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3-1 GENERAL

This section of the Standards provides guidelines for the design of storm and surface water drainage systems, including open channels, pipes, culverts, catch basins, flow control structures and stormwater treatment facilities. Each of the sections in this chapter contains the design guidelines and references Standard Details for the various systems or facilities.

Flow control and stormwater treatment shall be provided for all development projects within the City of Arlington per these Standards, the currently adopted *Department of Ecology Stormwater Management Manual for Western Washington* (*DOE Stormwater Management Manual*), and the *City of Arlington Land Use Code* Title 20. In case of conflict the more stringent requirements shall apply. The Design Engineer may impose additional or more stringent requirements than those specified in this chapter to mitigate drainage impacts or to protect public health, safety and welfare.

3-2 CONVEYANCE SYSTEMS

3-2.01 OVERVIEW

Conveyance systems include all drainage facilities that transport storm and surface water runoff, both natural and artificial, except those features protected as environmentally sensitive areas under the *City of Arlington Land Use Code*. Environmentally sensitive areas may only be modified as allowed under the *City of Arlington Land Use Code*. Stormwater must be treated and detained prior to discharge to an environmentally sensitive area, including those features created for mitigation.

3-2.02 HYDRAULIC DESIGN

Generally conveyance systems shall be designed to convey runoff from the 25-year storm event. Conveyance systems for major creeks and streams may be designed to convey runoff for a 100-year storm, if required by the City. The method used to determine the design flow will depend on the characteristics of the drainage area and the type of conveyance. These methods of determining design flows are explained in detail in the *DOE Stormwater Management Manual*.

A backwater analysis may be required for a proposed or existing pipe system if the ability of the pipe system to convey the peak rate of runoff from the 25-year storm event may be affected by tailwater conditions (outlet control) anywhere in the pipe system.
Structures for proposed pipe systems, such as catch basins and manholes, must provide a minimum of 0.5 foot of freeboard between the headwater surface (hydraulic grade line) and the top of the structure for flow from a 25-year storm. However, structures may overtop for flow resulting from a 100 year storm. When overtopping occurs for the 100 year storm, the additional flow over the ground surface is analyzed using the methods described in the *DOE Stormwater Management Manual* and is added to the flow capacity of the pipe system.

3-3 CONVEYANCE PIPE SYSTEMS

The hydraulic analysis of flow in the storm drain pipes is typically limited to "gravity flow". The following subsections give design guidelines for different components and aspects of pipe systems.

3-3.01 PIPE MATERIALS

1) Pipe material, joints, and protective treatment shall conform to the requirements set forth in Section 9-05 of the *WSDOT/APWA Standard Specifications*. The following pipe materials may be use for stormwater systems in the City of Arlington; other pipe materials may be approved on a case-by-case basis:

   - Plain concrete pipe (12 inches in diameter, used only for driveway culvert).
   - Reinforced concrete pipe.
   - PVC pipe (ASTM D 3034 SDR 35 with 3 feet of cover, minimum).
   - PVC pipe (C-900 used when cover is less that 3 feet).
   - Corrugated high density polyethylene pipe, with smooth interior. (AASHTO M294 Type S or D)
   - Ductile iron pipe (epoxy coated, class 50 or 52, used when cover is less than 3 feet).

2) Materials for concrete, rubber gaskets, metal castings, reinforcing steel, and masonry units shall meet the requirements of the appropriate sections of the *WSDOT/APWA Standard Specifications*.

3) Corrugated metal pipes (galvanized aluminum or steel) are not accepted by the City of Arlington.

3-3.02 PIPE SIZES, SLOPES, AND VELOCITIES

1) No storm drain pipe between catch basins or manholes in the public right-of-way shall be less than 12 inches in diameter; with the exception that 8-inch pipe may be used between inlets and catch basins in runs of 50 feet or less.

2) Pipes up to 18 inches in diameter shall be laid with a minimum slope of 0.5%. Pipes installed as water level equalizer, fish passages, and/or internal components of a detention/retention system may have a smaller slope.

3) The minimum velocity in any pipe or culvert carrying the design storm flow shall be 3

feet per second.

4) The maximum allowable velocity in concrete pipe shall be 30 feet per second.

5) Downstream decrease in pipe size is not a recommended practice and will only be allowed under special conditions.

6) Pipes shall be sized to convey 25-year storm using the Manning's equation.

3-3.03 PIPE ALIGNMENT, CONNECTIONS AND COVER

1) Pipes must be laid true to line and grade with no curves, bends, or deflections in any direction, except for HDPE and ductile iron pipe with flanged restrained joint bends (not greater than 30 degrees) on steep slopes.

2) A catch basin or manhole will be required at all changes in storm drain diameter and changes in grade or alignment.

3) Connections to a pipe system shall be made only at catch basins or manholes. No wyes or tees are allowed except for roof, footing, or yard drain systems for pipes 8 inches in diameter or less, with cleanouts upstream of each wye or tee.

4) Six inches minimum vertical clearance and 5 feet minimum horizontal clearance (between outside surfaces) shall be provided between storm drain pipes and other utility pipes and conduits.

5) Any closed storm drainage system collecting runoff from paved areas in the public right-of-way or private property shall provide for floatable material separation prior to discharge to the main storm drainage system in the public right-of-way, unless otherwise approved by the City Engineer.

6) All PVC connections to catch basins or manholes shall be made by grouting in an approved manhole adapter into which the PVC pipe is inserted.

7) Activities such as trench excavation, tunneling or boring, pipe embedment, backfilling, compaction, safety and pavement patching, whether for public or private pipes, shall conform to the requirements set forth in these Standards.

3-4 MANHOLES, CATCH BASINS AND INLETS

3-4.01 GENERAL

1) Manholes, catch basins, and inlets shall be constructed of pre-cast concrete units in accordance with Standard Details SD-010 through SD-040.

2) Catch basin or manhole diameter shall be determined by pipe sizes and orientation at the junction structure. A plan view of the junction structure, drawn to scale, will be required when more than four pipes enter the structure on the same plane, or if angles of approach and clearance between pipes is of concern. The plan view (and sections if necessary) must insure a minimum solid concrete wall distance between pipe knockouts of 8 inches for 48 inch and 54 inch catch basins and 12 inches for 72 inch and 96 inch catch basins.

3) Catch basin evaluation of structural integrity for H-20 loading may be required for multiple junction catch basins and other structures.

4) Catch basins shall be provided within 50 feet of the entrance to a pipe system to provide for silt and debris removal.

5) HDPE pipe systems longer than 100 feet must be secured at the upstream end and the downstream end must be placed in a 4 foot section of the next larger pipe size. This sliding sleeve connection accounts for the high thermal expansion/contraction coefficient of this pipe material.

6) The maximum slope of the ground surface for a radius of 5 feet around a catch basin grate shall be 3:1.

7) A Type 2 catch basin or a manhole shall be required when the depth to the invert exceeds 5 feet, regardless of the pipe size.

8) All Type 2 catch basins and all manholes shall be equipped with ladders per Standard Detail SD-050.

9) Concrete inlets shall not be used where the discharge goes directly into the main storm drain system.

10) As shown on the Standard Details, catch basin and manhole design assumes soil load-bearing capacity of 3,300 pounds per square foot (psf). Where the capacity is less, the base shall be designed by an engineer.

11) Manholes shall not be used except for special situations, such as angle points, difficult access or constricted areas, approved by the City Engineer.

3-4.02 FRAMES, LIDS, GRATES AND COVERS

1) In general, frames and grates shall be installed per Standard Details SD-060 through SD-110.

2) The cover or grating of a manhole or catch basin shall not be grouted to final grade until the final elevation of the pavement, gutter, ditch, or sidewalk in which it is to be placed has been established, and until permission thereafter is given by the City Inspector to grout the cover or grating in place.

3) Lids, grates, and covers shall be seated properly to prevent rocking.

4) All catch basins and manholes shall be equipped with locking frames and lids or grates per Standard Details SD-060 and SD-110.

5) Type 2 catch basins and manholes functioning exclusively as access structures shall be equipped with circular 24-inch covers and frames per Standard Details SD-110.

6) Circular lids on all storm drain structures shall have “DRAIN” cast into the lid.

7) The top surfaces of grates shall be embossed in block letters “OUT FALL TO STREAM, DUMP NO POLLUTANTS”. The block letters shall measure a minimum of ½ inch in height.

8) Where the roadway grade is 4% or greater, a ductile iron vaned grate in accordance with Standard Detail SD-070 shall be used.

3-4.03 THROUGH–CURB INLET

A through-curb inlet frame and grate shall be furnished and installed by the Developer per Standard Detail SD-100. Through-curb inlets are used when the high likelihood of clogging from leaf fall, especially in sag vertical curves; when the inlet is a surface drainage end point, such as a cul-de-sac; and when road grades exceed 12% which may cause normal inlet grates to be passed over, due to the road grade. Grates used in through-curb inlets shall be ductile iron vaned grates.

3-4.04 CATCH BASIN, MANHOLE AND INLET SPACING

Maximum spacing on surface drainage courses between catch basins, manholes or inlets shall be as shown in Table 3-1.

Table 3-1 Catch Basin, Manhole and Inlet Spacing

ROAD GRADE	SPACING
LESS THAN 1.0%	150 FEET
1.0% TO 3.0%	200 FEET
3.0% OR GREATER	300 FEET

Additional catch basins shall be installed as needed to confine drainage to the gutter and prevent flow into traffic lanes or intersections. On cul-de-sacs and curves, inlet spacing shall be measured along the flow line of the roadway. The maximum spacing between storm drain access structures, whether catch basins or manholes, or between a high point and an access structure, shall be 300 feet.

3-4.05 RESTRICTOR DEVICES

1) The minimum orifice size diameter allowed for use in the City of Arlington is 1 inch. Orifices less than 1 inch will need approval by the City Engineer.

2) Restrictor devices shall be constructed and installed in accordance with Standard Details SD-150 and SD-160.

3-4.06 DEBRIS BARRIERS

Debris barriers (trash racks) are required on all pipes entering or leaving a closed pipe system, including pipes entering or leaving a control/restrictor manhole or catch basin from a surface-type BMP (detention pond, infiltration basin, wetpond, biofiltration swale, etc.).

3-5 OPEN CHANNELS

Open channels, either natural or artificial, may be used to convey stormwater on and from a site. In general, however, natural channels are protected as environmentally sensitive areas under the *City of Arlington Land Use Code* and may not be used to convey untreated, undetained stormwater. Alteration of these channels, including bank stabilization projects, requires special permits. Artificial channels are those constructed from upland areas specifically to convey storm and surface water.

3-5.01 NATURAL CHANNELS

Natural channels are defined as those that have occurred naturally due to the flow of surface waters, or those that, although originally constructed by human activity, have taken on the appearance of a natural channel including a stable route and biological community. They may vary hydraulically along each channel reach and should be left in their natural condition, wherever feasible or required, in order to maintain natural hydraulic functions and wildlife habitat benefits from established vegetation.

3-5.02 CONSTRUCTED CHANNELS

Constructed channels are those constructed or maintained by human activity and include bank stabilization of natural channels. Constructed channels shall be either vegetation-lined, rock-lined, or lined with appropriate bioengineered vegetation.

1) Vegetation-lined channels are the most desirable of the constructed channels when properly designed and constructed. The vegetation stabilizes the slopes of the channel, controls erosion of the channel surfaces, and removes pollutants. The channel storage, low velocities, water quality benefits, and greenbelt multiple use benefits create significant advantages over other constructed channels. The presence of vegetation in channels creates turbulence which results in loss of energy and increased flow retardation; therefore, the Design Engineer must consider sediment deposition and scour, as well as flow capacity, when designing the channel.

2) Rock-lined channels are necessary where a vegetation lining will not provide adequate protection from erosive velocities. They may be constructed with riprap, gabions, or slope mattress linings. The rock lining increases the turbulence, resulting in a loss of energy and increased flow retardation. Rock lining also permits a higher design velocity and therefore a steeper design slope than grass-lined channels. Rock linings are also used for erosion control at culvert and storm drain outlets, sharp channel bends, channel confluences, and locally steepened channel sections.

3) Bioengineered vegetation lining is a desirable alternative to the conventional methods of rock armoring. Soil bioengineering is a highly specialized science that uses living plants and plant parts to stabilize eroded or damaged land. Properly bioengineered systems are capable of providing a measure of immediate soil protection and mechanical reinforcement. As the plants grow they produce a vegetative protective cover and a root reinforcement matrix in the soil mantle. The vegetative cover of bioengineered systems provides immediate protection during high flows by laying flat against the bank and covering the soil like a blanket. It also reduces pore pressure in saturated banks through transpiration by acting as a natural “pump” to pull the water out of the banks after the flows have receded.

When constructing artificial channels, vegetation-lined channels are preferred when properly designed and constructed. Rock-lining may be necessary along the length of channels or at specific locations (such as bends and outfalls) when a vegetative lining will not provide adequate protection from erosive velocities.

3-5.03 ARTIFICIAL CHANNELS

1) Open channels shall be designed to provide conveyance capacity while minimizing erosion and allowing for aesthetics, habitat preservation, and enhancement.

2) Channel section geometry shall be trapezoidal. Side slopes shall not be steeper than 3H:1V for vegetation-lined channels and 2H:1V for rock-lined channels, unless the channel is engineered specifically for steeper slopes. Roadside ditches must comply with Chapter 2 of these Standards and the *WSDOT Design Manual* and *Standard Plans*.

3) A minimum 0.5 foot freeboard above 100 year design flow must be provided.

4) Vegetation-lined channels shall have bottom slope gradients of 6% or less and a maximum average velocity at the design flow of 5 fps.

5) Rock-lined channels shall be used when design flow velocities exceed 5 fps.

6) A maintenance access easement of 10 feet wide (minimum) is required along all publicly maintained constructed channels located on private property. However, required easement widths and building setback lines may vary with channel top width. A minimum 20 feet setback must be provided between any structures and the top of the bank of the channel.

3-5.04 ROCK-LINING

In rock-lined channels, stone (riprap) is placed on the channel sides and bottom to protect the underlying material from erosion. Proper riprap design requires the determination of the median size of stone, the thickness of the riprap layer, the gradation of stone sizes, and the selection of angular stone which will interlock when placed. Research by the U.S. Army Corps of Engineers has provided criteria for selecting the median stone weight W_{50}. If the riprap is to be used in a highly turbulent zone, such as a culvert outfall, downstream of a stilling basin, at sharp changes in channel geometry, etc., the median stone W_{50} should be increased from 200% to 600%, depending on the severity of the locally high turbulence. The thickness of the riprap layer should generally be twice the median stone diameter D_{50} or at least that of the maximum stone diameter D_{max}. The riprap should have a reasonably well graded assortment of stone sizes within the following gradation:

$$1.25 \leq D_{max} / D_{50} \leq 1.50$$
$$D_{15} / D_{50} = 0.50$$
$$D_{min} / D_{50} = 0.25$$

For more detailed analysis and design procedures for riprap requiring water surface profiles and estimates of tractive force, refer to the paper by Maynord et al in the *Journal of Hydraulic Engineering* (ASCE), July 1989.

3-5.03 RIPRAP FILTERS

Riprap should be underlain by a sand and gravel filter (or filter fabric) to keep the fine materials in the natural or artificial channel from being washed through the voids in the riprap. Likewise, the filter material must be selected so that it is not washed through the voids in the riprap. Adequate filters can usually be provided by a reasonably well graded sand and gravel material where:

$$D_{15} < 5\ d_{85}$$

The variable d_{85} refers to the sieve opening through which 85% of the material being protected will pass, and D_{15} has the same interpretation for the filter material. A filter with a D_{50} of 0.5 mm will protect any finer material including clay. Where very large riprap is used it is sometimes necessary to use two filter layers between the material being protected and the riprap.

For additional information and procedures for specifying filters for riprap and general guidance, refer to the *Army Corps of Engineers Manual EM 1110-2-1601* (1970), *Hydraulic Design of Flood Control Channels*, paragraph 14, “Riprap Protection”.

3-6 CULVERT DESIGN CRITERIA

3-6.01 HEADWATERS

1) For circular culverts, box culverts and pipe arches, the maximum headwater depth for the design storm shall not exceed 2.0 times the culverts height for culverts 18 inches and less, or 1.5 times the culverts height for culverts greater that 18 inches.

2) For bottomless culverts, the headwater depth of the 100 year storm shall not exceed the top of the culvert.

3-6.02 INLETS

1) For culverts 18 inches in diameter and larger, the embankment around the culvert inlet shall be protected from erosion by rock lining, the length and width shall be a minimum of five feet (upstream of the culvert) and the height shall be at the design headwater elevation.

2) Trash racks/debris barriers are required on culverts that are over 60 feet in length and are 12 inches to 36 inches in diameter. Culverts on fish bearing streams do not need trash racks.

3) In order to maintain the stability of roadway embankments, concrete headwalls, wingwalls, or tapered inlets and outlets may be required if right-of-way and/or easement constraints prohibit the culvert from extending to the toe of the embankment slope. Normally, a concrete inlet structures/headwalls installed in or near roadway embankments must be flush with and conform to the slope of the embankment.

3-6.03 OUTLETS

The receiving channel at the outlet shall be protected from erosion by rock lining, except the height shall be one foot above the maximum tailwater elevation or one foot above the crown of the pipe, whichever is higher.

3-6.04 FISH PASSAGE

In fish-bearing waters, water-crossing structures must provide for fish passage as required by the *Washington State Department of Fish and Wildlife* (WDFW) Hydraulic Project Approval permit. The water-crossing must comply with AMC 20.88.730, WAC 222.16.020 and WAC 222.16.030. Culverts designed for fish passage must also meet conveyance system requirements.

Fish passage can generally be ensured by providing structures that do not confine the streambed, that is, a structure wide enough so that the stream can maintain its natural channel within the culvert. Bridges, bottomless arch culverts, and rectangular box culverts can often be used to accommodate stream channels. For design guidance refer to *"Design of Road Culverts for Fish Passage"* published by the *Washington State Department of Fish and Wildlife.*

3-7 OUTFALL DESIGN CRITERIA

3-7.01 GENERAL

1) All outfalls (at a minimum) shall be provided with rock protection. For outfalls with a velocity at the design flow greater than 10 fps, a gabion dissipater or engineered energy dissipater shall be required.

2) Mechanisms which reduce velocity prior to discharge from an outfall are encouraged.

3) Engineered energy dissipaters, including stilling basins, drop pools, hydraulic jump basins, baffled aprons, and bucket aprons, are required for outfalls with velocity at design flow greater than 20 fps.

4) Inlet control will usually dictate outfall pipe system capacity. The inlet conditions should be carefully examined, as well as the consequences should the inlet to the pipe system become plugged or capacity exceeded.

3-7.02 OUTFALL SYSTEMS TRAVERSING STEEP SLOPES

1) Outfall systems constructed of pipe segments which are banded and/or contain gaskets are not acceptable for traversing steep slopes. Leaks at the joints of the pipe will cause the system to fail.

2) Continuously fused, welded or restrained joint pipe systems, such as high density polyethylene pipe (HDPEP) or ductile iron pipe (restrained joints), with proper anchoring shall be used for outfall systems traversing steep slopes.

3) In general, outfall pipes systems shall be installed in trenches with standard bedding on slopes up to 20%. On slopes greater than 20%, outfall pipe systems shall be placed on the ground surface with proper pipe anchorage.

Table 3-2 Maximum Pipe Slopes and Velocities

MAXIMUM PIPE SLOPES AND VELOCITIES			
Pipe Material	**Pipe Slope above which Pipe Anchors Required and Minimum Anchor Spacing**	**Maximum Slope Allowed**	**Maximum Velocity at Full Flow**
PVC, CPE (1)	20% (1 anchor per 100 LF of pipe)	30% (3)	30 fps
Concrete or LCPE (1)	10% (1 anchor per 50 LF of pipe)	20% (3)	30 fps
Ductile Iron (2)	20% (1 anchor per pipe section)	None	None
SWPE (2)	20% (1 anchor per 100 LF or pipe, cross-slope installations only)	None	None

Notes:

(1) These materials are not allowed in landslide hazard areas.

(2) Butt-fused or flanged pipe joints are required; above ground installation is recommended on slopes greater than 40%.

(3) A maximum slope of 200% is allowed for these pipe materials with no joints (one section), with structures at each end, and with proper grouting.

3-8 DETENTION AND RETENTION FACILITIES

3-8.01 FACILITY LOCATION

Retention, detention and stormwater treatment facilities required for private land development shall not be placed in the public right-of-way. These facilities may be located in a private tract or easement, including those for a private road, subject to a determination that the private road will not likely be converted to a public road in the future.

3-8.02 FACILITY ACCESS

1) Adequate access shall be provided to operate and/or maintain all facilities and their controls, to provide for repair and improvement, and to perform maintenance during all times of the year. The City Engineer shall determine whether access is adequate.

2) Access shall be provided to:

   - All control structures, including weirs and emergency overflow structures.
   - All catch basins and vaults housing water quality treatment mechanisms.
   - All inlets and outlets of detention and retention systems.
   - All catch basins within detention and retention systems.
   - The bottom of earthen stormwater detention ponds, except those ponds designed to be maintained from the perimeter.

3) Vehicular access shall meet the following criteria:

   - The access road shall have a minimum width of 15 feet if a turnaround is provided; a 20 foot minimum width is required if a turnaround is not provided.
   - The access road shall meet H-20 loading requirements. At a minimum, the road shall have 4 inches of CSBC over 12 inches of compacted depth gravel borrow or pit run gravel. The road shall be paved with a minimum of 3 inches of ATB over the gravel layer if the grade exceeds 8%. The maximum allowable grade is 15%. Materials shall meet *WSDOT/APWA Standard Specifications 4-02 (Gravel Base)* and *5-04 (Asphalt Concrete Pavement*).
   - A hammerhead turnaround shall be provided if the access road:
     - o is 75 feet or longer, or
     - o connects to an arterial road right-of-way, or

  - has a grade of 5% or greater, or
  - has a horizontal curve radius of 100 feet or less.

- Hammerhead turnarounds shall have dimensions of 40 feet by 40 feet with a 15 foot inside radius.

3-8.03 OPEN STUCTURES

Open structures may include ponds, vaults, and water quality systems.

1) Facility Design

- Open facilities shall not be wider than 30 feet at the bottom of the pond, unless an access/maintenance road is constructed into the bottom of the facility.

- When facilities are not designed with a minimum of 0.5 feet of dead storage, the bottom shall have a minimum slope of 0.5% toward the outlet pipe.

- Open detention and retention systems shall have emergency overflow structures that convey the maximum design flow of the detention facility into the downstream drainage system without damage to any drainage facility.

2) Side Slopes

Interior (water-side) slopes for earthen detention, retention, infiltration, and water quality facilities shall have a maximum slope of 3 horizontal to 1 vertical. Exterior (non-water-side) slopes shall have a maximum slope of 2 horizontal to 1 vertical.

3) Berms

Berms with heights of 4 feet or less shall have a minimum top width of 6 feet. Berms more than 4 feet in height shall have a minimum top width of 15 feet and shall include a key section. All berms shall be placed in lifts not to exceed 1 foot in loose thickness. Each lift shall be compacted to at least 95% of the maximum dry density, as determined by ASTM Test Method D-1557-78 (Modified Proctor), before an additional fill is placed and compacted. In place density tests shall be performed at random locations within each lift of the fill to verify that this degree of compaction is being achieved.

4) Vertical Walls

Vertical walls shall be constructed with a minimum of 3000 psi structural reinforced concrete and shall be watertight. Porous materials, such as keystone, ecology blocks or rockeries shall not be used as an element of the wall below the waterline unless approved by the City Engineer.

5) Vegetation Cover

- Permanent vegetation shall be established on earthen detention, retention and water quality facilities. Water, shade and sun-tolerant grass species shall be used for the portions of slopes and berms exposed to water in the facilities.

- Trees shall not be planted on constructed perimeter berms designed for runoff impoundment. Trees may be planted at the top of facilities that are created solely by excavation (no fill or berms).

6) Fencing

- Fencing is required for safety and security purposes around all open detention or retention ponds, vaults, or water quality systems for which the maximum design water depth is greater than 3 feet or the inside slopes are steeper than 3 feet horizontal to 1 foot vertical.

- Fencing is not required if one (1) interior horizontal safety bench with a width of at least 10 feet is provided around the entire perimeter for each 3 three feet of water depth, and the interior side slopes are no steeper than 3 feet horizontal to 1 foot vertical. No benching or fencing is required where side slopes are 4 feet horizontal to 1 foot vertical or less.

- Fencing and gates shall be Type 1 or Type 3 chain link fence in accordance with *WSDOT/APWA Standard Specifications* and *WSDOT Standard Plan L-2*. Line posts for all fences shall be galvanized and set in concrete. Fences shall be powder coated or vinyl coated with no less than six (6) feet in height, from the ground to the top of the chain link. Wooden fences are not allowed as the security fence.

- The gap between the bottom of the chain link and the top of the ground shall not exceed two inches.

- An access opening with a minimum width of 16 feet shall be located at the access route entrance. Two gates of equal length shall be provided for the access opening. Gates shall be designed and constructed in accordance with *WSDOT/APWA Standard Specifications* and *Standard Plan L-3*. Gates shall include a combination lock.

3-8.04 VAULT DETENTION

1) Vaults for private land development projects shall not be located in the public right-of-way. However, vaults may be located in a private tract or easement, including those for a private road, subject to a determination that the private road will not likely be converted to a public road in the future.

2) Detention/retention vaults shall be located no closer than 50 feet from the top of a steep slope, as defined by AMC 20.88.

3) Structural plans for all vaults shall be prepared and stamped by a Professional Structural Engineer licensed in the State of Washington. The drawings shall include steel placement blockouts for inlet and outlet pipes, corner reinforcement, top attachment, water stops, construction joints, and design mix specifications for the concrete. When the vault top is to have a soil cover, it shall be designed for saturated soil loading with a minimum cover of 2 feet. The design shall be adequate for live loads, dead loads, and seismic loads in accordance with the *International Building Code*. Vaults shall be watertight and constructed with 3000 psi minimum compressive strength reinforced concrete.

4) Closed vaults shall be designed for H25 loading when located in the right-of-way or in areas where the lids may be subject to vehicle loads, such as commercial developments. Vaults in other areas may be designed for H20 loading. All design loads shall include an impact allowance in accordance with the *AASHTO Standard Specifications for Highway Bridges*.

5) The minimum internal height in a closed vault shall be 7 feet, the minimum internal width shall be 4 feet, and the maximum depth from ground elevation to the vault bottom shall be 20 feet.

6) The walls of all vaults shall have horizontal and vertical reinforcement on each face. Reinforcement shall be designed for both the hydrostatic pressure of a tank full of water and the earth pressure of the planned backfill plus any surcharge. The design of corners of vaults shall take into consideration the restraint provided by the adjoining walls and/or the lids.

7) Maintenance access and ventilation shall meet city, State and National Standards. Closed vault ventilation shall be provided by a venting manhole cover or catch basin grate.

8) Closed vaults used for detention, retention, or treatment shall have at least one access for every 50 feet of length, with a minimum of three access points. A ladder shall be provided to the bottom of each cell or compartment. Access points shall be located over the inlet/outlet and the sediment trap. Access shall consist of a round, locking ring and cover. The ladder shall be directly under the ring and cover. Access design shall provide sufficient clearance between walls and appurtenances to allow access for personnel and required safety and maintenance equipment.

9) Control structures shall be located outside of the vault in an appropriately sized manhole.

10) A catch basin or an alternative sediment removal best management practice (BMP) with sufficient capacity shall be constructed upstream of the vault for sediment removal. The volume of sediment storage required shall be determined by the Design Engineer of record. Vehicular access designed for H25 loading shall be provided for the sediment removal area. Vaults shall also contain a forebay for additional sediment capture. Access directly over the forebay shall be provided for maintenance purposes.

11) Enclosed detention structures, such as vaults, tanks, and pipes, shall not be considered sufficient for water quality treatment. While they may be designed to provide sediment removal, these systems must be used in conjunction with a vegetated system such as biofiltration swales or a water quality pond, or some other system proven to be effective at removing metals, organic pollutants, and if necessary, nutrients.

12) Water quality treatment systems are preferred to be installed downstream from vault detention systems. However, if topography makes a downstream location unfeasible, then a water quality system may be installed upstream from the detention system, provided that a sump or means of initial sediment removal is installed and that peak flow through the water quality system is controlled to not exceed the water quality design flow rate. Water quality treatment may be biofiltration or other approved treatment method. A "wet vault", or other system where settling is the only pollutant removal system, is not acceptable as the sole water quality treatment for runoff.

3-8.05 PIPE DETENTION

1) Pipes used for detention, retention, or treatment systems shall have at least one access point for every 100 feet of length. Each end of the pipe shall be connected to a Type 2 catch basin with a culvert section having a maximum length of 2 feet and a minimum diameter of 3 feet. Access points shall be located over the flow control device and the inlet pipe. Access shall consist of a round, locking ring and cover.

2) An air vent connection of appropriate size shall be provided at the top of the high end of the pipe. Maintenance access and ventilation shall meet State and National Standards.

3) Parallel pipes used for detention, retention, infiltration, or treatment shall meet the minimum clearance requirement of 2 feet unless approved by the City Engineer, with appropriate provisions for controlling the density of fill between the pipes.

4) Water quality treatment systems are preferred to be installed downstream from pipe detention systems. However, if topography makes a downstream location unfeasible, then a water quality system may be installed upstream from the detention system, provided that a sump or means of initial sediment removal is installed and that peak flow through the water quality system is controlled to not exceed the water quality design flow rate. Water quality treatment may be biofiltration or other approved method.

3-8.06 EMERGENCY OVERFLOW STRUCTURES

1) Enclosed vaults and open detention, retention, and infiltration systems shall have emergency overflow structures that convey the maximum undetained design flow of the detention facility into the downstream drainage system without damage to any drainage facility. Overflow structures may be open channel spillways or closed conduit systems, but shall not be connected to or through the control structure. The emergency flow outfall shall bypass any biofiltration system.

2) If the structure is an open channel, it shall be designed as a broad crested weir, to pass the 100-year, 24-hour undetained post-development event. It shall be armored with quarry spalls that conform to *WSDOT/APWA Standard Specifications*, provided that larger material shall be used if necessary to prevent erosion from the maximum design flow. The quarry spall layer shall be at least one (1) foot thick and individual rocks shall not protrude more than three inches from that surface.

3) All detention ponds and vaults shall have an emergency overflow system (spillway or closed conduit) that supplements the design overflow. The emergency overflow elevation shall be 0.5 feet above the maximum design water surface elevation. The pond freeboard shall be a minimum of one (1) foot above the undetained 100-year flow through the emergency overflow. The preferred method to establish the spillway invert elevation in an open channel is a concrete curb or sill.

3-8.07 SEDIMENT TRAPS

1) There shall be a separate sediment trap installed at the inlet of all stormwater detention and retention systems. The trap shall be designed such that the entire area is accessible by maintenance equipment. If the width across the top of the sediment trap is greater than 30 feet, an access road to the bottom of the sediment trap is required.

2) A control structure shall not be considered to perform the same function as a sediment trap.

3-8.08 WEIRS

1) All weirs shall have a debris barrier installed directly upstream of the weir.

2) All weir wall structures shall be reinforced concrete on a reinforced concrete pad poured in place for 5 feet upstream and downstream of the weir wall. The concrete pad shall extend 1 foot in width to each side of the outside edge of the weir.

3) If a chain link fence is constructed directly over or adjacent to the weir structure, the chain link fence shall extend to within 2 inches of the top of the weir, to prevent unauthorized access to the facility. A bottom rail meeting *WSDOT/APWA Standards Specifications* shall be installed, extending a minimum of 5 feet horizontally from each

edge of the weir.

4) All weirs shall be designed as sharp crested weirs using end contraction correction factors or other formulas approved by the City Engineer.

5) Metal weir plates shall be designed to be field adjusted, bolted, or otherwise fastened to the foundation, not embedded in concrete. Weir plate fasteners that allow field adjustment shall be used.

3-8.09 VORTEX FLOW REGULATORS

1) The vortex flow regulator control structure shall have a sediment trap and a spill-control device (oil-water separator, or equivalent as shown in Standard Detail SD-120) installed.

2) The vortex flow regulator shall be enclosed within a standard Type 2 catch basin or manhole for adequate access and protection from vandalism. Maintenance access shall be provided into the structure.

3) The vortex flow regulator shall be designed and constructed so that it is completely removable from the structure.

4) The vortex flow regulator system shall include a shear gate and an overflow, or some other method approved by the City Engineer that allows quick draining and cleaning of the detention facility.

3-9 INFILTRATION SYSTEMS

3-9.01 GENERAL

1) A proposal to use a drainage infiltration system shall include a system design, feasibility analysis and discussion. The design shall be based on tests performed on the proposed infiltration site, infiltration criteria, site limitations, and requirements for the selected best management practice (BMP) from the *DOE Stormwater Management Manual*.

2) Large infiltration systems receive runoff from 5,000 square feet or more of impervious area.

- The design report for a large infiltration system shall be prepared by a licensed Geotechnical Engineer, Engineering Geologist or Hydrogeologist. The report shall state whether the site is suitable for the proposed infiltration facility and recommend a design infiltration rate.

- At least one soil log, boring, or test pit shall be provided for each 5,000 square feet of infiltration pond bottom area (plan view), with a minimum of two soil logs per infiltration facility.

- For trenches, at least one soil log per 50 feet of trench length shall be provided, with a minimum of two per trench.

- Each soil log shall extend a minimum of 6 feet below the bottom of the proposed facility, and shall describe the SCS/NRCS series of the soil, the apparent textural class of the soil horizon(s) through each zone.

- The location of the soil logs shall be noted on the plans and in the report.

3) Small infiltration systems receive runoff from less than 5,000 square feet of impervious area.

- Infiltration trenches for roof drains may be designed and constructed per Standard Detail SD-140.

- The elevation must be reported relative to the NAVD88 vertical datum.

- Soil tests for small infiltration systems may be conducted by a licensed septic designer.

3-9.02 SOIL SAMPLING AND ANALYSIS

1) The soil log shall note the estimated or measured high groundwater level. The location of the seasonal high groundwater table can be determined by field observation of static water elevation in borings, changes in soil moisture content, and/or changes in soil color such as mottling.

2) The location of impermeable soil layers or dissimilar soil layers shall be noted.

3) Soil samples shall be taken in each distinct layer and to a depth of 3 feet below the proposed bottom of the infiltration facility. The soil's texture class may be established using the USDA Textural Triangle and the percentages of silt, clay, and sand determined from analysis of the soil samples. Laboratory analysis of soil samples is encouraged.

4) Each design report shall contain a clear statement of the depth to the maximum seasonal high water table. If any doubt exists about the maximum seasonal high water table measurements, monitoring wells shall be dug and monitored during a period when the water table elevation is expected to be at a maximum; that is, over a winter. Monitoring of the water table over a winter season shall include an analysis of rainfall for

comparison to normal amounts and conditions.

5) A groundwater mounding analysis shall be included with all large infiltration system designs when the depth to the seasonal high water table or low permeability stratum is less than 15 feet and the runoff collection area is more than 1 acre.

3-9.03 DESIGN

1) The use of infiltration systems in fill soils is not allowed. Soils shall be natural, undisturbed, and permeable in nature.

2) Soils are suitable for infiltration if they meet all of the following requirements:

   - The soil infiltration rate is at least 0.5 inch per hour or 2 hours per inch;
   - The soil has less than 30 percent clay content; and
   - The soil has less than 40 percent silt and clay content.

3) For infiltration systems to provide water quality treatment, the runoff must infiltrate through at least 18 inches of soil that has a minimum cation exchange capacity of five (5) milliequivalents per 100 grams of dry soil. The soil's infiltration rate and cation exchange capacity shall be determined using the values given in Table III-3.1 of the *1992 DOE Stormwater Management Manual*. The texture class shall be determined using the USDA Textural Triangle. For large infiltration systems, the soil's infiltration rate and cation exchange capacity shall be determined using USEPA Method 9081.

4) The bottom of the infiltration facility shall be a minimum of 3 feet above the maximum seasonal high water table, bedrock, hardpan or an impermeable layer. This depth requirement may be reduced to a minimum of 2 feet above the maximum seasonal high water table or bedrock/hardpan/impermeable layer for single family roof infiltration systems where the impermeable area is less than 5,000 square feet.

5) All infiltration system locations are subject to the regulations of the Snohomish County Health District. The following setback requirements shall be met unless a licensed Geotechnical Engineer, Hydrologist, or other appropriate expert provides sufficient information to justify a setback reduction:

   - A minimum of 100 feet from wells.
   - A minimum of 30 feet from septic tanks or drainfields.
   - A minimum of 10 feet upslope from any structure, property line, and wetland or stream Native Growth Protection Area (NGPA).

- A minimum of 30 feet down slope or 100 feet up slope from any structure and at least 20 feet from an NGPA (large infiltration systems only).

- A minimum of 50 feet from any geologically hazardous area. Any design requirements or concerns related to steep slopes or other sensitive area impacts identified by a licensed Engineer shall be addressed in the soil study.

- Sufficient separation shall be provided between adjacent infiltration systems so that the respective lines of soil saturation do not intersect. Lines of saturation shall be assumed to slope away from the design maximum water elevation at 1.5 horizontal to 1 vertical.

6) The design infiltration rate shall be determined by infiltration testing, or analysis of soil logs, or a combination of testing and analysis.

    - When infiltration rate tests are used to provide an estimate of the saturated soil hydraulic conductivity, the maximum infiltration rates determined through these tests shall not be faster than those shown in the table in *DOE Stormwater Management Manual* for the given soil textural class.

    - The design infiltration rate shall not be higher than the measured infiltration rate. The appropriate factor of safety (4 minimum) shall be applied. Long term clogging with fines shall be reflected in the design infiltration rate.

    - When a project is located near the boundary between 1 or more soil units, the unit yielding the most conservative infiltration rate shall be used.

    - The design infiltration rate analysis shall address the influence of geometric hydraulic constraints, groundwater mounding, shallow water table and/or any impervious layer(s).

7) Slope restrictions depend on the infiltration BMP selected. Infiltration facilities are generally feasible on slopes up to 15%.

8) The following drainage area limitations shall apply for infiltration BMPs:

    - Infiltration basins - 5 acres maximum.

    - Roof runoff infiltration/dispersion systems - 5000 square feet of impervious area maximum.

9) The use of infiltration systems for runoff from single family residential buildings with less than 5000 square feet of roof area is encouraged. Large lots are encouraged to use a combination infiltration/dispersion system to handle the two (2) year storm with excess

runoff dispersion for larger storms, provided that no downstream structures exist and wetlands or buffers are available to receive the runoff.

10) Infiltration BMPs are sized using standard routing and modeling techniques. Stage-storage and stage-discharge relationships are developed through an iterative process, the final infiltration facility size and geometry is determined by routing the appropriate design storm(s) through the facility. Darcy's law of ground water movement shall be used to determine the flow rate and stage discharge table.

Darcy's Law: Q = (f)(i)(As)

Where:
Q = flow rate at which runoff is infiltrated
f = soil infiltration rate (including minimum safety factor of 4) *
i = hydraulic gradient (set equal to one)
As = surface area available for infiltration (not cross-sectional area)
* *The infiltration rate is determined from the soil texture class or soil test.*

3-9.04 CONSTRUCTION

1) Construction plans shall specify the construction sequence for the infiltration BMP. Compaction of soil and later redevelopment is not allowed as the design is based on natural soil in the original location. Vehicles shall not be driven over the infiltration area during construction.

2) When constructing infiltration basins, the initial basin excavation shall be carried to within one (1) foot of the final elevation of the basin floor. Final excavation to the finished grade shall not be initiated until all disturbed areas in the watershed have been stabilized or protected. After the final grading is completed, the basin floor shall be deeply tilled using rotary tillers or disc harrows to provide a well aerated, highly porous surface texture.

3) Specifications for basin construction shall state the earliest point in the construction process when storm drainage may be directed to the basin. Details for bypassing the facility until it is operational shall be provided. Infiltration BMPs shall not be put into use until the drainage areas that contribute runoff to the facility have been adequately stabilized. Infiltration systems must be protected from sediment deposition at all times, especially during the plat build out phase.

3-9.05 MAINTENANCE

A plan for maintenance and/or replacement of the infiltration BMP is required. For an infiltration trench BMP, inspection and/or monitoring reports shall be provided.

3-10 FLOW DISPERSAL SYSTEMS

The primary purpose of a level spreader trench is to diffuse concentrated runoff and release it onto large areas stabilized by existing vegetation. Level spreaders may be used to disperse the outflow from detention facilities when a downstream conveyance system is not present.

3-10.01 LEVEL SPREADER TRENCHES

1) Level spreader trenches shall be constructed a minimum of 20 feet upstream from any adjoining downstream property.

2) Level spreader trenches shall be constructed of a grass swale and 4 inch drain rock or a level steel plate embedded in reinforced concrete. No wood structures shall be allowed.

3) A minimum of 10 feet of drain rock shall be laid downstream of the level spreader trench.

4) Level spreader trenches shall only be used on slopes 5% or less.

5) Downstream easements are required when the level spreader is closer than 20 feet to the downstream property line and whenever sheetflow patterns originally existed.

3-10.02 BUBBLE–UP SPREADERS

For runoff from roof areas larger than 700 square feet, a bubble-up spreader may be used.

3-11 WATER QUALITY SYSTEMS

1) Water quality systems are discussed in detail in the *DOE Stormwater Management Manual*, Volumes I-IV.

2) Biofiltration facilities to provide water quality treatment include biofiltration swales and vegetated filter strips. Biofiltration swales are specially designed vegetated channels for treating concentrated flow, while filter strips are vegetated areas for treating unconcentrated sheet flow.

3) Biofiltration facilities that provide stormwater treatment for private development are required to be placed in separate tracts, and shall not be located in the public right-of-way. While these channels may provide pollutant removal, they are not a substitute for required stormwater treatment systems such as biofilters.

4) Water quality treatment systems shall not be part of any conveyance system where the peak flow is uncontrolled.

5) Systems requiring periodic replacement of filter media may be used in drainage systems located outside the public right-of-way. Use of these systems within the public right-of-way is allowed if approval is granted by the City Engineer.

3-11.01 DESIGN

Design shall be based on hydraulic residence time, calculated by using the Manning Formula method. If not all of the stormwater treated in a biofilter enters at the same location, the design hydraulic residence time shall be the flow weighted average hydraulic residence time.

1) Biofilters shall be designed to receive flows no greater than the design flow rate. Flows exceeding the design flow rate shall bypass the biofilter. In cases where the City Engineer determines that bypass is not feasible, biofilters shall be designed and constructed in accordance with all standards and code requirements for both biofilters and conveyance systems. Additional exceptional design parameters may be required.

2) If flow is introduced to biofilters through curb cuts, the cuts shall be a minimum of 12 inches wide.

3-11.02 CONSTRUCTION

1) Biofilters shall be sodded and over-seeded. Examples of vegetation mixes are provided in the *DOE Stormwater Management Manual* of Western Washington. Vegetation shall be permanently established in biofilters before stormwater runoff is allowed to flow through them.

   - Biofilters with grades greater than 2% shall be over-seeded with water tolerant grasses.

   - Biofiltration swales with slopes of 2% and less shall be over-seeded with both water-tolerant grasses and emergent wetland vegetation.

2) Level spreaders shall be installed at a minimum of every fifty feet in biofiltration swales. If the swale is terraced, additional spreaders are required at the top and base of each terrace. If the terrace exceeds a vertical drop of 0.5 foot or a 1:1 grade drop of 1.0 foot, a concrete sump box is required at the base with a level spreader at the downstream lip of the box. Otherwise, a 4 foot long strip of 4- to 8-inch rock shall be placed immediately below the terrace.

3) Swales shall be constructed as follows:

   - Overexcavate the swale 8 to 12 inches and install 4 to 8 inches of compacted, amended topsoil and 4 inches of turf sod on the topsoil.

- Topsoil and turf shall extend at least one (1) foot above the design water surface and shall cover the entire bottom of the swale.
- The top of sod shall be two (2) inches below the invert of the inlet and outlet pipes.
- No wood is allowed.

3-12 DRAINAGE EASEMENTS

1) Public drainage easements shall be a minimum of 10 feet wide for maintenance and access of pipes located outside of the public right-of-way which convey runoff from public streets or other facilities. See Standard Detail SD-130.

2) Where possible, pipes shall be located in the center of the drainage easement, but in no case shall a pipe be closer than five feet to a property line.

3) Where possible, drainage easements shall be contained on one lot, and not bisected by a lot line.

4) Shared private pipes must be located within private drainage easements.

5) Easements for downspout roof drains, yard drains, and footing drains are not required unless these systems are shared by more than one property owner.

3-13 OPERATION AND MAINTENANCE

All stormwater facilities shall be maintained in accordance with the adopted *DOE Stormwater Manual*, the O&M manual in the drainage report prepared by the Design Engineer during the project review process, the City of Arlington Stormwater Utility policy approved by the City Council, the City Stormwater Comprehensive Plan, and the provisions provided herein.

Projects within the City of Arlington are eligible for a Stormwater Utility Credit for stormwater service customers who construct and maintain systems according to the adopted *DOE Stormwater Manual*. This credit is an ongoing reduction in the stormwater utility fee. The Stormwater Utility is outlined in Ordinances No. 1395 and 1396.

3-14 PRIVATE SYSTEMS

It shall be the responsibility of the property owner to maintain, repair and restore, at the owner's expense, all private stormwater and drainage systems located on the owner's property. Maintenance shall be performed in accordance with maintenance schedule in the drainage report prepared by the Design Engineer during the plan review process for constructing the facilities. The City shall be granted the right to inspect and conduct emergency maintenance as deemed necessary by the Public Works Director. The City will be reimbursed by the private owner for any emergency maintenance costs incurred.

Disposal of waste from maintenance activities shall be conducted in accordance with the minimum Functional Standards for Solid Waste Handling, Chapter 173-304 WAC, guidelines by the Washington State Department of Ecology for disposal of waste materials from stormwater maintenance activities, and where appropriate, the *Dangerous Waste Regulations*, Chapter 173-303 WAC.