

APPENDIX F

Standard Drainage Specifications

Streets shall be designed so that storm water is directed to inlets. Streets shall not be used to collect and convey storm water runoff other than that which falls on the street or on a lot near/along the street or along the side/rear lot lines.

Subdivision Drainage Requirements – Each lot shall have access to a drainage system. Lots shall be laid out so as to provide positive drainage away from all buildings, and individual lot drainage shall be coordinated with the general topographic drainage pattern. Storm water runoff shall be designed so as to avoid concentrated runoff from any lot onto adjacent lots, unless the runoff is in a designed conveyance system. Lots shall be graded to allow the overall drainage system to perform as designed and avoid damage to critical structures. Critical structures shall be defined as crawl space openings, garage, finished floor and HVAC units.

Subdivision/Site Detention Requirements – ~~Detention pond design requirements for the City of Forest Hills mirror the requirements shown in the Metro Nashville Stormwater Management Manual, Volume 2, Section 8.1 and its references. Detention ponds may be designed as dual-purpose facilities to meet both water quality/infiltration requirements and water quantity/volume control requirements. Detention & retention facilities or other flow attenuation methods can be used to protect downstream properties from flood increases and to reduce discharges that exceed the capacity of natural waterways. Retention & detention ponds shall be designed to limit the rate of runoff from the site and temporarily store the excess volume. A minimum contributing drainage area of 10 acres is recommended to sustain a permanent micro-pool to protect against clogging.~~

~~These facilities shall be sized such that the post-development peak discharge rate is less than or equal to the pre-development peak discharge rate for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year design storms. Rainfall data shall be taken from NOAA Atlas 14, and a 24-hour storm duration shall be used. The facilities shall be designed such that the cumulative post-development discharge volume is less than or equal to the cumulative pre-development discharge volume during the critical time for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year design storms. The critical time shall be between the hours of 11 and 18 of the 24-hour design storm unless otherwise specified by a Town accepted watershed plan. Tabular (time-series) hydrograph data, a summary table of discharges, and a comparison of storage volume data shall be submitted in the stormwater management report. These facilities' design shall meet requirements for both water quality/infiltration and water quantity/volume control.~~

Design: ~~The maximum storage depth of the detention pond shall not exceed 5 feet with a minimum 1-foot freeboard and side slope not steeper than 3:1 around the pond parameter for safety and vegetative purposes. The minimum length-to-width ratio is 3:1. Turf reinforcement matting shall be installed on all detention pond slopes for erosion control purposes. A minimum of one (1) foot of freeboard must be provided, measured~~

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from the top of the water surface elevation for the 100-year storm to the lowest point of the dam embankment, not counting the emergency spillway. Exemptions will be considered on a case-by-case basis. Retaining walls will not be permitted to be used as part of the detention pond design in highly visible basin areas including locations at development entrances, adjacent to primary or secondary roads, or directly behind proposed homes.

Low flow/Pilot Channel Design: Areas above the normal high-water elevation of detention/retention facilities should be sloped at a minimum of 5% toward the facilities to allow positive drainage and to prevent standing water, except in areas designed to control flow such as landscaped swales and biofilters.

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The bottom area of dry detention/retention facilities should be graded toward the outlet to prevent standing water conditions. A minimum of two (2) percent bottom slope is recommended. Concrete-lined low-flow or pilot channels constructed across the facility bottom from the inlet to the outlet are not preferred. Low flows should be distributed evenly into sheet flow across the bottom of the facility.

A low flow outlet should be sized considering the control of more frequent storm events, such as the 1-year-24-hour storm. The drawdown time of the pond must be greater than 24 hours and not exceed 72 hours preceded by no measurable rainfall.

Emergency spillway design: An emergency spillway and associated freeboard must be designed in accordance with applicable local or state dam safety requirements. The spillway opening must be designed and constructed with overflow capacity to safely pass the extreme flows (i.e., 100-year peak flow) through either the primary spillway or a vegetated or armored emergency spillway.

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Safety feature: The following safety features must be considered for storage practices:

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- The principal spillway opening must be designed and constructed to prevent access by small children.
- End walls above pipe outfalls greater than 48 inches in diameter must be fenced at the top of the wall to prevent a falling hazard.
- Storage practices must incorporate an additional 1 foot of freeboard above the emergency spillway, or 2 feet of freeboard if the design has no emergency spillway, for the maximum peak design flow unless more stringent state and local dam safety requirements apply.
- Both the safety bench and the aquatic bench should be landscaped with vegetation that hinders or prevents access to the pool.
- The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.

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- Underground maintenance access should be locked at all times.

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Other design requirements:

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- Areas above the normal high-water elevation of detention/retention facilities should be sloped at a minimum of 5% toward the facilities to allow drainage and to prevent standing water except in areas designed to control that flow such as landscape swales and biofilters. The bottom area of dry detention/retention facilities should be graded toward the outlet to prevent standing water conditions. A minimum of 2 percent bottom slope is recommended. Concrete-lined low-flow or pilot channels constructed across the facility bottom from the inlet to the outlet are not preferred. Low flows should be distributed evenly into sheet flow across the bottom of the facility.
- Detention and retention facilities shall not be in the right-of-way nor in the Waterway Natural Area.
- Detention and retention facilities shall only be located on commonly owned areas or parcels and shall not be located on parcels, or lots intended for single-family residential uses.
- Outlet Protection. Outlet velocities shall be checked, and the outlet ends of discharging pipes shall not result in velocities that equal or exceed the erosive velocity of the receiving channel unless energy dissipation and permanent erosion protection measures are placed at the outlet. Energy dissipation and erosion control devices shall have no overfall at the terminal end and shall discharge onto a stable section. The terminal section shall be considered stable if the terminal section design velocity is less than the erosive velocity. Refer to TDOT Design Division Drainage Manual and FHWA HEC-14 guidance for additional information on the design of energy dissipators. Rip-rap is not allowed at the inlet or outlet ends of culverts for velocity control unless approved by the Engineering Department. Timber outfall treatments or level spreaders shall not be used. Sufficient space downstream of discharge locations or outlet headwalls shall be provided to properly design and construct outlet protection devices within required drainage easements.

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Regional Detention Stormwater Facility: If practical, regional stormwater management practices for new development or redevelopment replacing/reducing the application of on-site stormwater management practices are encouraged at the discretion of the City Engineer at the following conditions: (i) serving 40 to 300 acres of tributary area, (ii) consistently and efficiently managed and maintained, and (iii). property site, downstream public and private properties, and infrastructure or waters of the state are adequately protected by the regional facility from stormwater quantity or quality impacts. As regional facilities, detention and retention facilities shall only be located in commonly owned areas or parcels, and shall not be located on parcels or lots intended for single-family residential uses.

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Major and Minor Drainage Systems - The major drainage system is the storm drainage system that conveys storm water runoff from a 100-year frequency storm event. The major drainage system usually includes features such as swales, ditches, and major drainage channels, creeks, or streams. Swales along property lines that convey storm water runoff in excess of the design event for culverts that convey roadway and cross drainage along property lines are also considered a component of the major drainage system. The major drainage system shall be designed so that water from a 100-year storm event is not allowed to encroach onto critical structures as defined above.

The minor drainage system is the storm drainage system that is typically used for collecting, transporting, and disposing of storm water runoff up to the design capacity of the system. The minor drainage system usually includes features such as curb and gutter, culverts, open drainage ways, or detention ponds. The major drainage system includes but is not limited to natural and man-made channels, large storm sewers (i.e., $\geq$ 54-inch diameter or equivalent), major culverts (i.e., cross-drains), bridges, and large water impoundments, overland relief swales, and infrequent floodplain storage. Swales along property lines that convey stormwater runoff events in excess of the design event and culverts that convey roadway and cross drainage along property lines are also considered components of the major drainage system. The major system shall be designed to pass the 100-year, 24-hour design flow, and meet the following conditions:

- The major system should provide relief such that no building is flooded with a 100-year design flow
- The major system shall be designed so that water from a 100-year storm event is not allowed to encroach onto critical structures (i.e., crawl space, garage, finished floor, and HVAC units)
- The man-made channels should be located as far away from buildings or structures as possible. The natural waterways should remain undisturbed, and improvements to natural open channels shall be designed without damage to the channel.
- The new roadways, existing roadways, and critical service roads shall not be inundated by more than three (3) inches of water over one-half the roadway width for a 100-year flood event.

Minor drainage system: The minor drainage system is typically used for collecting, transporting, and disposing of runoff and consists of features such as curb and gutter, roadway catch basin, connecting culverts, closed conduit, open channel system (i.e., diameter < 54-inch or equivalent), or detention ponds. The major system shall be designed to pass the 10-year, 24-hour design flow or as specified by the City Engineer, and meet the following conditions:

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- The analysis method for determining flows and system design to meet both volume and water quality requirements shall be determined by the Town Engineer.
- If the 10-year design flow for an open channel system is greater than 100 cfs (cubic feet per second), then the system shall be capable of passing the 100-year design flow within the drainage easement.
- Minor systems relying on sinkholes or drainage wells for discharge shall be capable of passing the 100-year design flow within the drainage easement, assuming plugged (0 cfs drawdown) conditions for the sinkhole.

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Specific design requirements:

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- Bridge is defined as a structure erected over a stream, watercourse, highway, railroad, or an opening with a length of more than 25 feet between the faces of end supports, measured along the centerline of the roadway.
- For designing bridges, channels, and cross-drains, calculations shall also be provided for the check event.
- Bridges shall be designed with a minimum of one (1) foot of freeboard between the minimum low chord elevation and the 100-year, 24-hour storm event water surface elevation. The design flow shall consider runoff from the total tributary area and will require stream channel routing, as appropriate.

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~~Analysis Methods~~ ~~The design engineer shall determine the appropriate analysis method for determining flow volumes and design of the drainage system. The rationale method shall be an acceptable method for peak flow estimating for watersheds less than one hundred (100) acres. The design engineer should be familiar with the limitations of each of the methods so that appropriate methods are applied. The City Engineer may require a particular method on critical portions of the drainage system.~~

~~Drainage and Hydrology Calculations~~ ~~Drainage and hydrology calculations shall be submitted with the construction plans. The calculations and provided documentation shall follow requirements in the City of Forest Hills Storm Water Ordinance Section 14-505. The City Engineer may require additional calculations for certain design situations.~~

Analysis Methods for Drainage and Hydrology Calculations: The developer or the developer's engineer should be familiar with the limitations of different hydrologic analysis methods so that the appropriate method is determined to estimate flow and for overall system design. The City Engineer may require a particular method for designing critical portions of the drainage system, and additional calculations for certain design situations.

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Considering peak runoff rates for design conditions is generally adequate for conveyance systems such as storm sewers or open channels. However, if the design includes flood routing (i.e., storage basins or complex conveyance networks and timing of peak runoff),

a volumetric flood hydrograph analysis utilizing the NRCS TR-55 method is generally required. Other acceptable methods for different conditions include, but are not limited to:

- The Rational Method can be used for the design of storm systems only (watersheds are less than 100 acres).
- NRCS/TR-55 graphical and tabular methods for watersheds larger than 100 acres to generate food hydrograph shall be used for detention design.
- USGS Regional Regression Equations for cross-drain analysis for small, ungagged rural and urban watersheds (if drainage areas are within acceptable limits of the equations stated by USGS or StreamStats), and
- Computer modeling with hydrologic routing capability utilizing software such as HEC-HMS, HydroCAD, HydraFlow and EPA SWMM, etc. for detention routing and complex study situations. Other methodologies may be used upon approval by the Town Engineer before calculations are submitted. Some studies may require methods specified by the Town Engineer. For critical portions of the drainage system, the City Engineer may require a particular method.

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Other requirements

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- In the computation of storm runoff, the runoff coefficients should be noted on the drainage plan. Provide a tabular summary and supporting data with the calculations. Provide narrative descriptions, tabular summaries, and drainage maps.
- The rainfall intensity, i.e., average rainfall rate (inch/hour) for a duration equal to the time of concentration for a selected return will be obtained by using the Intensity Atlas 14 Frequency Duration (IDF) curve of the City of Nashville. Supportive time of concentration data and derivation will be submitted.
- The developer or the developer's engineer shall be prepared to substantiate the basis for any proposed alternative method, which shall be submitted and approved by the Town Engineer before the submission of stormwater calculations.
- In addition to above requirements, drainage & hydrology calculations shall also meet the requirements of the City's Storm Water Ordinance Section 14-505.

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Curb and Grate Inlets—Curb and Grate inlets shall be designed to quickly drain the storm water from the roadway. The design storm frequency and allowable spread widths are shown in the table below. Spread shall not be allowed to overtop the curb. The maximum inlet spacing is generally 400 feet unless proven otherwise by computations. Inlets should be located at uphill corners of each street intersection to prevent sheet flow of storm water across intersections.

~~Storm Sewer Drainage System~~ The design storm frequency for storm sewers shall be in accordance with the table below. All storm sewer drainage pipes located within the roadway right of way shall be reinforced concrete pipe (RCP). The minimum size diameter for storm sewers is 18 inches. The minimum slope shall be one half percent (0.5%).

Stormwater infrastructure for roadway drainage shall be designed that meet the following requirements:

Design storm: The street shall collect and convey runoff that falls on the street or a lot near/along the street or along the side/rear lot lines through inlets. The roadway curb and gutter considered a minor drainage system, shall be designed to convey a 10-year event with storm duration equal to the time of concentration. The drainage system under the street of a new development including roadway catch basins and connecting culverts shall be designed to convey the 10-year design storm.

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New roads and critical service roads: All new streets shall be constructed a minimum of one-foot above the base flood or 100-year floodplain elevation (Brentwood). For a 100-year, 24-hour design storm event, critical service roads shall not be inundated by more than three (3) inches of water over one-half the roadway width. Other new roads shall be designed to have no more than six (6) inches of road overtopping at the 25-year, 24-hour design storm event.

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Public street: Drainage structures under public streets shall safely convey post-development flows of the following design storm: (i) local residential street, 10-year, (ii) collector-commercial/service institution street, 25-year, and (iii) arterial streets and highways, 50-year

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Drainage Design Criteria

Street Classification	Inlet Design Frequency	Storm Sewer Design Frequency	Culvert (Cross Drain) Design Frequency	Roadway Freeboard ²	Spread Width ³
Arterial	10-yr ¹	10-yr ¹	50-yr Check for 100-yr	50-yr	½ travel lane plus gutter width
Collector	10-yr ¹	10-yr ¹	50-yr Check for 100-yr	50-yr	½ travel lane plus gutter width
Local	10-yr	10-yr	10-yr Check for 25-yr	25-yr	Travel lane plus gutter width

¹ 50-yr for Roadway Sag Sections

² The design high water elevation should be at or below the bottom of the roadway subgrade.

³ Bike lanes and shoulders may be used full width for spread

Culverts (Cross Drains) - Allowable flow within culverts is subject to inlet control, outlet control, or some combination of the two controls. The storm frequency for culverts shall be in accordance with the table above. The minimum size diameter for cross drains is 18-inches. The minimum slope shall be one-half percent (0.5%).

Culvert data must be shown on the plans for all culverts or cross drains. Culvert data shall include Station, Structure Type/Size, Length, Skew, Drainage Area, Design Discharge (cfs), Minimum Roadway Overtopping Elevation, Allowable Headwater Elevation, Computed Headwater Elevation, Outlet Velocity (ft/s), Inlet Invert Elevation, and Outlet Invert Elevation.

All culverts that convey storm water runoff from the road surface or that serve as cross drains shall extend to the rear setback of the lots. All culverts must have concrete or stone veneer endwalls. Outlet velocities shall be checked and appropriate outlet protection shall be provided. Rip-rap is not allowed at the inlet or outlet ends of culverts for velocity control. If necessary, concrete energy dissipator endwalls may be used.

Other Design Requirements for Culvert:

- Culverts (i.e., pipe or box opening) shall be sized based on the worst-case inlet or outlet control and combinations of these two conditions. Headwater (HW) created by the design year storm shall neither overtop the bottom of the roadway subgrade nor cause an unduly large impoundment of water behind the culvert. All culverts shall be checked for the effects of the 100-year storm.
- Driveway culverts shall be designed to convey a 10-year 24-hour storm, with a minimum diameter of eighteen (18) inches, and a minimum length of twenty (20) feet.
- No flooding of buildings should result from the 100-year design flow. The maximum allowable HW/D for culverts shall be 1.5 for design-year storms. All piping underneath public streets shall be reinforced concrete pipe, (RCP). Typical wall thickness for RCP is type "B" for pipes up to 42" and type "C" for larger pipes shown in AASHTO Designation M-170.
- A Manning's "n" value of 0.012 shall be used for the design value of the concrete pipe. Drainage pipes that are routed along property lines shall be extended to the rear property line at a minimum. In addition to RCP, the Town will allow corrugated metal pipe (CMP), aluminized coated meeting AASHTO-M-274, 14-gauge minimum thickness, and high-density polyethylene pipe (HDPE) meeting AASHTO designation M-294-02 for driveway culverts only. A Manning's "n" value of 0.024 should be used for CMP driveway culverts. A Manning's "n" value of 0.013 shall be used for HDPE driveway culverts. Installation and maintenance of driveway culverts shall be the responsibility of the owner, lessee or other lawful holder of the property to be served unless necessitated by a city roadway, utility, or drainage improvement project.

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- The following data must be shown on the plans for culverts or cross drains: station, type/size, length, skew, drainage area, design discharge, minimum roadway overtopping elevation, and headwater elevation, (i.e., allowable and computed), outlet velocity, and Invert elevations (i.e., inlet & outlet). All culverts must have concrete or stone veneer end walls.

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Pipe Materials - All storm sewer drainage culverts and cross drains located within the roadway right-of-way shall be reinforced concrete pipe (RCP). Sections of culvert located outside of the roadway right-of-way may be of a different material (i.e. HDPE). Storm sewer pipes located within the roadway ROW shall be reinforced concrete pipe (RCP), with a minimum diameter of 15 inches, and a minimum slope of 0.5%, or that necessary to create a full-flow velocity of 2 feet/sec. The inlet shall be designed for the 10-year, 24-hour storm for all street classifications (i.e., arterial, collector, or local).

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Reinforced concrete pipe shall conform to the minimum standard for Class III reinforced pipes. HDPE shall be equivalent to ADS N-12 and approved by the Town Engineer. HDPE is **not** acceptable for use under roadway crossings. A.S.T.M. C-76 corrugated metal pipes, which are **not** typically acceptable for use under private or public street crossings, shall meet the following minimum gage requirements:

Gage requirements for various sizes of A.S.T.M. C-76 corrugated metal pipes			
For Cross Drains	18" 24" 30"	36" 42" 48" 54"	60" 66" 72"
	14 gage	12 gage	10 gage
For Driveway	18" 24" 30"	36" 42" 48"	54" 60" 66" 72"
	14 gage	12 gage	10 gage

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For pipes smaller than 48 inches in diameter, a minimum cover of one foot is required at the subgrade. A minimum cover of two feet at subgrade is required for pipes 48 inches in diameter and larger.

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Roadside ditches shall be built to a grade that will provide good drainage, and in no case shall the slope of the ditch be less than 1% percent (a fall of 1.0 foot in 100 feet).

Cross drains and driveway pipes shall be built on straight lines and grade and shall be laid on a firm base, but not on rock. Pipes shall be laid with the spigot end pointing in the direction of the flow and with the ends fitted and matched to provide tight joints and a smooth, uniform invert. Headwalls will be constructed at both ends of cross-drain and driveway pipes in accordance with these regulations.

Storm sewer shall be built with a maximum slope of 3% for outlet velocity control.

All drainage ditches shall be stabilized to prevent erosion.

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Open Channels - Open Channels shall be designed to the same storm frequency as storm sewers, except where these channels are considered part of the major drainage system, in which case they shall be designed for the 100-year storm event. A minimum 12-inch freeboard for the design storm is required for ditches and open channels that are adjacent to streets and roads. Channels shall be designed with stable side slopes and lining to withstand velocities and shear stress for the design storm event. Vegetative channels shall have a maximum side slope of 3H:1V. Channels with bottom widths greater than 10 feet shall have a minimum bottom cross slope of 12 to 1. Parabolic or trapezoidal channels are preferred while triangular shapes should be avoided. When the depth for the design storm event exceeds three (3) feet in depth, the design engineer shall use an alternate drainage system design.

Channel lining shall be checked for both velocity and shear stress. Channel lining may be vegetative, flexible or rigid. Rip-rap shall not be allowed as a channel lining. The design engineer shall refer to Chapter 5 of the TDOT Design Division Drainage Manual for maximum velocities and permissible shear stresses of various channel linings.