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SECTION 10 – STORMWATER QUALITY FACILITY DESIGN

10.1 INTRODUCTION

The purpose of this Section is to outline the design and construction guidelines for water quality facilities in the City of Independence. These guidelines may be used to comply with the water quality facility design standards in Chapter 3 Subsection "Water Quality Facility Design." It is the responsibility of the design engineer to determine the appropriate design criteria that ensures compliance with the City of Independence design standards, in combination with other federal, state, and local laws and ordinances. Safety of stormwater quality facilities shall be in conformance with "Safety" in Chapter 3 Subsection "Detention/Retention Facility Protection."

10.2 FILTRATION

10.2.1 Biofiltration Swale

A. Hydraulic design criteria
   1. Design storm = water quality storm
   2. Minimum hydraulic residence time = 9 minutes.
   3. Maximum water design depth = 0.5 feet.
   4. Minimum freeboard = 1.0 foot (for facilities not protected from high flows).
   5. Manning *n* value = 0.24.
   6. Maximum velocity = 2.0 feet per second based on 25-year flow.

B. Design criteria
   1. Provide an energy dissipater at the entrance to the swale as per Chapter 3 Subsection "Channel Protection." It shall be designed to reduce velocities and spread the flow across the treatment cross-section.
   1. Intermediate flow spreaders may be required.
   2. Minimum length = 100 feet.
   3. Minimum slope = 0.5%.
   4. Minimum bottom width = 2 feet.
   5. Maximum treatment depth (measured from top of gravel) = 0.5 feet.
   6. Maximum side slope:
      a) In treatment area = 4H:IV
      b) Above treatment area = 3H:IV
   7. Use 2"-¾" gap-graded river aggregate placed 2½ to 3 inches deep on jute matting placed over 6 inches of topsoil or use another base-stabilization method approved by the Public Works Department authorized representative. Extend river aggregate, jute, and topsoil to top of treatment area.
   8. If the swale slope is less than 1.5%, an underdrain shall be installed using a perforated pipe, or equivalent. Amend the soil, if necessary, to allow effective percolation of water to the underdrain. Underdrains can be made of 6-inch diameter Schedule 40 PVC perforated pipe with 6 inches of drain gravel over the pipe. The gravel and pipe must be enclosed by geotextile fabric. Slopes greater than 2.5% need check dams (riprap) at vertical drops of 12-15 inches.
   9. Retaining walls are not allowed in the treatment area.
   10. Provide an approved outlet structure for all flows.
   11. All exposed areas shall be protected with jute matting or an alternative approved by the Public Works Department authorized representative.
   12. Plant vegetation consistent with the requirements of Chapter 8 Landscape Requirements for Stormwater Facilities.

10.2.2 Sand Filter

A. Design Criteria

1. The design of sand filters is based on Darcy's Law (Safety Factor = 2):

   $A = Q \div (k \times i)$

   Where: A = area of sand filter.
   Q = peak flow rate (from hydrograph).
   k = sand permeability (3.5 feet/day).
   i = hydraulic gradient (see below).

   $I = (h + L) \div L$

   Where: h = height of water column over sand filter.
   L = thickness of sand filter.

2. No drainage shall be allowed directly to the filter; it must first go through a catch basin, inlet, sedimentation manhole, or similar large debris collection device.
3. The sand filter shall infiltrate the entire water quality volume without overflow.
4. The drawdown period for sand filters shall not exceed 24 hours.
5. The sand filter shall consist of an inlet structure, a sand bed, underdrain piping, and a basin liner. Criteria for these components are given below.

B. Inlet Structure

The inlet structure shall spread the flow of incoming water uniformly across the surface of the filter medium during all anticipated flow conditions. At a minimum, the inflow spreader shall meet the requirements as provided in Chapter 3 Subsection "Outfall Protection". It shall be designed to reduce velocities and spread the flow across the treatment cross-section. Flow shall be spread in a manner that prevents roiling or otherwise disturbing the filter medium.

C. Sand Bed—Filter Medium

1. The length-to-width ratio shall be 2:1 or greater.
2. The filter bed medium shall consist of clean, medium to fine sand, with no organics, frozen pieces, or other deleterious materials. Sand used as a filter medium shall be certified by a certified testing laboratory as meeting or exceeding the gradation requirements in **Table 10.1**. Sieve analysis shall be determined according to AASHTO T-27.

Table 10.1. GRADATION REQUIREMENTS FOR FILTER BED MEDIUM

Sieve Size	Percent Passing
3/8-inch	100
No. 4	95-100
No. 8	80-100
No. 16	45-85
No. 30	15-60
No. 50	3-15
No. 100	< 4

D. Sand Bed with Gravel Filter

1. The top layer shall be a minimum of 18 inches of sand meeting gradation requirements of **Table 10.1**.

2. The sand shall be placed over a non-woven geotextile fabric material, meeting the specifications provided in **Table 10.2**, covering a layer of ½- to 2-inch washed drain rock. The finished depth of this drain rock shall be sufficient to provide a minimum of 2 inches of cover over the underdrain piping system.
3. No gravel is required below the underdrain piping system.

Table 10.2. GEOTEXTILE FABRIC MATERIAL SPECIFICATIONS

Property	Test Method	Specification
Unit Weight	--	8 oz./SY (minimum)
Filtration Rate	--	0.08 inch/sec (minimum)
Puncture Strength	ASTM D-751 (modified)	125 lb. (minimum)
Mullen Burst Strength	ASTM D-751	400 psi (minimum)
Tensile Strength	ASTM D-1682	200 lb. (minimum)
Equivalent Opening Size	US Standard Sieve	80-120

E. Sand Bed Using Trench Design
1. The top layer shall be a minimum of 12 inches of sand meeting gradation requirements of **Table 10.1**.
2. The sand shall be placed over a non-woven geotextile fabric material, meeting the specifications provided in **Table 10.2**, covering a layer of ½- to 2-inch washed drain rock. The finished depth of this drain rock shall be sufficient to provide a minimum of 2 inches of cover over the underdrain piping system.
3. The piping and gravel shall be underlain with drainage matting meeting the specifications provided in **Table 10.3**.

Table 10.3. DRAINAGE MATTING MATERIAL SPECIFICATIONS

Property	Test Method	Specification
Unit Weight		20 oz./SY
Flow Rate (fabric)		180 gpm/SF (minimum)
Permeability	ASTM D-2434	0.124 cm/sec
Grab Strength (fabric)	ASTM D-1682	Dry Lg 90 Dry Wd 70 Wet Lg 95 Wet Wd 70
Puncture Strength (fabric)	COE CW-02215	42 (minimum)
Mullen Burst Strength	ASTM D-117	140 psi (minimum)
Equivalent Opening Size	US Standard Sieve	80 – 120
Flow Rate (drainage core)	Drexel Universal Test Method	14 gpm/ft. width

F. Underdrain Piping

1. The underdrain piping system shall consist of appropriately sized perforated pipes (minimum 4-inch diameter). The pipe used in this system shall be schedule 40 polyvinyl chloride (PVC) material, or an approved equal. Flexible perforated pipe will not be approved. Lateral spacing shall not exceed 10 feet.
2. The underdrain laterals shall be placed with positive gravity drainage to the collector pipe
3. The collector pipe shall have a minimum 1% grade toward the discharge point.
4. All laterals and collector pipe shall have cleanouts installed, accessible from the surface without removing or disturbing filter media.

G. Basin Liner
1. An impermeable liner is required for all sand filter systems. The liner shall comply with the requirements provided in Section 11, "Stormwater Quality Facility Liners."
2. Geomembrane liners shall meet the requirements provided in Subsection "Geomembrane Liners." They shall be placed on a smooth, compacted bed of sand, minimum 6 inches thick, graded as necessary to facilitate the hydraulic performance designed into the facility.

10.3 PONDS

10.3.1 Wet Ponds

A. Hydraulic design criteria
1. Permanent pool volume = 0.55 × WQV (Water Quality Volume).
2. Minimum water quality detention/retention volume = 1.0 × WQV.
3. Water quality drawdown time = 48 hours.
4. To calculate orifice size, use the following equation:

$$D = 24 \times [(Q / (\pi C_d[2gH]^{0.5})]^{0.5}$$

Where: D = orifice diameter (inches).
Q (cfs) = WQV (cf)/(48 hr. × 60 min/hr. × 60 sec/min).
C_d = orifice coefficient (0.62 for square-edged entrance).
g = gravitational constant (32.2 ft./sec^2).
H = ⅔ temporary detention height (feet) to orifice centerline.

5. Maximum depth of permanent pool = 6 feet
6. Maximum depth of water quality pool (not including permanent pool) = 2.5 feet.
7. Provide an emergency spillway sized to pass the 100-year storm event or an approved hydraulic equivalent. The emergency spillway shall be located in existing soils when feasible and shall be armored with riprap embedded in concrete, or other approved erosion protection extending to the toe of the embankment.
8. Provide for a basin dewatering system with a 24-hour maximum drawdown time.

B. Design Criteria
1. The pond configuration, as well as the inlet and outlet locations, shall maximize water travel time through the facility.
2. The pond shall be designed using the following surface-area-to-depth relationship (for the volume required by a permanent pool):

70% of the surface area @ 2- to 6-foot depth
30% of the surface area @ 0- to 2-foot depth

The maximum depth of the permanent pool shall be 6 feet. The 0-to-2-foot depth shall be distributed evenly around the perimeter of the pond.
3. The facility shall be divided into at least two cells. The first cell (forebay) shall contain approximately 10% of the design surface area.

4. The construction of wets ponds and maintenance accessibility shall be in conformance with Chapter 3 Subsection "Design Criteria," Chapter 3 Subsection "Detention/Retention Facility Protection," and Chapter 3 Subsection "Access Road Design."
5. Safety of stormwater quality facilities shall be in conformance with "Safety" in Chapter 3 Subsection "Detention/Retention Facility Protection."
6. The slopes in the treatment and surrounding areas of the pond shall be 3H:1V or flatter, unless approved by the Public Works Department authorized representative. If steeper slopes are desired, the site shall be fenced as described in Chapter 3 Subsection "Detention/Retention Facility Protection." The applicant shall provide calculations and geotechnical data indicating adequate slope stability. Calculations and data shall be provided from a Professional Engineer registered in the State of Oregon whose area of expertise is geotechnical engineering.
7. The average length-to-width ratio shall be at least 3:1. This ratio is critical to prevent "short-circuiting," where water passes directly through the facility without being detained for any time.
8. If a riser pipe outlet is used, it shall be protected by a trash rack and anti-vortex plate. If an orifice plate is used, it shall be protected with a trash rack with at least 10 square feet of open surface area. In either case, the rack must be hinged or easily removable to allow for cleaning. The rack shall be adequately secured to prevent it from being removed or opened when maintenance is not in progress.

C. Dead Storage
1. The dead (permanent) storage volume, V_{pond}, is equivalent to the post-development runoff.
2. Calculating runoff volume using the SBUH method can be approximated by the following equation:

$V = 25.9 \times A \times \% I + 27.7 \times A$

Where: V = runoff volume (cubic feet).
A = total contributing land area (acres).
% I = percent of land area that is impervious.
(i.e., if the land is 20% impervious, enter 20 in the equation).

10.3.2 Extended Wet Ponds

A. Hydraulic design criteria
1. Permanent pool volume = 0.55 × WQV.
2. Minimum water quality detention/retention volume = 1.0 × WQV.
3. Water quality drawdown time = 48 hours.
4. To calculate orifice size, use the following equation:

$D = 24 \times [(Q / (\pi C_d[2gH]^{0.5}))]^{0.5}$

Where: D = orifice diameter (inches).
Q (cfs) = WQV (cf)/(48 hr. × 60 min/hr. × 60 sec/min).
C_d = orifice coefficient (0.62 for square-edged entrance).
g = gravitational constant (32.2 ft./sec^2).
H = ⅔ temporary detention height (feet) to orifice centerline.
5. Maximum depth of permanent pool = 2 feet.
6. Maximum depth of water quality pool (not including permanent pool) = 2.5 feet.
7. Provide an emergency spillway sized to pass the 100-year storm event or an approved hydraulic equivalent. The emergency spillway shall be located in existing soils when feasible and shall be armored with riprap embedded in concrete, or other approved erosion protection extending to the toe of the embankment.
8. Provide for a basin dewatering system with a 24-hour maximum drawdown time.

B. Design criteria
   1. Minimum of two cells, with the first cell (forebay) at least 10% of the design surface area. The forebay shall also constitute 20% of the treatment volume. Where space limits multi-cell design, use one cell with a forebay at the inlet to settle sediments and distribute flow across the wet pond.
   2. Maximum side slopes in basin treatment area = 3H:IV
   3. Over excavate by a minimum of 20% to allow for sediment deposition.
   4. Minimum freeboard = 1 foot from 25-year design water surface elevation.
   5. Retaining walls are not allowed in the treatment area.
   6. Provide an approved outlet structure for all flows.
   7. The construction of wet ponds and maintenance accessibility shall be in conformance with Chapter 3 Subsection "Design Criteria," Chapter 3 Subsection "Detention/Retention Facility Protection," and Chapter 3 Subsection "Access Road Design."

10.3.3 Extended Dry Pond

A. Hydraulic design criteria
   1. Permanent pool depth = 0.4 feet.
   2. Permanent pool is to cover the entire bottom of the basin.
   3. Minimum water quality detention/retention volume = 1.0 × WQV.
   4. Water quality drawdown time = 48 hours.
   5. To calculate orifice size, use the following equation:

      $D = 24 \times [(Q / (\pi C_d[2gH]^{0.5})]^{0.5}$

      Where: D = orifice diameter (inches).
      Q (cfs) = WQV (cf)/(48 hr. × 60 min/hr. × 60 sec/min).
      C_d = orifice coefficient (0.62 for square-edged entrance).
      g = gravitational constant (32.2 ft./sec^2).
      H = ⅔ temporary detention height (feet) to orifice centerline.
   6. Maximum depth of water quality pool (not including permanent pool) = 4 feet.
   7. Provide an emergency spillway sized to pass the 100-year storm event or an approved hydraulic equivalent. The emergency spillway shall be located in existing soils when feasible and armored with riprap embedded in concrete, or other approved erosion protection extending to the toe of the embankment.

B. Design criteria
   1. Minimum of two cells, with the first cell (forebay) at least 10% of the design surface area. The forebay shall also constitute 20% of the treatment volume. Where space limits multi-cell design, use one cell with a forebay at the inlet to settle sediments and distribute flow across the wet pond.
   2. Minimum bottom width = 4 feet
   3. Maximum side slope in basin treatment area = 4H:IV.
   4. Minimum freeboard = 1 foot from 25-year design water surface elevation.
   5. Retaining walls are not allowed in the treatment area.
   6. An approved outlet structure shall be provided for all flows.
   7. The construction of dry ponds and maintenance accessibility shall be in conformance with Chapter 3 Subsection "Design Criteria," Chapter 3 Subsection "Detention/Retention Facility Protection," and Chapter 3 Subsection "Access Road Design."

10.4 WETLANDS

A. Hydraulic design criteria
   1. Permanent pool volume = 0.55 × WQV.
   2. Water quality detention/retention volume = 1.0 × WQV.

3. Water quality drawdown time = 48 hours.
4. To calculate orifice size, use the following equation:

$$D = 24 \times [(Q / (\pi C_d[2gH]^{0.5}))]^{0.5}$$

Where: D = orifice diameter (inches).
Q (cfs) = WQV (cf)/(48 hr. × 60 min/hr. × 60 sec/min).
C_d = orifice coefficient (0.62 for square-edged entrance).
g = gravitational constant (32.2 ft./sec^2).
H = ⅔ temporary detention height (feet) to orifice centerline.

5. Maximum depth of permanent pool = 2.5 feet.
6. Maximum velocity through the wetland should average less than 0.01 feet per second for the water quality flow. Design should distribute flow uniformly across the wetland.
7. Provide an emergency spillway sized to pass the 100-year storm event or an approved hydraulic equivalent. The emergency spillway shall be located in existing soils when feasible and shall be armored with riprap embedded in concrete, or other approved erosion protection extending to the toe of the embankment.
8. Provide for a basin dewatering system with a 24-hour maximum drawdown time.

B. Design Criteria
1. Minimum of two cells, with the first cell (forebay) at least 10% of the surface area. The forebay shall also constitute 20% of the treatment volume. Where space limits multi-cell design, use one cell with a forebay at the inlet to settle sediments and distribute flow across the wet pond.
2. Permanent pool depth to be spatially varied throughout wetland.
3. Provide a perimeter zone 10 to 20 feet wide that is inundated during storms.
4. Maximum side slopes for wetland planting = 5H:IV.
5. Maximum side slopes for non-wetland planting = 3H:IV.
6. Over excavate by a minimum of 20% to allow for sediment deposition.
7. Minimum freeboard = 1 foot from 25-year design water surface elevation.
8. Retaining walls are not allowed in the treatment area.
8. The construction of wetlands and maintenance accessibility shall be in conformance with Chapter 3 Subsection “Design Criteria,” Chapter 3 Subsection “Detention/Retention Facility Protection,” and Chapter 3 Subsection “Access Road Design.”
9. Provide an approved outlet structure for all flows.

10.5 INFILTRATION

10.5.1 Infiltration Trench

Design criteria

A. The design of infiltration trenches is based on Darcy’s Law (Safety Factor = 2):

$$A = 2.0 \times Q \div (f \times i)$$

Where: A = area of trench bottom (square feet).
Q = design flow rate (cfs).
f = infiltration rate of soil or infiltration media (ft./sec).
i = hydraulic gradient (see below).

$$i = (h + L) \div L$$

Where: h = height of water column over infiltration media.
L = distance from surface to bottom of trench

B. The infiltration trench shall infiltrate the entire water quality storm without overflow.
C. Infiltration facilities shall not be accepted in soils with a tested infiltration rate of less than 0.50 inches per hour.

D. There shall be no less than 3 feet of undisturbed depth of infiltration medium between the bottom of the facility and any impervious layer (hardpan, solid rock, high groundwater levels, etc.).
E. Drawdown time (time for the trench to empty water from the water quality storm) shall not exceed 24 hours.
F. Infiltration trenches shall meet the following setback requirements for downstream slopes: minimum of 100 feet from slopes of 16%; add 5 feet of setback for each additional percent of slope up to 30%; 200-foot setback for slopes of 30%; infiltration trenches shall not be used where slopes exceed 30%.
G. All infiltration trenches shall have an overflow installed that can transport the design capacity of the water delivery system through the facility to an approved stormwater receiving system if the facility infiltration capacity is exceeded. An approved stormwater receiving system is a stream, lake, or pond, or a storm sewer or drainage ditch. Overflows shall be designed with appropriate erosion-control devices.
H. Each trench shall have one slotted observation pipe (4-inch) that extends to the bottom of the trench, at a point approximately halfway along the trench. The observation pipe shall have a threaded or hinged cap or plug.
I. Drain medium shall have filter fabric between the medium and native soils or backfill meeting specifications established in Table 10.2.
J. Infiltration areas shall be clearly marked before site work begins to avoid soil disturbance during construction. No vehicular construction traffic, except that specifically used to construct the facility, shall be allowed within 10 feet of infiltration trench areas.
K. A certified soils scientist (ARCPACS certification), or suitably trained person working under the supervision of a Professional Engineer registered in the State of Oregon, shall inspect the soil after the system is excavated and before trenches are filled with drain medium, to confirm that soils remain in suitable condition to perform at anticipated infiltration rates.

10.5.2 Infiltration Basin

Design criteria

A. The design of infiltration trenches is based on Darcy's Law (Safety Factor = 2):

$$A = 2.0 \times Q \div (f \times i)$$

Where: A = area of trench bottom (square feet).
Q = design flow rate (cfs).
f = infiltration rate of soil or infiltration media (ft./sec).
i = hydraulic gradient (see below).

$$i = (h + L) \div L$$

Where: h = height of water column over infiltration media.
L = distance from surface to bottom of trench

B. The infiltration basin shall infiltrate the entire water quality storm without overflow.
C. Infiltration basins shall meet the following setback requirements for downstream slopes: minimum of 100 feet from slopes of 10%; add 5 feet of setback for each additional percent of slope up to 30%; 200-foot setback for slopes of 30%; infiltration trenches shall not be used where slopes exceed 30%.
D. All infiltration basins shall have an overflow installed that can transport the design capacity of the water delivery system through the facility to an approved stormwater receiving system if the facility infiltration capacity is exceeded. An approved stormwater receiving system is a stream, lake, or pond, or a storm sewer or drainage ditch. Overflows shall be designed with appropriate erosion-control devices.
E. Any imported drain medium shall have filter fabric between the medium and native soils or backfill.

F. Two staff gauges shall be installed, at opposite ends of the bottom of the basin, to enable maintenance staff to measure the depth of accumulated silts.
G. Infiltration areas shall be clearly marked before site work begins to avoid soil disturbance during construction. No vehicular traffic, except that specifically used to construct the facility, shall be allowed within 10 feet of infiltration basin areas.
H. A certified soils scientist (ARCPACS certification), or suitably trained person working under the supervision of a Professional Engineer registered in the State of Oregon, shall inspect the soil after the system is excavated and before the basin is filled with drain medium, to confirm that soils remain in suitable condition to accept anticipated infiltration.
I. Infiltration facilities shall not be accepted in soils with a tested infiltration rate of less than 0.50 inches per hour.
J. There shall be no less than 3 feet of undisturbed depth of infiltration medium between the bottom of the facility and any impervious layer (hardpan, solid rock, high groundwater levels, etc.).
K. Drawdown time (time for the basin to empty water from the water quality design storm) shall not exceed 24 hours.