normal size, shape, color and texture typical for the time of year and stage of growth of the species or cultivar. Shrubs shall not show signs of prolonged moisture stress or overwatering as indicated by wilted, shriveled, or dead leaves. Branching shall be uniformly distributed such that no holes, cavities or depressed areas exist due to broken or dead foliage. Shrubs with pest or mechanical damage constituting more than 10% of the total foliage are unacceptable. The root system shall be sturdily established in the ball or container with no large roots growing out of the container and not excessively root bound.

### **Paragraph C**

#### *Container Stock - Perennials*

Plants shall exhibit a healthy, well-distributed root structure through the container, such that at least 90% of the soil mass remains intact. Plants shall exhibit top growth with a base diameter of at least 50% of the diameter of the container. Above ground growth shall be healthy with the color, shape, size, buds, flowers, and leaves normal to the plant specified for the time of year and stage of growth of the species or cultivar. Perennials will be considered unacceptable if plants are excessively root bound beyond correction by the Contractor, have large roots growing out of the container, or if more than 25% of the foliage has been damaged by insects, mechanical damage, or displays signs of moisture stress or overwatering as indicated by wilted, shriveled, or dead leaves.

### **Paragraph D**

### *Plugs*

Plugs shall be in a minimum of 3" deep open-bottomed pots. Plugs shall be thoroughly rooted through the container, such that at least 75% of the soil mass remains intact but not with excessive root growth encircling the container. Top growth shall appear healthy and vigorous. Any plants that are root bound, have bent or broken stems, or exhibit more than 10% of top growth has been damaged by insects, mechanical damage or displays signs of moisture stress or overwatering as indicated by wilted, shriveled, or dead leaves shall be considered unacceptable.

### **Paragraph E**

Provide color photographs in digital format of each required species and size of plant material as it will be furnished to Project site. Take photographs from an angle depicting true size and condition of the typical plant to be furnished. Include a scale rod or other measuring device in each photograph. For species where more than 50 plants are required, include a minimum of three photographs showing the average plant, the best quality plant, and the worst quality plant to be furnished. Identify each photograph with the full scientific name of the plant, plant size, and name of the growing nursery. Photographs shall be provided to the Engineer to allow adequate time to locate alternate plant material if it does not meet the specifications described herein.

### **Paragraph F**

Engineer shall observe plant material either at place of growth or at site before planting for compliance with requirements for genus, species, variety, cultivar, size, and quality. Engineer may also observe plant material further for size and condition of root balls and root systems, pests, disease symptoms, injuries, and latent defects and may reject unsatisfactory or defective material at any time during progress of work. Contractor shall inform Engineer at least 2 days in advance of delivery of plant material to site for inspection prior to planting. If plant material is found to be unacceptable, Contractor shall remove rejected plant material immediately from Project site and obtain replacement plant material or approved substitutions within 14 days.

### **Paragraph G**

If completion of bioretention construction occurs outside of the spring or fall planting period and plants cannot be installed within 30 days, or if adequate plant material cannot be located and installed within the required time, Contractor shall seed all bioretention areas with a cover crop consisting of Common Oat (*Avena sativa*) and Annual Rye (*Lolium multiflorum*) at a rate of 28.75 pounds per acre until acceptable plant material can be obtained and installed during a fall or spring planting period at no additional cost to the Owner.

# UNDERDRAINS

## A. DESCRIPTION

This work consists of providing all labor, equipment and materials necessary for construction and installation of underdrains, cleanouts, observation wells, field connections to existing storm and/or combined sewer pipes or structures, and gate valves and backflow preventers as indicated on the Drawings, or as directed by the Engineer.

The work shall be in accordance with *Division 18 of the City of Grand Rapids Standard Construction Specifications*, and *Sections 403 and 404 of the Michigan Department of Transportation (MDOT) Standard Specifications* where applicable, except as specified herein.

## References

The following specifications and standards of the organizations and documents listed in this paragraph form a part of the specification to the extent required by the references thereto. In the event that the requirements of the following referenced standards and specification conflict with this specification section the requirements of this specification shall prevail. In the event that the requirements of any of the following referenced standards and specifications conflict with each other the more stringent requirement shall prevail or as determined by the Engineer.

1. American Association of State Highway and Transportation Officials (AASHTO) cited section numbers:
  1. AASHTO M 278 Standard Specification for Class PS46 Poly(Vinyl Chloride) (PVC) Pipe
2. American Society of Testing Materials (ASTM) cited section numbers
  1. ASTM D1785 Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120
  2. ASTM D2729 Standard Specification for Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings
  3. ASTM D3034 Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings
  4. ASTM D3212 Standard Specification for Joints to Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals
  5. ASTM D3350 Standard Specification for Polyethylene Plastics Pipe and Fittings Materials

## B. MATERIALS

All materials shall meet the requirements set forth in *Section 909 of the Michigan Department of Transportation (MDOT) Standard Specifications* and *Division 18 of the City of Grand Rapids Standard Construction Specifications*.

### Underdrain

Underdrain shall be Schedule 40 or SDR 35 smooth wall PVC pipe as specified on Plans. Underdrains within the bioretention areas shall be perforated with 3/8-inch perforations. Use solid sections of non-perforated PVC piping with watertight joints when underdrain is located outside of bioretention areas, connects to a drainage structure, or daylights to grade.

Underdrain shall be HDPE along curves, as indicated on Plans.

### Fittings and Caps

All fittings and connections shall be compatible with the underdrain materials used to prevent pipe separation. End caps shall be threaded PVC with 2-inch square lug in non-paved areas and lockable flush mounted caps rated for HS-20 loading in paved areas as shown on Plans.

### Cleanout

Cleanouts shall be constructed with vertical non-perforated schedule 40 PVC pipe as shown on Plans. Extend cleanout to the surface and cap with a watertight removable cap.

## **Valves**

### *Gate Valve*

Shall be manual slide valve, PVC plastic body and hubs with 304 stainless steel shaft and paddle (4-inch or 6-inch) and die cast aluminum handle, Valterra or approved equal as shown on Plans.

## **Delivery, Storage and Handling**

All flexible pipe shall be stored on flat surface so that barrel is evenly supported. Pipe shall not be stored in piles higher than 4 feet. If pipe is to be stored for over 1 month, it shall be covered with opaque material so that it is protected from sun's ray and bells shall be inverted in alternate rows so they are not supporting direct load. Deflection of pipe shall not exceed 5 percent. Follow manufacturer's instructions in storing and handling pipe during periods of extreme temperatures.

## **C. CONSTRUCTION**

### **Underdrain**

Place underdrains to the line and grade as shown on Plans or established by the Engineer. Perforated pipes shall be placed with perforations pointing down. Pipe shall be placed with the bell end up grade. Pipe sections shall be joined with appropriate couplings. The ends of underdrain pipe shall be plugged at the upstream ends as directed by the Engineer.

Underdrains are to be tapped to existing storm water structures and pipes as shown on Plans. Connections shall meet the requirements set forth in *GR Standard Specification 18.03*, and on Plans.

Do not wrap underdrain with geotextile fabric or pipe sock unless directed by the Engineer.

At the close of each day's work, the open ends of the pipe shall be satisfactorily protected against the entrance of water, earth or rubbish. If there is as much as ¼ inch or more of silt or earth deposited in pipe, the Contractor shall clean out and remove such deposits at no cost to the Owner.

### **Cleanouts**

Connect riser to underdrain pipe using approved fittings as shown on Plans. In non-paved areas set caps 6 inches above final grade. In paved areas, encase flush mounted caps in concrete as shown on Plans.

### **Valves**

Gate valve to be located per the plans and as directed by the Engineer within an accessible catch basin or overflow riser and upstream of proposed sewer field connection yet downstream of perforated underdrain pipe. The incoming non-perforated PVC pipe shall extend into the catch basin or overflow riser a sufficient distance to allow for connection of the valve as well as sufficient operation of the valve handle but not more than a distance of 8 inches. Valves may also be placed within valve boxes as per plans and specifications and as directed by the Engineer. Catch basins, overflow risers and/or valve boxes must have sufficient depth to allow for the height of the valve when in its fully open position plus at least 3 inches at the top.

## **D. TESTING AND ACCEPTANCE**

When construction is complete, the contractor shall test all completed underdrain systems for continuous, unimpeded flow.

Suggested acceptable test methods for each pipe run are as follows:

1. At highpoint or upstream end of underdrain pipe, open cleanout and insert hose from water source.
2. Turn on water
3. Acceptance of pipe run consists of free flow of water through drain outlet into the existing storm sewer structure.

Any sections of the underdrain that are clogged or crushed shall be repaired at the contractor's expense.

## **D. MEASUREMENT AND PAYMENT**

The work specified in this section shall be included in the price bid for bioretention and additional payment will be made therefor.

## SPECIAL SPECIFICATION FOR POROUS ASPHALT PAVEMENT

DESIGNER NOTE: The specifications below are based on the best available information. Designer should modify the specifications to satisfy project-specific constraints.

DESIGNER NOTE: Black text inside of an orange shaded box corresponds to notes to the designer. These notes should be deleted before using the specifications in contract documents.

### A. DESCRIPTION

This work consists of providing all labor, equipment and materials necessary for preparing the subsoil and constructing the porous asphalt pavement as indicated on the Drawings, or as directed by the Engineer. Work shall be in accordance with *Division 5, 6, 14, 15 and 23 of the City of Grand Rapids Standard Construction Specifications, MDOT Special Provision for Acceptance of Hot Mix Asphalt Mixture on Local Agency Projects 12SP-501J-03, and MDOT Section 501*, except as specified herein.

Design Responsibility: The HMA porous pavement mix design will be provide by the contractor in accordance with the *MDOT HMA Production Manual*. Use a 50 blow Superpave Gyrotory Compactor (SPG) for developing mix designs. Submit at least 10 working days prior to production.

### References

The following specifications and standards of the organizations and documents listed in this paragraph form a part of the specification to the extent required by the references thereto. In the event that the requirements of the following referenced standards and specification conflict with this specification section the requirements of this specification shall prevail. In the event that the requirements of any of the following referenced standards and specifications conflict with each other the more stringent requirement shall prevail or as determined by the Engineer.

1. American Association of State Highway and Transportation Officials (AASHTO): cited section numbers:
  - A. AASHTO M 288-06(2011) Standard Specification for Geotextile Specification for Highway Applications
  - B. AASHTO M 303 Standard Specification for Lime Asphalt Mixtures
  - C. AASHTO T 269-11 / ASTM D3203M-11 Standard Test Method for Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
  - D. AASHTO T 305-09 / ASTM D6390-11 Standard Test Method for Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures
  - E. AASHTO T 331-13 / ASTM D6857M-11 Standard Test Method for Maximum Specific Gravity and Density of Bituminous Paving Mixtures Using Automatic Vacuum Sealing Method
  - F. AASHO T-99 Standard Method of Test for Moisture-Density Relations of Soils
2. American Society of Testing Materials (ASTM) cited section numbers.
  - A. ASTM C1701 Standard Test Method for Infiltration Rate of In Place Pervious Concrete
  - B. ASTM D5821 Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate
  - C. ASTM D698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort
3. Michigan Department of Transportation
  - A. HMA Production Manual

- B. Manual for the Michigan Test Methods (MTM)
- C. Standard Specifications for Construction, 2012

**B. MATERIALS**

Handle and store materials in a manner which will prevent deterioration, damage, contamination with foreign matter, and damage by weather or elements, and according to Manufacturer's directions. Use all means necessary to protect the materials of this Section before, during, and after installation. Reject damaged, deteriorated or contaminated material and immediately remove from the Site. Replace rejected materials with new materials at no additional cost to Owner.

Recycled Mixtures: Substitution of up to 10% Reclaimed Asphalt Pavement (RAP) is allowed provided that the mixture is designed and produced to meet all criteria specified herein, unless otherwise prohibited.

DESIGNER NOTE: For design thicknesses requiring multiple lifts, consideration should be given to using larger stone mixes with higher air void contents in the base lifts and finer stone mixes in the surface lifts. This approach will aid in maintaining the pavement's porosity over the long term, since clogging would occur on the surface layers.

1. Bituminous Materials:

D. Asphalt Cement

- (1) Performance Grade:
  - (a) PG 70-28P, PG 70-28TR or PG 76-22, PG 76-22TR (Polymer modified).
  - (b) PG binder PG 64-28 modified with SBS or SBR (maximum 6%) to meet the PG 76-22P or 70-28P Specification.
- (2) Asphalt Content: Minimum 5.3% by weight.
  - (a) Minimum Calculated Film Thickness: 16µm.

E. Bituminous Mixture: mix gradation shall meet the following criteria:

- (1) Air Voids (porosity) at N (design): Minimum 18%; Maximum 22%
- (2) Draindown Test: ≤ 0.3%.
- (3) Retained Tensile Strength (TSR): ≥ 80% (Modified Lottman method).
- (4) Bituminous Mixture Gradation:

U.S. Standard Sieve Size	Percent Passing
3/4 inch (19.1 mm)	100%
1/2 inch (12.5 mm)	85-100%
3/8 inch (9.5 mm)	55-75%
No. 4 (4.75 mm)	10-25%
No. 8 (2.36 mm)	5-10%
No. 200 (0.075 mm)	2-4%

F. Coarse Aggregate: Aggregate portion retained on #8 sieve.

- (1) LA Abrasion: 35 maximum.
- (2) Crushed (min) % (MTM117) = 90

4. Additives: provide as necessary to meet minimum requirements specified herein.

A. Hydrated Lime: Hydrated lime may be used to prevent separation of asphalt binder from the aggregate and to achieve the required tensile strength ratio (TSR).

- (1) Hydrated lime shall meet AASHTO M303 Type 1 requirements.
- (2) Blend with damp aggregate at a rate of 1% by weight of the total dry aggregate.

B. Fibers

- (1) Cellulose or mineral fibers treated with a cationic sizing agent to enhance dispersal and increase cohesion to the bitumen.
- (2) Dosage rate is 0.2% to 0.4% by weight of total mix.
- (3) Mineral Fibers:
  - (a) Virgin, basalt, diabase or slag.
  - (b) Average Fiber Length: 6.35 mm.

- (c) Maximum Average Thickness: 0.005 mm.
- (4) Cellulose Fiber:
  - (a) Fiber Length: 6.4 mm (maximum).
  - (b) Ash Content: 18% non-volatiles ( $\pm 5\%$ ).
  - (c) pH: 7.5 ( $\pm 1$ ).
  - (d) Moisture Content: 5.0 (maximum).
  - (e) Oil Absorption (times fiber weight): 5.0 ( $\pm 1$ ).
- C. Anti-Stripping Additive
  - (1) Anti-Stripping additive to increase asphalt-aggregate adhesion.
  - (2) Dosage at 0.5% of weight of binder.
  - (3) Acceptable products include ArrMaz Products, AD-here® HP, or approved equal.
- 5. Aggregates for Stormwater Management (Pavement Base Materials)
  - A. Aggregate material shall consist of clean, mechanically crushed stone, substantially free from adherent coatings. Recycled crushed concrete is not allowed.
  - B. Materials shall be washed thoroughly to remove clay, organic matter, extraneous debris, or objectionable materials. Washed material that does not match the consistency of the approved material sample is subject to rejection and washing at Contractor's expense until requirements are met. If washing is to be completed on site, Contractor and/or supplier shall provide all resources and materials and cleanup required for washing the aggregate and completing the work in a method acceptable to the Engineer.
  - C. The Material shall be obtained only from a source(s) approved by the Engineer. The Engineer reserves the right to sample and test Material at any time including at the source.
  - D. Pavement Base shall consist of up to three (3) layers as specified on the Plans and included herein:
    - (1) "Choker Layer" shall be MDOT 6AA, MDOT 4G, or AASHTO #57 (modified).
    - (2) "Reservoir Layer" shall be MDOT 4AA, MDOT 6AA, MDOT 4G, AASHTO #2, AASHTO #3 or AASHTO #57.
    - (3) "Filter Layer" shall be MDOT 34G, MDOT 4G, or AASHTO #8.
  - E. Pavement Base Material shall meet the following specifications for grading and quality.
    - (1) Aggregate Gradation:

Sieve <sup>1</sup>	Percent Passing by Weight						
	AASHTO #2 Modified	AASHTO #3 Modified	MDOT 6AA	AASHTO #57 Modified	AASHTO #8 Modified	MDOT 4G	MDOT 34G
3 inch	100	-	-	-	-	-	-
2-1/2 inch	90 to 100	100	-	-	-	-	-
2 inch	35 to 70	90 to 100	-	-	-	-	-
1-1/2 inch	0 to 15	35 to 70	100	100	-	100	-
1 inch	-	0 to 15	90 to 100	95 to 100	-	-	-
3/4 inch	0 to 5	-	-	-	-	60 to 80	-
1/2 inch	-	0 to 5	30 to 60	25 to 60	100	35 to 65	100
3/8 inch	-	-	-	-	85 to 100	-	95 to 100
No. 4	-	-	0 to 8	0 to 10	10 to 30	-	-
No. 8	-	-	-	0 to 5	0 to 10	10 to 25	0 to 5
No. 16	-	-	-	-	0 to 5	-	-
No. 30	-	-	-	-	-	5 to 18	-
No. 100 <sup>2</sup>	$\leq 2.0$	$\leq 2.0$	-	$\leq 2.0$	$\leq 2.0$	-	-
No. 200 <sup>3</sup>	-	-	$\leq 1.0$	-	-	$\leq 3.0^4$	$\leq 3.0$

1. Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.
2. Gradation modified from AASHTO for portion passing the No. 100 sieve.
3. Loss by Washing (MTM 108) percent passing. Based on dry weights.
4. Gradation modified from MDOT for portion passing the No. 200 sieve.

- (2) Reservoir Layer material shall also contain 90 percent (minimum) crushed particles with two (2) or more fractured faces as determined by ASTM D5821 or MTM 117.

Geotextile is not typically required under permeable pavement applications unless recommended by a geotechnical engineer. Geotextile can be placed vertically for material separation between side walls of the reservoir course and native soil.

6. Geotextile

- A. Needled nonwoven polypropylene fibers.
- B. Geotextile shall meet AASHTO M288-06 (2011), for Class 2 strength property requirements and Subsurface Drainage requirements as shown below.
  - (1) Minimum Grab Strength (ASTM D 4632): 700 N (150 lbs.)
  - (2) Minimum Tear Strength (ASTM D 4533): 250 N (50lbs)
  - (3) Minimum Puncture Strength (ASTM D 6241): 1375 N (300 lbs.)
  - (4) Minimum Permittivity (ASTM D 4491): 0.5 per second
  - (5) Maximum Apparent Opening Size (ASTM D 4751): 0.215 mm (70 US Std. Sieve)
- C. Acceptable products include:
  - (1) Mirafi 160N
  - (2) Geotex 601
  - (3) US 160NW
  - (4) SKAPS GT 160
  - (5) or approved equal
- D. Location: In accordance with the Drawings.

**C. CONSTRUCTION**

1. Pre-Installation Examination and Preparation

- E. Examine previous work, related work, and conditions under which this work is to be performed and notify the Engineer in writing of all deficiencies and conditions detrimental to the proper completion of this work.
- F. Temporary erosion and sediment controls are needed during installation to divert stormwater away from the permeable pavement area until it is construed and contributing drainage areas have been stabilized.
- G. Proposed permeable pavement area must be kept free from sediment during the entire construction process.

7. Excavation

- A. Excavate as indicated on the grading drawings to conform to line, grade and elevations indicated.
- B. Use light earth-moving equipment or by excavating from the perimeter of the excavated area to avoid soil compaction.
- C. Only very low ground pressure (<0.03 MPa or <4psi) equipment is acceptable in the bed areas when excavation is within one (1) vertical foot of the final subgrade elevation. Appropriate equipment includes wide track or marsh track equipment, or light equipment with turf-type tires.
- D. Remove excavated materials from the site.

8. Subgrade Preparation and Protection

DESIGNER NOTE: The designer should set compaction requirements based on consideration of site specific geotechnical properties of the native soil (e.g. permeability, stiffness) and performance requirements for the pavement section (e.g. traffic loading, infiltration, costs).

DESIGNER NOTE: Optional Compaction Requirement: Compact subgrade to 90 percent (+/- 2 percent) of the maximum dry density per standard Proctor test (ASTM D698), or as directed by Engineer. Determination of in-place density shall be made using a nuclear gauge per ASTM D6939.

- A. No heavy equipment shall pass over the subsoils (subgrade) after they have been loosened. If the Contractor plans to utilize such areas for any use of heavy equipment, this work should be carried out prior to beginning the process of loosening soils or filling in that area.
- B. Avoid compaction of subgrade soil unless directed or approved by Engineer. Areas of the subgrade which are over-compacted, as determined by Engineer, shall be ripped or tilled to a depth of 12 inches (minimum) or as directed by Engineer.
- C. Prior to placing any aggregate, soil or any drainage materials beneath the permeable pavement area the entire subgrade shall be loosened using a soil ripper or subsoiler to break up the native soil to a minimum 6-inch depth. Remove ponded water at the bottom of the excavation before tilling or ripping. Soil shall be friable before tilling.
- D. Remove accumulation of fine materials due to ponding or surface erosion with light equipment. Excavate, fill, re-grade and scarify areas damaged by erosion, ponding or traffic compaction.
- E. Confirm that the subgrade is at the proper elevation as shown on the drawings.

#### 9. Proof Roll

- A. Proof-roll prepared subgrade to identify soft or unstable areas.
- B. Remove soft spots and replace with permeable structural fill as directed by Engineer to achieve uniform subgrade.
- C. Use light equipment and avoid over compacting the subgrade.
- D. Do not test where shallow underground utilities are present.
- E. Do not place geotextile or porous media bed until subgrade surface has been inspected and approved by Engineer.

#### 10. Geotextile

- A. Material shall be cut and fit to the dimensions shown on the plans with adequate lap lengths, a minimal number of seams, and with excess materials removed and disposed of properly.
- B. Clean and straight cuts are required to the line and grade of the plans.
- C. The graded surface shall be smooth and free of deleterious materials such as sharp objects or large protruding rocks that could cause the geotextile to tear.
- D. Geotextiles shall be placed on the prepared surface parallel to the longest side of the practice. Place geotextile in a manner that minimizes folds and creases. Successive sheets of geotextile shall be overlapped a minimum of 16 inches with the up-flow sheet overlapping the down flow sheet.
- E. Extend the filter fabric at least 4 feet outside the bed and fold the fabric over the stone bed to temporarily protect it from sediment until the asphalt surface is placed.

#### 11. Aggregate

- A. Place aggregate with a uniform gradation, free of contamination and segregation. Do not rut or distort the subbase material or aggregate base during spreading.
- B. Compact the aggregate layers of a uniform thickness, no greater than 8 inches.
  - (1) Compact each layer with static roller or single pass with vibration (low amplitude, high frequency) for aggregate interlock.
  - (2) Compact reservoir layers with a 10-ton roller with two passes in static mode or until there is no visible movement of the aggregate.

- (3) For No. 57 or similar sized stone layers, make two passes in vibratory mode and two passes in static mode or until there is no visible movement of the aggregate.
  - (4) Do not crush the aggregate with the roller.
  - (5) Corners and other areas where rollers cannot reach are compacted with a vibratory plate compactor capable of at least 13,500-pound force (lbf) and equipped with a compaction indicator.
- C. Where the aggregate course is constructed in more than one-layer, complete grading, and then clean previously constructed layers of loose and foreign matter prior to placing subsequent layers.
  - D. Do not place bituminous material until the aggregate surface has been inspected and approved by Engineer.
12. Weather and Seasonal Limitations
- A. March 15 to November 15.
  - B. Ambient Temperature:  $\geq 21$  degrees C (70 degrees F)
  - C. Actual Ground Temperature:  $\geq 16$  degrees C (60 degrees F)
  - D. Approval of Engineer required for adjustments in dates or temperature.
13. Transportation of Mixtures: Keep trucks off all freshly paved surfaces.
14. Rollers:
- A. Steel-Wheeled Rollers: Weigh at least 4 tons and not more than 12 tons, unless otherwise directed by Engineer.
  - B. Vibratory rollers are not permitted unless approved by Engineer.
  - C. Pneumatic-tired rollers are not permitted.
  - D. Minimum 1 roller dedicated to rolling and smoothing stone in front of bituminous paver.
15. Placing Bituminous Mixtures:
- A. Allowable Single Course Thickness: Maximum 3 inches.
  - B. Prevent tracking of soil onto porous pavement from construction equipment.
  - C. Place second lift prior to any traffic being allowed on the pavement. Place second lift either on the same day as the first course or the following day.
16. Rolling:
- A. The intent of compaction is for the installed porosity to be between 15% and 25%. Target 20% of Theoretical Maximum Density (TMD)
  - B. Use nuclear density gauge as guideline for compaction operations
  - C. Steel 3-wheeled rollers may be used for initial compaction immediately following the paver.
  - D. The final rolling operation on each layer of bituminous mixture use lightweight tandem steel-wheeled rollers.
  - E. Operate vibratory rollers in the static mode Pneumatic-tired rollers will not be permitted.
  - F. Continue finish rolling with light rollers until all roller marks are eliminated.
  - G. Keep all equipment off freshly placed and rolled pavement for 24 hours.
17. Bond Coat:
- A. No bond coat shall be used between pavement lifts.
  - B. Place adjacent lifts within 24 hours of each other.

18. Castings

- A. Raise all castings to proposed grade after both lifts of porous asphalt have been laid.
- B. After both lifts of asphalt have been placed, saw-cut a square around each casting down 4 inches or to the aggregate base layer.
- C. Raise casting up 4 inches or to grade of proposed road.
- D. After all pavement edges are smooth, free of irregularities, and approved by the engineer, place concrete around casting to match both the surrounding road grade and also the casting grade.
- E. Use Grade A concrete, vibrated.
- F. Finish concrete by floating the surface just enough to produce a smooth surface free of irregularities. Round all edges and joints with an approved finishing tool.
- G. Protect concrete during paving operations.

19. Coordination Meeting

- A. Organize and conduct a coordination meeting prior to the placement of porous asphalt.
- B. Attendees include, but not limited to: field engineers, supervising engineers, general contractor, asphalt contractor, material tester and supervisor from material testing company, and any other involved parties.
- C. Discuss schedule, equipment, means and methods, and any other items related to the installation and coordination of the porous asphalt.
- D. Time and location of the meeting to be decided between involved parties prior to the time of paving.

20. Acceptance

- A. Field Infiltration Test:
  - (1) One test per 25,000 square feet.
  - (2) Surface Infiltration Test: ASTM C1701.
  - (3) Acceptance: 150 inches per hour minimum.
  - (4) Witnessed by Engineer.

**D. MEASUREMENT AND PAYMENT**

The completed work, as described, shall be paid for at the contract unit price for the following contract items (pay items).

<b>Pay Item</b>	<b>Pay Unit</b>
Aggregate Base, ___-inch	Square Yard
HMA, Porous	Ton

The price shall be payment in full for furnishing al labor, equipment and materials to complete the work as specified and indicated on the Drawings. **Aggregate Base, \_\_\_-inch** shall be measured by width and length for the specified depth as shown on the plans. This work includes, but is not limited to, subgrade preparation and protection, geotextile, aggregate base for the pavement base, and for any necessary grading, excavation and backfill when not paid for separately.

The price shall be payment in full for furnishing al labor, equipment and materials to complete the work as specified and indicated on the Drawings. **HMA, Porous** shall be paid for based on the weight placed, as supported by weigh tickets. This work includes, but is not limited to, developing a mix design in accordance with this specification, porous HMA pavement, and for any necessary grading, excavation and backfill when not paid for separately.

**SPECIAL SPECIFICATION  
FOR  
PERVIOUS CONCRETE PAVEMENT**

DESIGNER NOTE: The specifications below are based on the best available information. Designer should modify the specifications to satisfy project-specific constraints.

DESIGNER NOTE: Black text inside of an orange shaded box corresponds to notes to the designer. These notes should be deleted before using the specifications in contract documents.

**A. DESCRIPTION**

This work shall consist of constructing pervious Portland cement concrete roadway pavements, alleys, sidewalks, or trails on a prepared sub-grade in accordance with these specifications and in conformity with the lines, grades, thicknesses and typical sections shown in the contract documents or as directed by the Engineer.

The pervious concrete pavements and sidewalks shall consist of a mixture of Portland cement, aggregate, water, admixtures and other ingredients as may be specified. Except as herein stated, the requirements specified for MDOT Standard Specification Division 6 Portland Cement Concrete Pavement and 801 and 803 are applicable to this specification.

**References**

The following specifications and standards of the organizations and documents listed in this paragraph form a part of the specification to the extent required by the references thereto. In the event that the requirements of the following referenced standards and specification conflict with this specification section the requirements of this specification shall prevail. In the event that the requirements of any of the following referenced standards and specifications conflict with each other the more stringent requirement shall prevail or as determined by the Engineer.

1. American Concrete Institute (ACI)
  - A. ACI 211.3R - Guide for Selecting Proportions for No-Slump Concrete
  - B. ACI 305 - "Hot Weather Concreting"
  - C. ACI 306 - "Cold Weather Concreting"
  - D. ACI 522 - "Report on Pervious Concrete"
  - E. ACI - Flatwork Finisher Certification Program
  - F. ACI - Field Technician Certification Program
2. American Society of Testing Materials (ASTM) cited section numbers.
  - A. ASTM C 29 - "Test for Bulk Density (Unit Weight) and Voids in Aggregate"
  - B. ASTM C 33 - "Specification for Concrete Aggregates"
  - C. ASTM C 42 - Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
  - D. ASTM C 94 - Standard Specification for Ready-Mixed Concrete
  - E. ASTM C 117 "Test Method for Material Finer than 75- $\mu$ m (No. 200) Sieve in Mineral Aggregates by Washing"
  - F. ASTM C 138 "Test Method for Density (Unit Weight), Yield and Air Content (Gravimetric) of Concrete"
  - G. ASTM C 150 — Standard Specification for Portland Cement
  - H. ASTM C 172 - "Practice for Sampling Freshly Mixed Concrete"

- I. ASTM C 260 - "Specification for Air-Entraining Admixtures for Concrete"
  - J. ASTM C 494 - "Specification for Chemical Admixtures for Concrete"
  - K. ASTM C 595 - Standard Specification for Blended Hydraulic Cements
  - L. ASTM C 979 — Standard Specification for Pigments for Integrally Colored Concrete
  - M. ASTM C 989 "Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars"
  - N. ASTM C 1077 - Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction
  - O. ASTM C 1116 — Standard Specification for Fiber Reinforced Concrete
  - P. ASTM C 1602 "Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete"
  - Q. ASTM C 1688 - Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete
  - R. ASTM C 1701 - Standard Test Method for Infiltration Rate of In Place Pervious Concrete
  - S. ASTM C 1754 - Standard Test Method for Density and Void Content of Hardened Pervious Concrete
  - T. ASTM D 448 "Classification for Sizes of Aggregate for Road and Bridge Construction"
  - U. ASTM D 994 - Standard Specification for Preformed Expansion Joint Filler for Concrete
  - V. ASTM D 1557 "Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lb/ft<sup>3</sup>)"
  - W. ASTM C 1688 "Test Method for Density and Void Content of Freshly Mixed Pervious Concrete"
  - X. ASTM D 1751 "Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Non-extruding and Resilient Bituminous Types)"
  - Y. ASTM D 1752 "Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction"
  - Z. ASTM D 2434 "Test Method for Permeability of Granular Soils (Constant Head)"
  - AA. ASTM D 3385 "Test Method for Infiltration Rate of Soils in Field Using Double-Ring" Infiltrometer"
  - BB. ASTM D 5093 "Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring"
  - CC. ASTM D 5084 "Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter (Falling Head, Method C)"
  - DD. ASTM D 6767 "Standard Test Method for Pore Size Characteristics of Geotextiles by Capillary Flow Test"
  - EE. ASTM E 329 "Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction"
3. Michigan Department of Transportation
    - A. Manual for the Michigan Test Methods (MTM)
    - B. Standard Specifications for Construction, 2012
  4. National Ready Mix Concrete Association (NRMCA) MCA Pervious Concrete Contractor Certification

**Quality Assurance:**

1. The Bidder/Contractor shall submit evidence at time of bid submission, that 20% of the crew or at least one member (crew leader), whichever is greater, shall be certified through the *NRMCA Pervious Concrete Contractor Certification* program, or equal. The minimum number of certified individuals listed above, must be present on each pervious concrete placement, and a certified individual must be in charge of the placement crew and procedures.
2. Bidder must provide evidence that at least one company employee is *NRMCA Pervious Concrete Certified*, and documentation of at least 1 successful pervious concrete pavement project, greater than 1,000 ft<sup>2</sup>, including but not limited to the following:
  - A. Project name and address, owner name and contact information
  - B. Test results including density (unit weight), void content and thickness
3. Qualifications of testing laboratories- The testing laboratory shall have its laboratory equipment and procedures inspected at intervals not to exceed 2 years by a qualified national authority as evidence of its competence to perform the required tests and material designs. Acceptable national authority will include the AASHTO Materials Reference Laboratory (AMRL) and/or the Cement and Concrete Reference Laboratory (CCRL), as appropriate. In addition, testing machines and equipment must be calibrated annually or more frequently by impartial means using devices of accuracy traceable to the National Bureau of Standards.
4. In fields other than those covered by the referenced ASTM standards, the testing laboratory shall accept only those assignments which it is able to perform competently by use of its own personnel and equipment. Any work to be subcontracted must be to laboratories meeting the same criteria.
5. The testing laboratory shall have demonstrated its competence in the applicable fields for a period of not less than 3 years.
6. The inspection and testing services of the testing laboratory shall be under the direction of a full-time employee registered as a professional engineer in the State of Michigan. He shall have a minimum of 5 years of professional engineering experience in inspection and testing of concrete construction.

**Special Equipment:**

Pervious concrete requires specific equipment for compaction and jointing. The concrete shall be jointed and compacted using the methods listed, or alternatives, as demonstrated and approved by the Architect/Engineer.

1. Rolling compaction shall be achieved using a steel pipe roller that spans the width of the section placed and exerts a minimum vertical pressure of 10 psi on the concrete, or they may use a hydraulically actuated rotating, weighted, tube screed.
2. Plate compaction (for small areas) shall be achieved using a standard soil plate compactor that has a base area of at least two square feet and exerts a minimum of 10 psi vertical pressure on the pavement surface through a temporary cover of a minimum of 3/4 in. plywood.
3. Contraction joints will be constructed in pervious pavements, by rolling, or forming. The sawing of joints is discouraged due to the sediment introduced into the pavement, and the increased probability of raveling along the joints. Rolled joints shall be formed using a "pizza cutter roller" to which a beveled fin with a minimum depth of 1/4 the thickness of the slab has been attached around the circumference of a steel roller. If the Engineer allows sawed joints in writing, they shall be constructed using an early entry or wet saw.

DESIGNER NOTE: Sawed joints may exhibit some raveling, and any dust or slurry generated shall be removed during the sawing operation.

**Submittals**

Administrative Requirements for Submittal Procedures. Prior to commencement of the work the contractor shall submit the following:

1. Concrete materials:
  - A. Proposed concrete mixture proportions including all material weights, volumes, density (unit weight), water-cement (cementitious ratio), and void content. If mix proportions are proprietary, a written submittal from the concrete supplier will be required documenting a minimum of two prior successful projects using the same mix design. The density, water to cement ratio, and void content is still required to be reported.
  - B. Aggregate type, source and grading.
  - C. Cement, supplementary cementitious materials and chemical admixture manufacturer certifications
2. Aggregate base materials: Washed aggregate type, source, grading and void content (percent porosity).
3. Qualifications: Evidence of qualifications listed under the Quality Assurance section.
4. Project details: Specific plans including a jointing plan, details, schedule, construction procedures and quality control plan.
5. Subcontractors: List all materials suppliers, subcontractors and testing laboratories to be used on the project.

#### **Test Panels**

Prior to construction, test panel(s) shall be placed, and approved by the Architect/Engineer. The Architect/Engineer may waive this requirement based on Contractor qualifications.

1. Test panel(s) shall be constructed in accordance with the plans and specifications. Regardless of qualification, the contractor is to place two test panels, each a minimum 225 ft<sup>2</sup> at the required project thickness, consolidated, jointed and cured using materials, equipment, and personnel proposed for the project, to demonstrate to the Architect/Engineer's satisfaction that in-place densities can be achieved and a satisfactory pavement can be installed at the site location.
2. Test panel(s) cost and removal, if necessary, shall be included as a line item in the contract proposal and contract. Test panels may be placed at any of the specified pervious concrete pavement locations on the project or at another test site.
3. Quality: Test panels shall have acceptable surface finish, joint details, thickness, porosity and curing procedures and shall comply with the testing and acceptance standards listed in the Quality Control section of this specification. Test panels shall be tested for thickness in accordance with ASTM C 42; void content in accordance with ASTM C 138, Gravimetric Air Determination; (determine fresh density in accordance with ASTM C 29, Section 11, Jigging Procedure) and core density in accordance with ASTM C 140, paragraph 9.3.
4. Satisfactory performance of the test panels shall be determined by:
  - A. Compacted thickness no more than 1/4 in. less than specified thickness ( $T_{\text{compacted}} \geq T_{\text{specified}} - 1/4$  in.)
  - B. Void Structure: 15% minimum; 25% maximum;
  - C. Density +/- 5 lb/ft<sup>3</sup> of the design weight. If measured void structure falls below 15% or if measured thickness is greater than 1/4 in. less than specified thickness or if measured density falls less than 5 lb/ft<sup>3</sup> below the design density, the test panel shall be removed at the Contractor's expense and disposed of in an approved landfill or recycling facility. If test panels are found to be satisfactory, they may be left in-place and included in the completed work, at no additional cost to the project.

#### **Project Conditions - Weather Restrictions**

1. The Contractor shall not place pervious concrete for pavement when the ambient temperature is 40 degrees F or lower, unless otherwise permitted in writing by the Architect/Engineer.

2. The contractor shall not place pervious concrete for pavement when the ambient temperature is 90-degree F or higher, unless otherwise permitted in writing by the Architect/Engineer.

### **Pre-paving Conference**

1. A pre-paving conference with the Architect/Engineer shall be held within one week prior to beginning placement. The contractor shall have the pervious concrete supplier, the foreman and the entire concrete crew that will form and place the concrete in attendance at this meeting.
2. As a guide for the meeting, the document Checklist for the Concrete Pre-Construction Conference (available from the National Ready Mixed Concrete Association or the American Society of Concrete Contractors) shall be used to review all requirements of the contract during the meeting. Meeting emphasis shall be on how paving with pervious concrete differs from paving with conventional concrete.

## **B. MATERIALS**

1. Pervious Concrete Pavement
  - A. Cement: Portland cement Type I, Type II, Type III, or Type V, conforming to ASTM C 150 or Portland cement Type IP or IS conforming to ASTM C 595.
  - B. Supplementary Cementitious Materials:
    - (1) Fly ash conforming to ASTM C 618
    - (2) Ground Granulated Blast-Furnace Slag conforming to ASTM C 989
2. Admixtures:
  - A. Air entraining admixtures meeting ASTM C 260
  - B. Chemical admixtures shall comply with ASTM C 494.
    - (1) Water reducing admixtures Type A, mid-range water reducing admixtures (MRWRA) or high range water reducing admixtures (HRWRA) Type F or G are permitted due to low water-cement (cementitious) ratios specified for pervious concrete.
    - (2) Hydration stabilizing admixtures meeting requirements of ASTM C 494 Type B retarding or Type D Water Reducing/Retarding admixtures **are required**. This stabilizer suspends cement hydration by forming a protective barrier around the cementitious particles, delaying the initial set. As the pervious concrete heats up in the truck, a standard retarder will not prevent premature hydration while the stabilizer will. The use of hot water during cold weather will require an increased dosage of Hydration Stabilizer.
3. Aggregates for pervious concrete:
  - A. Coarse Aggregate shall meet the grading and quality requirement of MDOT 17A, 25A, 26A, or 29A unless an alternate size or specification i.e. (ASTM C 33, ASHTO) for use, based on meeting the project requirements.
  - B. A combined coarse and fine aggregates gradation shall be provided and a minimum of 10% of the material shall pass the #4 sieve.
  - C. Larger aggregate sizes may increase porosity but can decrease workability and strength. Well graded aggregates shall be avoided as they may reduce porosity, and may not provide adequate void content.
  - D. Where available, natural rounded aggregates are recommended.
4. Water: Water shall be potable and comply with ASTM C 1602.
5. Fiber Reinforcement: fiber reinforcement shall comply with ASTM C 1116.
6. Mixture Proportions: The Contractor shall furnish a proposed mix design, with proportions of materials, or if mix proportions are proprietary, a written submittal from the concrete supplier, prior to commencement of work. The data shall include densities determined in accordance with ASTM C 29

section 11, Jigging Procedure. The composition of the proposed concrete mixture shall be submitted to the Architect/Engineer for review and/or approval and shall comply with the following provisions unless an alternative composition is demonstrated to comply with the project requirements. Mixture performance will be affected by the properties of the particular materials used. Trial mixtures must be tested to establish proper proportions and determine expected behavior. Concrete producers may have mixture proportions for pervious concrete optimized for performance with local materials. Appendix 6 of ACI 211.3R provides a guide for pervious concrete mixture proportioning. General mix recommendations are as follows:

- A. Concrete mixture density: range of 105 lb/ft<sup>3</sup> to 130 lb/ft<sup>3</sup> per ASTM C 29, section 11, Jigging Procedure.
  - B. Concrete mixture void content: range of 15% to 25%, per ASTM C 138, Gravimetric Air Determination.
  - C. Cementitious content: range of 300 lbs/yd<sup>3</sup> to 600 lb/yd<sup>3</sup>.
  - D. Supplementary cementitious content: Fly ash: 25% maximum; Slag: 50% maximum, or combined supplementary cementitious content: 50% maximum.
  - E. Water – cement (cementitious) ratio: range from 0.26 to 0.40.
  - F. Aggregate content: The bulk volume of aggregate per cubic yard shall be equal to 27 ft<sup>3</sup> when calculated from the density (unit weight) determined in accordance with ASTM C29 Jigging Procedure.
  - G. Admixtures: Admixtures shall be used in accordance with the manufacturer's instructions and recommendations.
  - H. Mix Water: The quantity of mixing water shall be established to produce a pervious concrete mixture of the desirable workability to facilitate placing, compaction and finishing to the desired surface characteristics. Mix water shall be such that the cement paste displays a wet metallic sheen without causing the paste to flow from the aggregate. (A cement paste with a dull-dry appearance has insufficient mix water for hydration.) Insufficient mix water results in inconsistency in the mix and poor bond strength. High water content may result in the paste sealing the void system primarily at the bottom and poor bond at the upper surface.
  - I. Air Entrainment: has been shown to increase freeze thaw durability of pervious concrete.
  - J. Fiber Reinforcement: has been shown to increase freeze thaw durability and tensile strength.
7. Isolation (Expansion) Joint Material. Isolation joint material shall be 1/4 in or 1/2 in. flexible foam expansion joint with relative density of 1.7 or higher, meeting ASTM D 4819-88, or vinyl expansion joint in compliance with ASTM D 1751 or ASTM D 1752.
8. Curing Materials
- A. Polyethylene sheeting - The primary method of curing pervious concrete shall be the placement of a waterproof covering, consisting of a minimum of 6 mil thick polyethylene sheeting.
  - B. Other moisture loss control - For prevention of moisture loss prior to the primary method of curing:
    - (1) Liquid membrane curing compounds may be used, but they do temporarily reduce initial porosity. Curing compounds must comply with ASTM C-309, Type 1, Class A unless otherwise approved by the Architect/Engineer, when applied at a rate of 200 ft<sup>2</sup> per gallon.
    - (2) Monomolecular film (Evaporation Retardant) applied per the manufacturer's instructions.
    - (3) A soybean oil based sealer/water repellent reduces surface color markings from plastic sheeting, enhances strength and durability, but does not reduce porosity.
9. Aggregates for Stormwater Management (Pavement Base Materials)
- A. Aggregate material shall consist of clean, mechanically crushed stone, substantially free from adherent coatings. Recycled crushed concrete is not allowed.

- B. Materials shall be washed thoroughly to remove clay, organic matter, extraneous debris, or objectionable materials. Washed material that does not match the consistency of the approved material sample is subject to rejection and washing at Contractor's expense until requirements are met. If washing is to be completed on site, Contractor and/or supplier shall provide all resources and materials and cleanup required for washing the aggregate and completing the work in a method acceptable to the Engineer.
- C. The Material shall be obtained only from a source(s) approved by the Engineer. The Engineer reserves the right to sample and test Material at any time including at the source.
- D. Pavement Base shall consist of up to three (3) layers as specified on the Plans and included herein:  
 (1) "Choker Layer" shall be MDOT 6AA, MDOT 4G, or AASHTO #57 (modified).  
 (2) "Reservoir Layer" shall be MDOT 4AA, MDOT 6AA, MDOT 4G, AASHTO #2, AASHTO #3 or AASHTO #57.  
 (3) "Filter Layer" shall be MDOT 34G, MDOT 4G, or AASHTO #8.
- E. Pavement Base Material shall meet the following specifications for grading and quality.  
 (1) Aggregate Gradation:

Sieve <sup>1</sup>	Percent Passing by Weight						
	AASHTO #2 Modified	AASHTO #3 Modified	MDOT 6AA	AASHTO #57 Modified	AASHTO #8 Modified	MDOT 4G	MDOT 34G
3 inch	100	-	-	-	-	-	-
2-1/2 inch	90 to 100	100	-	-	-	-	-
2 inch	35 to 70	90 to 100	-	-	-	-	-
1-1/2 inch	0 to 15	35 to 70	100	100	-	100	-
1 inch	-	0 to 15	90 to 100	95 to 100	-	-	-
3/4 inch	0 to 5	-	-	-	-	60 to 80	-
1/2 inch	-	0 to 5	30 to 60	25 to 60	100	35 to 65	100
3/8 inch	-	-	-	-	85 to 100	-	95 to 100
No. 4	-	-	0 to 8	0 to 10	10 to 30	-	-
No. 8	-	-	-	0 to 5	0 to 10	10 to 25	0 to 5
No. 16	-	-	-	-	0 to 5	-	-
No. 30	-	-	-	-	-	5 to 18	-
No. 100 <sup>2</sup>	≤2.0	≤2.0	-	≤2.0	≤2.0	-	-
No. 200 <sup>3</sup>	-	-	≤ 1.0	-	-	≤ 3.0 <sup>4</sup>	≤ 3.0

5. Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.  
 6. Gradation modified from AASHTO for portion passing the No. 100 sieve.  
 7. Loss by Washing (MTM 108) percent passing. Based on dry weights.  
 8. Gradation modified from MDOT for portion passing the No. 200 sieve.

- (2) Reservoir Layer material shall also contain 90 percent (minimum) crushed particles with two (2) or more fractured faces as determined by ASTM D5821 or MTM 117.

Geotextile is not typically required under permeable pavement applications unless recommended by a geotechnical engineer. Geotextile can be placed vertically for material separation between side walls of the reservoir course and native soil.

#### 10. Geotextile

- A. Needled nonwoven polypropylene fibers.
- B. Geotextile shall meet AASHTO M288-06 (2011), for Class 2 strength property requirements and Subsurface Drainage requirements as shown below.  
 (1) Minimum Grab Strength (ASTM D 4632): 700 N (150 lbs)  
 (2) Minimum Tear Strength (ASTM D 4533): 250 N (50lbs)  
 (3) Minimum Puncture Strength (ASTM D 6241): 1375 N (300 lbs)  
 (4) Minimum Permittivity (ASTM D 4491): 0.5 per second

(5) Maximum Apparent Opening Size (ASTM D 4751): 0.215 mm (70 US Std. Sieve)

C. Acceptable products include:

- (1) Mirafi 160N
- (2) Geotex 601
- (3) US 160NW
- (4) SKAPS GT 160
- (5) or approved equal

D. Location: In accordance with the Drawings.

## C. CONSTRUCTION

### 1. Pre-Installation Examination and Preparation

- A. Examine previous work, related work, and conditions under which this work is to be performed and notify the Engineer in writing of all deficiencies and conditions detrimental to the proper completion of this work.
- B. Temporary erosion and sediment controls are needed during installation to divert stormwater away from the permeable pavement area until it is construed and contributing drainage areas have been stabilized.
- C. Proposed permeable pavement area must be kept free from sediment during the entire construction process.

### 2. Excavation

- A. Excavate as indicated on the grading drawings to conform to line, grade and elevations indicated.
- B. Use light earth-moving equipment or by excavating from the perimeter of the excavated area to avoid soil compaction.
- C. Only very low ground pressure (<0.03 MPa or <4psi) equipment is acceptable in the bed areas when excavation is within one (1) vertical foot of the final subgrade elevation. Appropriate equipment includes wide track or marsh track equipment, or light equipment with turf-type tires.
- D. Remove excavated materials from the site.

DESIGNER NOTE: The designer should set compaction requirements based on consideration of site specific geotechnical properties of the native soil (e.g. permeability, stiffness) and performance requirements for the pavement section (e.g. traffic loading, infiltration, costs).

DESIGNER NOTE: Optional Compaction Requirement: Compact subgrade to 90 percent (+/- 2 percent) of the maximum dry density per standard Proctor test (ASTM D698), or as directed by Engineer. Determination of in-place density shall be made using a nuclear gauge per ASTM D6939.

### 3. Subgrade Preparation and Protection

- A. No heavy equipment shall pass over the subsoils (subgrade) after they have been loosened. If the Contractor plans to utilize such areas for any use of heavy equipment, this work should be carried out prior to beginning the process of loosening soils or filling in that area.
- B. Avoid compaction of subgrade soil unless directed or approved by Engineer. Areas of the subgrade which are over-compacted, as determined by Engineer, shall be ripped or tilled to a depth of 12 inches (minimum) or as directed by Engineer.
- C. Prior to placing any aggregate, soil or any drainage materials beneath the permeable pavement area the entire subgrade shall be loosened using a soil ripper or subsoiler to break up the native soil to a minimum 6-inch depth. Remove ponded water at the bottom of the excavation before tilling or ripping. Soil shall be friable before tilling.

- D. Remove accumulation of fine materials due to ponding or surface erosion with light equipment. Excavate, fill, re-grade and scarify areas damaged by erosion, ponding or traffic compaction.
  - E. Confirm that the subgrade is at the proper elevation as shown on the drawings.
4. Proof Roll
- A. Proof-roll prepared subgrade to identify soft or unstable areas.
  - B. Remove soft spots and replace with permeable structural fill as directed by Engineer to achieve uniform subgrade.
  - C. Use light equipment and avoid over compacting the subgrade.
  - D. Do not test where shallow underground utilities are present.
  - E. Do not place geotextile or porous media bed until subgrade surface has been inspected and approved by Engineer.
5. Geotextile
- A. Material shall be cut and fit to the dimensions shown on the plans with adequate lap lengths, a minimal number of seams, and with excess materials removed and disposed of properly.
  - B. Clean and straight cuts are required to the line and grade of the plans.
  - C. The graded surface shall be smooth and free of deleterious materials such as sharp objects or large protruding rocks that could cause the geotextile to tear.
  - D. Geotextiles shall be placed on the prepared surface parallel to the longest side of the practice. Place geotextile in a manner that minimizes folds and creases. Successive sheets of geotextile shall be overlapped a minimum of 16 inches with the up-flow sheet overlapping the down flow sheet.
  - E. Extend the filter fabric at least 4 feet outside the bed and fold the fabric over the stone bed to temporarily protect it from sediment until the asphalt surface is placed.
6. Aggregate
- A. Place aggregate with a uniform gradation, free of contamination and segregation. Do not rut or distort the subbase material or aggregate base during spreading.
  - B. Compact the aggregate layers of a uniform thickness, no greater than 8 inches.
    - (1) Compact each layer with static roller or single pass with vibration (low amplitude, high frequency) for aggregate interlock.
    - (2) Compact reservoir layers with a 10-ton roller with two passes in static mode or until there is no visible movement of the aggregate.
    - (3) For No. 57 or similar sized stone layers, make two passes in vibratory mode and two passes in static mode or until there is no visible movement of the aggregate.
    - (4) Do not crush the aggregate with the roller.
    - (5) Corners and other areas where rollers cannot reach are compacted with a vibratory plate compactor capable of at least 13,500-pound force (lbf) and equipped with a compaction indicator.
  - C. Where the aggregate course is constructed in more than one-layer, complete grading, and then clean previously constructed layers of loose and foreign matter prior to placing subsequent layers.
  - D. Do not place concrete material until the aggregate surface has been inspected and approved by Engineer.
7. Pervious Concrete Pavement

- A. Pavement Thickness: Pavement thickness for all applications (excluding heavy traffic loads) shall be a single-course placement 6 inches thick unless otherwise specified in the plans. Heavy truck traffic may require special design.
- B. Formwork: Form materials are permitted to be of wood or steel and shall be the full depth of the pavement. Caution: protect filter fabric, and impermeable membranes from puncture or tear when placing forms and form pins. Forms shall be of sufficient strength and stability to support mechanical equipment without deformation of plan profiles following spreading, strike-off and compaction operations. Forms may have a removable spacer of 1/2 in. to 3/4 in. thickness placed above the depth of pavement. The spacers shall be removed following placement and vibratory strike-off to allow roller compaction. (Removable spacers may not be necessary if other means of strike-off and consolidation are used, such as a hydraulically actuated weighted pipe roller screed.)
- C. Mixing and Hauling:
- (1) Production: Pervious concrete shall be manufactured and delivered in accordance with ASTM C 94.
  - (2) Mixing: Pervious concrete shall be batched in central mixers or in transit (truck) mixers. (When concrete is delivered in agitating or non-agitating units, the concrete shall be mixed in the central mixer for a minimum of 1.0 minute or until a homogenous mix is achieved.) Concrete mixed in transit mixers shall be mixed at the mixing speed designated by the manufacturer for 70 – 100 revolutions.
  - (3) Transportation: Pervious concrete may be transported or mixed on site and discharge of individual loads shall be completed within one (1) hour of the introduction of mix water to the cement. Discharge times may be extended beyond 60 minutes when an increased dosage of hydration stabilizer is used to maintain a wet metallic sheen.
  - (4) Discharge: Each truckload shall be visually inspected for moisture consistency. Water addition shall be permitted at the point of discharge to obtain the required mix consistency, and as needed to maintain a wet metallic sheen. A minimum of 30 revolutions at the manufacturer's designated mixing speed shall be required following the addition of any water to the mix, prior to further discharge. If water is added more than three times to a load, the dosage rate of hydration stabilizing admixture should be increased in subsequent loads. Discharge shall be a continuous operation and shall be completed as quickly as possible. Concrete shall be deposited as close to its final position as practical and such that discharged concrete is incorporated into previously placed plastic concrete. If consolidation occurs during concrete discharge, placement shall be halted, the mix shall be addressed, and the consolidated portion removed and replaced immediately.
- D. Placing and Finishing:
- (1) The base shall be in a damp condition at time of placement. Failure to provide a moist base will result in a reduction in concrete strength.
  - (2) Concrete may be deposited into the forms by mixer truck chute, conveyor or buggy.
  - (3) Unless otherwise permitted, the Contractor shall utilize a mechanical vibratory screed to strike off the concrete 1/2 in. to 3/4 in. above final height, utilizing the form spacers described in Formwork. An alternative method to strike off and compaction is to use a motorized or hydraulically actuated weighted pipe roller screed, as described in the Special Equipment section. If approved by the Architect/Engineer in writing, the Contractor may place the pervious concrete with either slip form or vibratory form riding equipment followed by a compacting unit that will provide a minimum of 10 psi vertical force to the concrete. Similarly, strike off by hand straightedge may be permitted for sidewalks and other small areas followed by compaction.
  - (4) Care must be taken to prevent closing the void structure of pervious concrete. After mechanical or other approved strike-off /compaction operation the surface is cross rolled, no other finishing operation will be allowed. Internal vibration shall not be permitted. (If surface vibration is applied, it shall be shut off immediately when forward progress is halted for any reason.)
  - (5) Placed concrete shall not be disturbed while in the plastic state including edging. Low spots after the screeding operation shall be over-filled for surface repair and tamped to the desired elevation with hand tampers, or re-screeded with the motorized or hydraulically actuated weighted pipe roller screed.

- (6) Following strike-off, remove spacers and compact the concrete to the form level utilizing a steel roller, a plate compactor on plywood or other method approved by the Architect/Engineer. Longitudinal rolling shall be followed immediately by cross rolling and joint rolling (if specified). Care shall be taken during compaction that sufficient compactive force is achieved without excessively working the concrete surface that might result in sealing off the surface porosity.
- (7) The pervious concrete pavement shall be compacted to the required cross-section and shall not deviate more than +/- 3/8 in. in 10 ft. from profile grade.

E. Jointing

- (1) Joints in pervious pavements may be omitted at the option of the owner, who may instead choose to accept or prefer the appearance of random cracking.
- (2) Although longer joint spacing may control cracking, for conservative design, contraction (control) joints shall be installed at regular intervals not to exceed 20 ft., and slab length shall not exceed 1.5 times the width of the slab. Transverse contraction joints shall be installed at 1/4 the depth of the thickness of the pavement. These joints are to be installed as quickly as possible in the plastic concrete.
- (3) Jointing plastic concrete: Joints installed in the plastic concrete may be constructed utilizing a small roller as described in the Special Equipment section. When this option is used it shall be performed immediately after roller compaction and prior to curing. If the Engineer allows sawed joints in writing, they shall be constructed using an early entry or wet saw. Note: Sawed joints may exhibit some raveling, and any dust or slurry generated shall be removed during the sawing operation.
- (4) Transverse construction joints: Transverse construction joints shall be installed whenever placement is suspended for 30 minutes or whenever concrete is no longer workable.
- (5) Isolation joints: Isolate slabs from other parts of the structure, such as walls, footings or columns; and driveways and patios from sidewalks, garage slabs, stairs, light poles and other points of restraint.

DESIGNER NOTES: Isolation joints permit independent vertical and horizontal movement between adjoining parts of the structure and help minimize cracking when such movements are restrained.

- (6) Edging, shall be performed along isolation joints and construction joints, in order to reduce potential for raveling under traffic.

F. Curing:

- (1) Curing procedures shall begin immediately but no later than 20 minutes from the time the pervious concrete is discharged from the truck. Placing, finishing, and tooled jointing must be completed within the 20-minute window after discharge. The pavement surface shall be covered with a minimum of 6 mil thick polyethylene sheet or other approved covering material. Prior to covering, a soybean oil based product may be applied to the surface of the concrete. The cover shall overlap at all exposed edges and shall be secured (without using dirt or stone) to prevent uncovering due to winds or adjacent traffic conditions. A spray glue is recommended to secure separate plastic sections and prevent moisture loss. For additional guidance on hot weather concreting, see ACI 305, and for cold weather concreting see ACI 306.
- (2) Due to the low water/cement (cementitious) ratio and large areas of exposed surface, pervious concrete is especially susceptible to drying out. Immediately after screeding, the surface shall be kept moist and evaporation prevented using water or a soybean based, spray applied curing compound and/or evaporation retarder following screeding. Immediately after each transverse jointing, the polyethylene sheet curing shall be applied then cross rolling shall be performed.
- (3) The curing cover shall remain securely in place, uninterrupted, for a minimum of 7 days in warm weather, or 10 days in cold weather. No vehicular traffic shall be permitted on the pavement until curing is complete (7 days) and no truck traffic shall be permitted for at least 14 days without written permission from Engineer. Pedestrian traffic may be permitted on the curing concrete after 24 hours. The Engineer may permit earlier traffic opening times.
- (4) The owner and general contractor are responsible to notify the contractor if the polyethylene sheeting has been removed from the finished surface, and to re-cover the material immediately until the contractor can re-install covering.

G. Quality Control - Concrete:

- (1) The Architect/Engineer shall employ a testing laboratory that conforms to the requirements of ASTM E329 and ASTM C1077. All personnel engaged in concrete testing shall be certified as a Michigan Level I Field Testing Technician.
- (2) Traditional concrete testing procedures for strength and slump control are not applicable to this type of pavement material. Procedures to be used per this guide specification include: ASTM C 172, ASTM C 29, ASTM C 42 and ASTM C 138.
- (3) Concrete tests shall be performed for each 150 yd<sup>3</sup>, or fraction thereof, with a minimum of one set of tests for each day's placement.
- (4) Sampling - Plastic concrete shall be sampled in accordance with ASTM C 172.
- (5) Density (unit weight) – Density shall be performed in accordance with ASTM C 1688 “Test Method for Density and Void Content of Freshly Mixed Pervious Concrete”. The density of the delivered concrete shall be within +/- 5 lb/ft<sup>3</sup> of the design density (unit weight).
- (6) Void content - Void content of the plastic concrete shall be determined in accordance to ASTM C138 Gravimetric Air Determination (determine fresh density in accordance with ASTM C 29, Section 11, Jigging Procedure) and core density in accordance with ASTM C 140, paragraph 9.3., and compared to the void percentage required by design. Unless otherwise specified, the void content shall be between 15% and 25%.
- (7) After a minimum of seven (7) days, hardened concrete shall be tested at a rate of one set of three cores per 150 yd<sup>3</sup> of concrete placed on one day or fraction thereof. Cores shall be drilled in accordance with ASTM C 42. The cores shall be measured for thickness, void structure and density.
- (8) Thickness – Untrimmed hardened core samples shall be used to determine placement thickness. The average of all production cores when measured for length shall not be more than 1/2 in. less than the specified design thickness.
- (9) Core density (unit weight) and void content - The cores shall be tested for density (unit weight) and void content following ASTM C 140. Density (unit weight) of cores trimmed and tested in the saturated condition, per ASTM C 140, paragraph 9.3.1, shall be +/- 5 lb/ft<sup>3</sup> of the design density. Void content shall not be more than 2% below the specified design void content. Void content shall be calculated as follows:

$$\% \text{ Voids} = 1 - (Dd/Di) * 100$$

where: Dd = oven dried density of core

Di = immersed density of core

8. Performance/Maintenance

- A. Excessive raveling – At or before 28 days after placement, any areas of excessive surface raveling, as determined by the Architect/Engineer, shall be removed and replaced or repaired by the Contractor at no additional cost to the project.

DESIGNER NOTE: Optional language – at the unit price established in the contract.

- B. Surface drainage – At or before 28 days after placement, any areas of insufficient surface porosity, as determined by the Architect/Engineer in their design calculations, shall be removed and replaced by the Contractor at no additional cost to the project.

DESIGNER NOTE: Optional language – at the unit price established in the contract.

**G. MEASUREMENT AND PAYMENT**

The completed work, as described, shall be paid for at the contract unit price for the following contract item (pay item):

<b>Pay Item</b>	<b>Pay Unit</b>
Aggregate Base, ___-inch	Square Yard
Pervious Concrete Pavement, ___-inch	Square Yard

The price shall be payment in full for furnishing all labor, equipment and materials to complete the work as specified and indicated on the Drawings. **Aggregate Base, \_\_\_-inch** shall be measured by width and length for the specified depth as shown on the plans. This work includes, but is not limited to, subgrade preparation and protection, geotextile, aggregate base for the pavement base, and for any necessary grading, excavation and backfill when not paid for separately.

The unit of measure for **Pervious Concrete Pavement, \_\_\_-inch** will be the square yard at the specified thickness. The actual number of square yards, complete in place measured along the surface, will be paid for at the contract unit price per square yard. Payment shall include furnishing, hauling, and placing all materials, including formwork, concrete work, joints, expansion joint materials, waterproofing, load transfer devices, impervious material, sealing of joints and curing. Payment for will include all costs for furnishing all materials, labor, tools, equipment and incidentals to complete the work.

**SPECIAL SPECIFICATION  
FOR  
PERMEABLE INTERLOCKING UNIT PAVERS PAVEMENT**

DESIGNER NOTE: The specifications below are based on the best available information. Designer should modify the specifications to satisfy project-specific constraints.

DESIGNER NOTE: Black text inside of an orange shaded box corresponds to notes to the designer. These notes should be deleted before using the specifications in contract documents.

**A. DESCRIPTION**

This work consists of providing all labor, equipment and materials necessary for preparing the subsoil and constructing the permeable interlocking unit pavers pavement as indicated on the Drawings, or as directed by the Engineer. The permeable interlocking unit pavers shall consist of a combination of unit pavers and aggregate for the joints and bedding layer, to form an integrated, structural wearing surface when compacted.

**References**

The following specifications and standards of the organizations and documents listed in this paragraph form a part of the specification to the extent required by the references thereto. In the event that the requirements of the following referenced standards and specification conflict with this specification section the requirements of this specification shall prevail. In the event that the requirements of any of the following referenced standards and specifications conflict with each other the more stringent requirement shall prevail or as determined by the Engineer.

1. Brick Industry Association
2. American Society for Testing and Materials (ASTM)
  - A. ASTM C131 Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
  - B. ASTM C136 Method for Sieve Analysis for Fine and Coarse Aggregate.
  - C. ASTM C140 Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units.
  - D. ASTM D448 Standard Classification for Sizes of Aggregate for Road and Bridge Construction.
  - E. ASTM C936 Standard Specification for Solid Interlocking Concrete Pavers.
  - F. ASTM C979 Specification for Pigments for Integrally Colored Concrete.
  - G. ASTM C1645 Standard Test Method for Freeze-thaw and De-icing Salt Durability of Solid Concrete Interlocking Paving Units.
  - H. ASTM C1781 Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems.
  - I. ASTM D3385 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer.
  - J. ASTM E2835 Standard Test Method for Measuring Deflections using a Portable Impulse Plate Load Test Device
3. Interlocking Concrete Pavement Institute (ICPI)
4. Michigan Department of Transportation
  - A. Manual for the Michigan Test Methods (MTM)
  - B. Standard Specifications for Construction, 2012

## B. SUBMITTALS

1. Demonstrate that job foremen on the project have a current certificate from the Interlocking Concrete Pavement Institute Concrete Paver Installer Certification program and a record of completion from the PICP Installer Course.
2. Job references from projects of a comparable size and complexity. Provide Owner/Client/General Contractor names, postal address, phone, fax, and email address.
3. Written Method Statement and Quality Control Plan that describes material staging and flow, paving direction and installation procedures, including representative reporting forms that ensure conformance to the project specifications.

## C. QUALITY ASSURANCE TEST PANEL

1. Install a minimum 10 ft. x 10 ft. (3 x 3 m) paver area.
2. Use this area to determine surcharge of the bedding layer, joint sizes, and lines, laying pattern, color and texture of the job.
3. This area will be used as the standard by which the work will be judged.
4. Subject to acceptance by owner, mock-up may be retained as part of finished work.
5. If mock-up is not retained, remove and properly dispose of mock-up.

## D. MATERIALS

DESIGNER NOTE: Some projects may include permeable and solid interlocking concrete pavements. Specify each product as required.

1. Paving Units
  - A. Manufacturer: *[Specify manufacturer name]*.
    - (1) Contact: *[Specify manufacturer contact information]*.
  - B. Permeable Interlocking Concrete Paver Units:
    - (1) Paver Type: *[Specify name of product group, family, series, etc.]*.
      - (a) Material Standard: Comply with ASTM C936. Use -15 deg. C as the lowest temperature for freeze-thaw durability testing while test specimens are immersed in a 3% saline solution per ASTM C1645.
      - (b) Color: *[Specify color.] [Specify finish]*.
      - (c) Color Pigment Material Standard: Comply with ASTM C979.
      - (d) Size: *[Specify]* inches (*[Specify]* mm) x *[Specify]* inches (*[Specify]* mm) x *[Specify]* inches (*[Specify]* mm) thick.

DESIGNER NOTE: Concrete pavers may have spacer bars on each unit. Spacer bars are recommended for mechanically installed pavers. Manually installed pavers may be installed with or without spacer bars. Verify with manufacturers that overall dimensions do not include spacer bars.

2. Crushed Stone Filler, Bedding, Base and Subbase
  - A. Crushed stone with 90% fractured faces, LA Abrasion < 40 per ASTM C 131.
  - B. Do not use rounded river gravel for vehicular applications.
  - C. All stone materials shall be washed with less than 2% passing the No. 200 sieve.
  - D. Joint/opening filler, bedding, base and subbase: conforming to ASTM D448 gradation as shown in Tables 1, 2 and 3 below:

DESIGNER NOTE: No. 89 or No. 9 stone may be used to fill pavers with narrow joints.

Table 1  
ASTM No. 8 Grading Requirements  
Bedding and Joint/Opening Filler

Sieve Size	Percent Passing
12.5 mm (1/2 in.)	100%
9.5 mm (3/8 in.)	85 to 100%
4.75 mm (No. 4)	10 to 30%
2.36 mm (No. 8)	0 to 10%
1.16 mm (No. 16)	0 to 5%

Table 2  
ASTM No. 57 Base  
Grading Requirements

Sieve Size	Percent Passing
37.5 mm (1 1/2 in.)	100%
25 mm (1 in.)	95 to 100%
12.5 mm (1/2 in.)	25 to 60%
4.75 mm (No. 4)	0 to 10%
2.36 mm (No. 8)	0 to 5%

DESIGNER NOTE: ASTM No. 3 or No. 4 stone may be used as subbase material if ASTM No. 2 stone is unavailable.

Table 3  
Grading Requirement for ASTM No. 2 Subbase

Sieve Size	Percent Passing
75 mm (3 in.)	100%
63 mm (2 1/2 in.)	90 to 100%
50 mm (2 in.)	35 to 70%
37.5 mm (1 1/2 in.)	0 to 15%
19 mm (3/4 in.)	0 to 5%

DESIGNER NOTE: Curbs will typically be cast-in-place concrete or precast set in concrete haunches. Concrete curbs may be specified in another Section. Do not use plastic edging with steel spikes to restrain the paving units for vehicular applications.

### 3. Edge Restraints

- A. Manufacturer: [Specify manufacturer]
- B. Material: [Pre-cast concrete] [Cut stone] [Concrete]
- C. Material Standard: [Specify material standard]

DESIGNER NOTE: See ICPI publication, Permeable Interlocking Concrete Pavements for guidance on geotextile selection. Geotextile use is a designer option.

### 9. Geotextile

- A. Needled nonwoven polypropylene fibers.
- B. Geotextile shall meet AASHTO M288-06 (2011), for Class 2 strength property requirements and Subsurface Drainage requirements as shown below.
  - (1) Minimum Grab Strength (ASTM D 4632): 700 N (150 lbs)
  - (2) Minimum Tear Strength (ASTM D 4533): 250 N (50lbs)
  - (3) Minimum Puncture Strength (ASTM D 6241): 1375 N (300 lbs)

- (4) Minimum Permittivity (ASTM D 4491): 0.5 per second
- (5) Maximum Apparent Opening Size (ASTM D 4751): 0.215 mm (70 US Std. Sieve)

C. Acceptable products include:

- (1) Mirafi 160N
- (2) Geotex 601
- (3) US 160NW
- (4) SKAPS GT 160
- (5) or approved equal

D. Location: In accordance with the Drawings.

## E. CONSTRUCTION

DESIGNER NOTE: The elevations and surface tolerance of the soil subgrade determine the final surface elevations of concrete pavers. The paver installation contractor cannot correct deficiencies excavation and grading of the soil subgrade with additional bedding materials. Therefore, the surface elevations of the soil subgrade should be checked and accepted by the General Contractor or designated party, with written certification presented to the paver installation subcontractor prior to starting work.

DESIGNER NOTE: Compaction of the soil subgrade is optional and should be determined by the project engineer. If the soil subgrade requires compaction, compact to a minimum of 95% standard Proctor density per ASTM C698. Compacted soil density and moisture should be checked in the field with a nuclear density gauge or other test methods for compliance to specifications. Stabilization of the soil and/or base material may be necessary with weak or continually saturated soils, or when subject to high wheel loads. Compaction will reduce the permeability of soils. If soil compaction is necessary, estimate the infiltration rate per ASTM D3385 for hydrologic design after compacting the test area(s) and measuring density. Reduced infiltration may require drain pipes within the open-graded subbase to conform to local storm drainage requirements.

### 1. Pre-Installation Examination and Preparation

- E. Examine previous work, related work, and conditions under which this work is to be performed and notify the Engineer in writing of all deficiencies and conditions detrimental to the proper completion of this work.
- F. Temporary erosion and sediment controls are needed during installation to divert stormwater away from the permeable pavement area until it is construed and contributing drainage areas have been stabilized.
- G. Proposed permeable pavement area must be kept free from sediment during the entire construction process.

### 10. Excavation

- A. Excavate as indicated on the grading drawings to conform to line, grade and elevations indicated.
- B. Use light earth-moving equipment or by excavating from the perimeter of the excavated area to avoid soil compaction.
- C. Only very low ground pressure (<0.03 MPa or <4psi) equipment is acceptable in the bed areas when excavation is within one (1) vertical foot of the final subgrade elevation. Appropriate equipment includes wide track or marsh track equipment, or light equipment with turf-type tires.
- D. Remove excavated materials from the site.

### 11. Subgrade Preparation and Protection

DESIGNER NOTE: The designer should set compaction requirements based on consideration of site specific geotechnical properties of the native soil (e.g. permeability, stiffness) and performance requirements for the pavement section (e.g. traffic loading, infiltration, costs).

DESIGNER NOTE: Optional Compaction Requirement: Compact subgrade to 90 percent (+/- 2 percent) of the maximum dry density per standard Proctor test (ASTM D698), or as directed by Engineer. Determination of in-place density shall be made using a nuclear gauge per ASTM D6939.

- A. No heavy equipment shall pass over the subsoils (subgrade) after they have been loosened. If the Contractor plans to utilize such areas for any use of heavy equipment, this work should be carried out prior to beginning the process of loosening soils or filling in that area.
- B. Avoid compaction of subgrade soil unless directed or approved by Engineer. Areas of the subgrade which are over-compacted, as determined by Engineer, shall be ripped or tilled to a depth of 12 inches (minimum) or as directed by Engineer.
- C. Prior to placing any aggregate, soil or any drainage materials beneath the permeable pavement area the entire subgrade shall be loosened using a soil ripper or subsoiler to break up the native soil to a minimum 6-inch depth. Remove ponded water at the bottom of the excavation before tilling or ripping. Soil shall be friable before tilling.
- D. Remove accumulation of fine materials due to ponding or surface erosion with light equipment. Excavate, fill, re-grade and scarify areas damaged by erosion, ponding or traffic compaction.
- E. Confirm that the subgrade is at the proper elevation as shown on the drawings.

#### 12. Proof Roll

- A. Proof-roll prepared subgrade to identify soft or unstable areas.
- B. Remove soft spots and replace with permeable structural fill as directed by Engineer to achieve uniform subgrade.
- C. Use light equipment and avoid over compacting the subgrade.
- D. Do not test where shallow underground utilities are present.
- E. Do not place geotextile or porous media bed until subgrade surface has been inspected and approved by Engineer.

#### 13. Geotextile

- A. Material shall be cut and fit to the dimensions shown on the plans with adequate lap lengths, a minimal number of seams, and with excess materials removed and disposed of properly.
- B. Clean and straight cuts are required to the line and grade of the plans.
- C. The graded surface shall be smooth and free of deleterious materials such as sharp objects or large protruding rocks that could cause the geotextile to tear.
- D. Geotextiles shall be placed on the prepared surface parallel to the longest side of the practice. Place geotextile in a manner that minimizes folds and creases. Successive sheets of geotextile shall be overlapped a minimum of 16 inches with the up-flow sheet overlapping the down flow sheet.
- E. Extend the filter fabric at least 4 feet outside the bed and fold the fabric over the stone bed to temporarily protect it from sediment until the asphalt surface is placed.

#### 14. Aggregate

- A. Place aggregate with a uniform gradation, free of contamination and segregation. Do not rut or distort the subbase material or aggregate base during spreading.
- B. Compact the aggregate layers of a uniform thickness, no greater than 8 inches.
  - (1) Compact each layer with static roller or single pass with vibration (low amplitude, high frequency) for aggregate interlock.
  - (2) Compact reservoir layers with a 10-ton roller with two passes in static mode or until there is no visible movement of the aggregate.

- (3) For No. 57 or similar sized stone layers, make two passes in vibratory mode and two passes in static mode or until there is no visible movement of the aggregate.
  - (4) Do not crush the aggregate with the roller.
  - (5) Corners and other areas where rollers cannot reach are compacted with a vibratory plate compactor capable of at least 13,500-pound force (lbf) and equipped with a compaction indicator.
- C. Where the aggregate course is constructed in more than one-layer, complete grading, and then clean previously constructed layers of loose and foreign matter prior to placing subsequent layers.
  - D. Do not place bedding layer until the aggregate surface has been inspected and approved by Engineer.
15. Underdrain. Where subsurface drainage is required, install in accordance with *Special Specification for Underdrains for Stormwater Facilities*.

DESIGNER NOTE: The minimum slope of the soil subgrade is typically 0.5%. Actual slope of soil subgrade will depend on the drainage design and exfiltration type. All drain pipes, observation wells, overflow pipes, and (if applicable) geotextiles, berms, baffles and impermeable liners should be in place per the drawings prior to or during placement of the subbase and base, depending on their location. Care must be taken not to damage drainpipes during compaction and paving. Base/subbase thicknesses and drainage should be determined using ICPI's Permeable Interlocking Concrete Pavements manual and Permeable Design Pro software.

16. Bedding layer

- A. Moisten, spread and screed the No. 8 stone bedding material.
- B. Fill voids left by removed screed rails with No. 8 stone.
- C. The surface tolerance of the screeded No. 8 bedding layer shall be  $\pm 3/8$  in (10 mm) over a 10 ft. (3 m) straightedge.
- D. Do not subject screeded bedding material to any pedestrian or vehicular traffic before paving unit installation begins.

17. Permeable interlocking unit pavers and joint/opening fill material

- A. Lay the paving units in the pattern(s) and joint widths shown on the drawings. Maintain straight pattern lines.
- B. Fill gaps at the edges of the paved area with cut units. Cut pavers subject to tire traffic shall be no smaller than 1/3 of a whole unit.
- C. Cut pavers and place along the edges with a [double-bladed splitter or] masonry saw.
- D. Fill the openings and joints with [No. 8] stone.

DESIGNER NOTE: Some paver joint widths may be narrow and not accept most of the No. 8 stone. Use joint material that will fill joints such as washed ASTM No. 89 or No. 9 stone.

- E. Remove excess aggregate on the surface by sweeping pavers clean.
- F. Compact and seat the pavers into the bedding material using a low-amplitude, 75-90 Hz plate compactor capable of at least 5,000 lbf (22 kN). This will require at least two passes with the plate compactor.
- G. Do not compact within 6 ft. (2 m) of the unrestrained edges of the paving units.
- H. Apply additional aggregate to the openings and joints if needed, filling them completely. Remove excess aggregate by sweeping then compact the pavers. This will require at least two passes with the plate compactor.
- I. All pavers within 6 ft. (2 m) of the laying face must be left fully compacted at the completion of each day.

- J. The final surface tolerance of compacted pavers shall not deviate more than  $\pm 3/8$  (10 mm) under a 10 ft. (3 m) long straightedge.
- K. The surface elevation of pavers shall be 1/8 to 1/4 in. (3 to 6 mm) above adjacent drainage inlets, concrete collars or channels.

18. Field Quality Control

- A. After sweeping the surface clean, check final elevations for conformance to the drawings.
- B. Lippage: No greater than 1/8 in. (3 mm) difference in height between adjacent pavers.

DESIGNER NOTE: The surface of the pavers may be 1/8 to 1/4 in. (3 to 6 mm) above the final elevations after compaction. This helps compensate for possible minor settling normal to pavements.

- C. The surface elevation of pavers shall be 1/8 to 1/4 in. (3 to 6 mm) above adjacent drainage inlets, concrete collars or channels.
- D. Bond lines for paver courses:  $\pm 1/2$  in. ( $\pm 15$  mm) over a 50 ft. (15 m) string line.
- E. Verify the surface infiltration at a minimum of 100 in./hour using test method C 1781.

19. Protection

- A. After work in this section is complete, the General Contractor shall be responsible for protecting work from sediment deposition and damage due to subsequent construction activity on the site.
- B. PICP installation contractor shall return to site after 6 months from the completion of the work and provide the following as required: fill paver joints with stones, replace broken or cracked pavers, and re-level settled pavers to initial elevations. Any additional work shall be considered part of original bid price and with no additional compensation.

**F. MEASUREMENT AND PAYMENT**

The completed work, as described, shall be paid for at the contract unit price for the following contract items (pay items).

<b>Pay Item</b>	<b>Pay Unit</b>
Aggregate Base, ___-inch	Square Yard
Permeable Interlocking Unit Paver Pavement	Square Yard

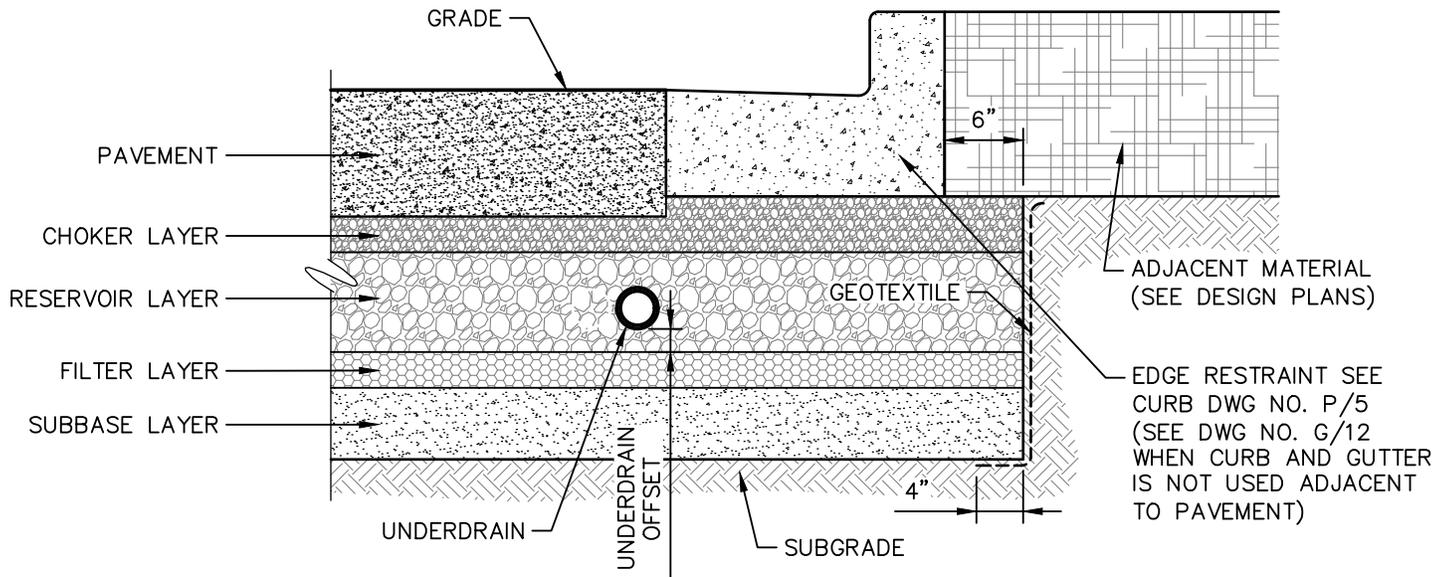
The price shall be payment in full for furnishing all labor, equipment and materials to complete the work as specified and indicated on the Drawings. **Aggregate Base, \_\_\_-inch** shall be measured by width and length for the specified depth as shown on the plans. This work includes, but is not limited to, subgrade preparation and protection, geotextile, aggregate base for the pavement base, and for any necessary grading, excavation and backfill when not paid for separately.

The unit of measure for **Permeable Interlocking Unit Paver Pavement** will be in square yards for the type(s) specified in the Contract Documents. The actual number of square yards complete in place will be paid for at the contract unit price per square yard, or adjusted unit price per square yard, which payment includes unit pavers, bedding material, and joint filler, complete and in place. Payment will include costs for furnishing all materials, labor, tools, equipment and incidentals to complete the work.

City of Grand Rapids Michigan

Green Infrastructure

Supplement to Standard Drawings



ITEM	MATERIAL	CLASS A ALLEY, PARKING LANE, LOCAL STREETS	CLASS B COLLECTOR OR ARTERIAL (NOT CURRENTLY ALLOWED)
PAVEMENT	PERVIOUS PORTLAND CEMENT CONCRETE.	7 INCH	8 INCH
CHOKER LAYER	MDOT 6AA OR 4G, AASHTO #57 OR APPROVED EQUIVALENT.	4 INCH	4 INCH
RESERVOIR LAYER	MDOT 4AA, 6AA, OR 4G, AASHTO #2, #3 OR #57 OR APPROVED EQUIVALENT.	___ INCH	___ INCH
FILTER LAYER	MDOT 34G, 4G, AASHTO #8 OR APPROVED EQUIVALENT. WHEN FILTER LAYER IS OMITTED, PROVIDE GEOTEXTILE CLASS 2 MATERIAL BENEATH RESERVOIR LAYER.	4 INCH	4 INCH
SUBBASE LAYER	MDOT CLASS II	8 INCH	8 INCH
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPERATION. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.		
UNDERDRAIN	PERFORATED PVC UNDERDRAIN WHEN CALLED FOR PER DESIGN PLANS. CLEANOUT AT TERMINAL ENDS DWG NO. G/51. PIPE BEDDING AND CATCH BASIN CONNECTION DWG NO. G/52.	4 INCH	4 INCH
UNDERDRAIN OFFSET	OFFSET DISTANCE UNDERDRAIN SET ABOVE THE FILTER LAYER.	___ INCH	___ INCH
GEOTEXTILE	GEOTEXTILE CLASS 2, LOCATED ON SIDES OF FACILITY ONLY.		

**NOTES**

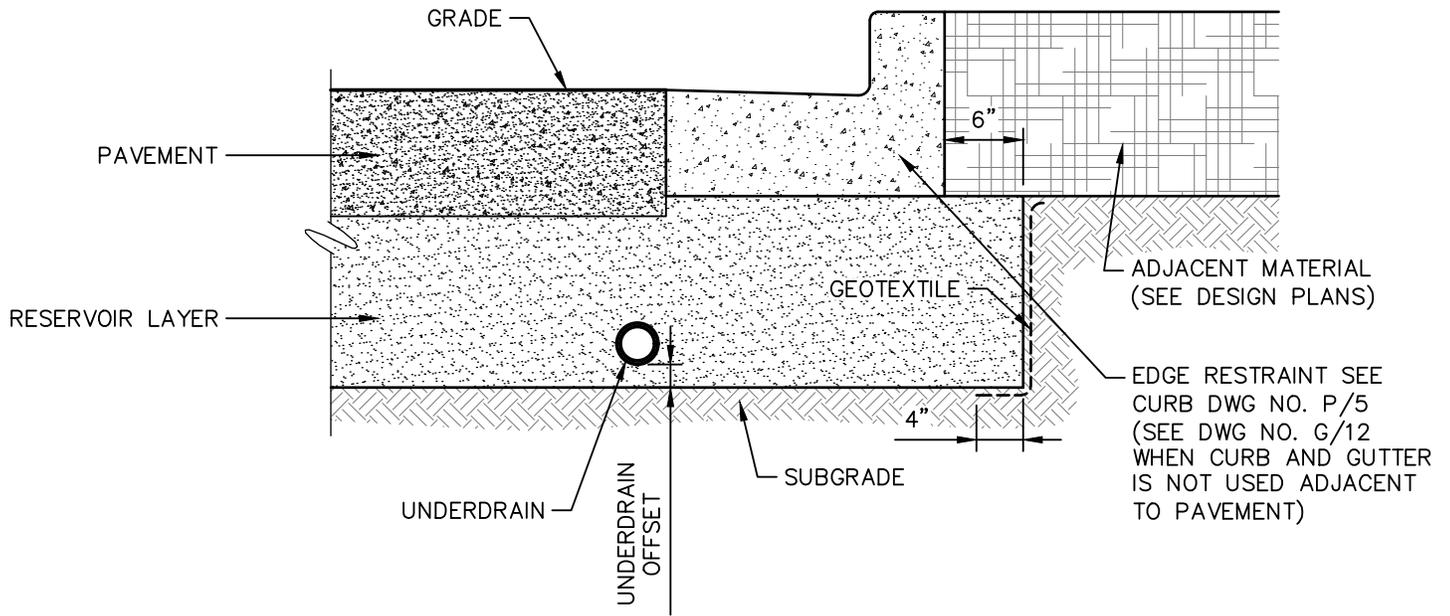
1. SEE DWG NOS. G/10 AND G/11 FOR LONGITUDINAL AND CROSS SLOPE REQUIREMENTS.

CITY OF GRAND RAPIDS, MICHIGAN

**PERVIOUS CONCRETE  
PAVEMENT  
(ROADWAY AND ALLEY)**

<b>G 01</b>	APPROVED		
	DRAWN	CITY ENGINEER CHECKED	DATE SCALE: N.T.S.

**\*NOTE**  
 NOT APPROVED FOR GENERAL USE.  
 SPECIAL PERMISSION REQUIRED



ITEM	MATERIAL	CLASS A ALLEY, PARKING LANE, LOCAL STREETS	CLASS B COLLECTOR OR ARTERIAL (NOT CURRENTLY ALLOWED)
PAVEMENT	PERVIOUS PORTLAND CEMENT CONCRETE.	7 INCH	8 INCH
RESERVOIR LAYER	MDOT CLASS II	__ INCH	__ INCH
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPERATION. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.		
UNDERDRAIN	PERFORATED PVC UNDERDRAIN WHEN CALLED FOR PER DESIGN PLANS. CLEANOUT AT TERMINAL ENDS DWG NO. G/51. PIPE BEDDING AND CATCH BASIN CONNECTION DWG NO. G/52.	4 INCH	4 INCH
UNDERDRAIN OFFSET	OFFSET DISTANCE UNDERDRAIN SET ABOVE THE FILTER LAYER.	__ INCH	__ INCH
GEOTEXTILE	GEOTEXTILE CLASS 2, LOCATED ON SIDES OF FACILITY ONLY.		

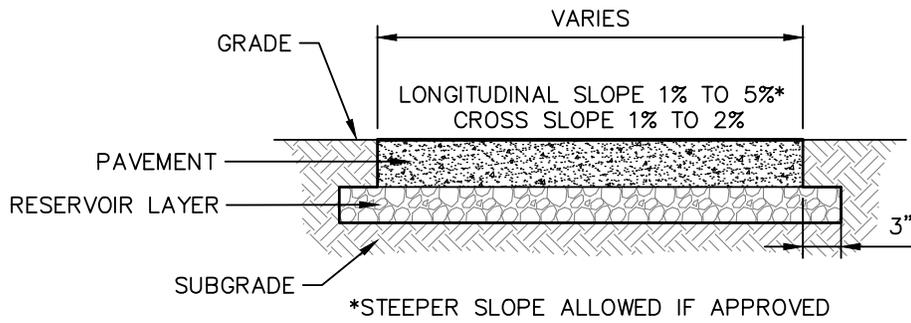
**NOTES**

1. SEE DWG NOS. G/10 AND G/11 FOR LONGITUDINAL AND CROSS SLOPE REQUIREMENTS.

CITY OF GRAND RAPIDS, MICHIGAN

**PERVIOUS CONCRETE  
 PAVEMENT  
 (ROADWAY AND ALLEY)**

<b>G</b> <b>01-a</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



**SIDEWALK SECTION**

ITEM	MATERIAL	
PAVEMENT	PERVIOUS PORTLAND CEMENT CONCRETE.	4 INCH
RESERVOIR LAYER	MDOT 6AA, 4G, AASHTO #57, MDOT CLASS II, OR APPROVED EQUIVALENT.	__ INCH
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPERATION. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.	

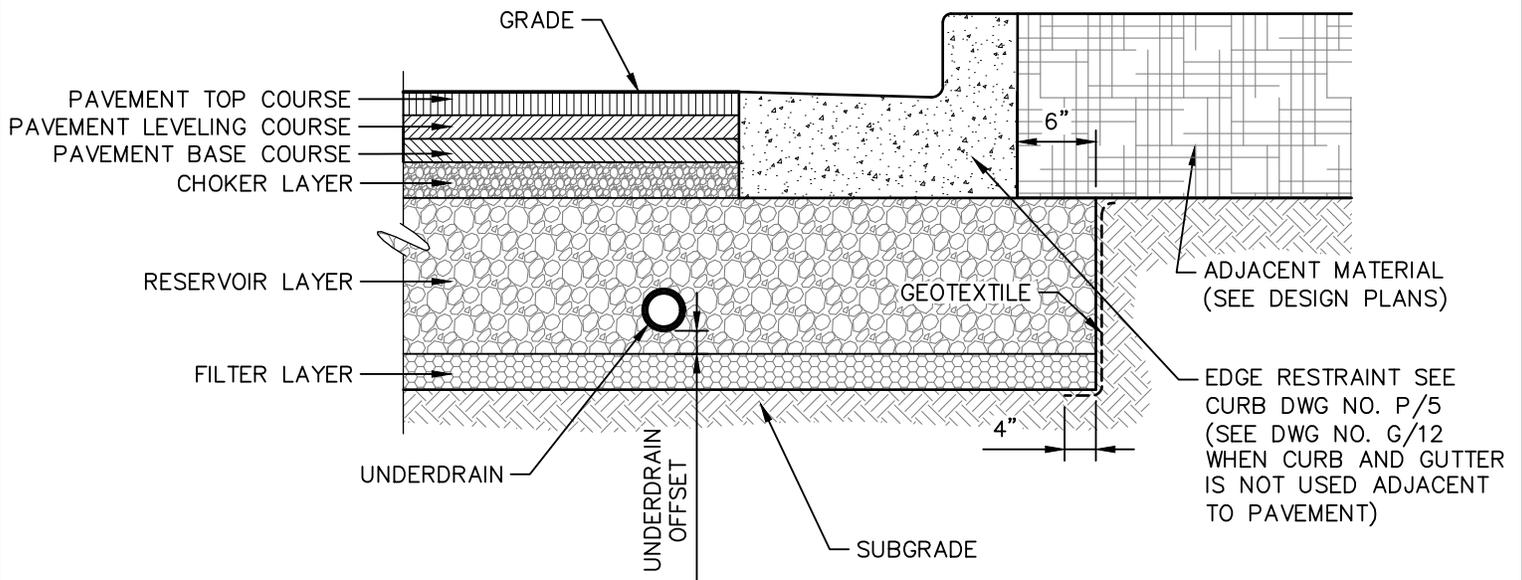
NOTES

1. FOR SIDEWALK JOINT LAYOUT, REFER TO DIVISION 10 OF THE CURRENT GRAND RAPIDS STANDARD CONSTRUCTION SPECIFICATIONS.

CITY OF GRAND RAPIDS, MICHIGAN

**PERVIOUS CONCRETE  
SIDEWALK**

<b>G</b> <b>02</b>	APPROVED		
	DRAWN	CITY ENGINEER CHECKED	DATE SCALE: N.T.S.



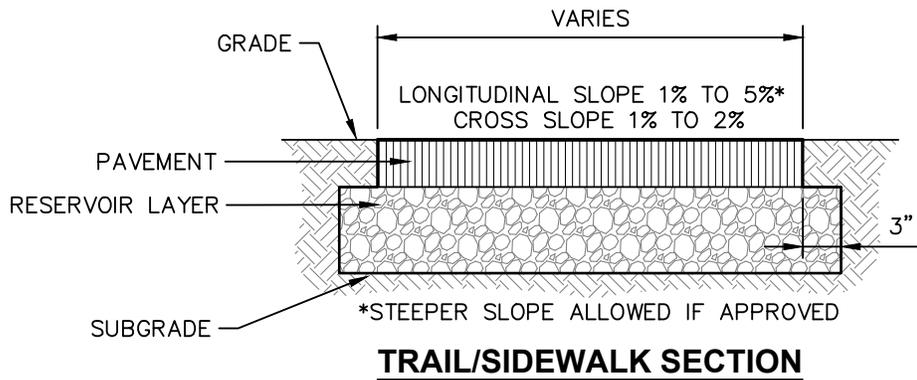
ITEM	MATERIAL	CLASS A ALLEY, PARKING LANE, LOCAL STREETS	CLASS B COLLECTOR OR ARTERIAL (NOT CURRENTLY ALLOWED)
PAVEMENT, TOP COURSE	HMA, POROUS	__ INCH	__ INCH
PAVEMENT, LEVELING COURSE	HMA, POROUS	__ INCH	__ INCH
PAVEMENT, BASE COURSE	HMA, POROUS (OPTIONAL)	__ INCH	__ INCH
CHOKER LAYER	MDOT 6AA, 4G, AASHTO #57 OR APPROVED EQUIVALENT.	4 INCH	4 INCH
RESERVOIR LAYER	MDOT 4AA OR 6AA, 4G, AASHTO #2, #3, #57 OR APPROVED EQUIVALENT.	__ INCH	__ INCH
FILTER LAYER	MDOT 34G, 4G, AASHTO #8 OR APPROVED EQUIVALENT. WHEN FILTER LAYER IS OMITTED, PROVIDE GEOTEXTILE CLASS 2 MATERIAL BENEATH RESERVOIR LAYER.	4 INCH	4 INCH
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPERATION. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.		
UNDERDRAIN	PERFORATED PVC UNDERDRAIN WHEN CALLED FOR PER DESIGN PLANS. CLEANOUT AT TERMINAL ENDS DWG NO. G/51. PIPE BEDDING AND CATCH BASIN CONNECTION DWG NO. G/52.	4 INCH	4 INCH
UNDERDRAIN OFFSET	OFFSET DISTANCE UNDERDRAIN SET ABOVE THE FILTER LAYER.	__ INCH	__ INCH
GEOTEXTILE	GEOTEXTILE CLASS 2, LOCATED ON SIDES OF FACILITY ONLY.		

**NOTES**

- SEE DWG NOS. G/10 AND G/11 FOR LONGITUDINAL AND CROSS SLOPE REQUIREMENTS.
- GEOMEMBRANE TO BE USED WHEN FACILITY IS WITHIN 10' OF ADJACENT BUILDING AND TO AVOID INFILTRATION AROUND UTILITIES. SEE DESIGN PLANS.

CITY OF GRAND RAPIDS, MICHIGAN  
**POROUS ASPHALT  
 PAVEMENT  
 (ROADWAY AND ALLEY)**

<b>G 03</b>	APPROVED		
	DRAWN	CITY ENGINEER CHECKED	DATE SCALE: N.T.S.



ITEM	MATERIAL	LAYER THICKNESS
PAVEMENT, TOP COURSE	HMA, POROUS	3 INCH
RESERVOIR LAYER	MDOT 6AA, 4G, AASHTO #57 OR APPROVED EQUIVALENT.	6 INCH
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPERATION. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.	

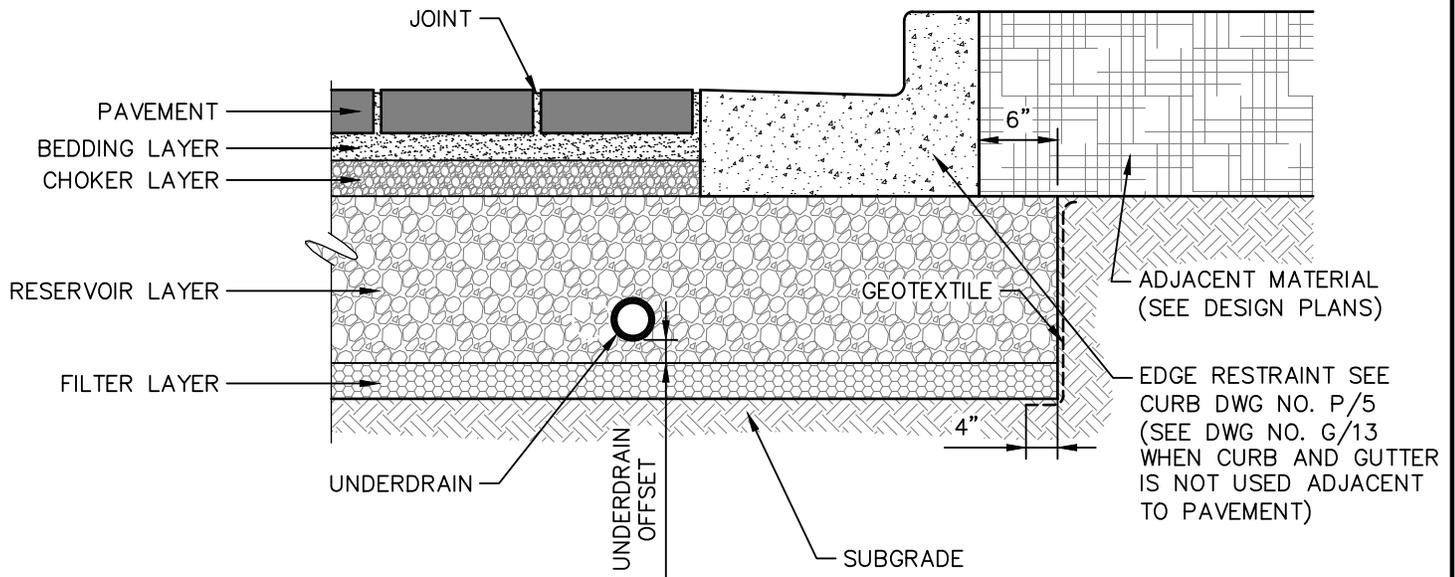
**NOTES**

1. GEOMEMBRANE TO BE USED WHEN FACILITY IS WITHIN 10' OF ADJACENT BUILDING AND TO AVOID INFILTRATION AROUND UTILITIES. SEE DESIGN PLANS.
2. RESERVOIR LAYER AGGREGATE DEPTH MAY BE GREATER THAN THE MINIMUM SHOWN TO ACHIEVE ADDITIONAL STORMWATER STORAGE.

CITY OF GRAND RAPIDS, MICHIGAN

**POROUS ASPHALT  
SIDEWALK**

<b>G</b> <b>04</b>	APPROVED		
	DRAWN	CITY ENGINEER CHECKED	DATE SCALE: N.T.S.



ITEM	MATERIAL	LAYER THICKNESS
PAVEMENT	PERMEABLE INTERLOCKING UNIT PAVERS.	3 INCH MIN.
BEDDING LAYER	MDOT 34G, 4G, AASHTO #8 OR APPROVED EQUIVALENT.	2 INCH
CHOKER LAYER	MDOT 6AA, 4G, AASHTO #57 OR APPROVED EQUIVALENT.	4 INCH
RESERVOIR LAYER	MDOT 4AA OR 6AA, 4G, AASHTO #2, #3 OR #57 OR APPROVED EQUIVALENT.	__ INCH
FILTER LAYER	MDOT 34G, 4G, AASHTO #8 OR APPROVED EQUIVALENT. WHEN FILTER LAYER IS OMITTED, PROVIDE GEOTEXTILE CLASS 2 MATERIAL BENEATH RESERVOIR LAYER.	4 INCH
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPERATION. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.	
UNDERDRAIN	PERFORATED PVC UNDERDRAIN WHEN CALLED FOR PER DESIGN PLANS. CLEANOUT AT TERMINAL ENDS DWG NO. G/51. PIPE BEDDING AND CATCH BASIN CONNECTION DWG NO. G/52.	4 INCH
UNDERDRAIN OFFSET	OFFSET DISTANCE UNDERDRAIN SET ABOVE THE FILTER LAYER.	__ INCH
GEOTEXTILE	GEOTEXTILE CLASS 2, LOCATED ON SIDES OF FACILITY ONLY.	
JOINT	JOINT TO HAVE 1/2 INCH MAXIMUM GAP IN ACCORDANCE WITH THE LATEST ADA REQUIREMENTS AND TO BE FILLED WITH MDOT 34G, 4G, AASHTO #8 OR APPROVED EQUIVALENT. MINIMUM GAP SHALL BE 1/4 INCH OR PER MANUFACTURERS RECOMMENDATIONS.	

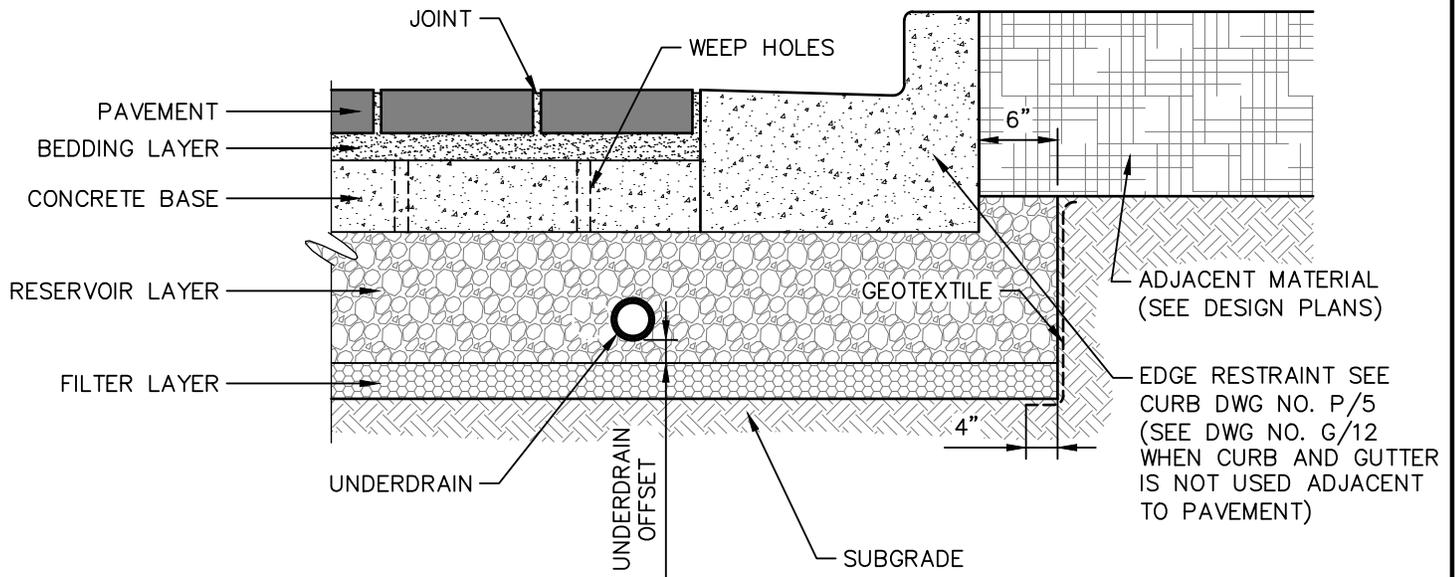
**NOTES**

1. SEE DWG NOS. G/10 AND G/11 FOR LONGITUDINAL AND CROSS SLOPE REQUIREMENTS.
2. GEOMEMBRANE TO BE USED WHEN FACILITY IS WITHIN 10' OF ADJACENT BUILDING AND TO AVOID INFILTRATION AROUND UTILITIES. SEE DESIGN PLANS.
3. OTHER TYPES OF EDGE RESTRAINTS SUCH AS STEEL OR PLASTIC SHALL BE ALLOWED AS APPROVED BY THE ENGINEER AND BASED ON MANUFACTURER'S RECOMMENDATIONS.

CITY OF GRAND RAPIDS, MICHIGAN

**PERMEABLE  
INTERLOCKING UNIT  
PAVER PAVEMENT  
(ROADWAY AND ALLEY)**

<b>G 05</b>	APPROVED		
	DRAWN	CITY ENGINEER CHECKED	DATE SCALE: N.T.S.



ITEM	MATERIAL	LAYER THICKNESS
PAVEMENT	PERMEABLE INTERLOCKING UNIT PAVERS.	3 INCH MIN.
BEDDING LAYER	MDOT 34G, AASHTO #8 OR APPROVED EQUIVALENT.	2 INCH
CONCRETE BASE	CONCRETE BASE WITH WEEP HOLES - 1" DIA. AT 12" O.C. BOTH WAYS AND AT LOW POINTS. ALTERNATIVELY PERVIOUS PORTLAND CEMENT CONCRETE MAY BE USED INSTEAD OF TRADITIONAL CONCRETE WITH WEEP HOLES.	__ INCH
RESERVOIR LAYER	MDOT 4AA OR 6AA, 4G, AASHTO #2, #3 OR #57 OR APPROVED EQUIVALENT.	__ INCH
FILTER LAYER	MDOT 34G, 4G, AASHTO #8 OR APPROVED EQUIVALENT. WHEN FILTER LAYER IS OMITTED, PROVIDE GEOTEXTILE CLASS 2 MATERIAL BENEATH RESERVOIR LAYER.	4 INCH
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPARATION. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.	
UNDERDRAIN	PERFORATED PVC UNDERDRAIN WHEN CALLED FOR PER DESIGN PLANS. CLEANOUT AT TERMINAL ENDS DWG NO. G/51. PIPE BEDDING AND CATCH BASIN CONNECTION DWG NO. G/52.	4 INCH
UNDERDRAIN OFFSET	OFFSET DISTANCE UNDERDRAIN SET ABOVE THE FILTER LAYER.	__ INCH
GEOTEXTILE	GEOTEXTILE CLASS 2, LOCATED ON SIDES OF FACILITY ONLY	
JOINT	JOINT TO HAVE 1/2 INCH MAXIMUM GAP IN ACCORDANCE WITH THE LATEST ADA REQUIREMENTS AND TO BE FILLED WITH MDOT 34G, AASHTO #8 OR APPROVED EQUIVALENT. MINIMUM GAP SHALL BE 1/4 INCH OR PER MANUFACTURERS RECOMMENDATIONS.	
WEEP HOLES	FILL WEEP HOLES WITH BEDDING LAYER MATERIAL AND COMPACT PRIOR TO PLACING BEDDING LAYER.	

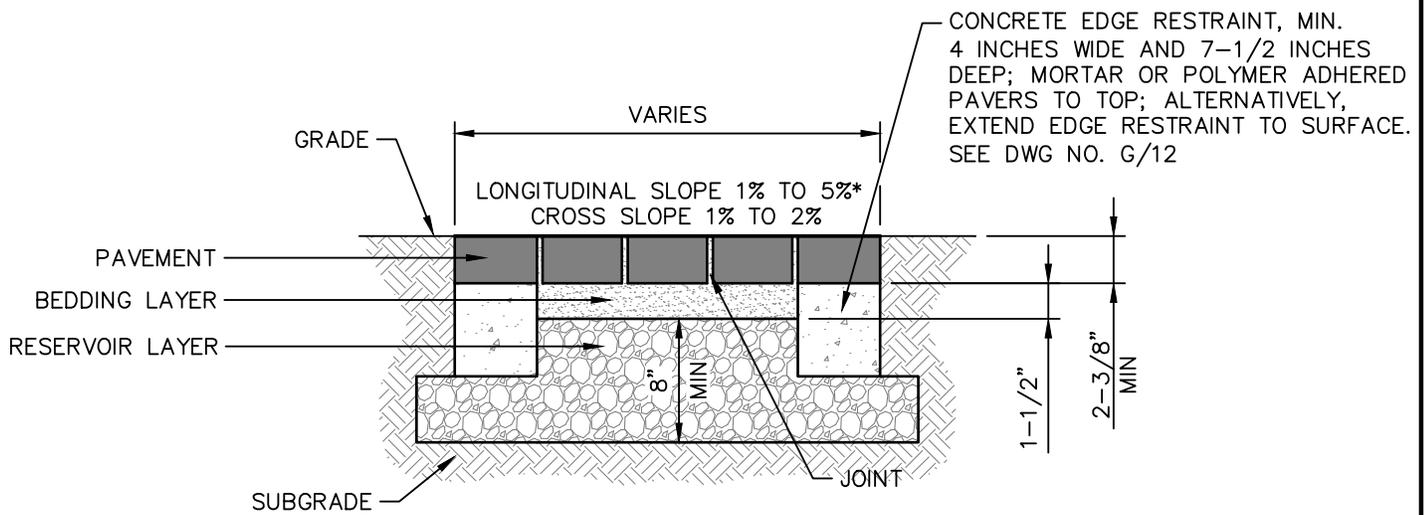
**NOTES**

1. SEE DWG NOS. G/10 AND G/11 FOR LONGITUDINAL AND CROSS SLOPE REQUIREMENTS.
2. GEOMEMBRANE TO BE USED WHEN FACILITY IS WITHIN 10' OF ADJACENT BUILDING AND TO AVOID INFILTRATION AROUND UTILITIES. SEE DESIGN PLANS.
3. OTHER TYPES OF EDGE RESTRAINTS SUCH AS STEEL OR PLASTIC SHALL BE ALLOWED AS APPROVED BY THE ENGINEER AND BASED ON MANUFACTURER'S RECOMMENDATIONS.

CITY OF GRAND RAPIDS, MICHIGAN

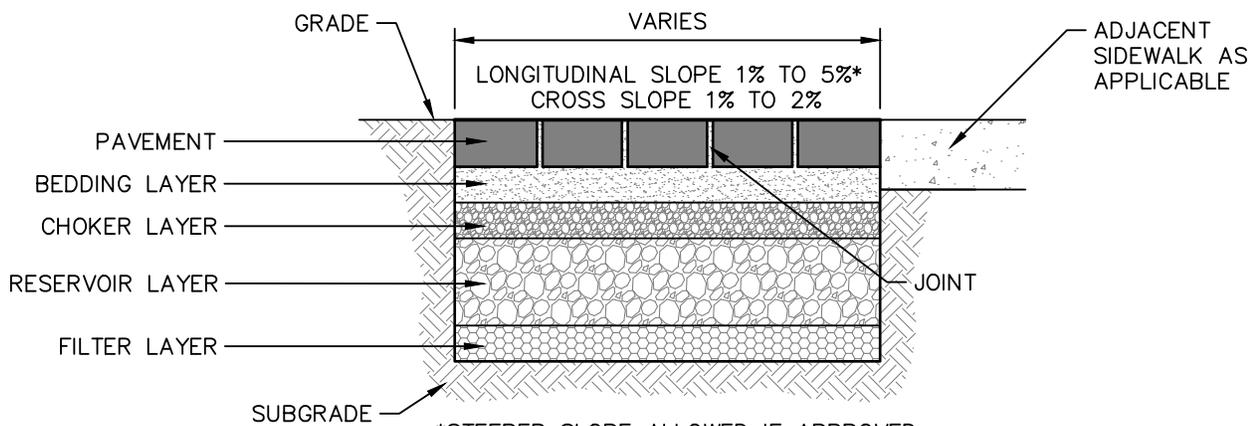
**PERMEABLE  
INTERLOCKING UNIT  
PAVER PAVEMENT WITH  
CONCRETE BASE  
(ROADWAY AND ALLEY)**

<b>G 06</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



\*STEEPER SLOPE ALLOWED IF APPROVED

**PATHWAY SECTION**



\*STEEPER SLOPE ALLOWED IF APPROVED

**NON-INTERLOCKING PAVERS OVER SAND BASED STRUCTURAL SOIL**

ITEM	MATERIAL	LAYER THICKNESS
PAVEMENT	PERMEABLE INTERLOCKING UNIT PAVERS.	2-3/8 INCH MIN.
BEDDING LAYER	MDOT 34G, AASHTO #8 OR APPROVED EQUIVALENT.	1-1/2 INCH
CHOKER LAYER	MDOT 6AA OR 4G, AASHTO #57 OR APPROVED EQUIVALENT.	1-1/2 INCH
RESERVOIR LAYER	MDOT 6AA, 4G, AASHTO #57 OR APPROVED EQUIVALENT.	__ INCH
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPARATION. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.	
JOINT	JOINT TO HAVE 1/2 INCH MAXIMUM GAP IN ACCORDANCE WITH THE LATEST ADA REQUIREMENTS AND TO BE FILLED WITH MDOT 34G, AASHTO #8 OR APPROVED EQUIVALENT. MINIMUM GAP SHALL BE 1/4 INCH OR PER MANUFACTURERS RECOMMENDATIONS.	

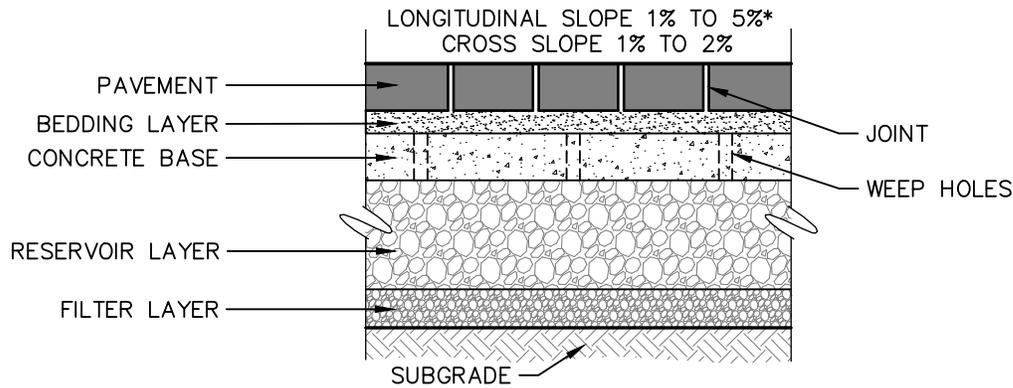
NOTES

1. GEOMEMBRANE TO BE USED WHEN FACILITY IS WITHIN 10' OF ADJACENT BUILDING AND TO AVOID INFILTRATION AROUND UTILITIES. SEE DESIGN PLANS.
2. OTHER TYPES OF EDGE RESTRAINTS SUCH AS STEEL OR PLASTIC SHALL BE ALLOWED AS APPROVED BY THE ENGINEER AND BASED ON MANUFACTURER'S RECOMMENDATIONS.

CITY OF GRAND RAPIDS, MICHIGAN

**PERMEABLE PAVER PATH**

<b>G</b> <b>07</b>	APPROVED		
	DRAWN	CITY ENGINEER CHECKED	DATE SCALE: N.T.S.



\*STEEPER SLOPE ALLOWED IF APPROVED

**SIDEWALK SECTION**

ITEM	MATERIAL	LAYER THICKNESS
PAVEMENT	PERMEABLE INTERLOCKING UNIT PAVERS.	2-3/8 INCH MIN.
BEDDING LAYER	MDOT 34G, AASHTO #8 OR APPROVED EQUIVALENT.	1-1/2 INCH
CONCRETE BASE	CONCRETE BASE WITH WEEP HOLES - 1" DIA. AT 12" O.C. BOTH WAYS AND AT LOW POINTS. ALTERNATIVELY PERVIOUS PORTLAND CEMENT CONCRETE MAY BE USED INSTEAD OF TRADITIONAL CONCRETE WITH WEEP HOLES.	__ INCH
RESERVOIR LAYER	MDOT 6AA, 4G, AASHTO #57 OR APPROVED EQUIVALENT.	__ INCH
FILTER LAYER	MDOT 34G, 4G, AASHTO #8 OR APPROVED EQUIVALENT. WHEN FILTER LAYER IS OMITTED, PROVIDE GEOTEXTILE CLASS 2 MATERIAL BENEATH RESERVOIR LAYER.	4 INCH
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPARATION. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.	
JOINT	JOINT TO HAVE 1/2 INCH MAXIMUM GAP IN ACCORDANCE WITH THE LATEST ADA REQUIREMENTS AND TO BE FILLED WITH MDOT 34G, AASHTO #8 OR APPROVED EQUIVALENT. MINIMUM GAP SHALL BE 1/4 INCH OR PER MANUFACTURERS RECOMMENDATIONS.	
WEEP HOLES	FILL WEEP HOLES WITH BEDDING LAYER MATERIAL AND COMPACT PRIOR TO PLACING BEDDING LAYER.	

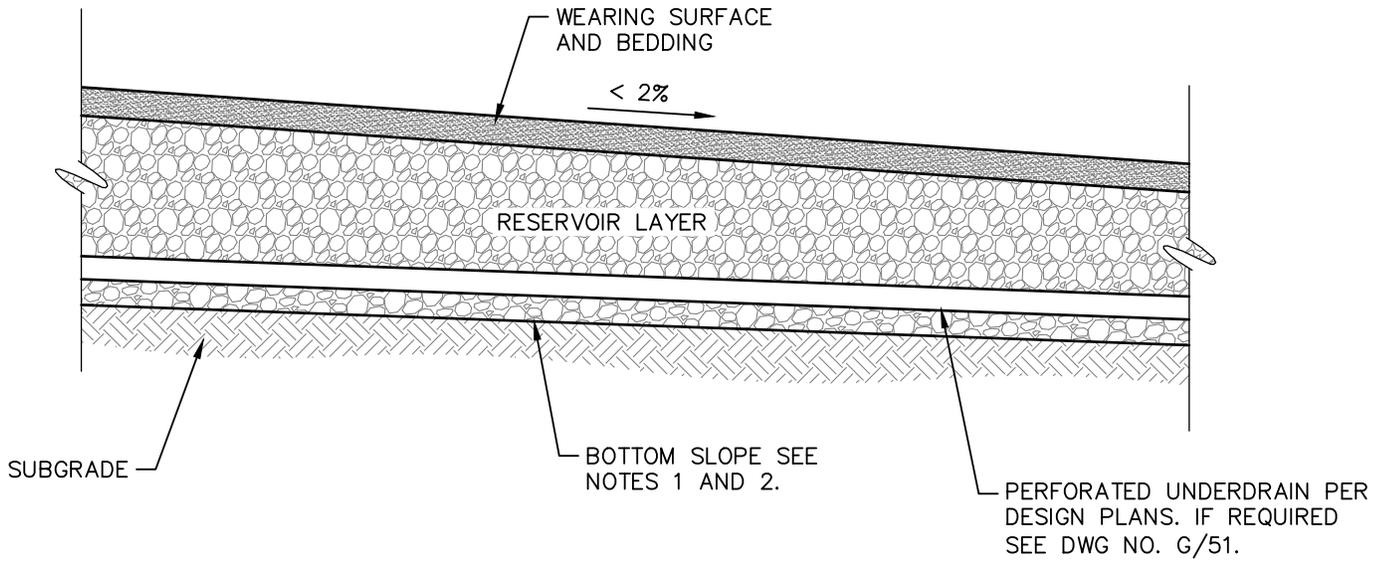
NOTES

1. CONCRETE BASE TO RECEIVE BULL FLOAT FINISH. ALIGN AND MATCH LOCATION OF CONTROL JOINTS WITH THOSE IN ADJACENT CONCRETE WALK.

CITY OF GRAND RAPIDS, MICHIGAN

**PERMEABLE PAVER  
SIDEWALK WITH  
CONCRETE BASE**

<b>G</b> <b>08</b>	APPROVED	
	DRAWN	DATE
	CITY ENGINEER	CHECKED
	SCALE:	N.T.S.



**CONTINUOUS BOTTOM SLOPE**  
**LONGITUDINAL SLOPE, <2%**

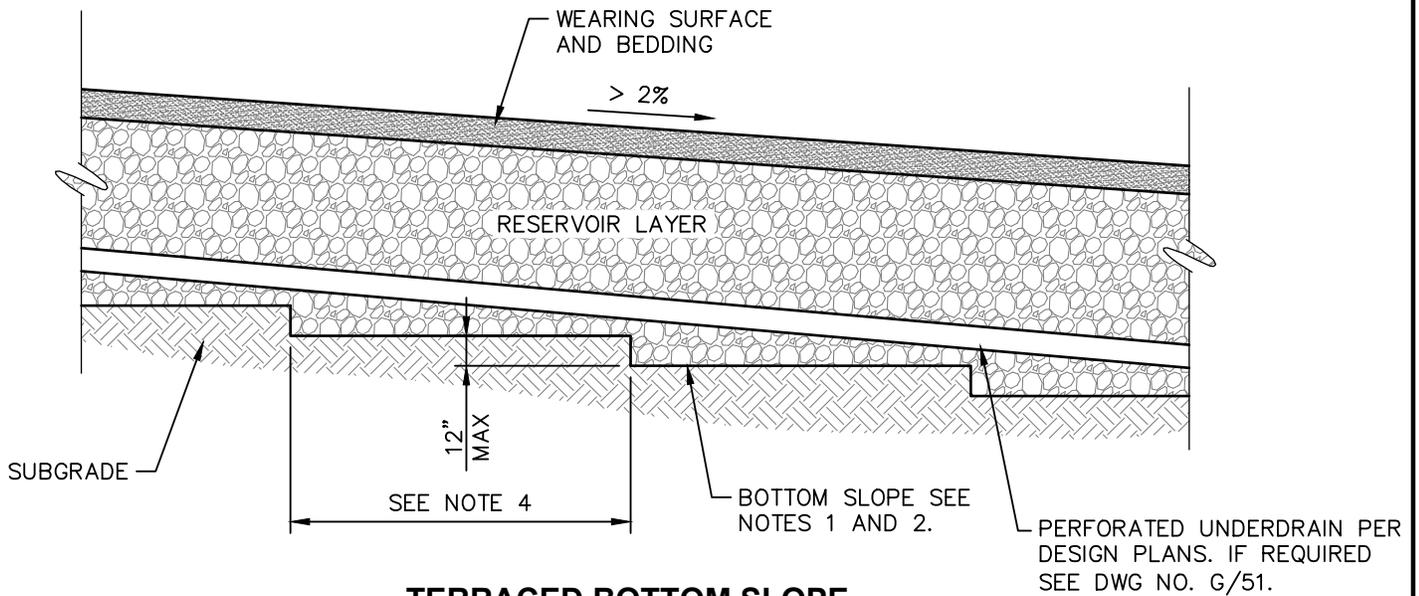
**NOTES**

1. BOTTOM SLOPE IS LESS THAN OR EQUAL TO 5% BUT NO STEEPER THAN TOP SLOPE, PER DESIGN PLANS. BOTTOM SLOPE DOES NOT HAVE TO BE PARALLEL TO TOP SLOPE.
2. FOR FACILITIES WITH WATERPROOF MEMBRANE, MINIMUM BOTTOM SLOPE SHALL BE 2% TO DRAIN DRY.
3. TRANSVERSE BOTTOM SLOPES AND CROSS SLOPES SHALL BE LESS THAN 3%.

CITY OF GRAND RAPIDS, MICHIGAN

**PERMEABLE PAVER  
WITH CONTINUOUS  
BOTTOM SLOPE, <2%**

<b>G</b> <b>10</b>	APPROVED		
	DRAWN	CITY ENGINEER CHECKED	DATE SCALE: N.T.S.



**TERRACED BOTTOM SLOPE**  
**LONGITUDINAL SLOPE, >2%**

PERFORATED UNDERDRAIN PER DESIGN PLANS. IF REQUIRED SEE DWG NO. G/51.

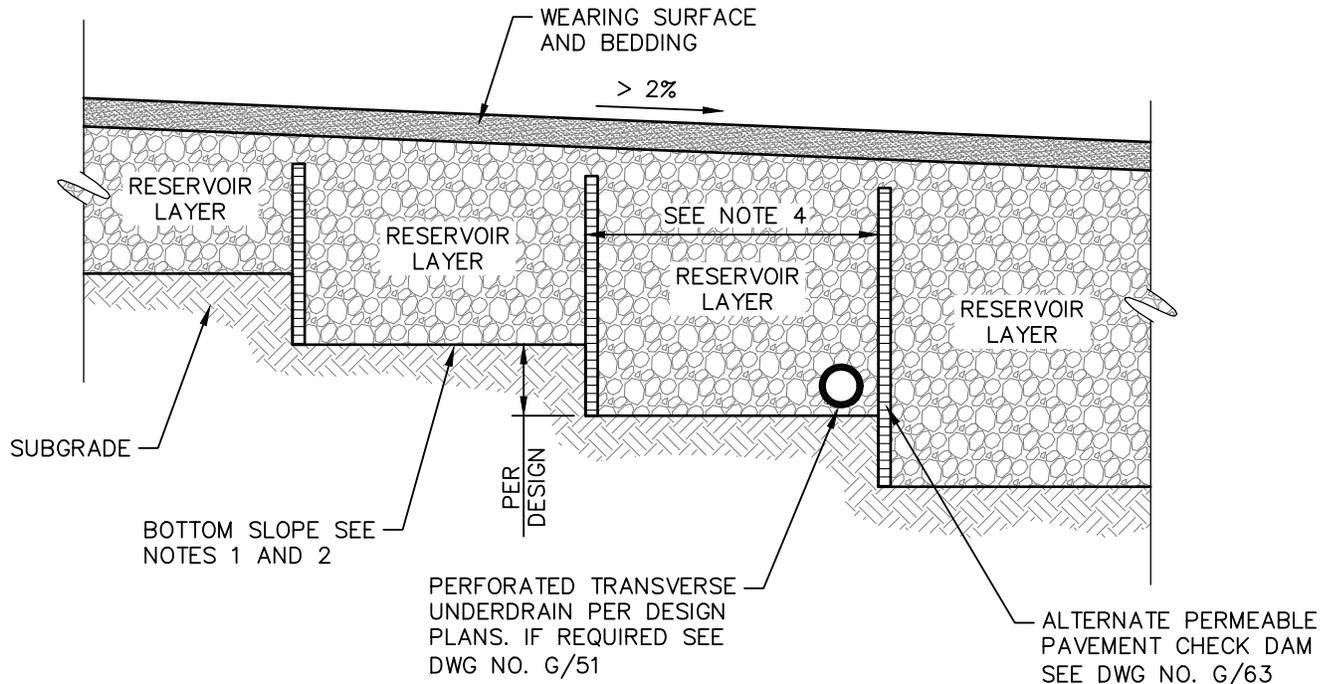
**NOTES**

1. BOTTOM SLOPE IS LESS THAN OR EQUAL TO 5% BUT NO STEEPER THAN TOP SLOPE, PER DESIGN PLANS. BOTTOM SLOPE DOES NOT HAVE TO BE PARALLEL TO TOP SLOPE.
2. FOR FACILITIES WITH WATERPROOF MEMBRANE, MINIMUM BOTTOM SLOPE SHALL BE 2% TO DRAIN DRY.
3. TRANSVERSE BOTTOM SLOPES AND CROSS SLOPES SHALL BE LESS THAN 3%.
4. DISTANCE BETWEEN STEPS IS DETERMINED BY THE SLOPE OF THE PAVEMENT TO ACHIEVE A STEP NO MORE THAN 12 INCHES TALL.

CITY OF GRAND RAPIDS, MICHIGAN

**PERMEABLE PAVER**  
**WITH TERRACED**  
**BOTTOM SLOPE, >2%**

<b>G</b> <b>11</b>	APPROVED		
	DRAWN	CITY ENGINEER CHECKED	DATE SCALE: N.T.S.



**BOTTOM SLOPE CHECK DAMS**  
**LONGITUDINAL SLOPE: >2%**

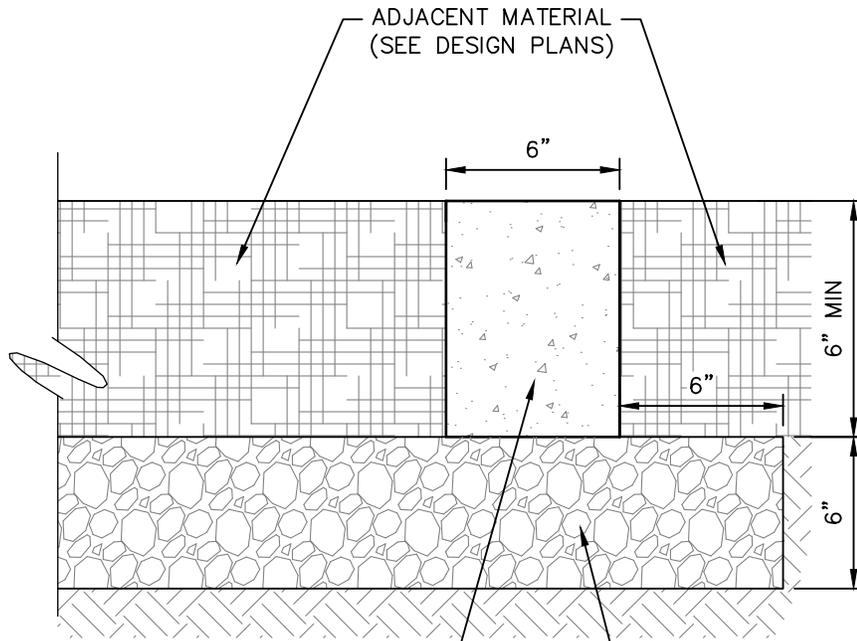
NOTES

1. BOTTOM SLOPE IS LESS THAN OR EQUAL TO 5% BUT NO STEEPER THAN TOP SLOPE, PER DESIGN PLANS. BOTTOM SLOPE DOES NOT HAVE TO BE PARALLEL TO TOP SLOPE.
2. FOR FACILITIES WITH WATERPROOF MEMBRANE, MINIMUM BOTTOM SLOPE SHALL BE 2% TO DRAIN DRY.
3. TRANSVERSE BOTTOM SLOPES AND CROSS SLOPES SHALL BE LESS THAN 3%.
4. DISTANCE BETWEEN STEPS IS DETERMINED BY THE SLOPE OF THE PAVEMENT TO ACHIEVE A STEP NO MORE THAN 12 INCHES TALL.

CITY OF GRAND RAPIDS, MICHIGAN

**PERMEABLE PAVER  
 WITH BOTTOM CHECK  
 DAMS, > 2%**

<b>G</b> <b>12</b>	APPROVED	
	DRAWN	DATE
	CITY ENGINEER	CHECKED
	SCALE:	N.T.S.



MATERIALS: TYPE F, 3,500 PSI CONCRETE; OTHER TYPES OF EDGE RESTRAINTS, SUCH AS STEEL OR PLASTIC SHALL BE ALLOWED AS APPROVED BY THE ENGINEER, AND BASED ON MANUFACTURER'S RECOMMENDATIONS.

AGGREGATE PER PAVEMENT DETAIL

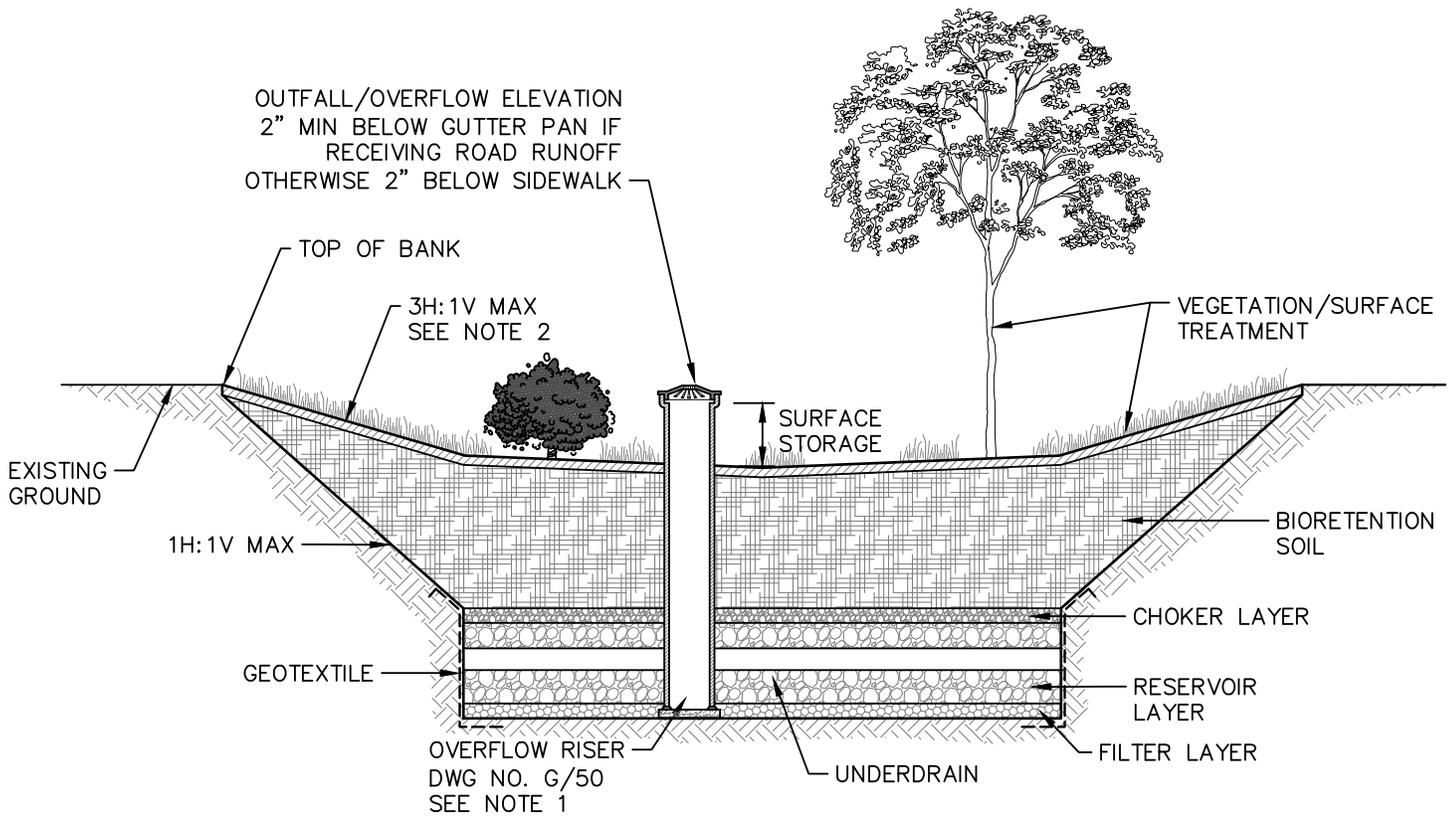
NOTE

1. PERIMETER RESTRAINTS ARE REQUIRED FOR PERMEABLE INTERLOCKING UNIT PAVEMENT SYSTEMS. ENGINEER TO DETERMINE IF EDGE RESTRAINTS ARE NECESSARY FOR POROUS ASPHALT AND PERVIOUS CONCRETE INSTALLATIONS.

CITY OF GRAND RAPIDS, MICHIGAN

## PERMEABLE PAVEMENT EDGE RESTRAINT

<b>G</b> <b>13</b>	APPROVED		
	DRAWN	CITY ENGINEER CHECKED	DATE SCALE: N.T.S.



ITEM	MATERIAL	LAYER THICKNESS
SURFACE STORAGE		__ INCH
VEGETATION/SURFACE TREATMENT	PER PLANTING PLAN.	
BIORETENTION SOIL	BIORETENTION SOIL MIX ____.	__ INCH
CHOKER LAYER	MDOT 6AA, AASHTO #57 OR APPROVED EQUIVALENT.	4 INCH
RESERVOIR LAYER	MDOT 4AA OR 6AA, AASHTO #2, #3 OR #57 OR APPROVED EQUIVALENT.	__ INCH
FILTER LAYER	MDOT 34G, 4G, AASHTO #8 OR APPROVED EQUIVALENT. WHEN FILTER LAYER IS OMITTED, PROVIDE GEOTEXTILE CLASS 2 MATERIAL BENEATH RESERVOIR LAYER.	4 INCH
UNDERDRAIN	PERFORATED PVC UNDERDRAIN WHEN CALLED FOR PER DESIGN PLANS. CLEANOUT AT TERMINAL ENDS DWG NO. G/51. PIPE BEDDING AND CATCH BASIN CONNECTION DWG NO. G/52.	4 INCH
UNDERDRAIN OFFSET	OFFSET DISTANCE UNDERDRAIN SET ABOVE THE FILTER LAYER.	__ INCH
GEOTEXTILE	GEOTEXTILE CLASS 2, LOCATED ON SIDES OF FACILITY ONLY.	
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPERATION.	

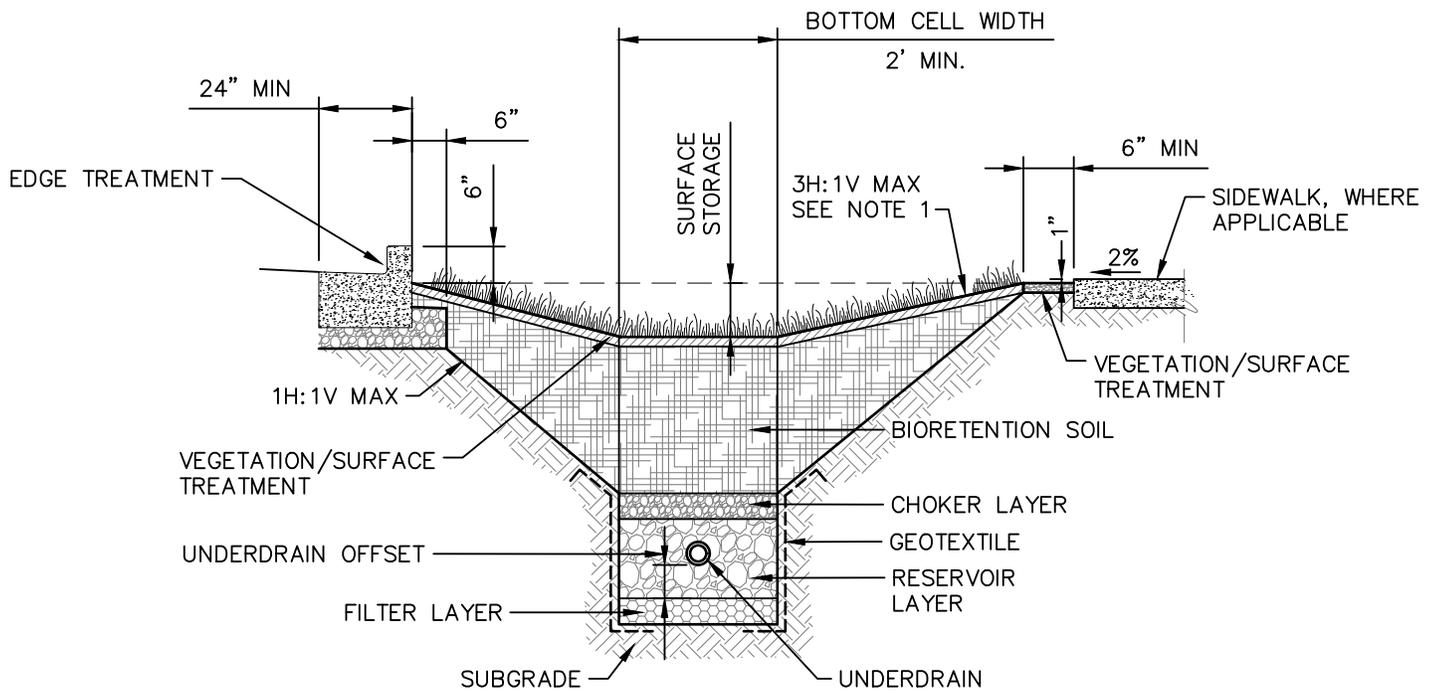
**NOTES**

1. BIORETENTION FACILITY DEPICTED IS ONE WITH AN OVERFLOW STRUCTURE. 'OFF-LINE' FACILITIES DESIGNED TO LIMIT INFLOW SO THAT OVERFLOW STRUCTURES ARE NOT REQUIRED ARE ALSO PERMISSIBLE, AS SHOWN ON DESIGN PLANS.
2. IF WATER DEPTH IS OVER 2 FEET DEEP, SURFACE STORAGE GRADING OF 4H:1V IS REQUIRED.

CITY OF GRAND RAPIDS, MICHIGAN

**BIORETENTION  
IN OPEN AREA**

<b>G</b> <b>20</b>	APPROVED		
	DRAWN	CITY ENGINEER CHECKED	DATE SCALE: N.T.S.



ITEM	MATERIAL	LAYER THICKNESS
SURFACE STORAGE		__ INCH
VEGETATION/SURFACE TREATMENT	PER PLANTING PLAN.	
BIORETENTION SOIL	BIORETENTION SOIL MIX ____.	__ INCH
CHOKER LAYER	MDOT 6AA, AASHTO #57 OR APPROVED EQUIVALENT.	4 INCH
RESERVOIR LAYER	MDOT 4AA OR 6AA, AASHTO #2, #3 OR #57 OR APPROVED EQUIVALENT.	__ INCH
FILTER LAYER	MDOT 34G, 4G, AASHTO #8 OR APPROVED EQUIVALENT. WHEN FILTER LAYER IS OMITTED, PROVIDE GEOTEXTILE CLASS 2 MATERIAL BENEATH RESERVOIR LAYER.	4 INCH
UNDERDRAIN	PERFORATED PVC UNDERDRAIN WHEN CALLED FOR PER DESIGN PLANS. CLEANOUT AT TERMINAL ENDS DWG NO. G/51. PIPE BEDDING AND CATCH BASIN CONNECTION DWG NO. G/52.	4 INCH
UNDERDRAIN OFFSET	OFFSET DISTANCE UNDERDRAIN SET ABOVE THE FILTER LAYER.	__ INCH
GEOTEXTILE	GEOTEXTILE CLASS 2, LOCATED ON SIDES OF FACILITY ONLY.	
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPERATION.	
EDGE TREATMENT	REFER TO DWG NO. G/30.	
INLET AND OUTLET	LOCATIONS PER DESIGN PLANS. REFER TO DWG NOS. G/40 - G/42.	

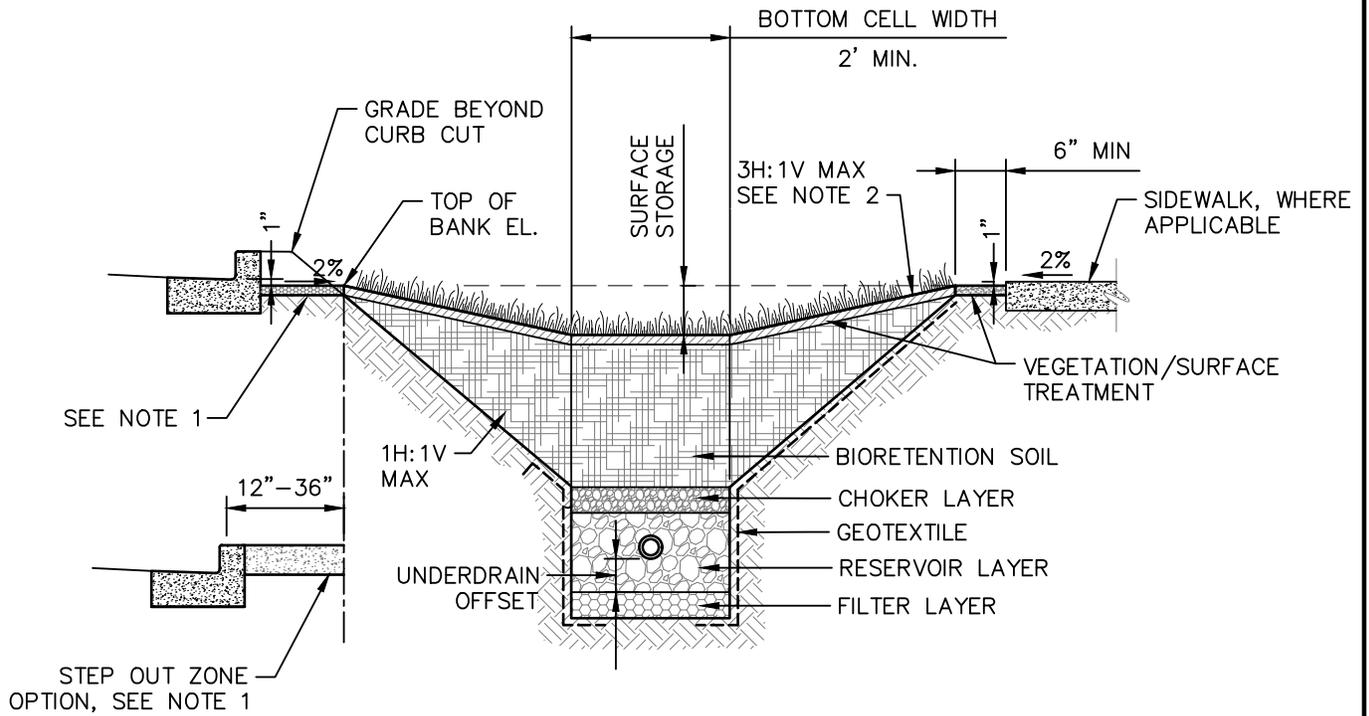
**NOTES**

1. IF WATER DEPTH IS OVER 2 FEET DEEP, SURFACE STORAGE GRADING OF 4H:1V IS REQUIRED.
2. GEOMEMBRANE TO BE USED WHEN FACILITY IS WITHIN 10' OF ADJACENT BUILDING AND TO AVOID INFILTRATION AROUND UTILITIES. SEE DESIGN PLANS.

CITY OF GRAND RAPIDS, MICHIGAN

**LINEAR BIORETENTION  
ADJACENT TO  
ROADWAY  
NO STEP OUT ZONE**

<b>G 21</b>	APPROVED		
	DRAWN	CITY ENGINEER CHECKED	DATE SCALE: N.T.S.



ITEM	MATERIAL	LAYER THICKNESS
SURFACE STORAGE		__ INCH
VEGETATION/SURFACE TREATMENT	PER PLANTING PLAN.	
BIORETENTION SOIL	BIORETENTION SOIL MIX ____.	__ INCH
CHOKER LAYER	MDOT 6AA, AASHTO #57 OR APPROVED EQUIVALENT.	4 INCH
RESERVOIR LAYER	MDOT 4AA OR 6AA, AASHTO #2, #3 OR #57 OR APPROVED EQUIVALENT.	__ INCH
FILTER LAYER	MDOT 34G, 4G, AASHTO #8 OR APPROVED EQUIVALENT. WHEN FILTER LAYER IS OMITTED, PROVIDE GEOTEXTILE CLASS 2 MATERIAL BENEATH RESERVOIR LAYER.	4 INCH
UNDERDRAIN	PERFORATED PVC UNDERDRAIN WHEN CALLED FOR PER DESIGN PLANS. CLEANOUT AT TERMINAL ENDS DWG NO. G/51. PIPE BEDDING AND CATCH BASIN CONNECTION DWG NO. G/52.	4 INCH
UNDERDRAIN OFFSET	OFFSET DISTANCE UNDERDRAIN SET ABOVE THE FILTER LAYER.	__ INCH
GEOTEXTILE	GEOTEXTILE CLASS 2, LOCATED ON SIDES OF FACILITY ONLY.	
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPERATION.	

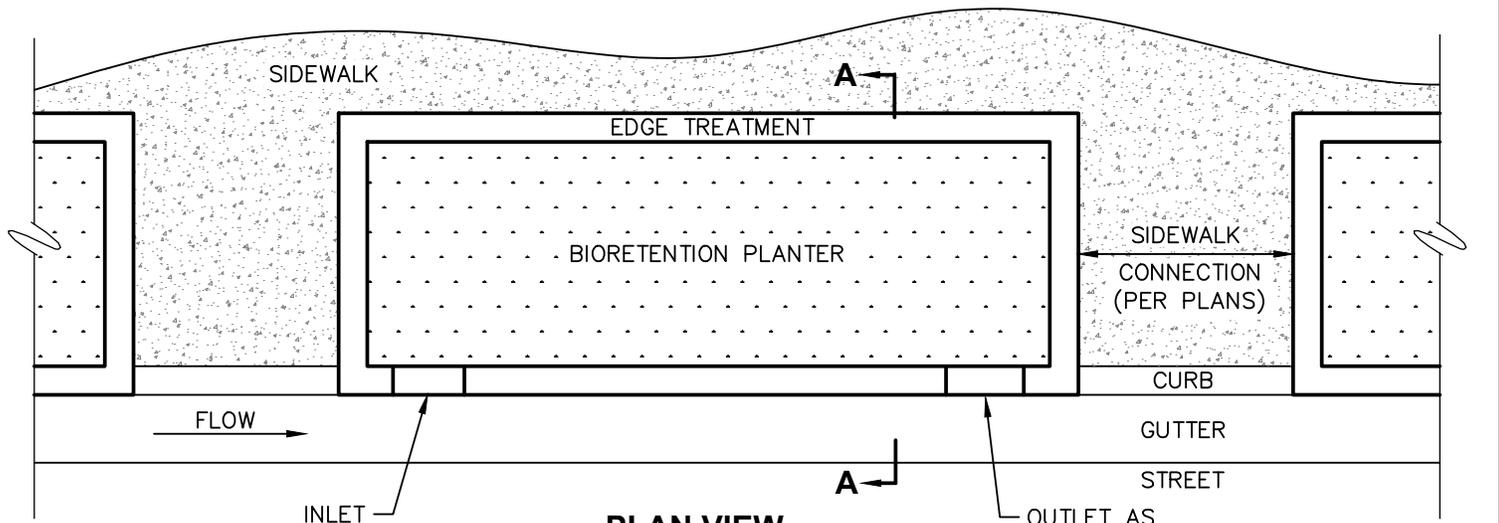
**NOTES**

- STEP OUT ZONE REQUIRED WHEN PARALLEL PARKING IS PROVIDED. INSTALLATION SHALL BE VEGETATION/SURFACE TREATMENT AS SPECIFIED ON DESIGN PLANS.
- IF WATER DEPTH IS OVER 2 FEET DEEP, SURFACE STORAGE GRADING OF 4H:1V IS REQUIRED.

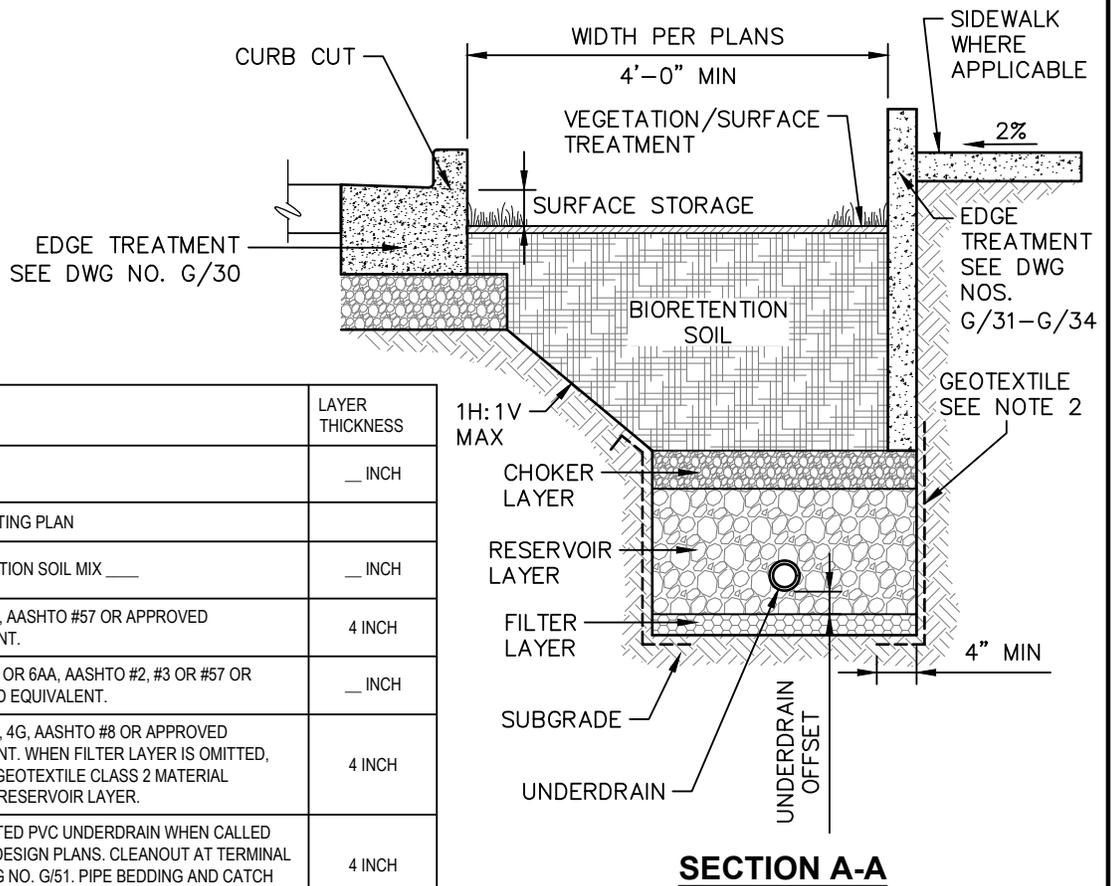
CITY OF GRAND RAPIDS, MICHIGAN

**LINEAR BIORETENTION  
ADJACENT TO  
ROADWAY  
WITH STEP OUT ZONE**

<b>G</b> <b>22</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



**PLAN VIEW**



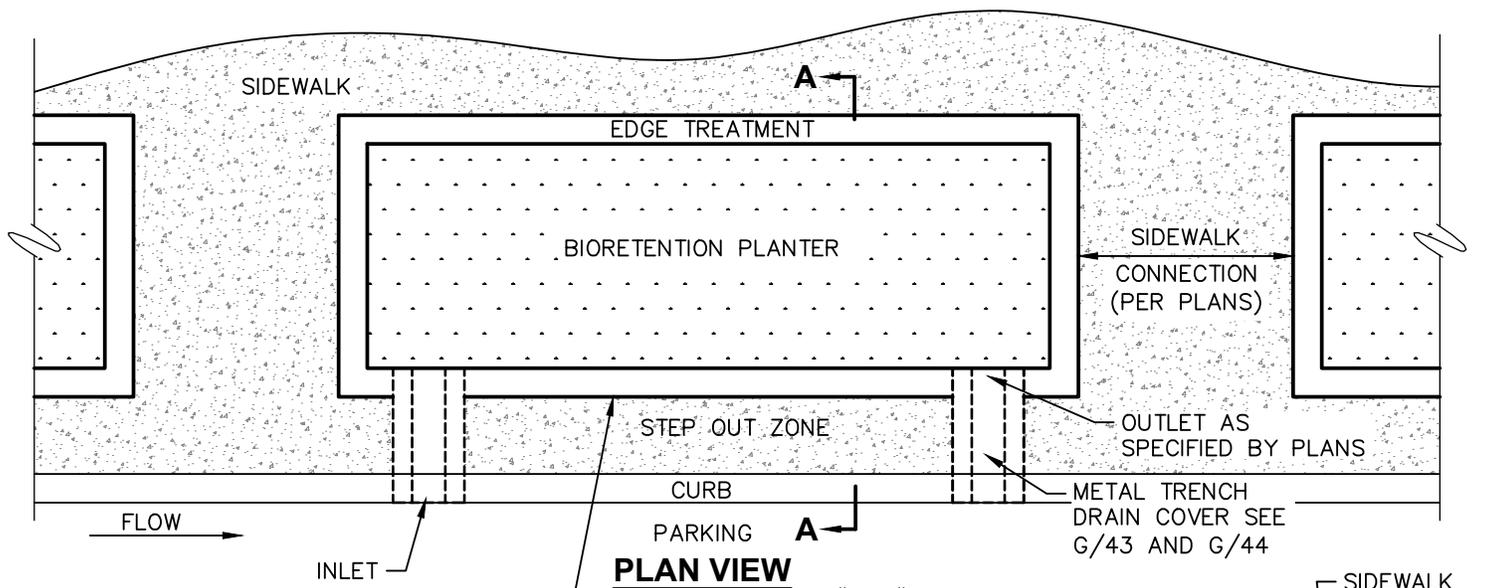
**SECTION A-A**

ITEM	MATERIAL	LAYER THICKNESS
SURFACE STORAGE		__ INCH
VEGETATION/SURFACE TREATMENT	PER PLANTING PLAN	
BIORETENTION SOIL	BIORETENTION SOIL MIX ____	__ INCH
CHOKER LAYER	MDOT 6AA, AASHTO #57 OR APPROVED EQUIVALENT.	4 INCH
RESERVOIR LAYER	MDOT 4AA OR 6AA, AASHTO #2, #3 OR #57 OR APPROVED EQUIVALENT.	__ INCH
FILTER LAYER	MDOT 34G, 4G, AASHTO #8 OR APPROVED EQUIVALENT. WHEN FILTER LAYER IS OMITTED, PROVIDE GEOTEXTILE CLASS 2 MATERIAL BENEATH RESERVOIR LAYER.	4 INCH
UNDERDRAIN	PERFORATED PVC UNDERDRAIN WHEN CALLED FOR PER DESIGN PLANS. CLEANOUT AT TERMINAL ENDS DWG NO. G/51. PIPE BEDDING AND CATCH BASIN CONNECTION DWG NO. G/52.	4 INCH
UNDERDRAIN OFFSET	OFFSET DISTANCE UNDERDRAIN SET ABOVE THE FILTER LAYER.	__ INCH
GEOTEXTILE	GEOTEXTILE CLASS 2, LOCATED ON SIDES OF FACILITY ONLY.	
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPARATION.	
EDGE TREATMENT	FOR STREET SIDE EDGE TREATMENT CONDITIONS, SEE DWG. NO. G/30. FOR OTHER THREE SIDES, SEE DWG NOS. G/31 - G/34.	
INLET AND OUTLET	LOCATIONS PER DESIGN PLANS. REFER TO DWG NOS. G/40 - G/42.	

CITY OF GRAND RAPIDS, MICHIGAN  
**BIORETENTION PLANTER  
 ADJACENT TO  
 ROADWAY  
 WITH NO STEP OUT ZONE**

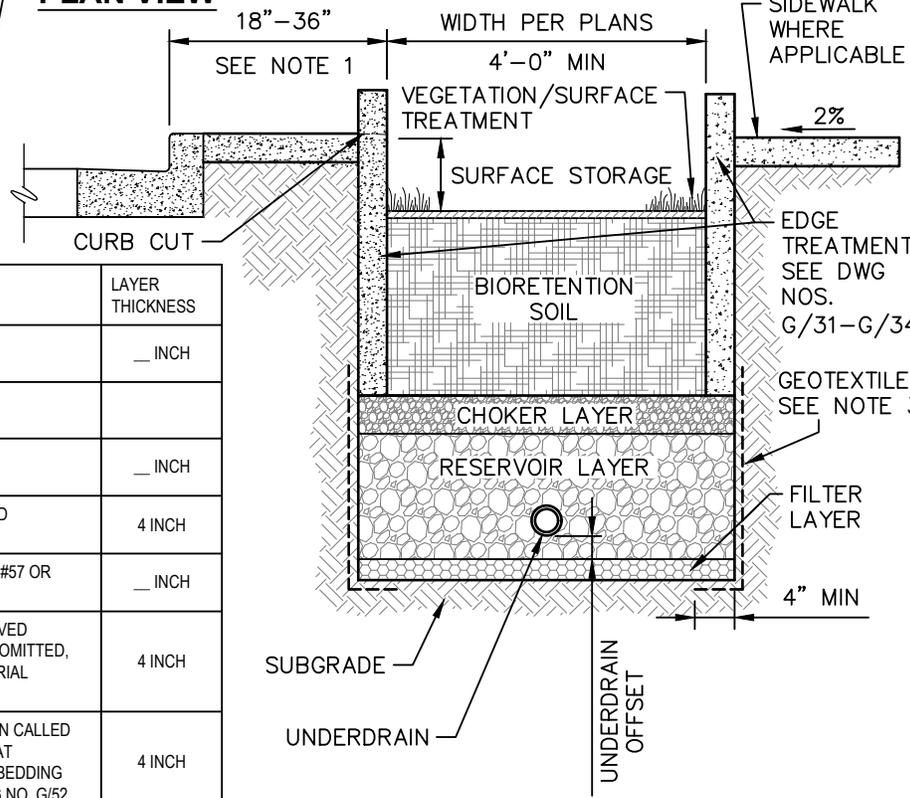
- NOTES  
 1. OUTLET REQUIRED AS SPECIFIED BY DESIGN PLANS.  
 2. GEOTEXTILE REQUIRED WHEN FACILITY IS WITHIN 10' OF BUILDING OR AS INDICATED BY ENGINEER.

<b>G</b> <b>23</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



**PLAN VIEW**

PROVIDE CURB CUTS THROUGHOUT EDGE TREATMENT AS NECESSARY, FOR SIDEWALK DRAINAGE



**SECTION A-A**

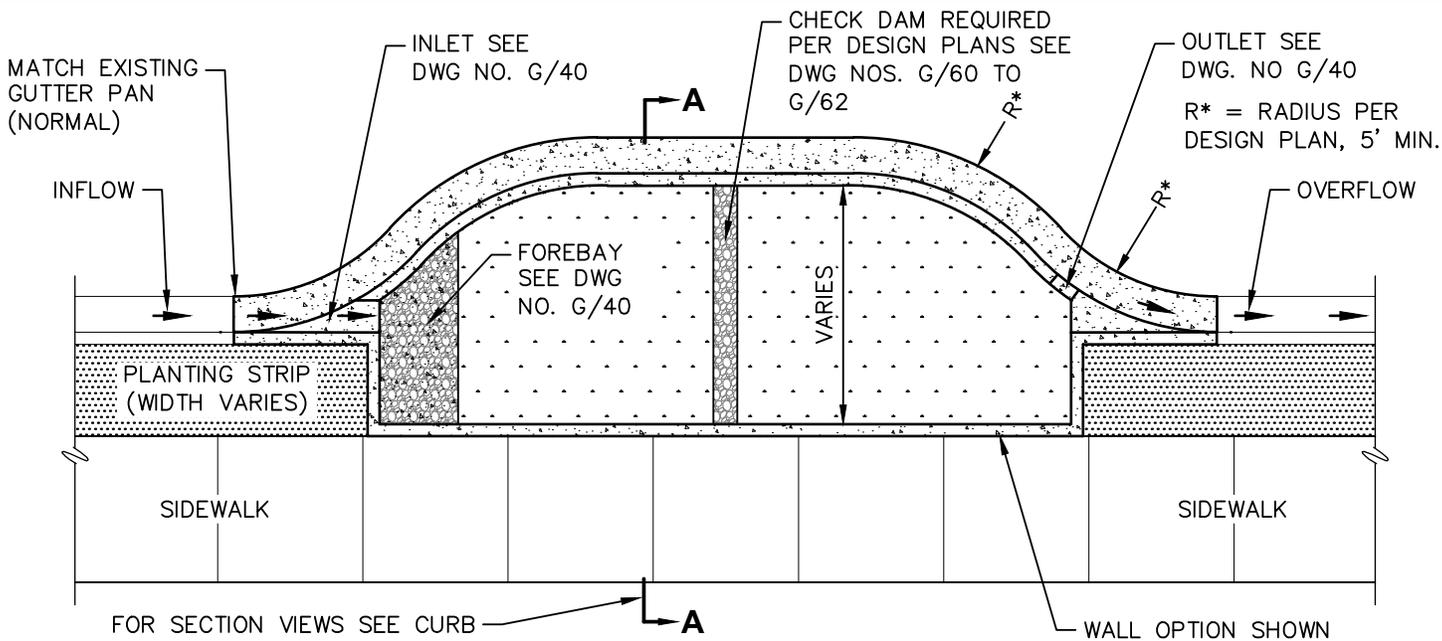
ITEM	MATERIAL	LAYER THICKNESS
SURFACE STORAGE		__ INCH
VEGETATION/SURFACE TREATMENT	PER PLANTING PLAN.	
BIORETENTION SOIL	BIORETENTION SOIL MIX ____.	__ INCH
CHOKER LAYER	MDOT 6AA, AASHTO #57 OR APPROVED EQUIVALENT.	4 INCH
RESERVOIR LAYER	MDOT 4AA OR 6AA, AASHTO #2, #3 OR #57 OR APPROVED EQUIVALENT.	__ INCH
FILTER LAYER	MDOT 34G, 4G, AASHTO #8 OR APPROVED EQUIVALENT. WHEN FILTER LAYER IS OMITTED, PROVIDE GEOTEXTILE CLASS 2 MATERIAL BENEATH RESERVOIR LAYER.	4 INCH
UNDERDRAIN	PERFORATED PVC UNDERDRAIN WHEN CALLED FOR PER DESIGN PLANS. CLEANOUT AT TERMINAL ENDS DWG NO. G/51. PIPE BEDDING AND CATCH BASIN CONNECTION DWG NO. G/52.	4 INCH
UNDERDRAIN OFFSET	OFFSET DISTANCE UNDERDRAIN SET ABOVE THE FILTER LAYER.	__ INCH
GEOTEXTILE	GEOTEXTILE CLASS 2, LOCATED ON SIDES OF FACILITY ONLY.	
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPARATION.	
EDGE TREATMENT	FOR ALTERNATIVE EDGE TREATMENT CONDITIONS, SEE DWG. NOS. G/31 TO G/34.	
INLET AND OUTLET	LOCATIONS PER DESIGN PLANS. REFER TO DWG NO. G/43 AND G/44.	

- NOTES
1. STEP OUT ZONE REQUIRED WHEN PARALLEL PARKING IS PROVIDED. INSTALLATION SHALL BE VEGETATION/SURFACE TREATMENT OR PAVEMENT BASED ON SURROUNDING CONDITIONS. SIDEWALK SHALL BE SLOPED IN EITHER DIRECTION.
  2. OUTLET REQUIRED AS SPECIFIED BY DESIGN PLANS.
  3. GEOTEXTILE REQUIRED WHEN FACILITY IS WITHIN 10' OF BUILDING OR AS INDICATED BY ENGINEER.

CITY OF GRAND RAPIDS, MICHIGAN

## BIORETENTION PLANTER ADJACENT TO ROADWAY WITH STEP OUT ZONE

<b>G</b> <b>24</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



FOR SECTION VIEWS SEE CURB BULB-OUT IN-PLANTING STRIP BIORETENTION PAGE 2

**CURB BULB-OUT PLAN**

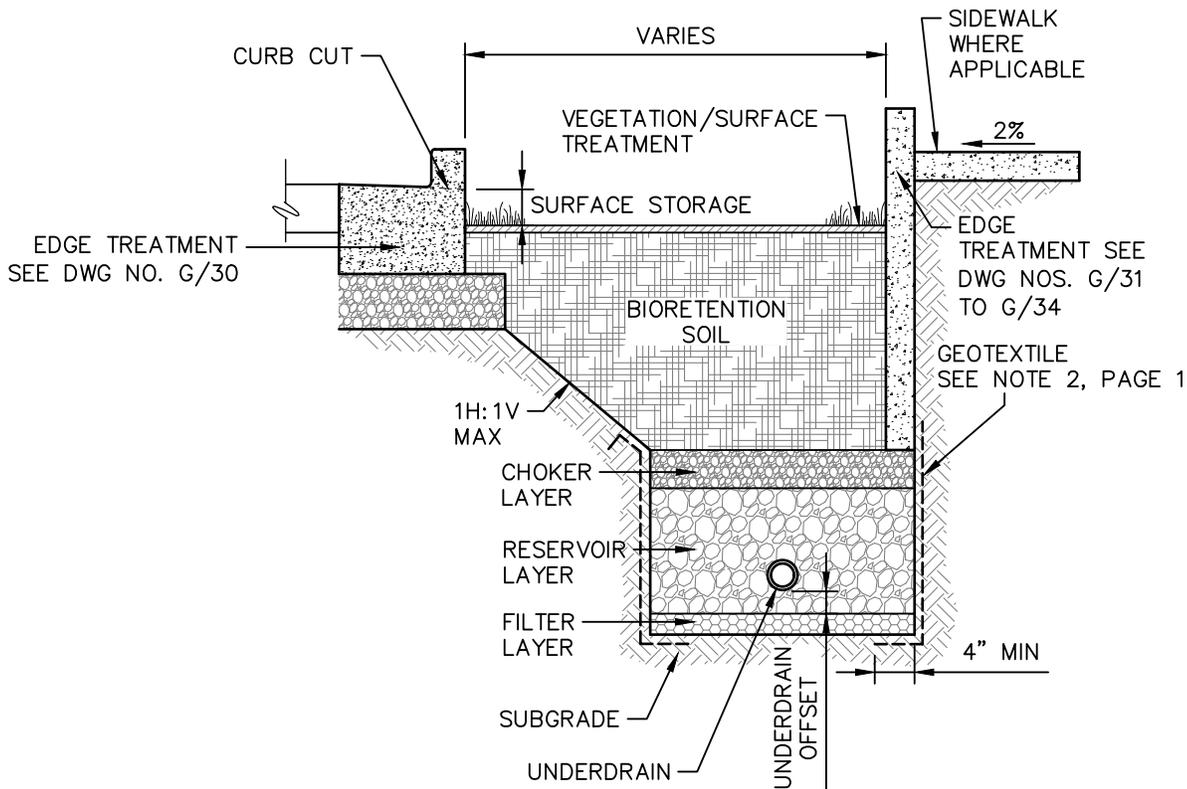
ITEM	MATERIAL	LAYER THICKNESS
SURFACE STORAGE		__ INCH
VEGETATION/SURFACE TREATMENT	PER PLANTING PLAN.	
BIORETENTION SOIL	BIORETENTION SOIL MIX ____.	__ INCH
CHOKER LAYER	MDOT 6AA, AASHTO #57 OR APPROVED EQUIVALENT.	4 INCH
RESERVOIR LAYER	MDOT 4AA OR 6AA, AASHTO #2, #3 OR #57 OR APPROVED EQUIVALENT.	__ INCH
FILTER LAYER	MDOT 34G, 4G, AASHTO #8 OR APPROVED EQUIVALENT. WHEN FILTER LAYER IS OMITTED, PROVIDE GEOTEXTILE CLASS 2 MATERIAL BENEATH RESERVOIR LAYER.	4 INCH
UNDERDRAIN	PERFORATED PVC UNDERDRAIN WHEN CALLED FOR PER DESIGN PLANS. CLEANOUT AT TERMINAL ENDS DWG NO. G/51. PIPE BEDDING AND CATCH BASIN CONNECTION DWG NO. G/52.	4 INCH
UNDERDRAIN OFFSET	OFFSET DISTANCE UNDERDRAIN SET ABOVE THE FILTER LAYER.	__ INCH
GEOTEXTILE	GEOTEXTILE CLASS 2, LOCATED ON SIDES OF FACILITY ONLY.	
SUBGRADE	REFER TO SPECIFICATION FOR SUBGRADE PREPERATION.	
EDGE TREATMENT	FOR STREETSIDE EDGE TREATMENT, SEE DWG. NO G/30. FOR OTHER THREE SIDES, SEE DWG NOS. G/31 TO G/34.	
INLET AND OUTLET	REFER TO DWG NO. G/40.	
CHECK DAMS	REQUIRED AS PER DESIGN PLANS. SEE DWG. NO. G/60 TO G/62.	

- NOTES
1. LONGITUDINAL SLOPE OF CURB BULB-OUT MATCHES ROAD, OR FLATTER AS REQUIRED PER DESIGN PLANS.
  2. SIDEWALK ELEVATION MUST BE SET ABOVE INLET AND OUTLET ELEVATIONS TO ALLOW OVERFLOW TO DRAIN TO STREET BEFORE PONDING LEVEL REACHES SIDEWALK.

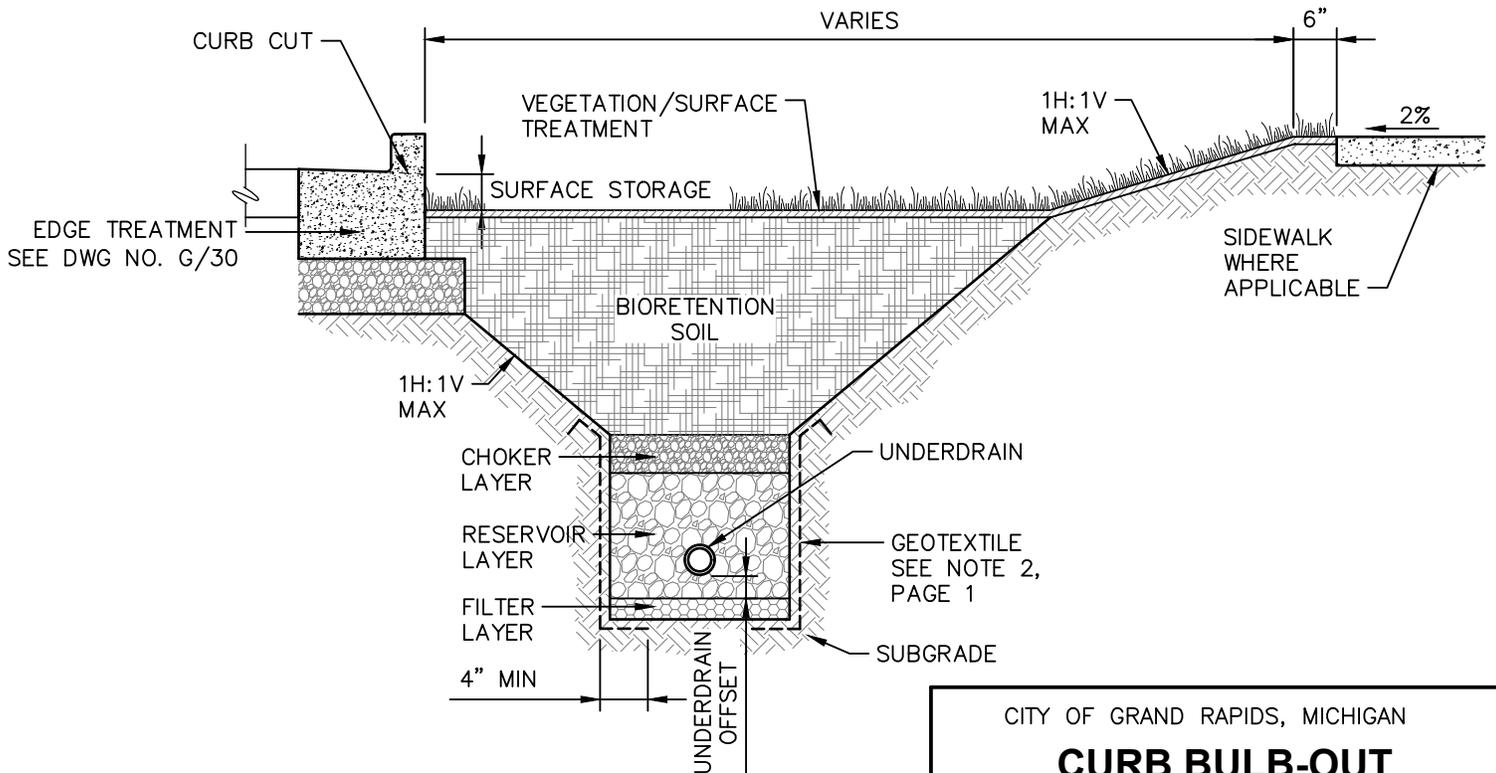
CITY OF GRAND RAPIDS, MICHIGAN

**CURB BULB-OUT  
IN-PLANTING STRIP  
BIORETENTION  
PAGE 1**

<b>G</b> <b>25</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



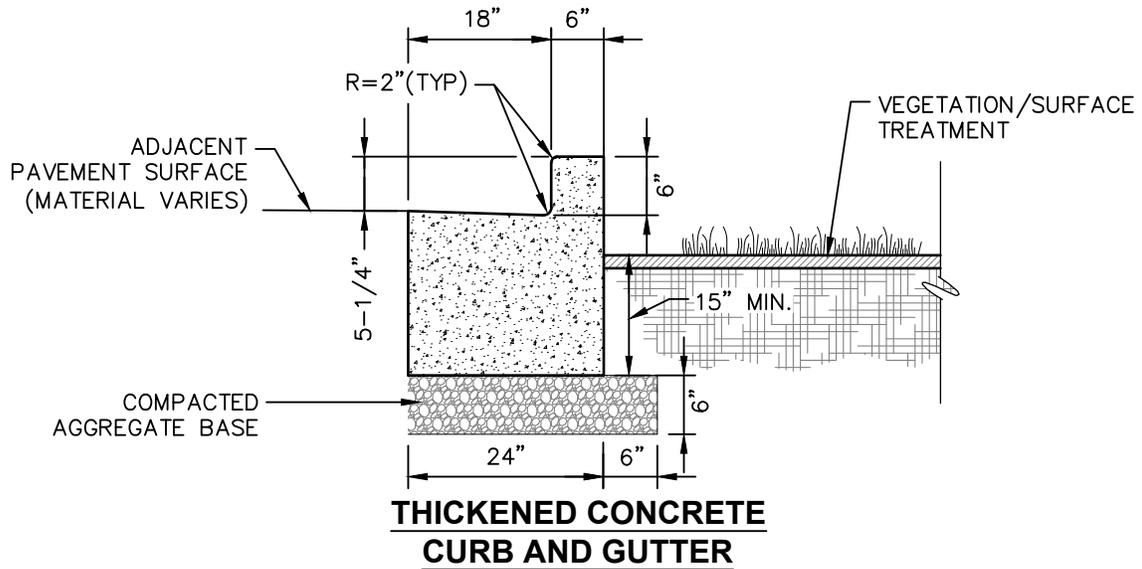
**SECTION A-A  
(WALL OPTION)**



**SECTION A-A  
(SLOPE OPTION)**

CITY OF GRAND RAPIDS, MICHIGAN  
**CURB BULB-OUT  
 IN-PLANTING STRIP  
 BIORETENTION  
 PAGE 2**

<b>G</b> <b>25</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.

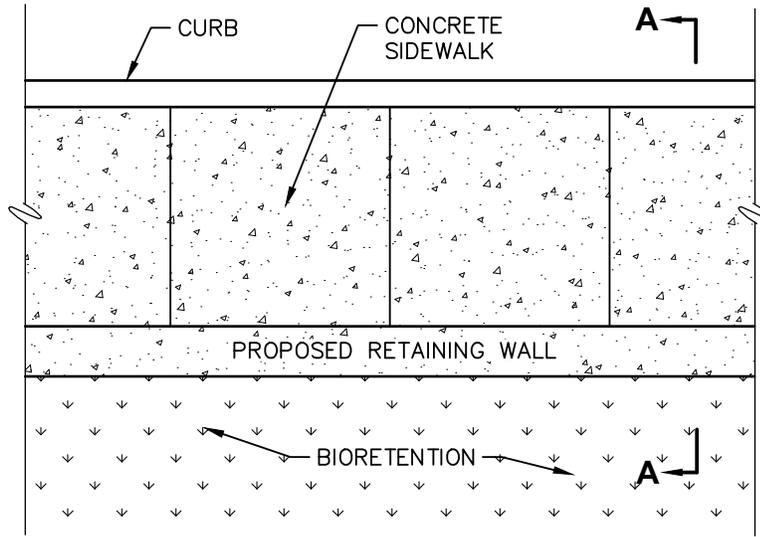


NOTES

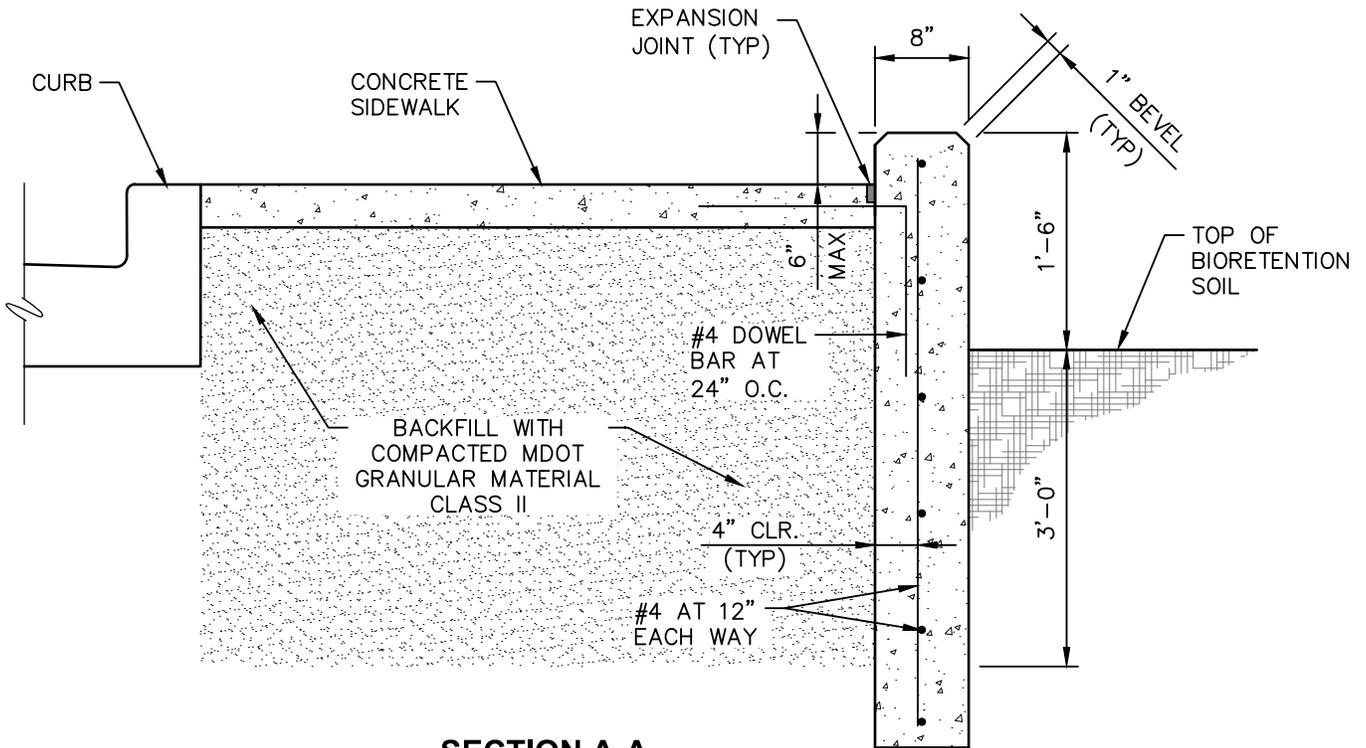
1. SLOPE OF GUTTER AND CURB REVEAL TO MATCH STANDARD CURB AND GUTTER.

CITY OF GRAND RAPIDS, MICHIGAN  
**THICKENED CONCRETE  
 CURB AND GUTTER  
 EDGE TREATMENT**

<b>G</b> <b>30</b>	APPROVED	
	DRAWN	DATE
	CITY ENGINEER	CHECKED
	SCALE:	N.T.S.



**PLAN VIEW**



**SECTION A-A**

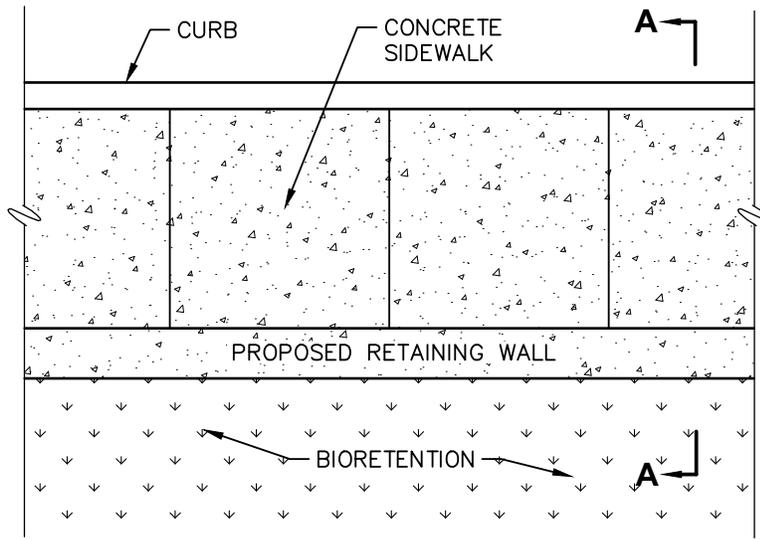
**NOTES:**

1. CONCRETE WALL MUST BE SHORED UNTIL ALL BACKFILL IS PLACED.
2. WALL SHALL BE SHORED DURING ANY FUTURE OPERATIONS TO REMOVE THE SIDEWALK OR REPLACE THE SOIL FILL FOR PLANTS.
3. CONCRETE STRENGTH =  $f'_c = 4,000$  PSI
4. STEEL REINFORCEMENT STRENGTH =  $f_y = 60,000$  PSI

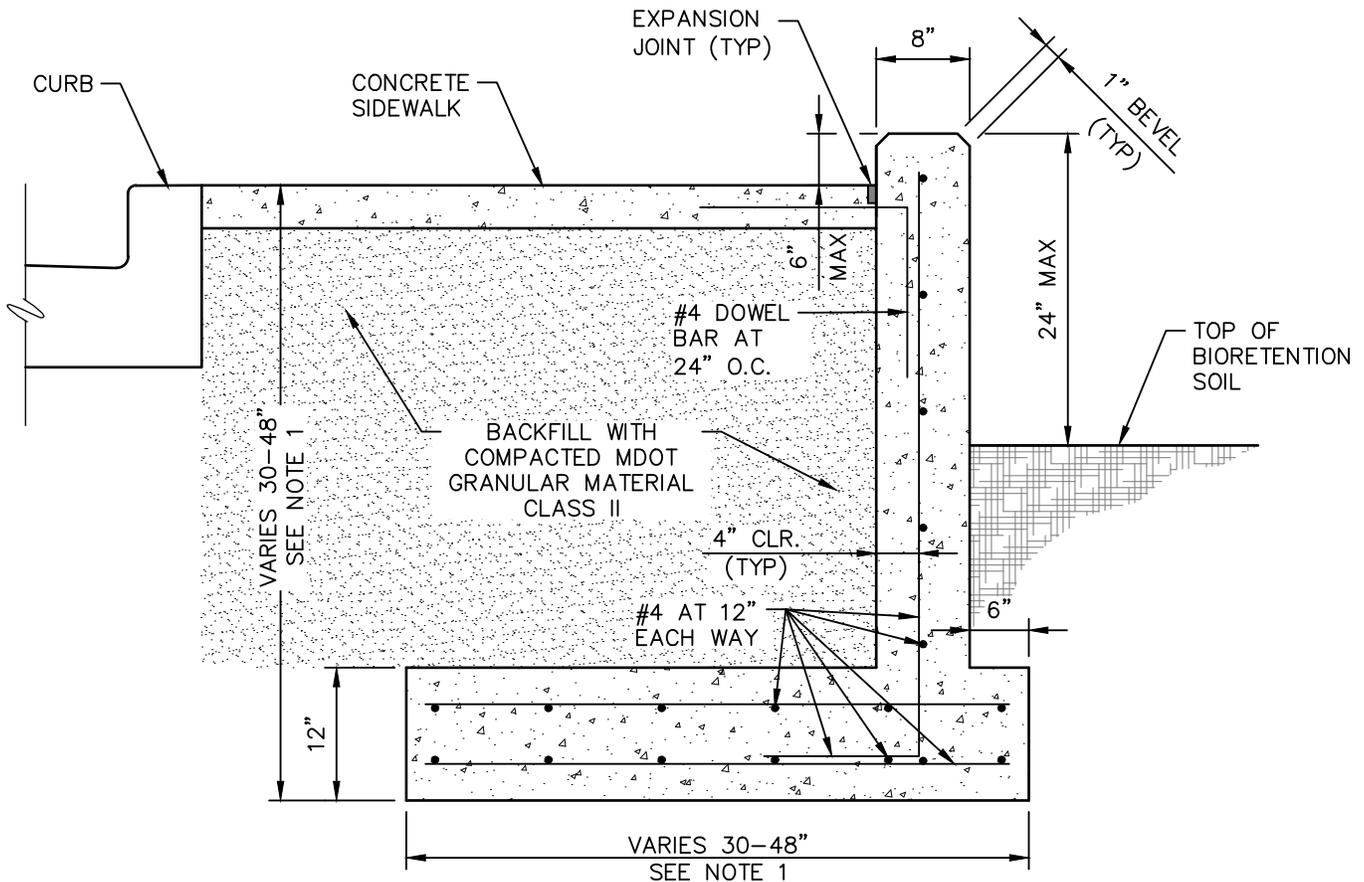
CITY OF GRAND RAPIDS, MICHIGAN

**CONCRETE RETAINING WALL  
EDGE TREATMENT**

<b>G</b> <b>31</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



**PLAN VIEW**



**SECTION A-A**

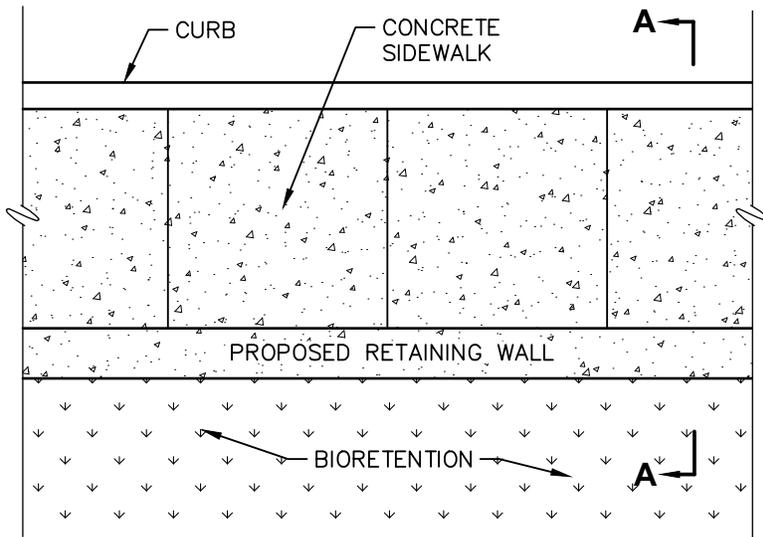
**NOTES**

1. WALL HEIGHT AND FOOTING WIDTH ARE VARIABLE FROM 30" TO 48". WALL HEIGHT AND FOOTING DIMENSION ARE KEPT EQUAL, HENCE A 30" WALL HEIGHT HAS A 30" WIDE FOOTING.
2. CONCRETE STRENGTH =  $f'_c = 4,000$  PSI.
3. STEEL REINFORCEMENT STRENGTH =  $f_y = 60,000$  PSI.

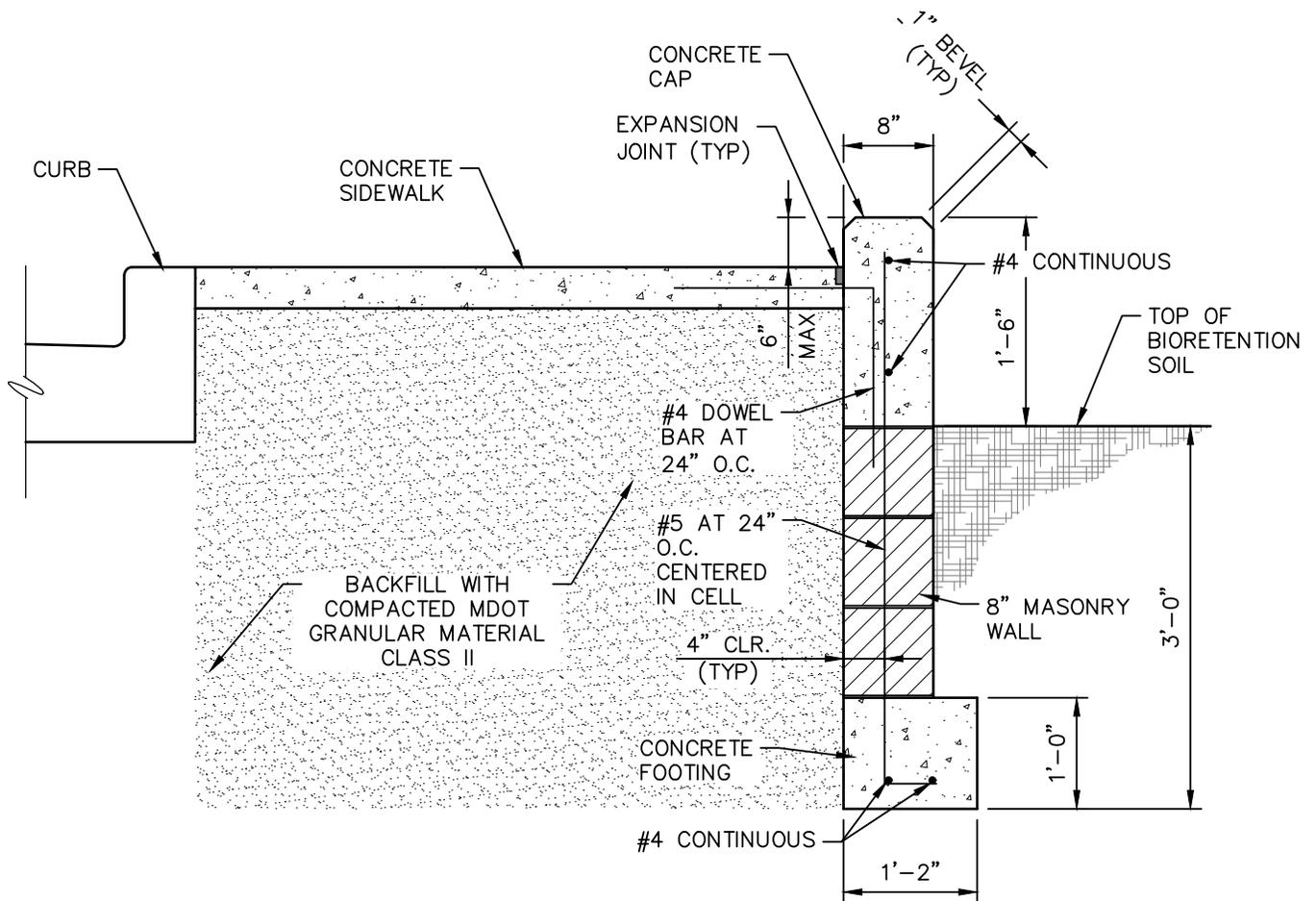
CITY OF GRAND RAPIDS, MICHIGAN

**CONCRETE RETAINING WALL  
EDGE TREATMENT  
WITH FOOTING**

<b>G</b> <b>32</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



**PLAN VIEW**



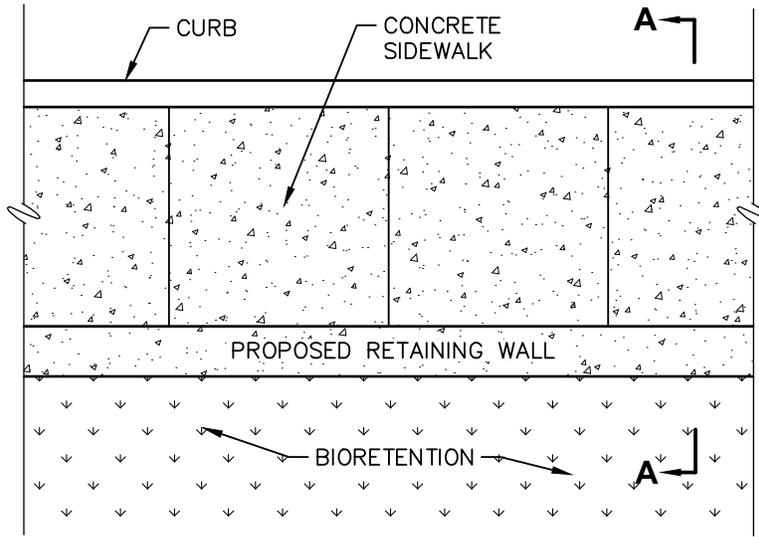
**NOTES:**

1. WALL SHALL BE SHORED DURING ANY FUTURE OPERATIONS TO REMOVE THE SIDEWALK.
2. MASONRY STRENGTH =  $f'_m = 1,500$  PSI
3. CONCRETE STRENGTH =  $f'_c = 4,000$  PSI
4. STEEL REINFORCEMENT STRENGTH =  $f_y = 60,000$  PSI

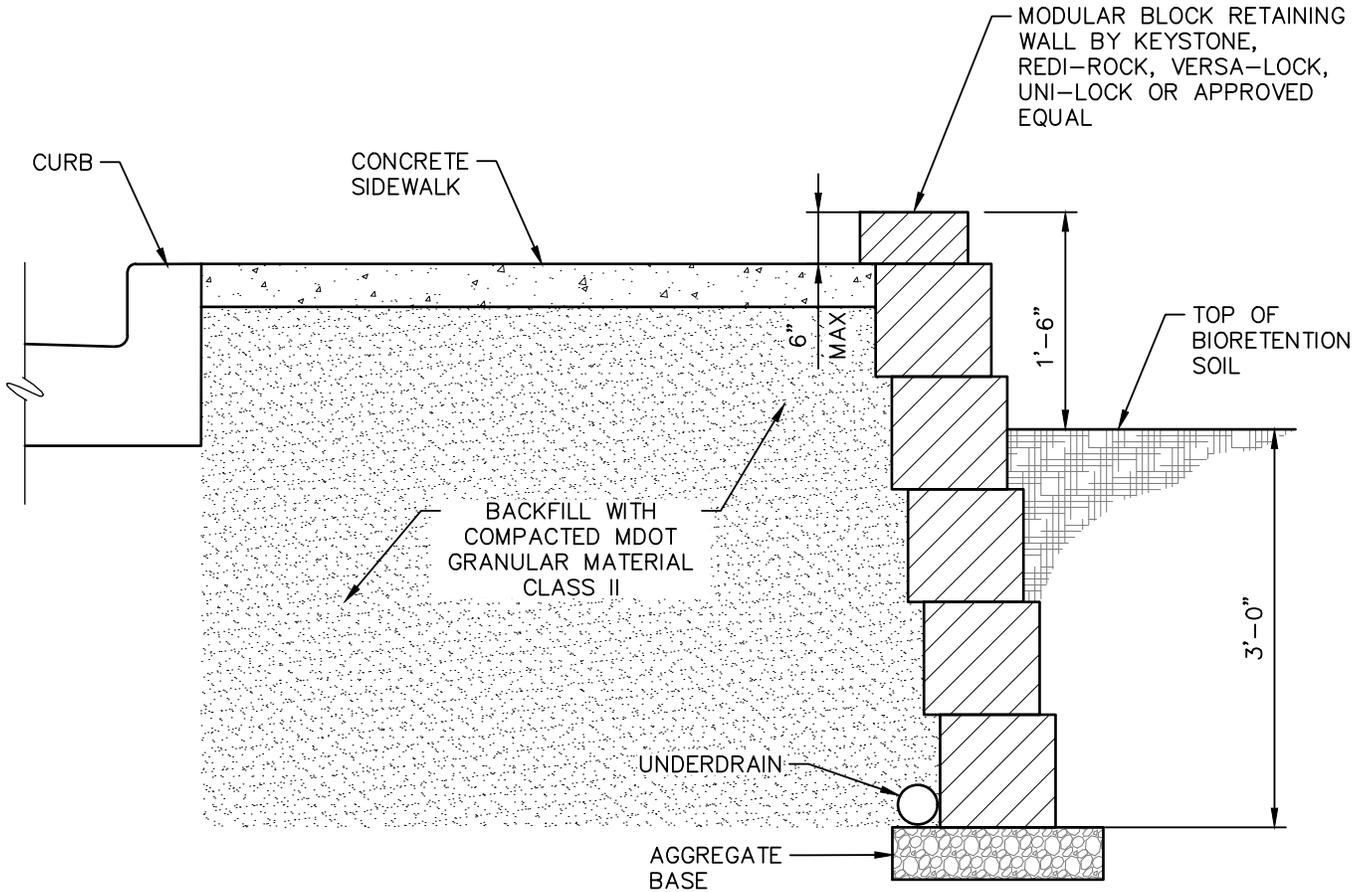
CITY OF GRAND RAPIDS, MICHIGAN

**MASONRY RETAINING WALL  
EDGE TREATMENT**

<b>G</b> <b>33</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



**PLAN VIEW**



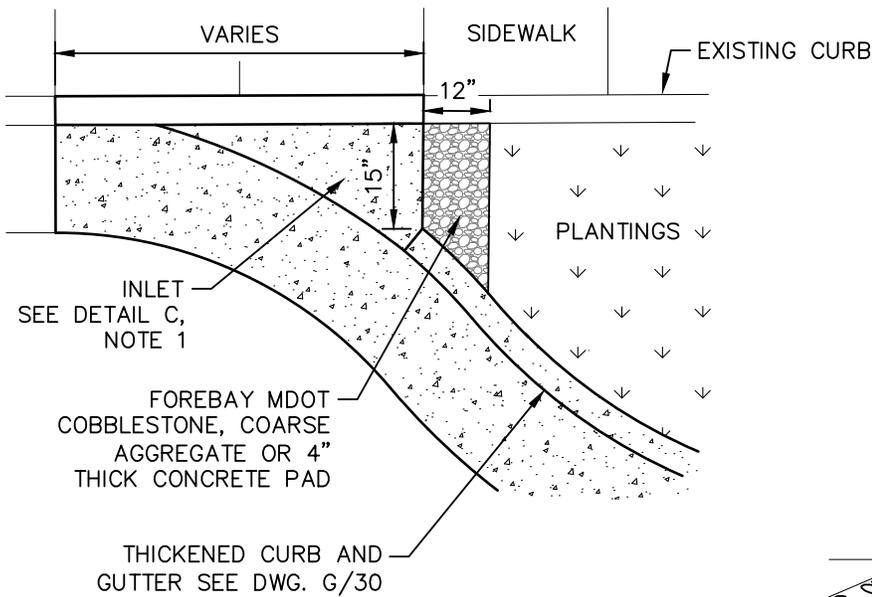
**NOTES:**

1. WALL FACE PATTERN TO BE APPROVED BY THE CITY.
2. WALL TO BE GRAVITY TYPE WITH A SET BACK.
3. WALL MANUFACTURER TO SUBMIT DESIGN CALCULATIONS SEALED BY A LICENSED ENGINEER REGISTERED IN MICHIGAN.

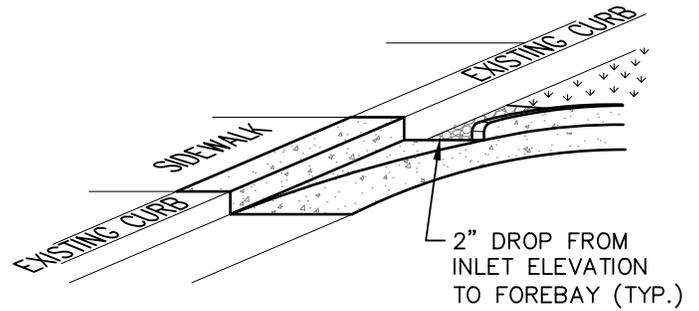
CITY OF GRAND RAPIDS, MICHIGAN

**MODULAR BLOCK  
RETAINING WALL  
EDGE TREATMENT**

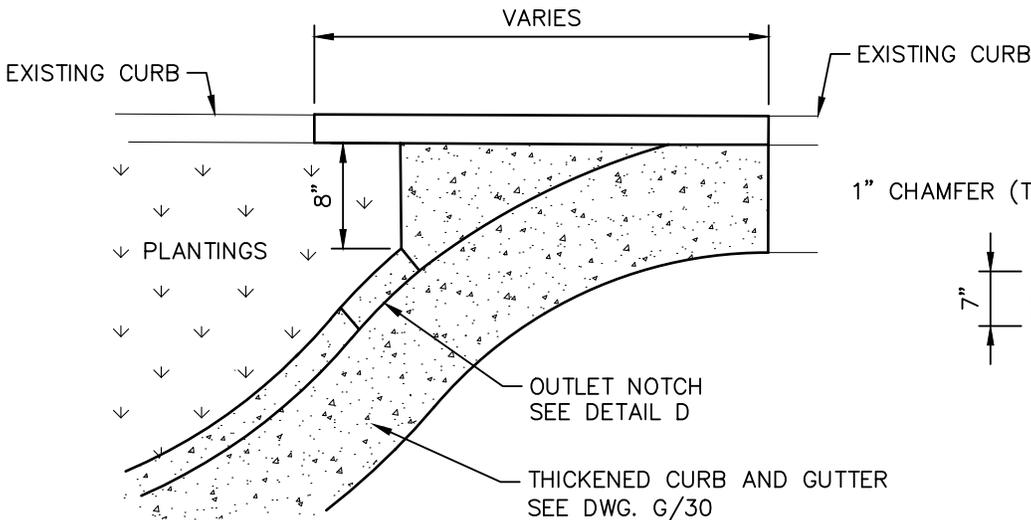
<b>G</b> <b>34</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



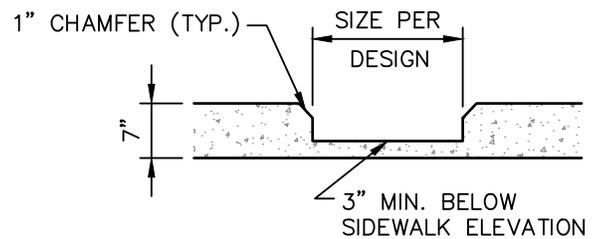
**DETAIL A  
INLET PLAN VIEW**



**DETAIL C  
INLET ISOMETRIC  
VIEW**



**DETAIL B  
OUTLET CURB PLAN**



**DETAIL D  
OUTLET NOTCH**

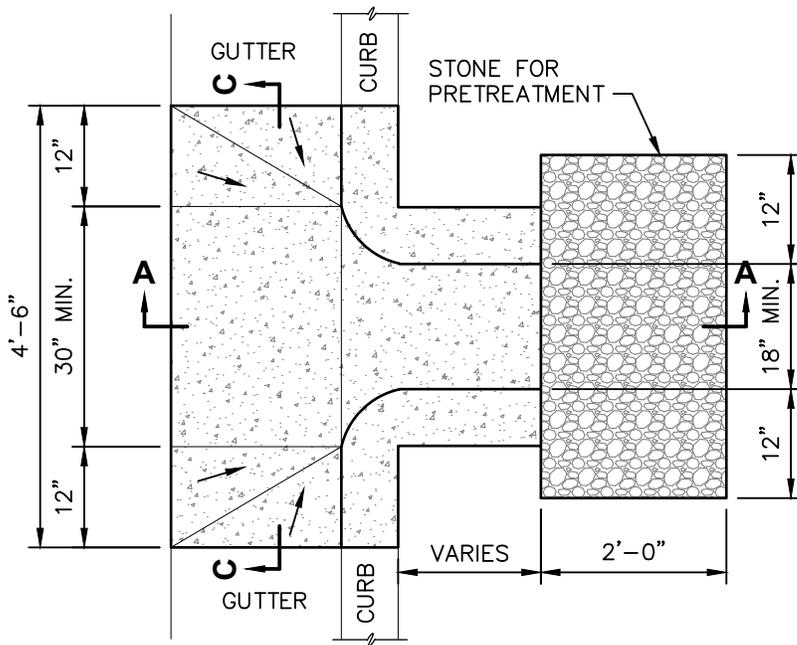
**NOTES**

1. INLET MAY BE MODIFIED TO CONTROL THE AMOUNT OF FLOW RATE ENTERING THE STORMWATER FACILITY.

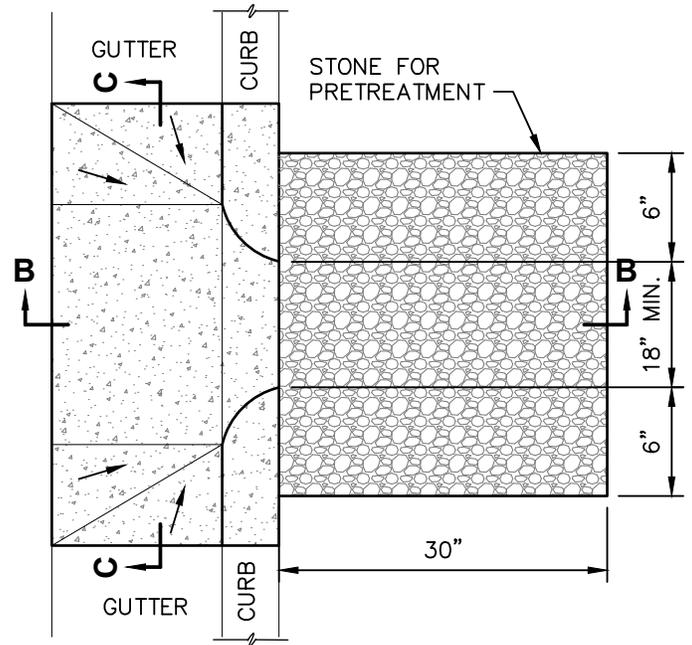
CITY OF GRAND RAPIDS, MICHIGAN

**INLET AND OUTLET FOR  
CURB BULB-OUT  
BIORETENTION**

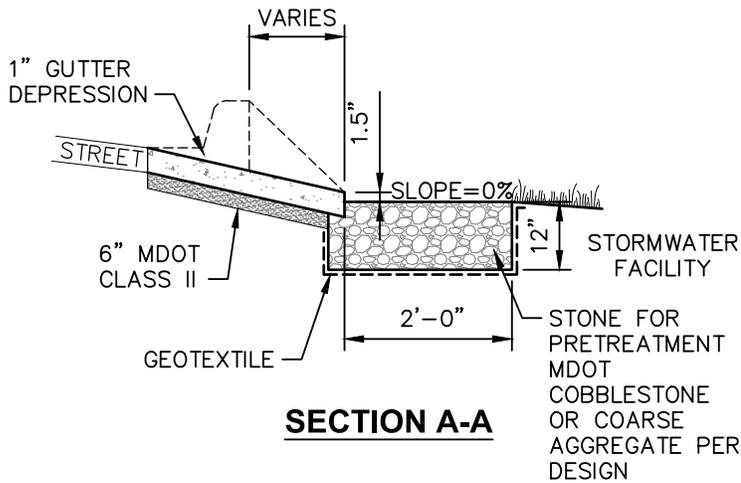
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	DRAWN	DATE
	CITY ENGINEER	CHECKED
	SCALE:	N.T.S.



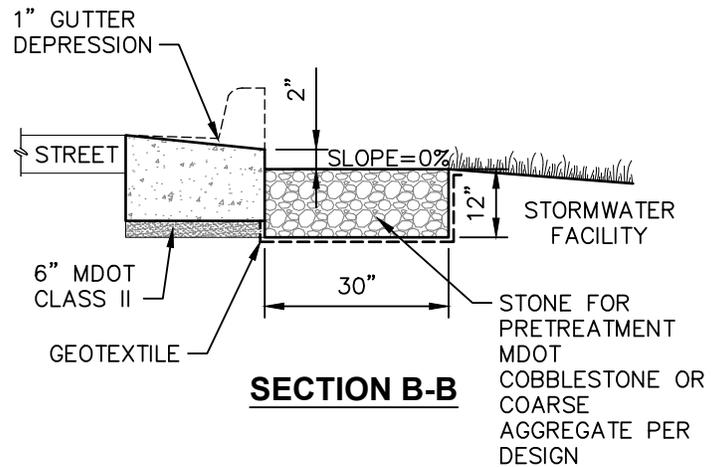
**DETAIL A**  
**INLET WITH WINGWALLS AND**  
**STONE SPLASH PAD**



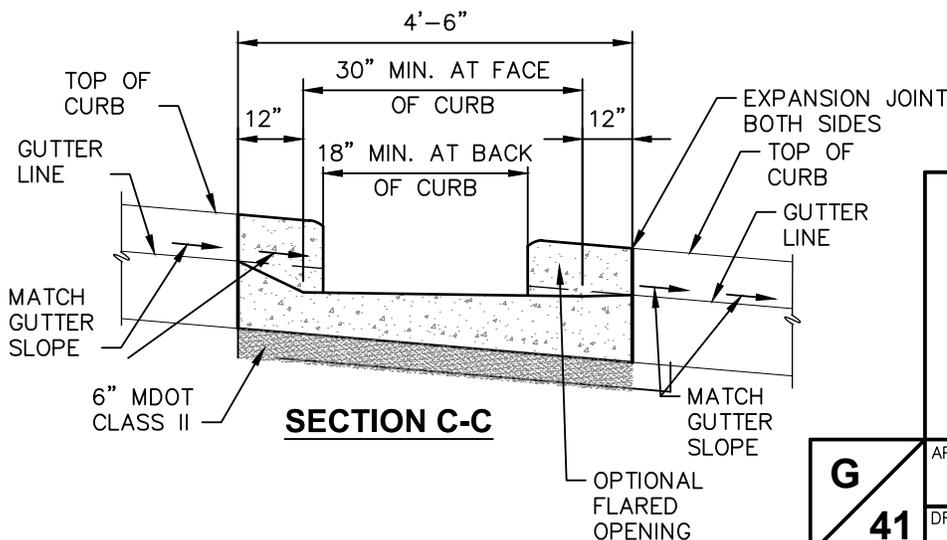
**DETAIL B**  
**INLET WITH STONE SPLASH PAD**



**SECTION A-A**



**SECTION B-B**

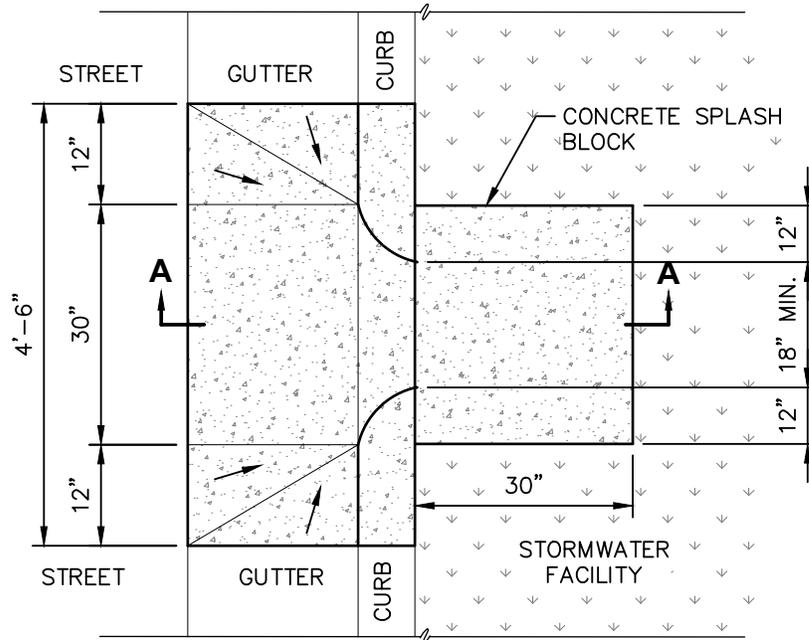


**SECTION C-C**

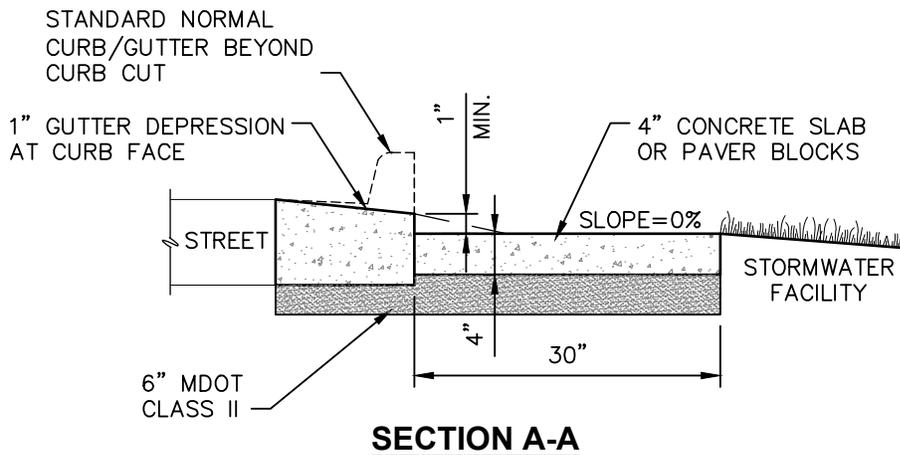
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**CURB AND GUTTER**  
**INLET WITH STONE**  
**SPLASH PAD**

<b>G</b> <b>41</b>	APPROVED		DATE
	DRAWN	CITY ENGINEER CHECKED	SCALE: N.T.S.



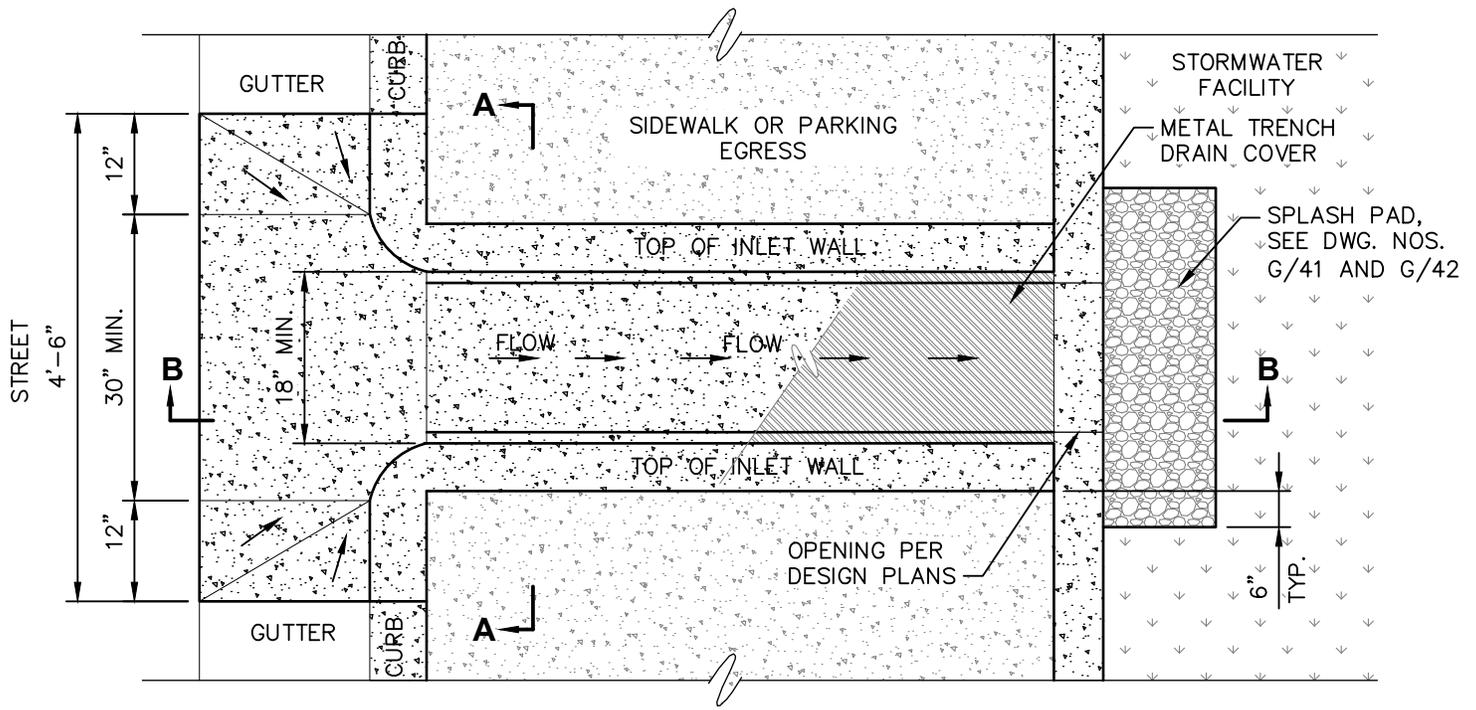
**INLET WITH WINGWALLS AND  
CONCRETE SPLASH PAD**



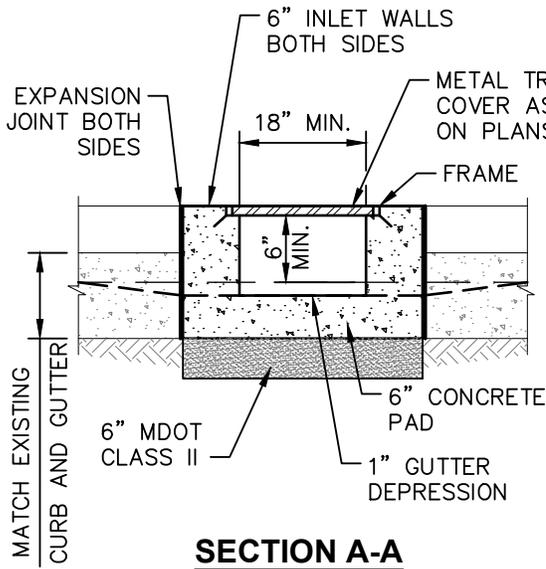
CITY OF GRAND RAPIDS, MICHIGAN

**CURB AND GUTTER  
INLET WITH CONCRETE  
SPLASH PAD**

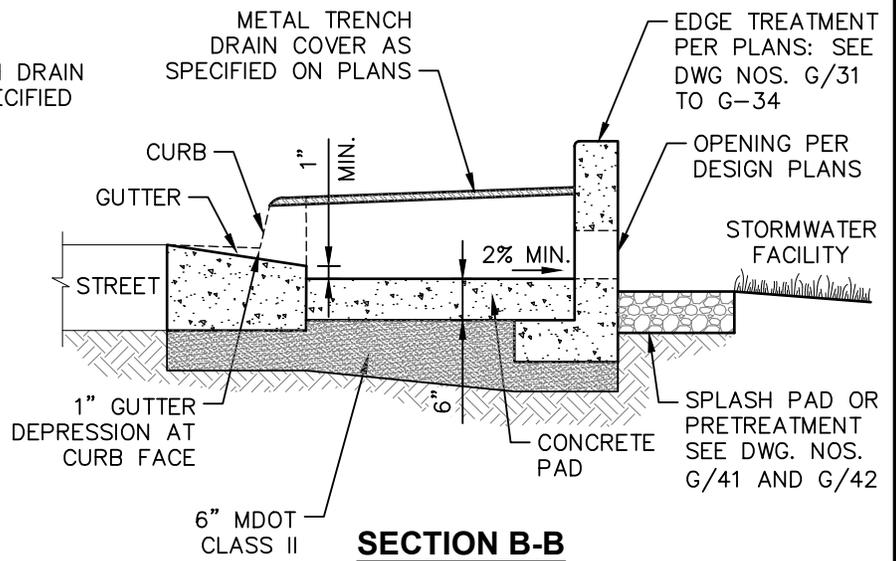
<b>G</b> <b>42</b>	APPROVED		DATE
	DRAWN	CITY ENGINEER CHECKED	SCALE: N.T.S.



**PLAN VIEW**



**SECTION A-A**



**SECTION B-B**

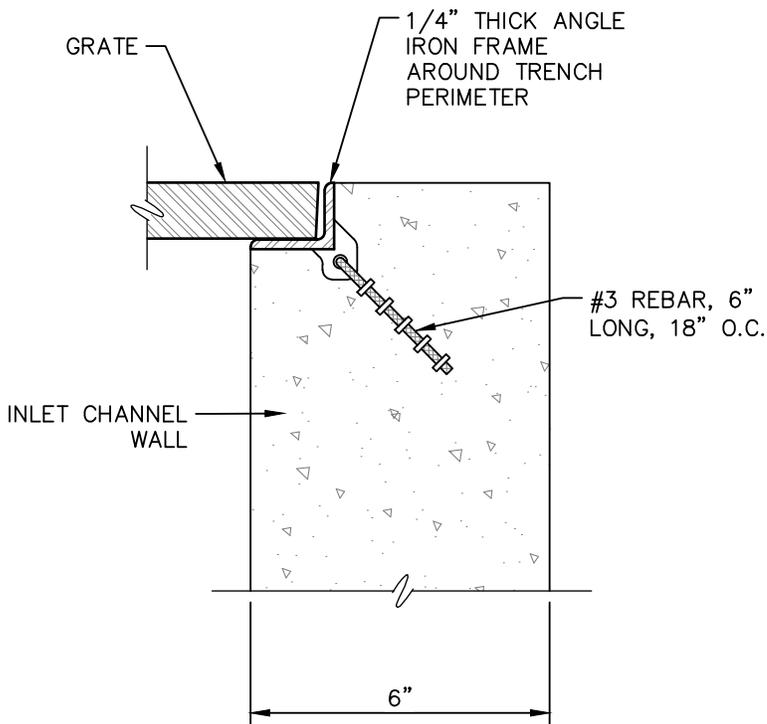
**NOTES**

1. CURB OPENING DIMENSION SHOWN IS A MINIMUM.
2. REFER TO DESIGN PLANS FOR SIZE AND TYPE OF GRATE.
3. METAL TRENCH DRAIN COVER TO BE BOLTED DOWN (THEFT PROTECTED) BUT REMOVABLE.
4. REFER TO DESIGN PLANS FOR DIMENSIONS AND SLOPES.

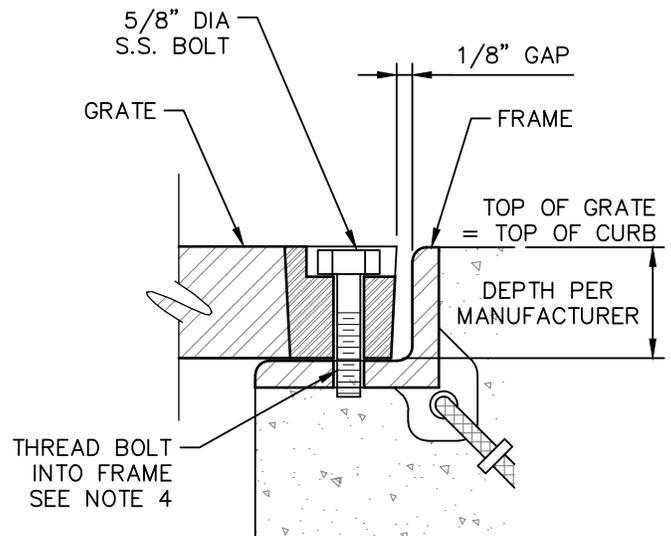
CITY OF GRAND RAPIDS, MICHIGAN

**CURB CUT METAL  
TRENCH DRAIN COVER  
PAGE 1**

<b>G</b> <b>43</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



**FRAME DETAIL**



**GRATE ATTACHMENT DETAIL**

**NOTES**

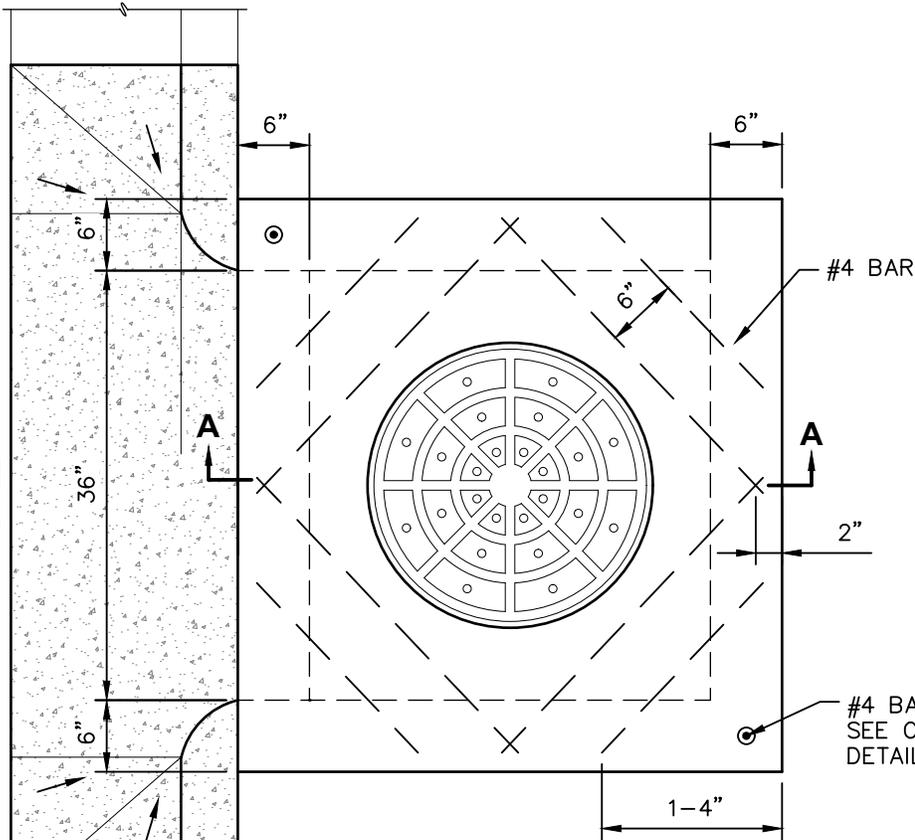
1. CAST IRON, NATURAL FINISH.
2. NO OPENING GREATER THAN 3/8 INCH.
3. PROTECT THREADED HOLES IN FRAME FROM CLOGGING DURING FRAME INSTALLATION.
4. TRENCH GRATE AND FRAME ASSEMBLY FOR ADA COMPLIANT NON-TRAFFIC CONDITIONS SHALL BE EAST JORDAN V7396-20, NEENAH R-4991-FX P, OR EQUAL. TRENCH DRAINS IN TRAFFIC CONDITIONS SHALL BE EAST JORDAN V7386-20, NEENAH R-4999-FX P, OR EQUAL.
5. GRATES SHALL BE FURNISHED WITH STAINLESS STEEL BOLTS AND A NON-SLIP SURFACE.

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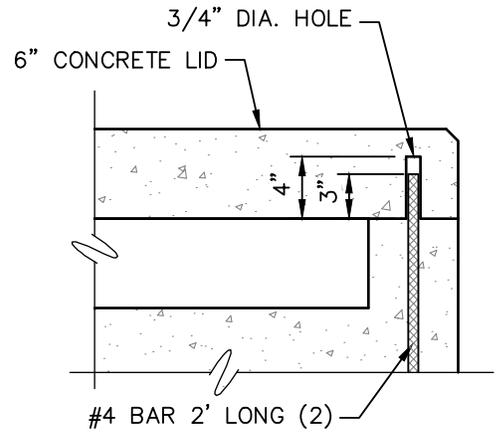
**CURB CUT METAL  
TRENCH DRAIN COVER  
PAGE 2**

<b>G</b> <b>43</b>	APPROVED	
	DRAWN	DATE
	CITY ENGINEER	CHECKED
	SCALE:	N.T.S.

STREET

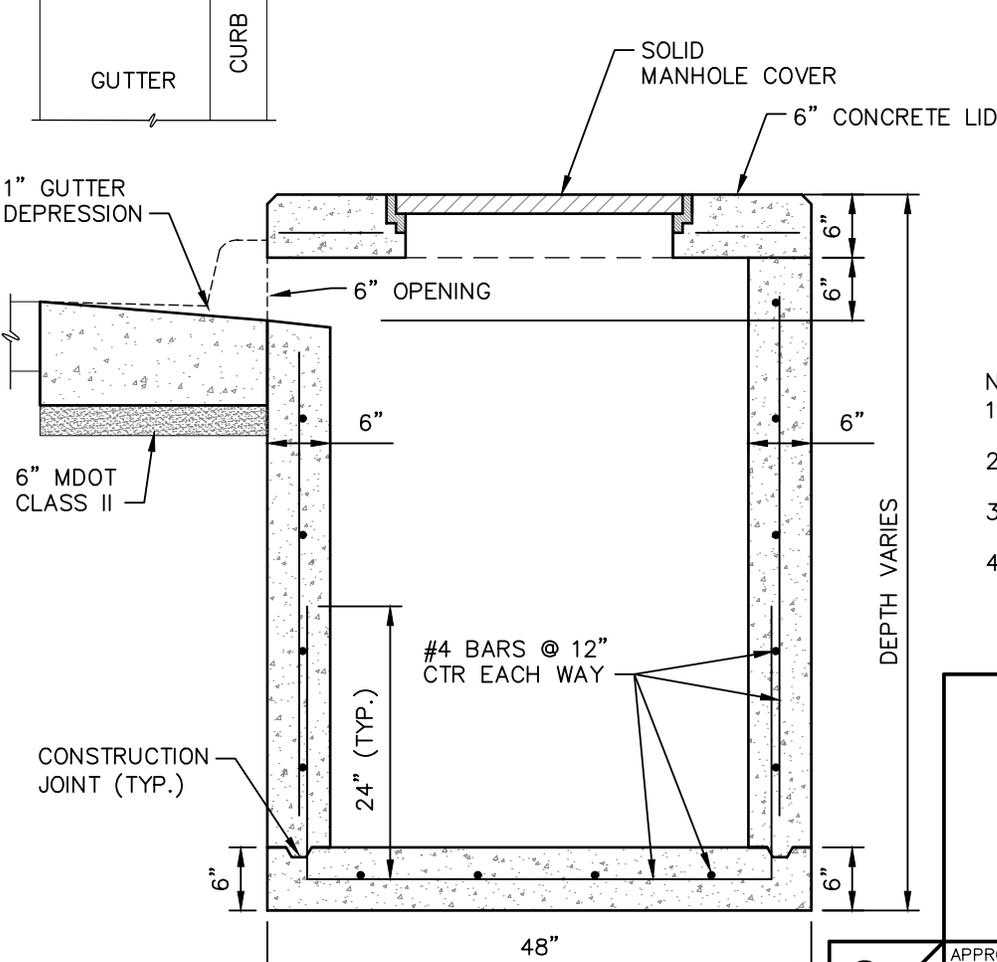


**PLAN VIEW**



**COVER SUPPORT DETAIL**

#4 BAR (ANCHOR BAR)  
SEE COVER SUPPORT  
DETAIL



**SECTION A-A**

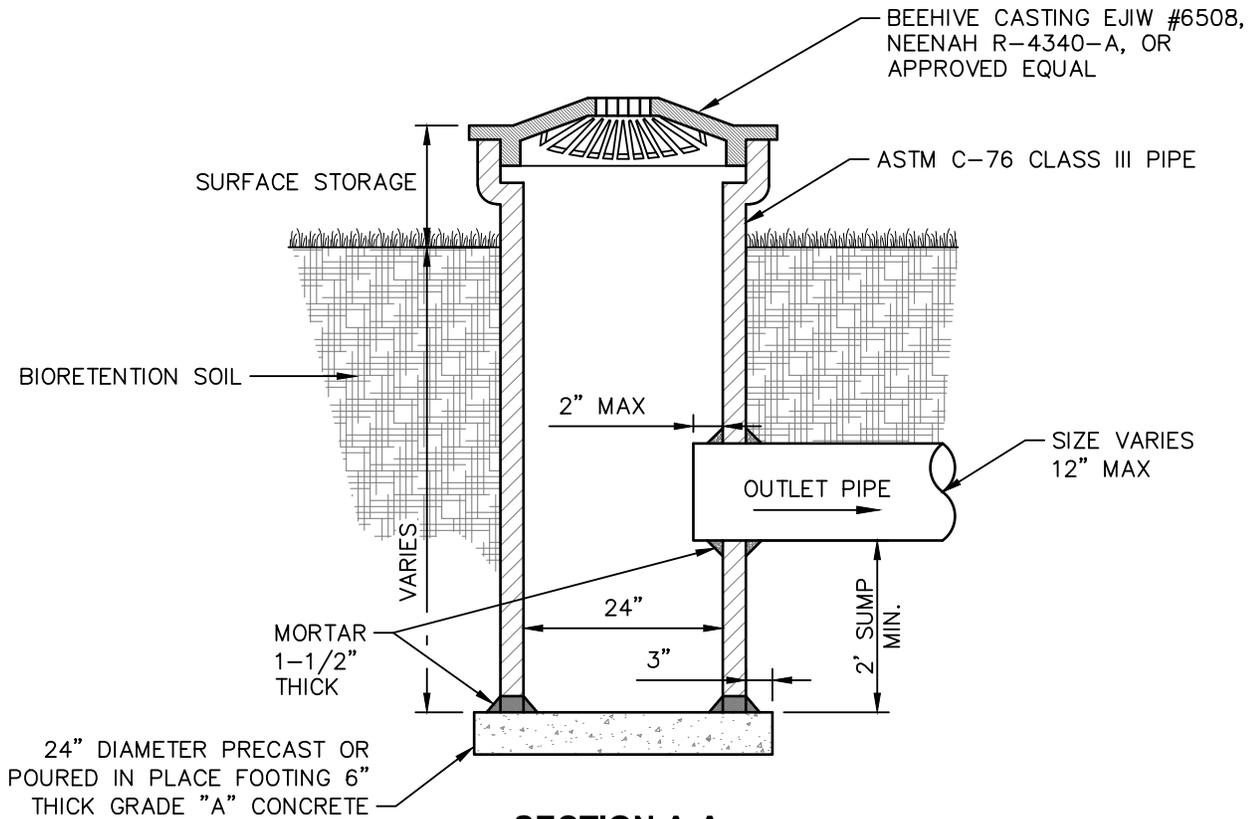
NOTE:

1. LEAD PIPE - ANY SIZE UP TO 30" MAY BE INSTALLED IN ANY WALL
2. OPENINGS - NUMBER AND LOCATION TO FIT FIELD CONDITIONS.
3. ALL EXPOSED EDGES OF BOX TO BE CAMFERED.
4. ALL REINFORCING STEEL SHALL CLEAR ALL SURFACES A MINIMUM OF 2".

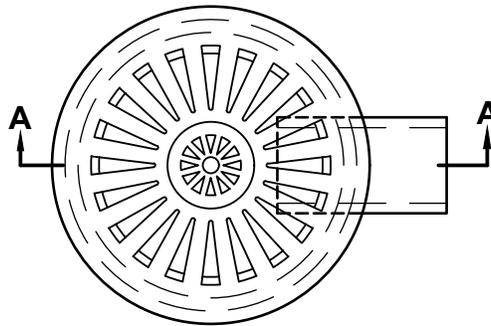
CITY OF GRAND RAPIDS, MICHIGAN

**AREA INLET  
TYPE 1**

<b>G</b> <b>44</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



**SECTION A-A**

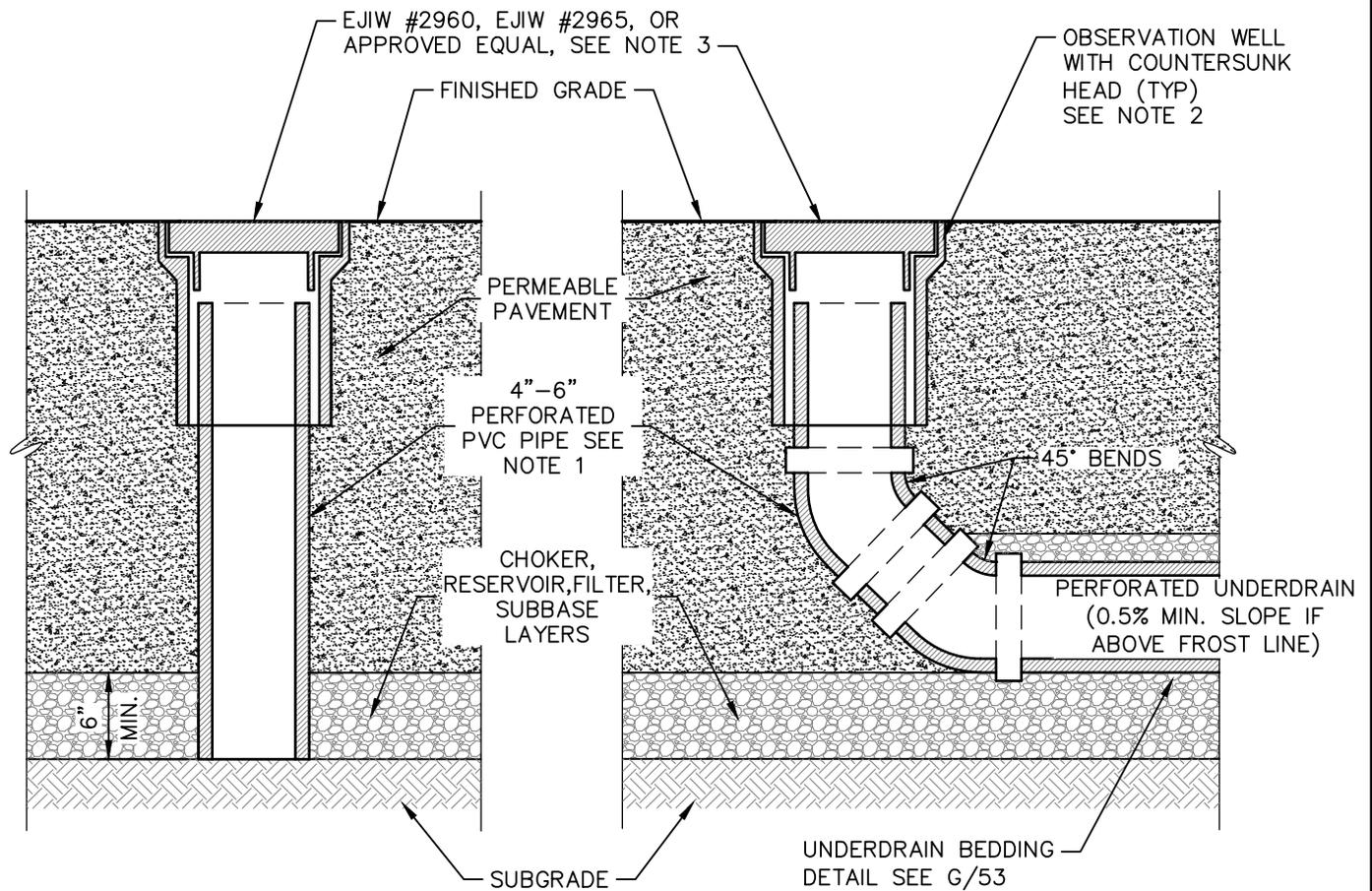


**PLAN**

CITY OF GRAND RAPIDS, MICHIGAN

**OVERFLOW RISER WITH BEEHIVE GRATE**

<b>G</b> <b>50</b>	APPROVED	
	DRAWN	DATE
	CITY ENGINEER	CHECKED
	SCALE:	N.T.S.



**DETAIL A**  
**OBSERVATION WELL IN PERMEABLE PAVEMENT**

**DETAIL B**  
**CLEANOUT/OBSERVATION WELL IN PERMEABLE PAVEMENT (SEE NOTE 6)**

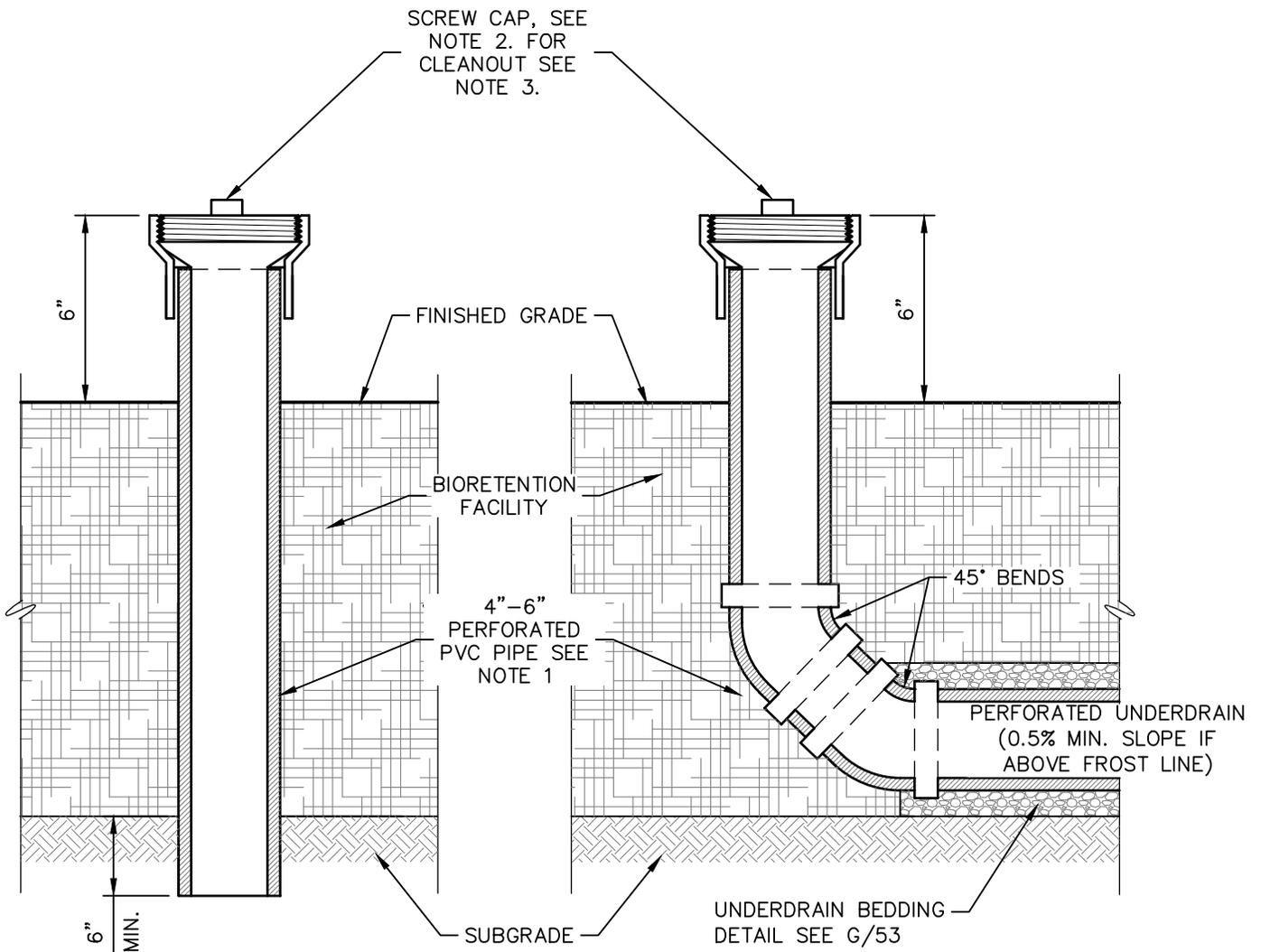
**NOTES**

1. UNDERDRAIN SHALL BE PVC SCHEDULE 40 OR EQUAL WITH AN INSIDE DIAMETER OF 4 TO 6 INCHES. PERFORATED PIPE IS REQUIRED FOR ALL OBSERVATION WELLS, OR CLEANOUTS USED AS OBSERVATION WELLS.
2. FACTORY ATTACHED BRASS OR HIGH IMPACT PLASTIC HEAD WITH RIBS TO PREVENT ROTATION WHEN REMOVING LOCKABLE CAP.
3. LOCKABLE CAP SHALL BE BRASS AND RATED FOR HS-20 LOADING IN VEHICULAR AREAS, MOUNTED FLUSH TO GRADE. LOCKABLE CAP MAY BE HIGH IMPACT PLASTIC THAT IS UV STABLE IN NON-VEHICULAR LOADING AREA.
4. IN FACILITIES SUBJECT TO VEHICULAR TRAFFIC, CONCRETE APRONS AROUND CLEANOUTS ARE AN OPTION, AS SHOWN IN DESIGN PLANS.

CITY OF GRAND RAPIDS, MICHIGAN

**STORMWATER FACILITY  
 UNDERDRAIN PIPE  
 RISERS IN PERMEABLE  
 PAVEMENTS**

<b>G</b> <b>51</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



**DETAIL A  
OBSERVATION WELL IN  
BIORETENTION**

**DETAIL B  
CLEANOUT/OBSERVATION  
WELL FOR BIORETENTION**

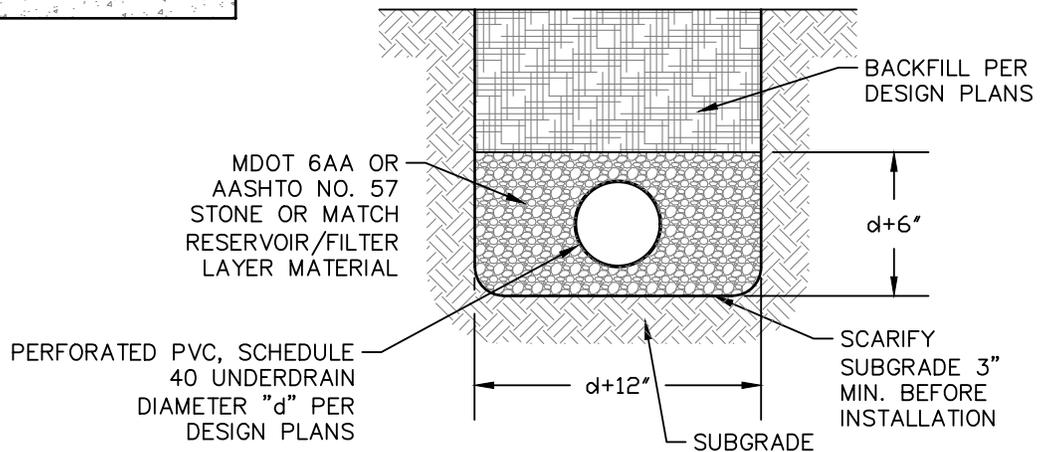
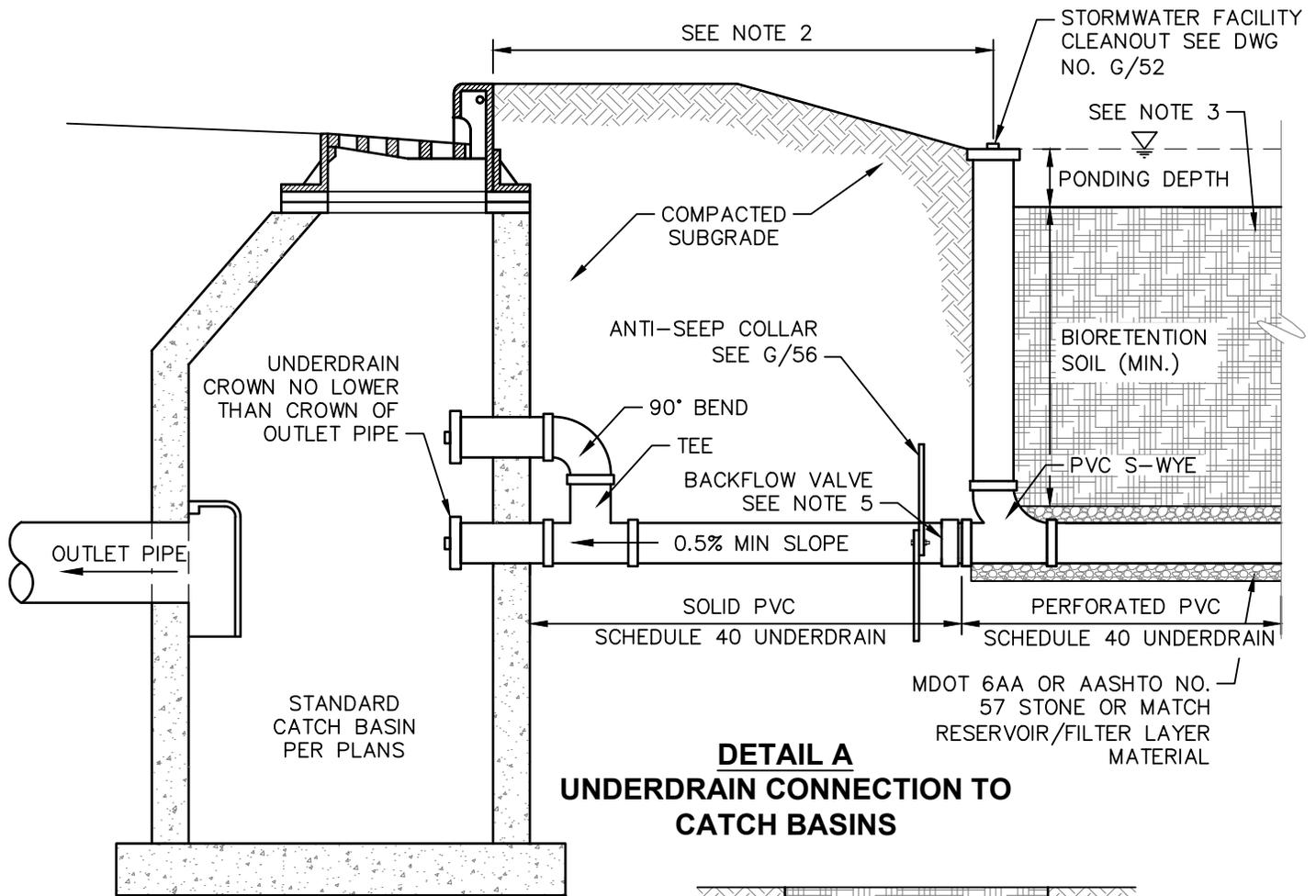
**NOTES**

1. UNDERDRAIN SHALL BE PVC SCHEDULE 40 OR EQUAL WITH AN INSIDE DIAMETER OF 4 TO 6 INCHES. PERFORATED PIPE IS REQUIRED FOR ALL OBSERVATION WELLS, OR CLEANOUTS USED AS OBSERVATION WELLS.
2. CAP ON RISERS IN BIORETENTION FACILITY SHALL BE PVC SCREW IN PLUG.
3. FOR CLEANOUT IN BIORETENTION (NOT SHOWN), USE SIMILAR DETAIL, BUT USE PVC SCREW CAP SET 6 INCH ABOVE FINISHED GRADE.

CITY OF GRAND RAPIDS, MICHIGAN

**STORMWATER FACILITY  
UNDERDRAIN PIPE  
RISERS IN  
BIORETENTION**

<b>G</b> <b>52</b>	APPROVED	
	DRAWN	CHECKED
	CITY ENGINEER	DATE
		SCALE: N.T.S.



**DETAIL C**  
**UNDERDRAIN AND BEDDING**  
**CONNECTION**

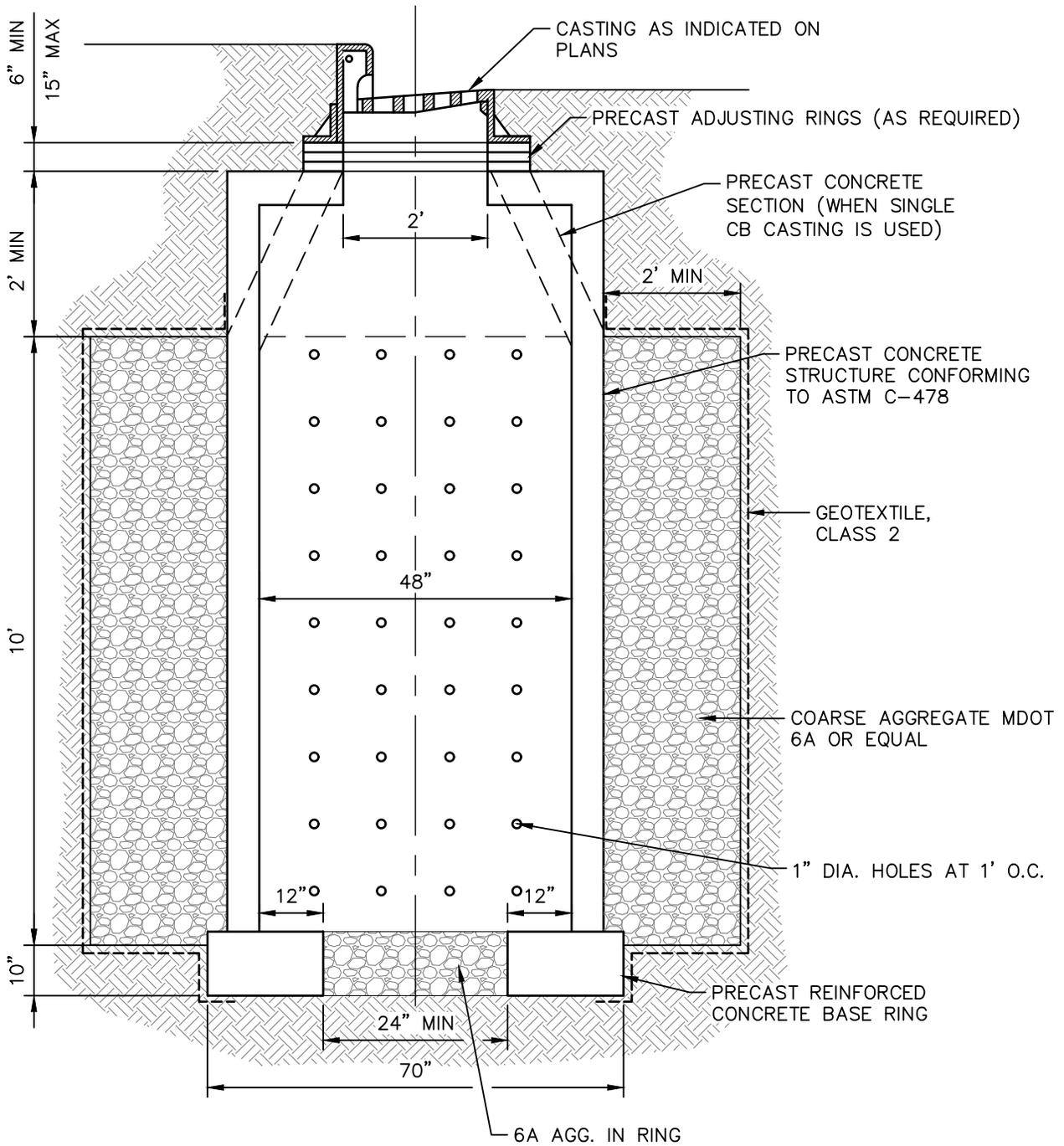
**NOTES**

1. CATCH BASIN CONNECTIONS FROM UNDERDRAINS SERVICING PRIVATE PROPERTY ARE PROHIBITED.
2. WHEN STORMWATER FACILITY IS LOCATED MORE THAN 10 FEET FROM CATCH BASIN, PROVIDE ADDITIONAL CLEANOUT OUTSIDE OF STORMWATER FACILITY WITHIN 10 FEET OF CATCH BASIN.
3. STORMWATER FACILITY DEPICTED IS BIORETENTION FACILITY. CONNECTIONS TO CATCH BASIN WILL ALSO APPLY TO PERMEABLE PAVEMENTS AND LINEAR BIORETENTION SYSTEMS WITH UNDERDRAINS.
4. OPTIONAL PVC GATE VALVE OR PVC PIPE CAP TO BE USED TO REGULATE FLOW IN UNDERDRAIN PIPE AS INDICATED IN DESIGN PLANS. VALVE MAY ALSO BE USED IN OVERFLOW RISER AS DIRECTED.
5. WHEN CONNECTING TO A COMBINED SEWER SYSTEM, A BACKFLOW VALVE WITH SERVICE ACCESS EXTENSION IS REQUIRED AT CONNECTION BETWEEN PERFORATED AND NON-PERFORATED PIPE.

CITY OF GRAND RAPIDS, MICHIGAN

**STORMWATER FACILITY**  
**UNDERDRAIN BEDDING**  
**AND CATCH BASIN**  
**CONNECTION**

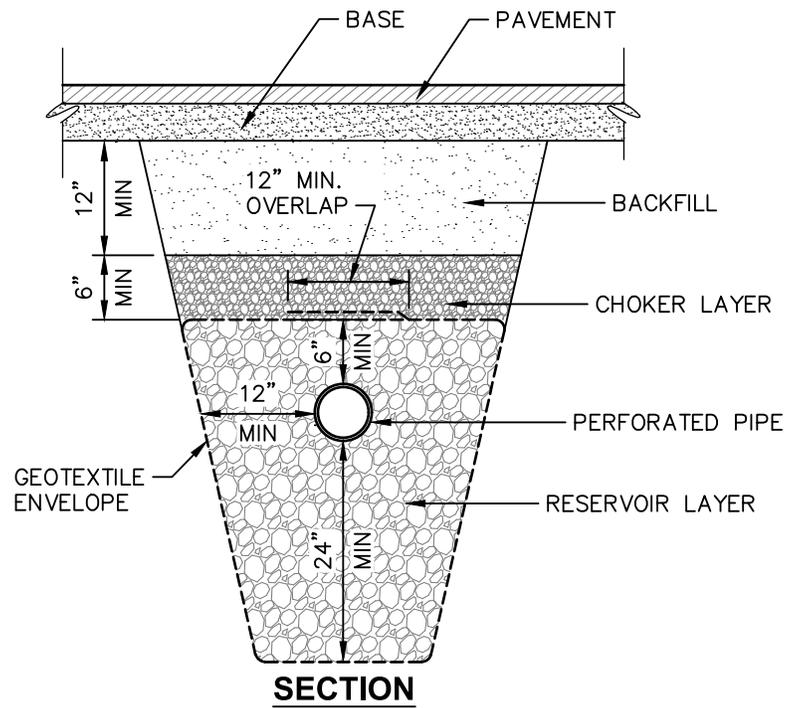
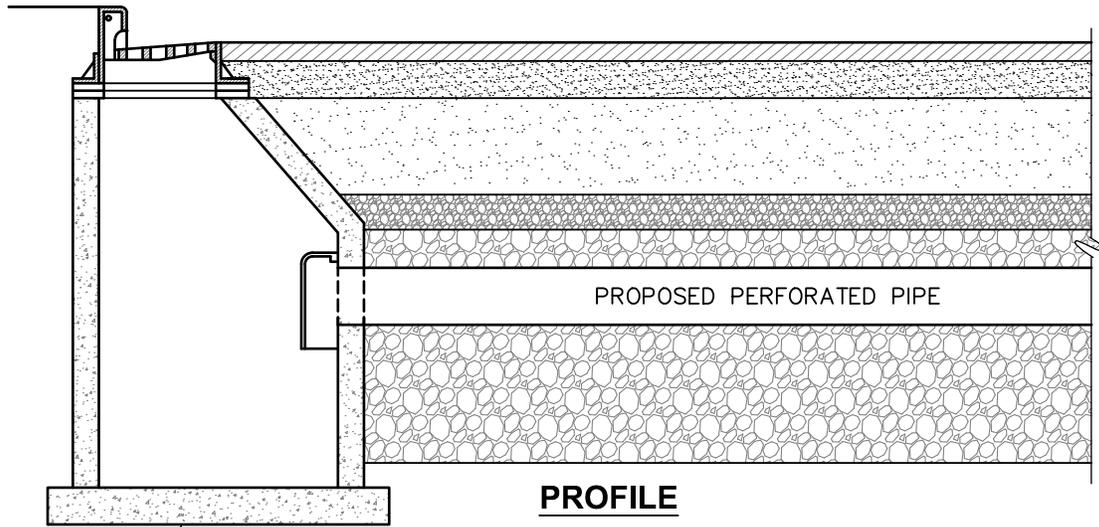
<p><b>G</b> <b>53</b></p>	<p>APPROVED</p>	<p>DATE</p>
<p>DRAWN</p>	<p>CITY ENGINEER CHECKED</p>	<p>SCALE: N.T.S.</p>



CITY OF GRAND RAPIDS, MICHIGAN

## LEACHING BASIN

<b>G</b> <b>54</b>	APPROVED		DATE
	DRAWN	CITY ENGINEER CHECKED	SCALE: N.T.S.

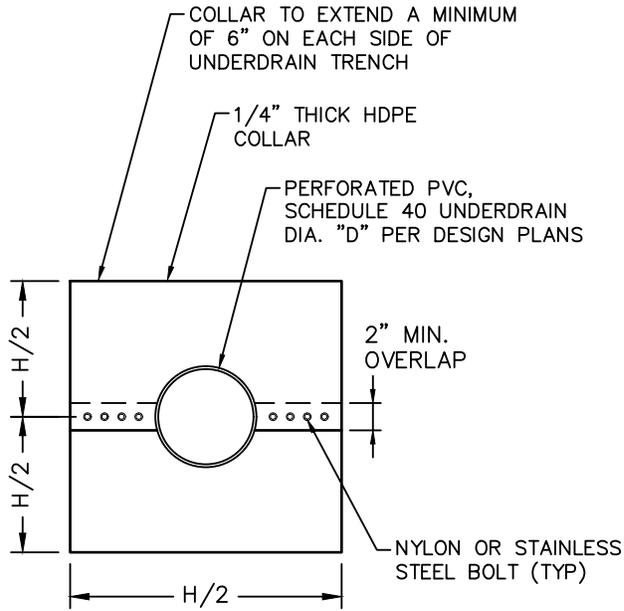


ITEM	MATERIAL	LAYER THICKNESS
CHOKER LAYER	MDOT 6AA OR 4G, AASHTO #57 OR APPROVED EQUIVALENT.	_ INCH
RESERVOIR LAYER	MDOT 4AA, 6AA, OR 4G, AASHTO #2, #3 OR #57 OR APPROVED EQUIVALENT.	_ INCH
GEOTEXTILE	GEOTEXTILE CLASS 2, LOCATED ON SIDES OF FACILITY ONLY.	

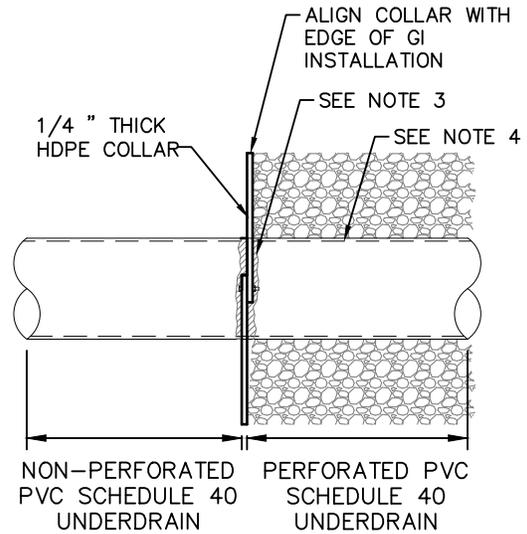
CITY OF GRAND RAPIDS, MICHIGAN

## EXFILTRATION TRENCH

<b>G</b> <b>55</b>	APPROVED	
	DRAWN	DATE
	CITY ENGINEER	CHECKED
	SCALE:	N.T.S.



**SECTION  
ANTI-SEEP COLLAR**



**DETAIL A  
UNDERDRAIN CONNECTION WITH  
ANTI-SEEP COLLAR**

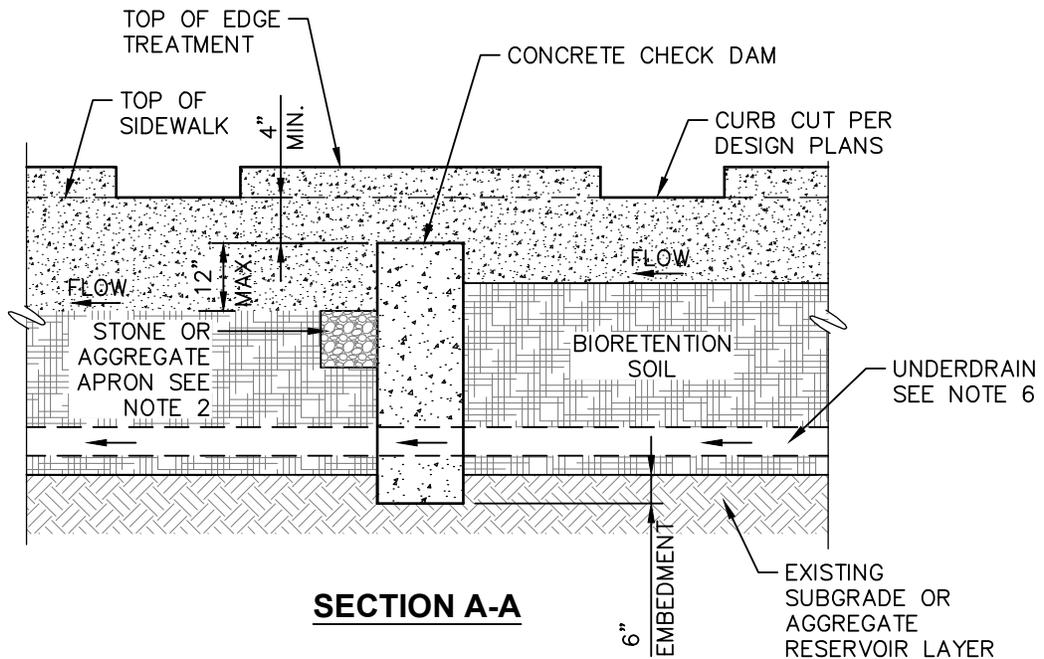
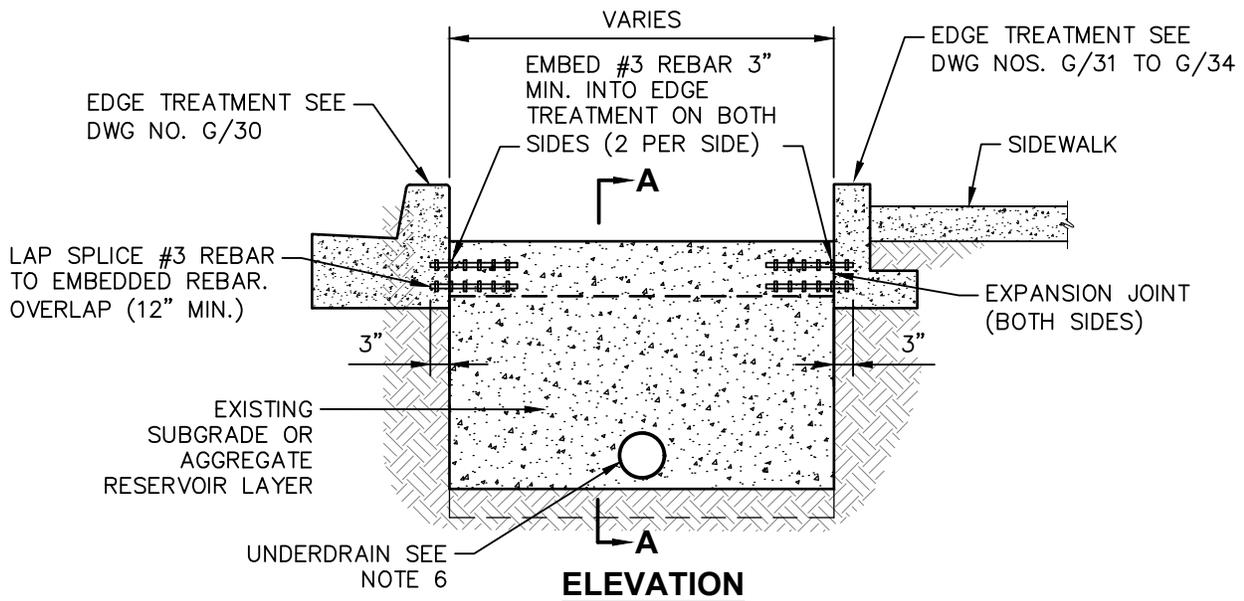
**NOTES:**

1. DIMENSION "H" SHALL BE MINIMUM OF 3X THE DIAMETER OF THE INTERSECTION PIPE.
2. COLLAR SHALL BE CONSTRUCTED OF HDPE OR EQUAL MATERIAL SPECIFIED BY ENGINEER. BOLTS SHALL BE GRADE 304 STAINLESS STEEL OR BETTER/
3. SEAL SURFACE OF PIPE AND ANTI-SEEP COLLAR WITH NON-SHRINK FLEXIBLE SEALANT THAT WILL ADHERE TO PIPE.
4. PIPE MATERIAL AND SIZING WILL VARY BY FUNCTION.

CITY OF GRAND RAPIDS, MICHIGAN

**STORMWATER FACILITY  
ANTI-SEEP COLLAR**

<b>G</b> <b>56</b>	APPROVED	
	DRAWN	DATE
	CITY ENGINEER	CHECKED
		SCALE: N.T.S.



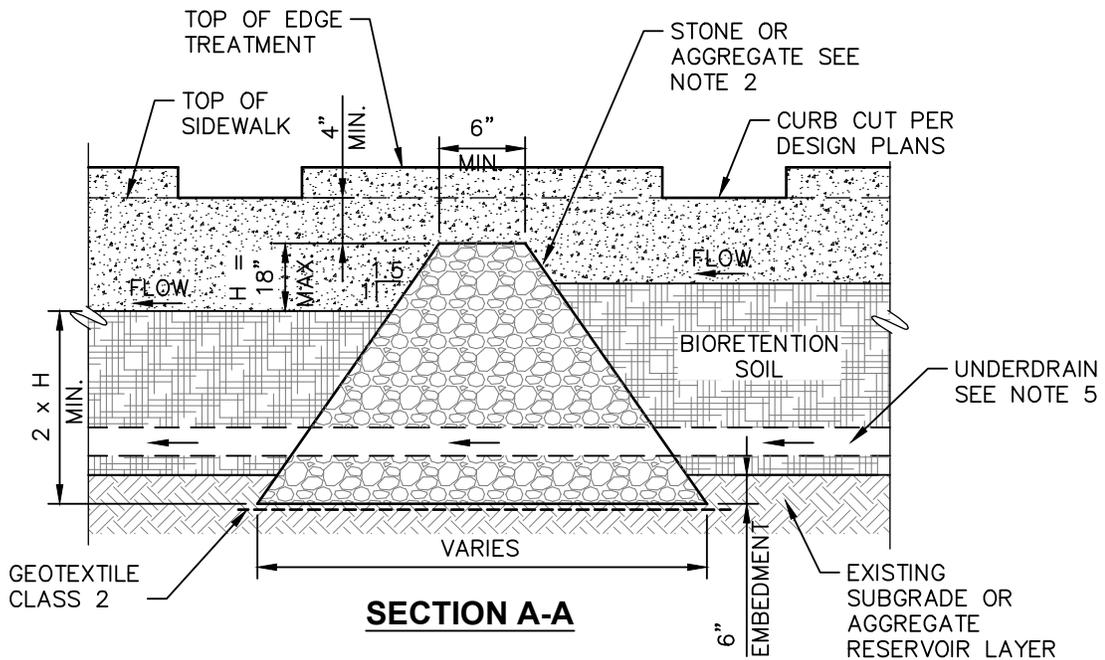
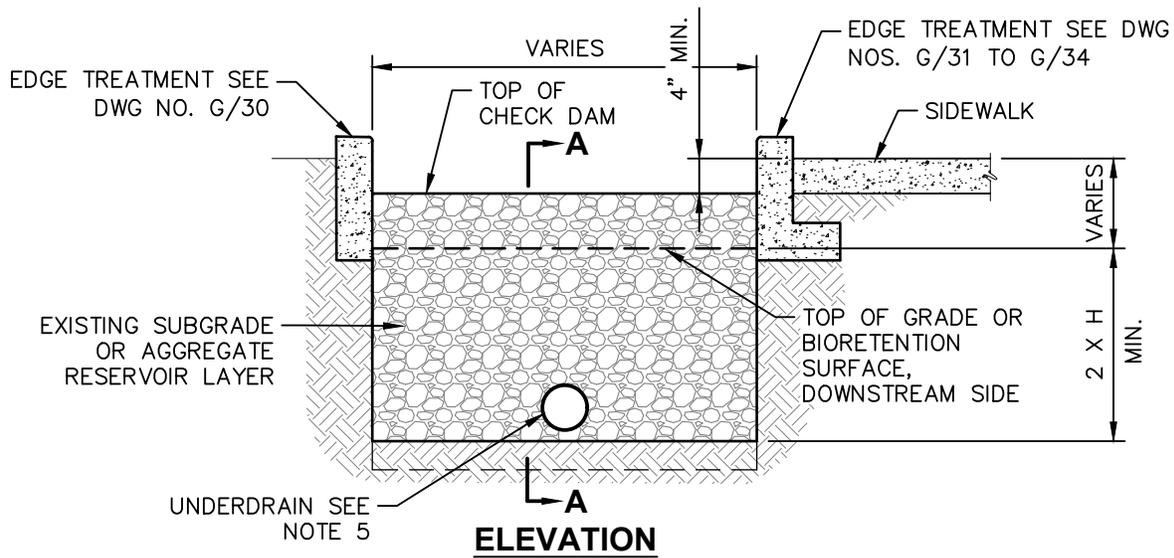
**NOTES**

1. LOCATIONS, HEIGHTS, AND WIDTHS OF CHECK DAMS TO BE SPECIFIED IN THE DESIGN PLANS.
2. SIZE OF STONE OR AGGREGATE APRON TO BE SPECIFIED IN THE DESIGN PLANS.
3. CONCRETE CHECK DAM SHALL BE CONTINUOUS (NO JOINTS).
4. THIS CHECK DAM MAY BE USED IN PLANTERS OR CURB BULB-OUTS.
5. DEPTH OF CHECK DAM VARIES DEPENDING ON DEPTH OF THE FACILITY.
6. IF PRESENT, UNDERDRAIN TO PASS THROUGH CHECK DAM IN A NON-PERFORATED PVC PIPE.

CITY OF GRAND RAPIDS, MICHIGAN

**CONCRETE CHECK DAM**

<b>G</b> <b>60</b>	APPROVED		DATE
	DRAWN	CITY ENGINEER CHECKED	SCALE: N.T.S.



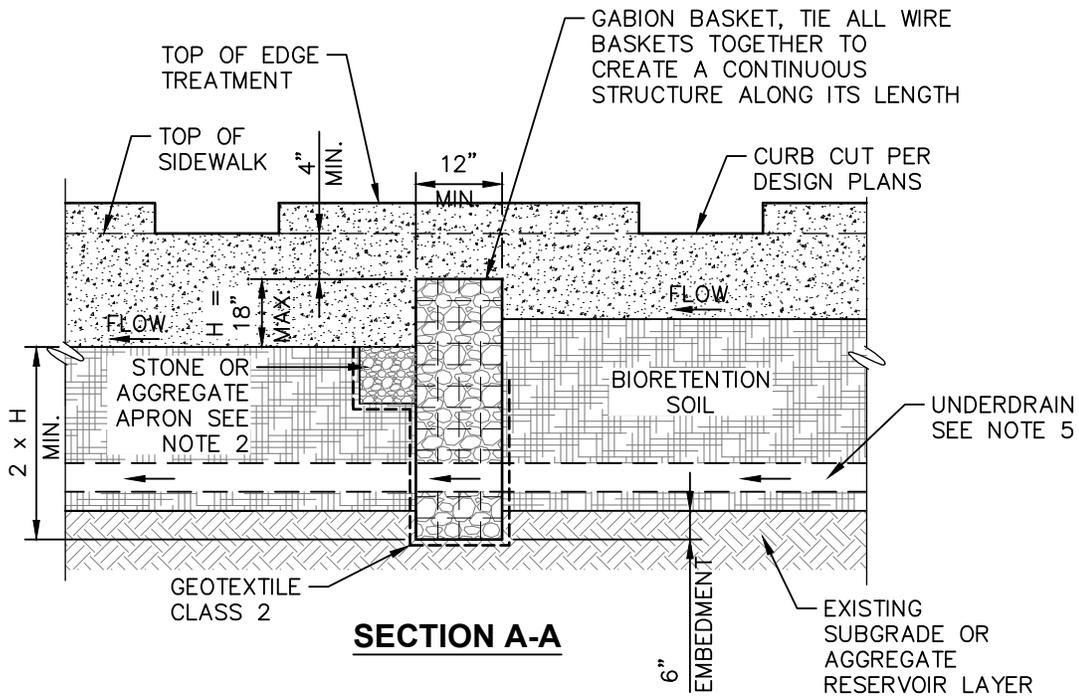
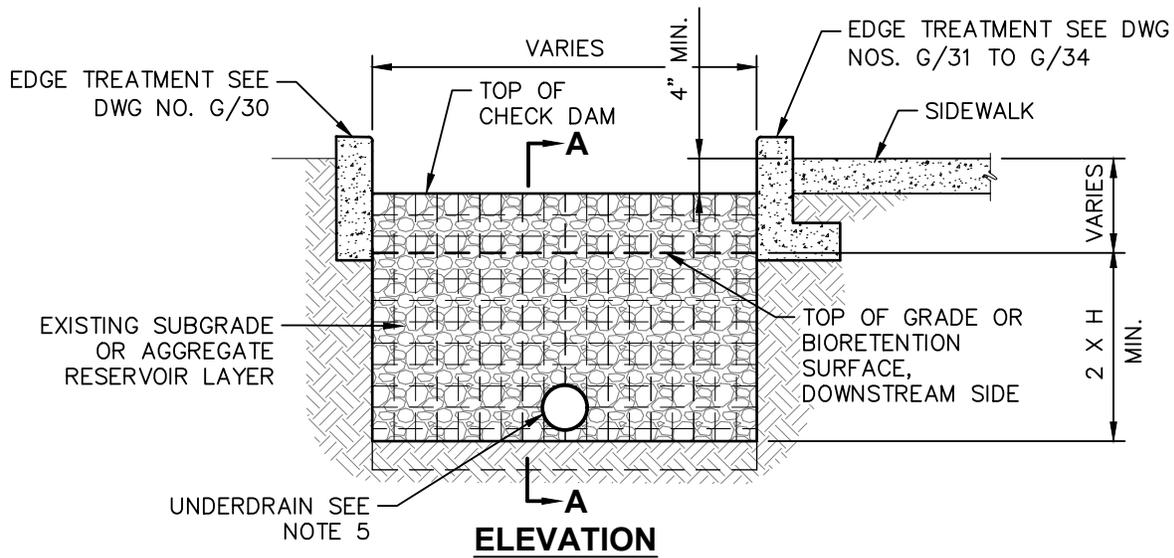
**NOTES**

1. LOCATIONS, HEIGHTS, AND WIDTHS OF CHECK DAMS TO BE SPECIFIED IN THE DESIGN PLANS.
2. SIZE OF STONE OR AGGREGATE APRON TO BE SPECIFIED IN THE DESIGN PLANS.
3. THIS CHECK DAM MAY BE USED IN LINEAR BIORETENTION, PLANTERS, AND CURB BULB-OUTS.
4. DEPTH OF CHECK DAM VARIES DEPENDING ON DEPTH OF THE FACILITY.
5. IF PRESENT, UNDERDRAIN TO PASS THROUGH CHECK DAM IN A NON-PERFORATED PVC PIPE.

CITY OF GRAND RAPIDS, MICHIGAN

**ROCK CHECK DAM  
SLOPED**

<b>G</b> <b>61</b>	APPROVED		DATE
	DRAWN	CITY ENGINEER CHECKED	SCALE: N.T.S.



**NOTES**

1. LOCATIONS, HEIGHTS, AND WIDTHS OF CHECK DAMS TO BE SPECIFIED IN THE DESIGN PLANS.
2. SIZE OF STONE OR AGGREGATE APRON TO BE SPECIFIED IN THE DESIGN PLANS.
3. THIS CHECK DAM MAY BE USED IN LINEAR BIORETENTION, PLANTERS, AND CURB BULB-OUTS.
4. DEPTH OF CHECK DAM VARIES DEPENDING ON DEPTH OF THE FACILITY.
5. IF PRESENT, UNDERDRAIN TO PASS THROUGH CHECK DAM IN A NON-PERFORATED PVC PIPE.

CITY OF GRAND RAPIDS, MICHIGAN

**ROCK CHECK DAM  
GABION BASKET**

<b>G 62</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.

4"X4"X24" BRACKETS  
SEE NOTES 4 AND 5

EDGE TREATMENT SEE  
DWG NOS. G/31 TO G/34

VARIABLES

UNDERDRAIN  
SEE NOTE 8

FLOW

2"X12" BOARDS  
SEE NOTE 3

12" MIN 2"

**PLAN**

TOP OF EDGE  
TREATMENT

TOP OF  
SIDEWALK

4" MIN.

CURB CUT PER  
DESIGN PLANS

STAINLESS STEEL  
ROUND HEAD  
BOLT

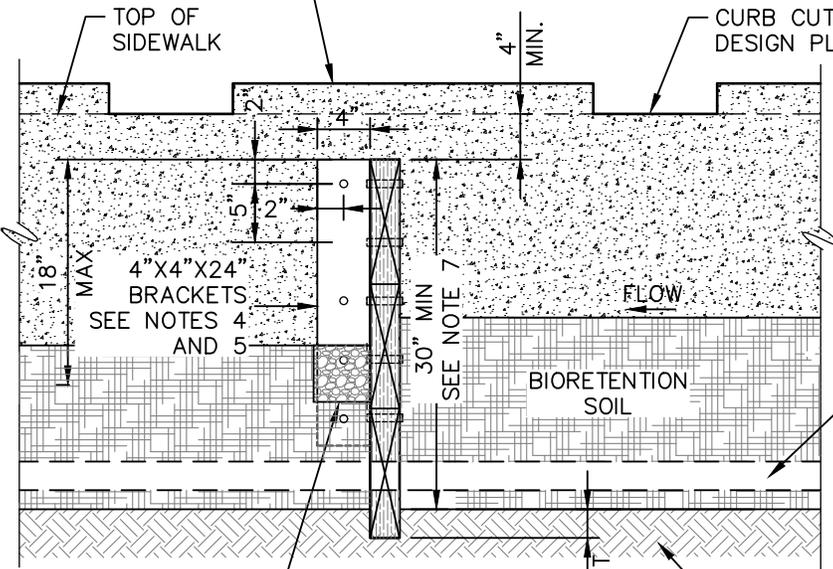
2"X12" LUMBER  
STAINLESS  
STEEL  
WASHER

STAINLESS  
STEEL  
NUT

4"X4"X24"  
BRACKET SEE  
NOTES 4 AND 5

OVERSIZED  
HOLE (3/8"  
DIA.)

**LUMBER BOLTING  
DETAIL**



**SECTION A-A**

STONE OR AGGREGATE  
APRON SEE NOTE 2

6" EMBEDMENT

EXISTING  
SUBGRADE OR  
AGGREGATE  
RESERVOIR LAYER

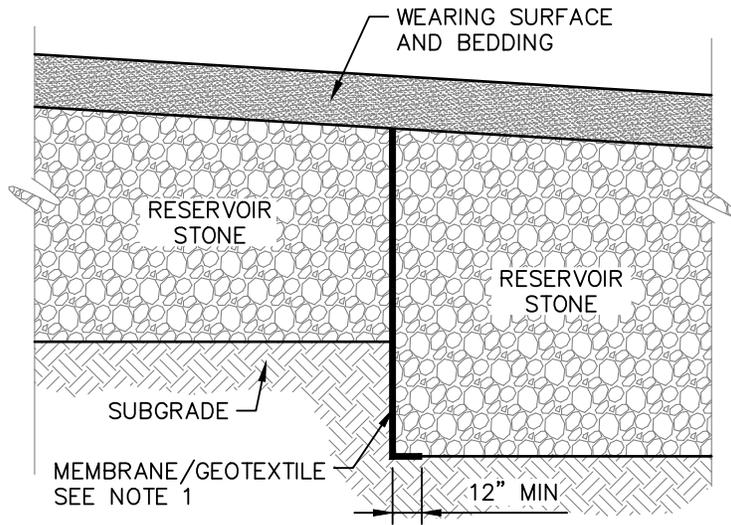
**NOTES**

1. LOCATIONS, HEIGHTS, AND WIDTHS OF CHECK DAMS TO BE SPECIFIED IN THE DESIGN PLANS.
2. SIZE OF STONE OR AGGREGATE APRON TO BE SPECIFIED IN THE DESIGN PLANS.
3. LUMBER TO BE A NATURALLY ROT-RESISTANT WOOD (E.G. CEDAR). MANUFACTURED PRODUCTS CAN BE USED WITH APPROVAL. NO CHEMICALLY TREATED WOOD WILL BE ALLOWED.
4. ALL FASTENERS TO BE STAINLESS STEEL OR GALVANIZED. BOLTS TO BE 5/16 INCH DIAMETER.
5. BRACKET TO BE MADE OF MIN. 3/16 INCH STAINLESS STEEL OR ALUMINUM. TOP OF BRACKET TO BE NO HIGHER THAN TOP OF CHECK DAM.
6. THIS CHECK DAM MAY BE USED IN BIORETENTION PLANTERS OR CURB BULB-OUTS.
7. DEPTH OF CHECK DAM VARIES DEPENDING ON THE DEPTH OF THE FACILITY.
8. IF PRESENT, UNDERDRAIN TO PASS THROUGH CHECK DAM IN A NON-PERFORATED PVC PIPE. GAPS AROUND PIPE TO BE FILLED WITH POLYURETHANE FOAM.

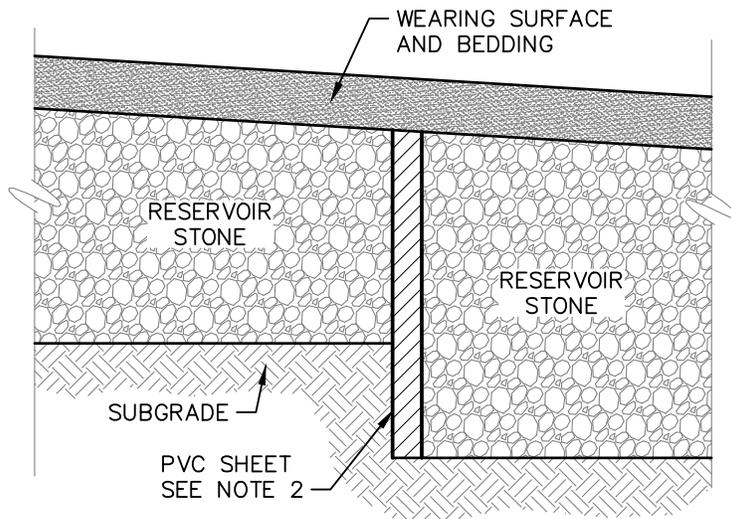
CITY OF GRAND RAPIDS, MICHIGAN

**LUMBER CHECK DAM**

<b>G</b> <b>63</b>	APPROVED	
	CITY ENGINEER	DATE
DRAWN	CHECKED	SCALE: N.T.S.



**MEMBRANE/GEOTEXTILE CHECK DAM**



**PVC SHEET CHECK DAM**

NOTES

1. WATERPROOF MEMBRANE OR LOW PERMEABILITY GEOTEXTILE (PERMEABILITY OF 0.05 SEC OR LESS).
2. SHEET TO BE 3/8 INCH PVC SHEET TYPE I, GRAY.

CITY OF GRAND RAPIDS, MICHIGAN

**ALTERNATE  
PERMEABLE PAVEMENT  
CHECK DAM**

<b>G</b> <b>64</b>	APPROVED	
	DRAWN	DATE
	CITY ENGINEER	CHECKED
	SCALE:	N.T.S.

DO NOT PRUNE TERMINAL LEADER OR BRANCH TIPS

PRUNE AWAY DEAD OR BROKEN BRANCHES ONLY

REMOVE NURSERY APPLIED TREE WRAP

MULCH 3" DEEP. TAPER MULCH AT TRUNK LEAVING A 3" CIRCLE OF BARE SOIL AROUND TRUNK OF TREE

BREAK UP (SCARIFY) SIDES OF PLANTING HOLE

REMOVE ALL WIRE, STRINGS AND OTHER NON-BIODEGRADABLE MATERIALS ONCE ROOT BALL IS PLACED IN HOLE. REMOVE BURLAP FROM TOP 2/3 OF BALL. CUT AND SPREAD ROOTS TO ELIMINATE ROOT CIRCLING FROM CONTAINER STOCK

**NOTES:**

1. MINIMIZE DAMAGE TO BALLED AND BURLAP ROOT BALLS DURING PLANTING.
2. SET TREE VERTICAL REGARDLESS OF FINISH GRADE SLOPE.
3. FORM 3" TO 4" HIGH WATERING RING WITH SOIL AND COVER WITH MULCH AS SHOWN.
4. BACKFILL HOLE HALF FULL OF NATIVE SOIL AND NO AMENDMENTS. TAMP SOIL TO STABILIZE ROOT BALL. FINISH BACKFILLING AND TAMP AGAIN. TREES OF 3" CALIPER OR LARGER SHOULD BE BACKFILLED AND TAMPED IN 3 EQUAL LEVELS.
5. WATER ONLY AFTER PLANTING IS COMPLETED.

PRUNE SUCKERS

BRUSH AWAY EXCESS SOIL AT TOP OF ROOT BALL TO EXPOSE BASE OF ROOT CROWN. PLANT ROOT BALL WITH BASE OF ROOT CROWN LEVEL WITH EXISTING GRADE OR UP TO 1" ABOVE GRADE IN HEAVY OR HIGHLY COMPACTED SOIL.

FORM WATERING RING AT OUTER EDGE OF PLANTING HOLE

UNAMENDED BACKFILL SOIL, OR COMPOST AMENDED BIOSWALE SOIL - FINE GRADE. SEE PLAN FOR LOCATIONS.

DEPRESSED AREA FOR DRAINAGE

LEAVE SOIL PEDESTAL EQUAL TO WIDTH OF ROOT BALL. DO NOT DIG DEEPER THAN BALL DEPTH AS MEASURED FROM BASE OF ROOT CROWN TO BOTTOM OF BALL. MEASURE BEFORE DIGGING TO AVOID OVER EXCAVATION.

2 TIMES ROOT BALL DIAMETER

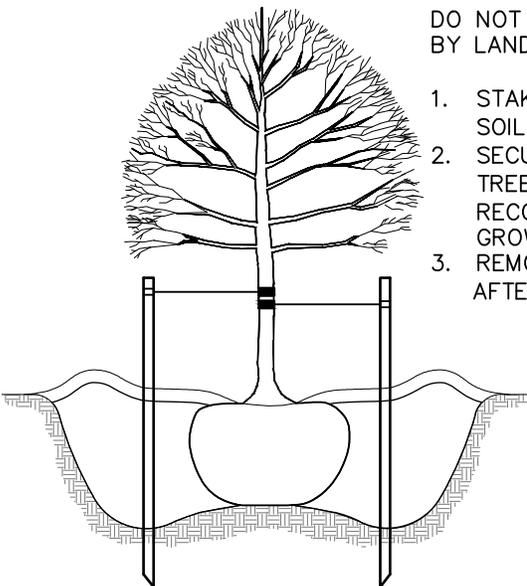
3 TIMES ROOT BALL DIAMETER

DO NOT STAKE UNLESS IN HEAVY CLAY SOILS OR WINDY CONDITIONS ARE DETERMINED BY LANDSCAPE ARCHITECT. IF STAKING IS REQUIRED:

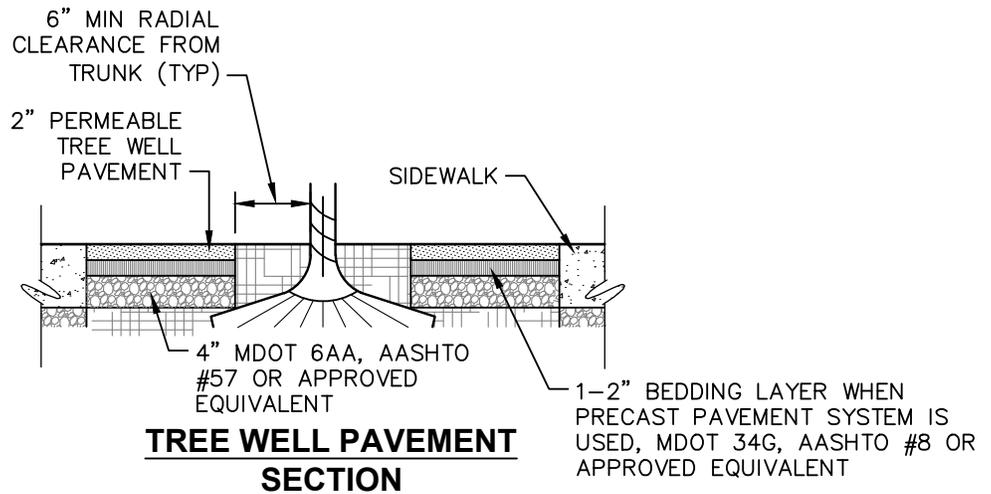
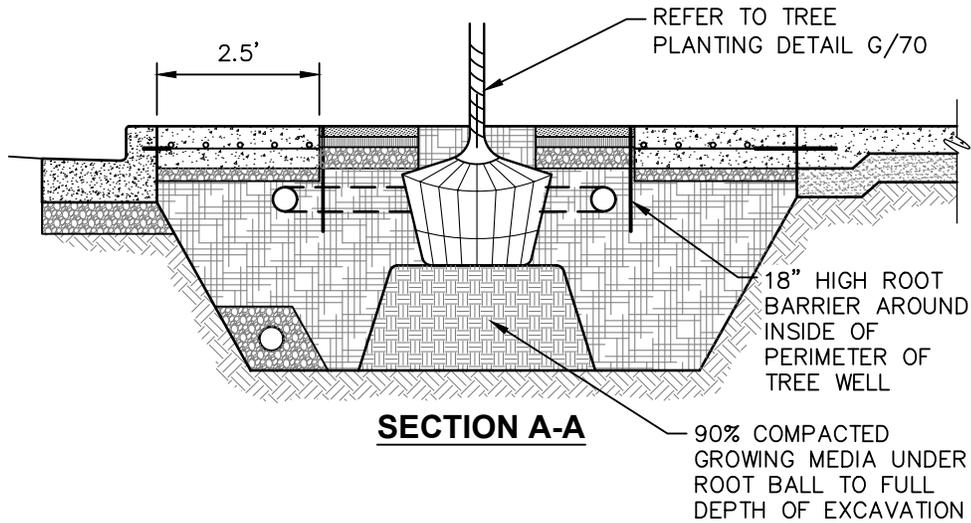
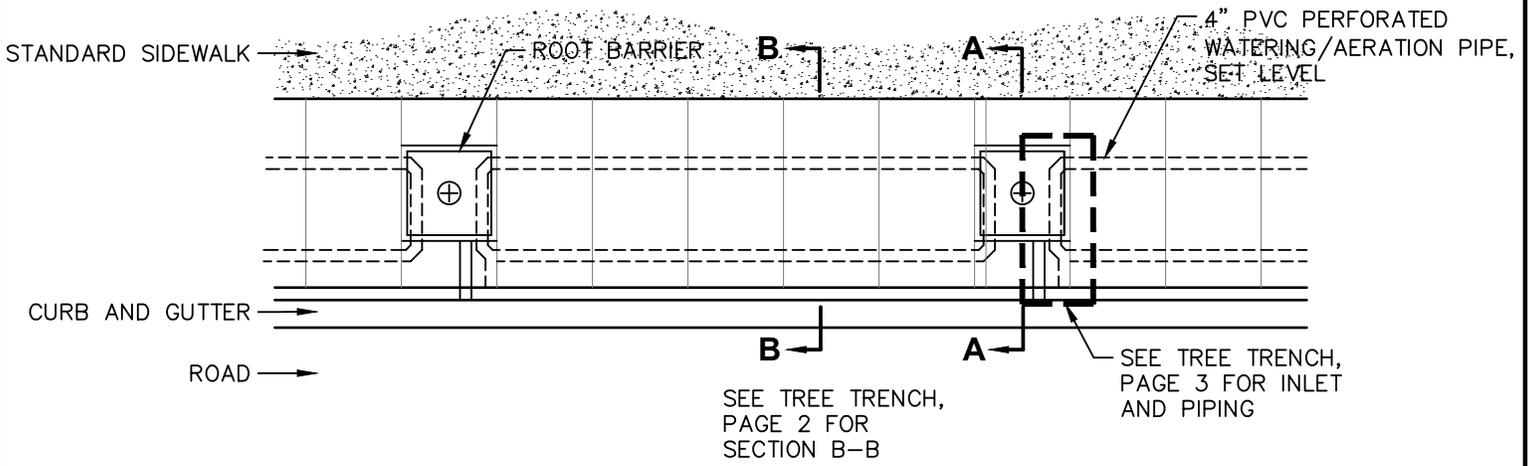
1. STAKE WITH 2"x2" HARDWOOD STAKES OR APPROVED METAL POST DRIVEN INTO SOIL OUTSIDE OF ROOT BALL, (3) PER TREE.
2. SECURE TO TREE USING 1" 'CHAINLOCK' OR LANDSCAPE ARCHITECT APPROVED TREE TIE MATERIAL. SECURE TREE TIE MATERIAL TO STAKE PER MANUFACTURER'S RECOMMENDATIONS. LOOP TIE AROUND TREE TO PROVIDE 1" SLACK FOR TRUNK GROWTH.
3. REMOVE ALL STAKING MATERIAL AFTER (1) YEAR.

CITY OF GRAND RAPIDS, MICHIGAN

**TREE PLANTING**



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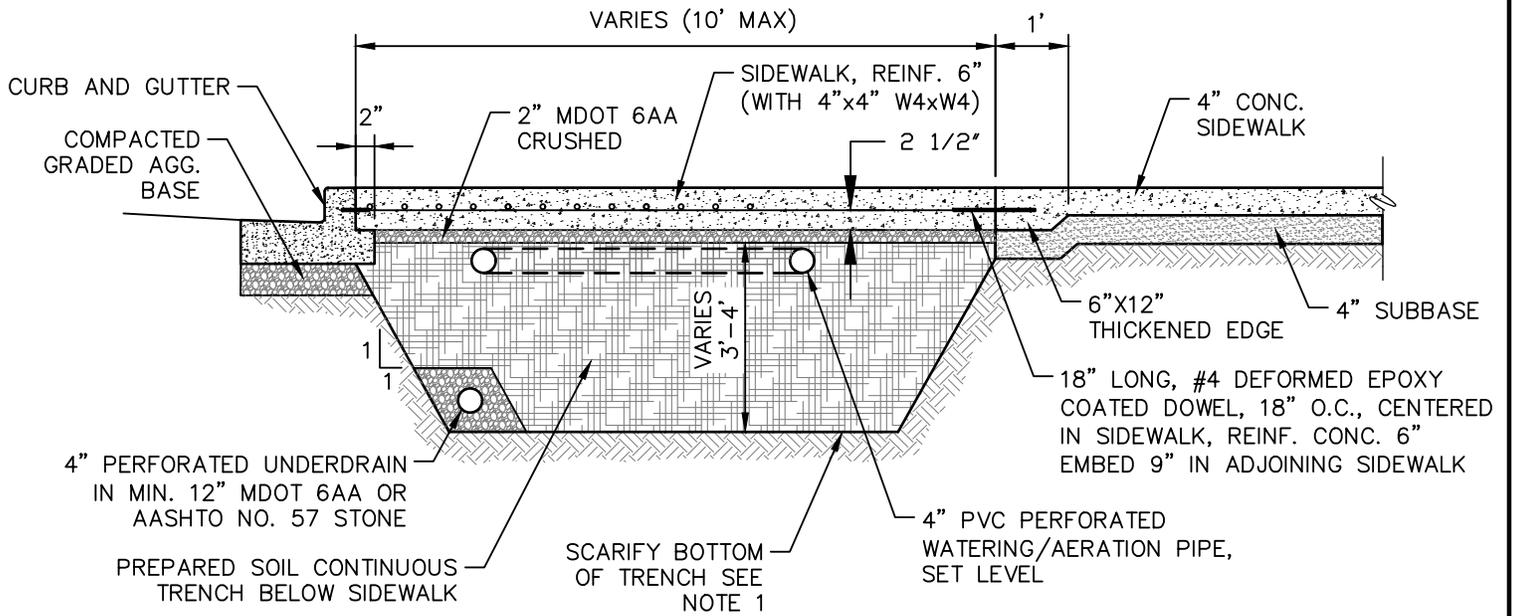


- NOTES
1. LOOSEN OR TILL THE SUBSOIL OF THE SUBGRADE TO A DEPTH OF 3" TO 6" WITH BACKHOE OR SUITABLE DEVICE.
  2. SPREAD A LAYER OF GROWING MEDIUM 3" TO 6" OVER SUBGRADE. THOROUGHLY TILL THE SUBGRADE AND GROWING MEDIUM TOGETHER.
  3. INSTALL AND LIGHTLY COMPACT THE REMAINING GROWING MEDIUM IN 12" TO 16" LIFTS TO THE REQUIRED DEPTHS.
  4. LIGHTLY COMPACT EACH LIFT TO ACHIEVE THE FOLLOWING TEST RESULTS. GROWING MEDIUM COMPACTION SHALL BE TESTED AT EACH LIFT USING A CONE PENETROMETER TO BETWEEN 100 AND 200 PSI WHEN SOIL IS BETWEEN 12% AND 20% MOISTURE.
  5. PROTECT THE INSTALLED GROWING MEDIUM, FROM FURTHER COMPACTION DURING THE INSTALLATION OF THE PAVING ABOVE.

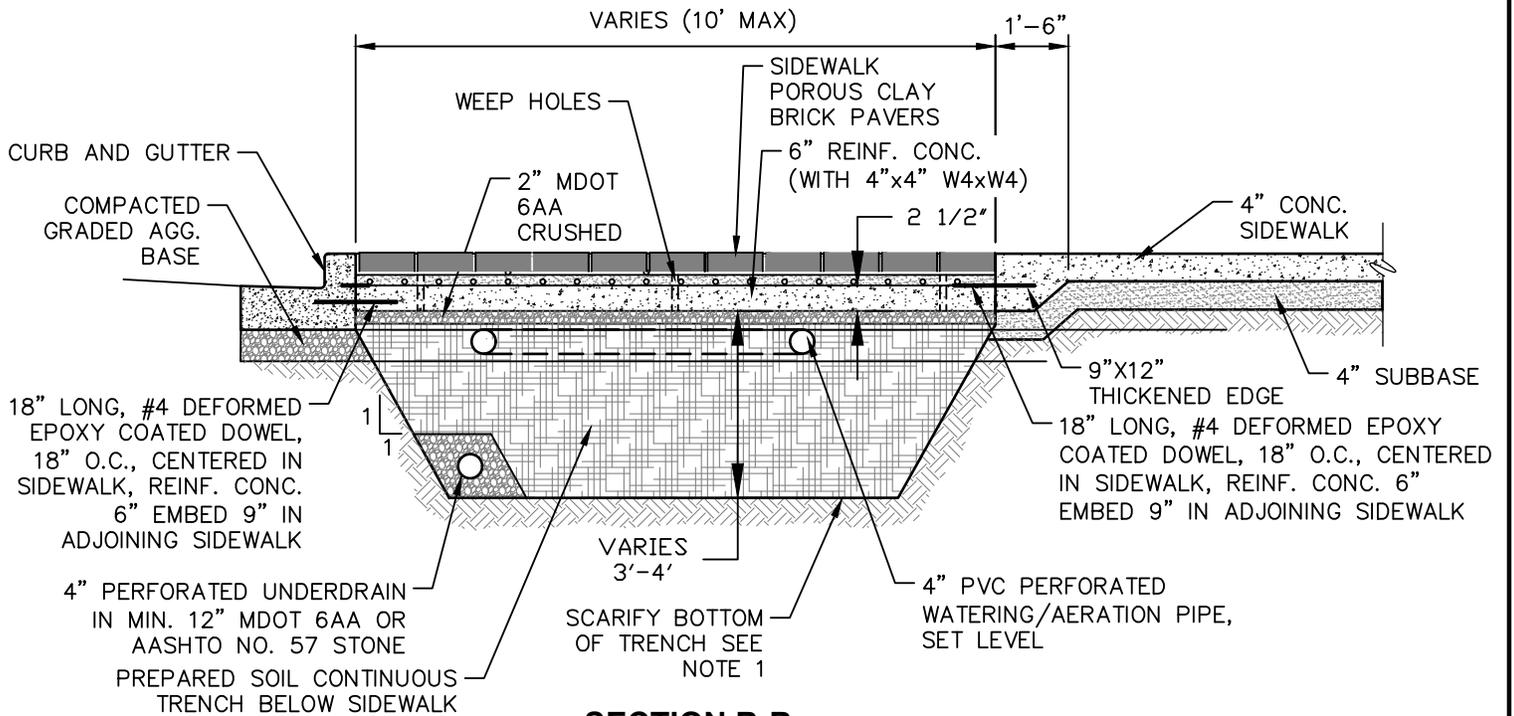
CITY OF GRAND RAPIDS, MICHIGAN

**TREE TRENCH  
PAGE 1**

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**SECTION B-B  
REINFORCED 6" CONCRETE SIDEWALK**



**SECTION B-B  
POROUS CLAY BRICK PAVER SIDEWALK**

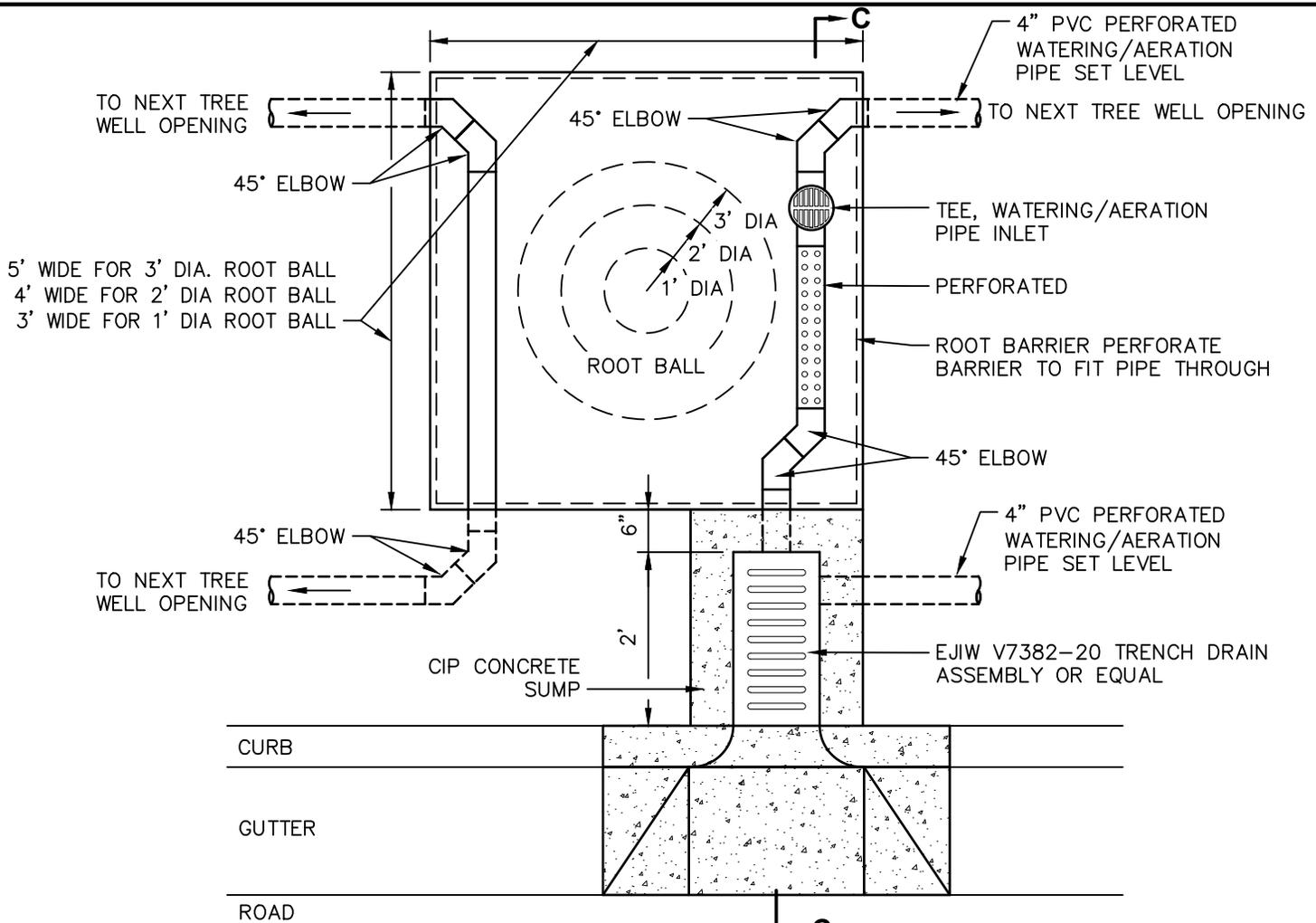
**NOTES**

1. LOOSEN OR TILL THE SUBSOIL OF THE SUBGRADE TO A DEPTH OF 3" TO 6" WITH BACKHOE OR SUITABLE DEVICE.
2. WELDED WIRE FABRIC STRENGTH = 70,000 PSI (ASTM A497)
3. STRUCTURAL SLAB LIVE LOADING = 100 PSI

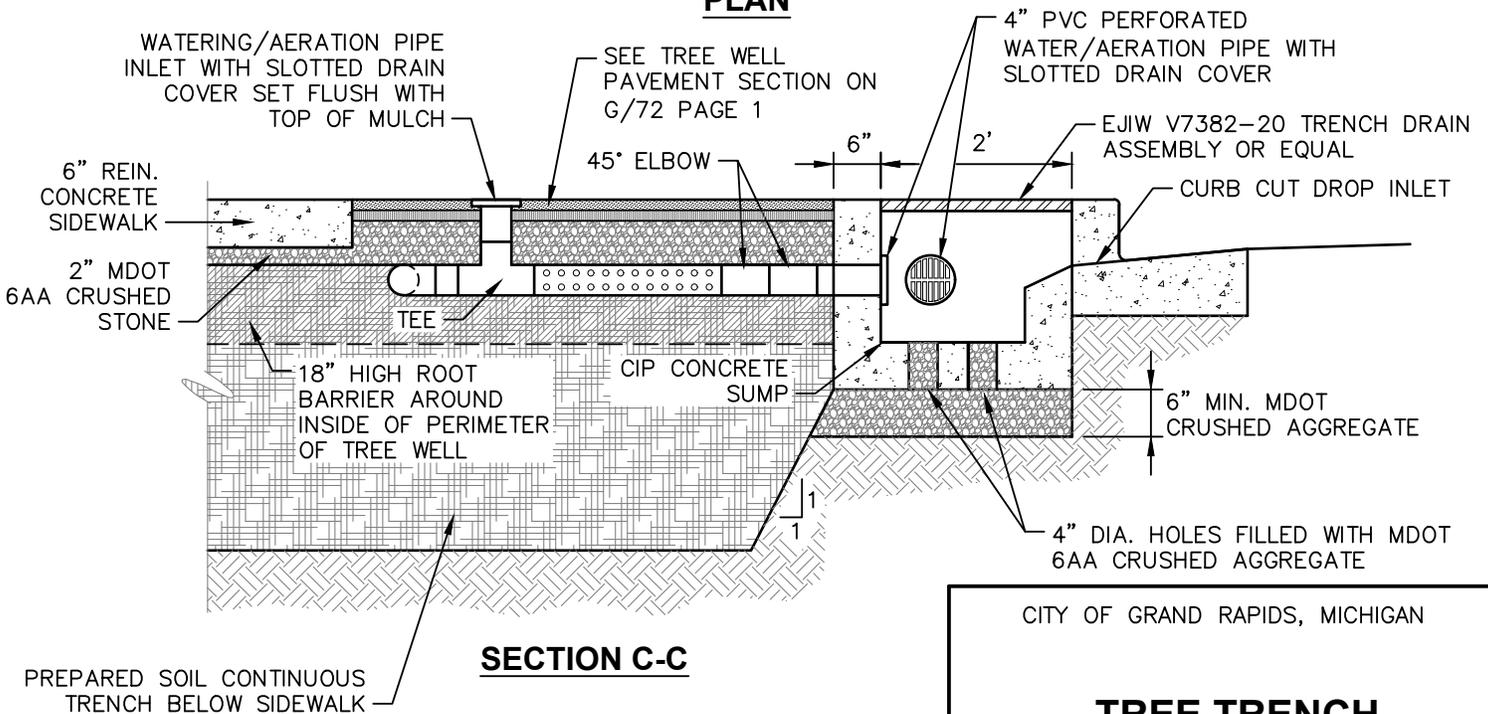
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**PLAN**



**SECTION C-C**

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