



# Stormwater Design Standards

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## ACKNOWLEDGEMENTS

These design standards were developed based on City policies in place at the time of development of the standards, including the City's 2002 Stormwater Master Plan, South Corvallis Stormwater Master Plan and the 2006 Corvallis Land Development Code. These design standards are intended to be implemented in conjunction with the City's Standard Construction Specifications, Design Criteria Manual, and the City's Public Improvement by Private Contract (PIPC) Manual.

The primary source documents for facility design and maintenance guidance is from the King County Surface Water Design Manual (2009) and this manual is largely excerpted from that document. Additional content was drawn from the Oregon Department of Transportation (ODOT) standard detail drawings, the Oregon City Stormwater and Grading Design Standards (2015), Clackamas County's Stormwater Management Design Standards (June 2010 Draft), City of Portland Stormwater Management Manual (2014), and additional local resources.

The manual was developed by Brown and Caldwell based on City policies and direction from City staff.

## ABBREVIATIONS

2h:1v	Two-horizontal to one-vertical
3h:1v	Three-horizontal to one-vertical
4h:1v	Four-horizontal to one-vertical
AASHTO	American Association of State Highway and Transportation Officials
AC	asphalt concrete
APWA	American Public Works Association
ASTM	American Society of Testing and Materials
BMP	best management practice
CEG	Certified Engineering Geologist
cfs	cubic foot/feet per second
City	City of Corvallis
CFR	Code of Federal Regulations
CMP	corrugated metal pipe
CPEP	corrugated high-density polyethylene
CSS	Contech Stormwater Solutions
CWA	Federal Clean Water Act of 1972
EPSC	erosion prevention and sediment control
FEMA	Federal Emergency Management Agency
fps	foot/feet per second
gpm	gallon(s) per minute
HDPE	high-density polyethylene
HGL	hydraulic grade line
LCPE	lined corrugated polyethylene pipe
LDC	Corvallis Land Development Code
LID	low-impact development
MEP	maximum extent practicable
MS4	municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NURP	Nationwide Urban Runoff Program
ODEQ	Oregon Department of Environmental Quality
ODSL	Oregon Department of State Lands
ODOT	Oregon Department of Transportation
O&M	operations and maintenance
OPSC	Oregon Plumbing Specialty Code
ORS	Oregon Revised Statutes

OSHA	Occupational Safety and Health Administration
OWRD	Oregon Water Resources Department
PC	point of curvature
PE	Professional Engineer
PIPC	Public Improvement by Private Contract
ppm	part(s) per million
psi	pound(s) per square inch
PT	point of tangency
PVC	polyvinyl chloride
RCB	reinforced concrete box
RG	Registered Geologist
ROW	right-of-way
SBUH	Santa Barbara Urban Hydrograph Method
SC	spill control
SCS	Soil Conservation Service (See NRCS)
SF	square foot/feet
SPCC	spill prevention, countermeasure, and containment
Standards	Corvallis Stormwater Design Standards
SMP	Corvallis Stormwater Master Plan
SWMP	Corvallis Stormwater Management Plan
TAPE	Technology Assessment Protocol - Ecology
Tc	time of concentration
TR-20	Technical Release 20
TR-55	Technical Release 55
TSS	total suspended solids
UPC	Uniform Plumbing Code
UIC	underground injection control
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WPCF	water pollution control facility
WQRA	Water Quality Resource Area

## DEFINITIONS

Definitions referenced below are specific to the use and interpretation of these Corvallis Stormwater Design Standards (Standards).

**Applicant:** Any person who applies for an approval and/or permit from the City.

**Approved point of discharge:** A location down-slope from a development that the City has deemed adequate to accept stormwater flows from all or a portion of the development area.

**Biofiltration swale:** A long, gently sloped, vegetated ditch designed to filter pollutants from storm water. Grass is the most common vegetation, but wetland vegetation can be used if the soil is saturated.

**City Engineer:** Corvallis City Engineer and designated representative responsible for implementation of the Standards.

**Contractor:** A person duly licensed or approved by the State of Oregon to perform the type of work to be done under a permit or contract issued by the City.

**Design storm:** The distribution of rainfall intensity over time, identified to have a probability of recurrence, given in years (i.e., 5-year design storm).

**Detention:** The release of surface water runoff from a site at a slower rate than it is collected by the drainage system, the difference being held in temporary storage.

**Development:** Making a material change in the use or appearance of a structure or land, dividing land into two or more parcels, changing the land use designation, or creating or terminating a right of access. Where appropriate to the context, development refers to the act of developing or the result of development.

**Development, Infill:** Developing vacant and partially vacant land within a built environment. To be considered infill, such land shall be less than 0.5 acres in size for residentially designated lands or less than 1.0 acre in size for lands designated otherwise.

**Development Site:** Legally established lots, parcels, or tracts of land involved in a land use application or building/construction permit application. Sites that are occupied or capable of being occupied by a building or group of buildings including accessory structures and accessory uses, together with yards or open spaces, setback areas, and access as required by the Standards.

**Discharge:** Any addition of water, stormwater, wastewater, process water, or any pollutant or combination of pollutants to waters of the State, directly or indirectly, by actions of dumping, spilling, disposing, or physically connecting to the public storm system or natural drainage conveyance.

**Drainageway:** A natural or artificial watercourse, including adjacent riparian vegetation, that transmits natural stream or stormwater runoff from a higher elevation to a lower elevation.

**Easement:** A permanent or temporary interest or right to lay down, construct, reconstruct, replace, operate, inspect, and perpetually maintain storm drainage or surface water



pipelines, and all related facilities through, under, and along a described property, either public or private.

**Engineer:** A registered professional engineer licensed to practice in the State of Oregon.

**Erosion:** Movement or displacement of soil resulting from natural and human-induced processes including weathering, dissolution, abrasion, corrosion, and transportation.

**Government agency:** Any municipal or quasi-municipal jurisdiction, county, state, or federal agency.

**Hazardous materials:** Materials described as hazardous by ODEQ, including any toxic chemicals listed as toxic under Section 307(a) of the Clean Water Act or Section 313 of Title III of the Superfund Amendments and Reauthorization Act (SARA).

**Impervious surface:** A hard surface area that prevents or retards the entry of water into the soil mantle and/or causes water to run off the surface in greater than natural quantities or at an increased rate. Impervious surfaces may include, but are not limited to, rooftops, walkways, patios, driveways, parking lots, concrete or asphalt paving, gravel surfaces with compacted subgrade, packed earthen materials, and oiled macadam or other surfaces that similarly impede the natural infiltration of stormwater. Open, uncovered stormwater management facilities shall not be considered impervious surfaces.

**Infiltration:** The hydrologic process by which water on the ground surface enters the soil.

**Infiltration, Maximizing:** The use of a stormwater management facility such as a detention pond that maximizes soil to water contact area and disposal of stormwater into the ground surface.

**Infiltration-based facility:** A stormwater management facility that may be used for water quality or flow control, designed to use the hydrologic process of surface water and stormwater runoff soaking into the ground to dispose of surface water and stormwater runoff.

**Intermittent streams:** Streams and springs that consistently do not have year-round water or saturated soil within their channel or swale in a year with wet to average precipitation patterns. Intermittent flow must occur with some degree of regularity and must be in a definite direction.

**Landscape architect:** A registered Landscape Architect licensed to practice in the State of Oregon.

**Low-impact development (LID):** A sustainable site design and development approach that is used to replicate the natural watershed functions and/or address targeted watershed goals and objectives, including protection of existing sensitive areas.

**LID facility:** An infiltration-based stormwater management facility that mimics natural surface hydrological functions through infiltration or evapotranspiration, or that involves stormwater reuse. For purposes of these Standards, LID facilities are considered an alternative stormwater facility.

**Manufactured treatment device:** A manufactured device, often proprietary, in which stormwater receives treatment before being discharged to the conveyance system, another stormwater management facility, or the receiving water. This is a broad category

of stormwater management facilities with a variety of pollutant removal mechanisms and varying pollutant removal efficiencies.

**Municipal separate storm sewer system (MS4):** A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) as defined in Code of Federal Regulations (CFR) Title 40 Section 122.26(b)(8).

**National Pollutant Discharge Elimination System, or NPDES, Permit:** A permit issued pursuant to Chapter 402 of the Federal Clean Water Act (40 CFR 122, 123, 124, and 504).

**Owner:** The owners of record title or the purchasers under a recorded sale agreement and other persons having an interest of record in the described real property.

**Parcel of land:** A lot, parcel, block, or other tract of land that may be occupied by a structure or structures or other use, and includes yards and other undeveloped areas required under the zoning, subdivision, or other development ordinances.

**Perennial streams:** Streams and springs that have flowing water year round during a typical year. The water table is located above the streambed for most of the year. Groundwater is the primary source of water for stream flow; runoff from rainfall is a supplemental source of water for stream flow.

**Permeable pavers:** A type of pervious pavement which uses interlocking concrete or stone units with open, permeable spaces between the units. Typical applications include light traffic roads and parking areas.

**Permit:** Any authorization required pursuant to these standards or any other regulation.

**Person:** Any individual or legal entity.

**Public Improvement by Private Contractor (PIPC):** Refers to a City permitting process where public improvements are constructed in conjunction with private development.

**Plant community:** A grouping of plants that often occur together growing in a uniform habitat.

**Pollutant:** Any of the following, but not restricted to: oil; grease; soil; mining waste; spoil; solid waste; incinerator residue; sewage; garbage; sewage sludge; munitions; chemical wastes; biological materials; radioactive materials; heat; heavy metals; asbestos; wrecked or discharged equipment; cellar dirt; and untreated industrial, municipal, and agricultural discharges into water.

**Pollution-generating impervious surface:** An impervious area specifically used to determine adherence to the water quality impervious area threshold. Includes impervious surface area accessible to motor vehicles that does not promote infiltration and rooftop areas containing galvanized metal components.

**Porous/ pervious pavement:** Alternative pavement systems that allow water to percolate into subsurface drainage systems or the ground. Examples are permeable pavers, pervious concrete, and pervious asphalt.

**Post-developed conditions:** Conditions after development.

**Pre-developed conditions:** The conditions of the land prior to the original development. For the purpose of hydrological evaluations and flow control facility design for redeveloped impervious area, the pre-developed conditions shall assume a runoff pattern based on good condition grass and the corresponding native hydrologic soil group for the site.

**Pretreatment or treatment:** The reduction of the amount of pollutants to the maximum extent practicable (MEP), the elimination of pollutants, or the alteration of the nature of pollutant properties in water to a less harmful state.

**Private facility:** A stormwater management facility owned and maintained by a private entity (person, business, etc.), located outside of the public right-of-way.

**Private storm system:** That portion of the storm system owned and/or located outside of the public right-of-way.

**Public facility:** A stormwater management facility owned and maintained by the City of Corvallis and located within a dedicated right-of-way, tract, or within a public stormwater easement.

**Public stormwater system:** In general, those portions of the stormwater conveyance systems that are within a dedicated right-of-way, tract, or within a public stormwater easement. Public stormwater systems also include those stormwater conveyance systems or facilities that are within a dedicated right-of-way.

**Public right-of-way:** A right-of-way on which legal right of passage has been given to the public and is under city, county, state, or federal jurisdiction.

**Redevelopment:** Restoring or replacing existing buildings. See also Development, Infill.

**Retention:** The process of collecting and holding surface water runoff from a design storm with no surface outflow.

**Retrofit:** The creation or modification of an urban runoff management system in a previously developed area. A retrofit can consist of the construction of a new stormwater management facility in a developed area, the enhancement of an existing runoff management structure, or a combination of improvement and new construction.

**Riparian:** Land adjacent to a water body that directly affects or is affected by the aquatic environment. This includes streams, rivers, and lakes and their side channels, floodplains, and wetlands, and portions of the adjacent slopes that shade the channel or provide streamside habitat.

**Source control:** Stormwater management facilities and/or specific actions taken that attempt to control pollutant loading from high-risk sites.

**Standards:** These adopted principles and policies established by the City to meet the intent of preserving water quality and minimizing the impacts development has on the environment.

**Storm drainage/storm sewer:** A pipe or drainageway or any method of conveyance that carries stormwater, surface runoff, or drainage.

**Stormwater:** Waters on the surface of the ground resulting from precipitation.

**Stormwater management:** Surface water quality and quantity control through structural and nonstructural methods and capital improvement projects.

**Stormwater management facility:** Any water quality or flow control structure or drainageway that is designed, constructed, and maintained to collect, filter, retain, or detain surface water runoff during and after a storm event for the purpose of controlling flows and/or reducing pollutants in stormwater runoff. It may include, but is not limited to, stormwater wetlands, filter strips, biofiltration swales, proprietary stormwater controls, and ponds.

**Stream corridor:** A corridor of land of variable width along each side of a stream channel that is reserved primarily for stormwater-related and other stream function and processes.

**Underground Injection Control (UIC):** Defined by the Oregon Department of Environmental Quality as any system, structure, or activity that is intended to discharge fluids below the ground surface such as sumps, drywells, and soakage trenches.

**Undue hardship:** Special or specified circumstances that compel an applicant for development to request a modification of these standards so as to avoid an unreasonable or disproportionate burden or obstacle to development.

**Waters of the State:** Those waters defined in Oregon Revised Statutes (ORS) Chapter 468B.005 or as amended, which include lakes, bays, ponds, impounding reservoirs, springs, wells, rivers, streams, creeks, estuaries, marshes, inlets, canals, the Pacific Ocean within the territorial limits of the state of Oregon, and all other bodies of surface or underground waters, natural or artificial, inland or coastal, fresh or salt, public or private (except those private waters that do not combine or effect a junction with natural surface or underground waters), which are wholly or partially within or bordering the state or within its jurisdiction.

**Wetland:** Areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands are those areas identified and delineated by a qualified wetlands specialist as set forth in the Federal Manual for Identifying and Delineating Jurisdictional Wetlands, January 1987, or by an Oregon Department of State Lands (ODSL)/U.S. Army Corps of Engineers (USACE) 404 permit. Wetlands may also consist of:

- *Constructed wetlands.* As defined in Section 404 of the Clean Water Act, constructed wetlands are those areas developed as a water quality or quantity facility, subject to maintenance as such. These areas must be clearly separated from existing or created wetlands. Also called stormwater wetlands.
- *Created wetlands.* Created wetlands are those wetlands developed in an area previously identified as a non-wetland to replace or mitigate wetland destruction or displacement.
- *Existing wetlands.* Existing wetlands are those identified and delineated as set forth in the Federal Manual for Identifying the Delineating Jurisdictional Wetlands, January 1987, or as amended, by a qualified wetlands specialist.

**Wet pond:** A constructed treatment facility where a portion of the facility is dedicated to being an open body of water.

**Work area:** Areas of disturbance for activities defined under “Development.” Work areas include areas used for storage of equipment or materials that are used for these activities.

## **1. GENERAL INFORMATION**

These City of Corvallis (City) Stormwater Design Standards (Standards) describe requirements and methods for managing stormwater runoff from development activities within the City of Corvallis. The standards contained in this manual are implementing the City's *Stormwater Master Plan, Appendix F*. Implementing these standards will help to protect water resources that, in turn, will benefit human health, fish and wildlife habitat, and recreational resources.

This chapter describes the purpose, applicability, and administrative requirements of the Standards.

### **1.1 PURPOSE OF THE STORMWATER DESIGN STANDARDS**

The purposes of the Standards include, but are not limited to, the following:

- Meet federal and state National Pollutant Discharge Elimination System (NPDES) municipal separate storm sewer system (MS4) permit requirements for post-construction stormwater management
- Minimize the introduction of pollutants and provide water quality treatment of stormwater runoff to preserve the beneficial uses of drainageways, lakes, ponds, wetlands, and other sensitive areas
- Minimize common effects of urbanization on drainageways and conveyance channels including sediment transport, erosion, and degradation
- Protect the safety of persons and property by safely conveying all stormwater runoff from site development and preventing the uncontrolled or irresponsible discharge of stormwater onto adjoining public or private property
- Provide for orderly development by preserving the drainageways and natural conveyance systems created by the existing topography and creating man-made conveyance systems with adequate capacity for future development upstream
- Construct stormwater management facilities that are safe, effective, and economical to maintain and that minimize future replacement costs
- Provide guidance to designers and engineers in meeting the requirements of stormwater regulations when developing land and constructing infrastructure within the city
- Address the need for documented stormwater design standards as outlined in the City's *Stormwater Master Plan, Appendix F*

### **1.2 APPLICABILITY OF THE STORMWATER DESIGN STANDARDS**

These standards are intended for use by property owners, developers, and design professionals as design guidelines for all publicly and privately owned and maintained stormwater management facilities within the city.

All development, as defined by the City, is subject to the requirements of these Standards during the land use decision and permitting processes. These processes generally include all land use proposals, site development and permit approvals within, or proposed to be within, city boundaries.

### 1.2.1 GENERAL DEVELOPMENT EXEMPTIONS

The following development categories are generally exempt from the requirements of these Standards:

- A. Stream enhancement or restoration projects approved by the City
- B. **Farming practices** as defined by Oregon Revised Statutes (ORS) 30.930 and **farm use** as defined in ORS 214.200, except that buildings and pollution generating impervious pavement associated with farm practices and farm use are subject to the requirements of these Standards
- C. Actions by a public utility or any other governmental agency **to remove or alleviate an emergency condition**
- D. **Road and parking area preservation/maintenance projects** such as pothole and square cut patching, surface sealing, replacement or overlay of existing pavement, grind-inlays, and full depth pavement reconstruction.
- E. **Pedestrian and bicycle improvements** (sidewalks, trails, pathways, and bicycle paths) where no other impervious surfaces are created or replaced, built to direct stormwater runoff to adjacent vegetated areas
- F. **Underground utility projects** that replace the ground surface with materials that have similar runoff characteristics
- G. **Maintenance or repair** of existing utilities

### 1.2.2 IMPERVIOUS AREA THRESHOLDS

New development, expansion to existing development, or redevelopment activities that result in changes to the overall impervious surface for a site are subject to requirements for water quality and/or detention as defined by impervious area thresholds below. The impervious area thresholds must be considered for current development activities or cumulative development activities within an approved phasing plan.

Developers must complete the **Stormwater Facility Tracking Form** to define the addition and modification of impervious surfaces at a site and to specify the water quality and/or detention facilities proposed for a site. The Stormwater Facility Tracking Form shall be submitted to Community Development for private facilities concurrent with the building permit submittal. The Stormwater Facility Tracking Form shall be submitted to Public Works for public facilities concurrent with the PIPC permit submittal. The Stormwater Facility Tracking Form is provided at the end of this chapter.

#### 1.2.2.1 IMPERVIOUS AREA THRESHOLDS FOR WATER QUALITY

Water quality facilities must be installed for new development, expansion to existing development, and redevelopment activities that cumulatively add and/or replace 5,000 square feet or more pollution-generating impervious surface area.

Pollution-generating impervious surface area is defined as impervious area accessible to motor vehicles and rooftop areas containing galvanized metal components. See Section 1.2.3 for a list of impervious areas exempt from the water quality impervious area threshold calculation, as they are not considered pollution-generating surfaces for purposes of these Standards.

### **1.2.2.2 IMPERVIOUS AREA THRESHOLDS FOR DETENTION**

To reduce the risk of flooding and degradation to downstream properties, detention facilities must be installed for new development, expansion to existing development, or redevelopment in accordance with the following thresholds:

1. New development that creates impervious surfaces of 25,000 square feet or more.
2. Development that creates new or redeveloped impervious area totaling 10,000 square feet or more, that results in a total post-development project site impervious area of 25,000 square feet or greater. Redeveloped impervious area consists of roof area and replaced impervious area, minus any reduction in overall impervious area, associated with improvement or replacement of structures. Only runoff from new and replaced portions needs to be detained.

Impervious surfaces applicable to detention standards include all impervious surfaces such as roads, driveways, parking lots, walks, patios, and roofs.

### **1.2.3 AREA EXEMPTIONS**

The following area exemptions may be considered in the calculation of new and redeveloped impervious area subject to water quality and/or detention requirements. Please note that area exemptions apply solely to the impervious area threshold that triggers the water quality and/or detention requirements. Once the requirements are triggered, the area exemptions do not apply to the design of water quality and/or detention facilities.

Area exemptions must be noted on the Stormwater Facility Tracking Form.

#### **1.2.3.1 WATER QUALITY AREA EXEMPTIONS**

The water quality impervious area threshold defined in Section 1.2.2.2 applies to pollution-generating impervious surface area. The following areas are not considered pollution generating impervious surfaces:

1. Impervious surface areas including paved surfaces not accessible to motor vehicles (i.e., sidewalks, pathways, and courtyards).
2. Rooftop areas without galvanized metal components.
3. Porous pavement.
4. Development sites that drain to a combined sewer system on a case by case basis.

It should be noted that non-pollution-generating impervious surfaces (defined above) may need to be considered in the design of water quality facilities (see Chapter 2) if the area is not hydraulically separated from pollution-generating impervious surface area and conveyed to a separate point of discharge from the site.

#### **1.2.3.2 DETENTION AREA EXEMPTIONS**

Projects located in any of the following areas are exempt from detention requirements:

1. Areas that discharge directly to the Mary's River or Willamette River where the conveyance system between the project site and the ordinary high water line is composed entirely of man-made elements (e.g., piped systems) with sufficient hydraulic capacity and erosion stabilization measures to meet the conveyance system requirements in Appendix A.

2. Properties east of the Mary's River and south of Highway 20/34 and areas subject to the South Corvallis Master Plan (unless a downstream capacity issue has been identified). These areas are shown in Figure 1-1.
3. Expansion and redevelopment excludes the square footage of underground parking or of each additional level of structured parking from the square footage subject to the detention requirements.
4. Porous pavements. Porous pavement applications are subject to City approval as an alternative facility and require infiltration testing in accordance with Section 1.3.3.

Note that non-pollution-generating surface areas (defined in Section 1.2.3.1 as exempt from the water quality impervious area threshold) are still subject to the detention impervious area threshold and detention requirements. In addition, detention exemption areas are still subject to requirements for a downstream analysis (see Appendix A.2.4).

## **1.3 STORMWATER MANAGEMENT REQUIREMENTS**

The City restricts the uncontrolled and untreated discharge of stormwater into any stormwater system and/or natural drainageway area, subject to thresholds defined in Section 1.2.

These Standards are intended to provide guidance for the reduction of pollutants in stormwater to the maximum extent practicable (MEP) and to mitigate peak flow downstream from new development and redevelopment areas. This section documents the basic requirements for selection and design of stormwater management systems for developing sites.

### **1.3.1 GENERAL REQUIREMENTS**

Design of stormwater management facilities (for water quality, detention, and conveyance) must control runoff within and upstream of the development without exceeding capacities of available facilities and downstream drainageways. General design considerations are as follows:

1. Surface or subsurface drainage, caused or affected by development, shall not flow over adjacent public or private property in a volume or location significantly different from that which existed prior to development, but shall be collected and conveyed to an acceptable point of discharge as approved by the City.
2. The City generally does not allow the diversion of stormwater from one drainage basin or watershed to be directed to another drainage basin or watershed.
3. Surface drainage entering a development from offsite areas shall be intercepted at the naturally occurring locations. Offsite surface drainage shall be conveyed through the site in a separate system and will not be mixed with the stormwater collected and treated in onsite stormwater management facilities unless the onsite stormwater management facilities are designed to manage the additional flows from the upstream drainage basin(s) assuming full development potential.
4. All public storm drainage systems shall be gravity systems without the use of pumps or other mechanical means to convey or transport stormwater.



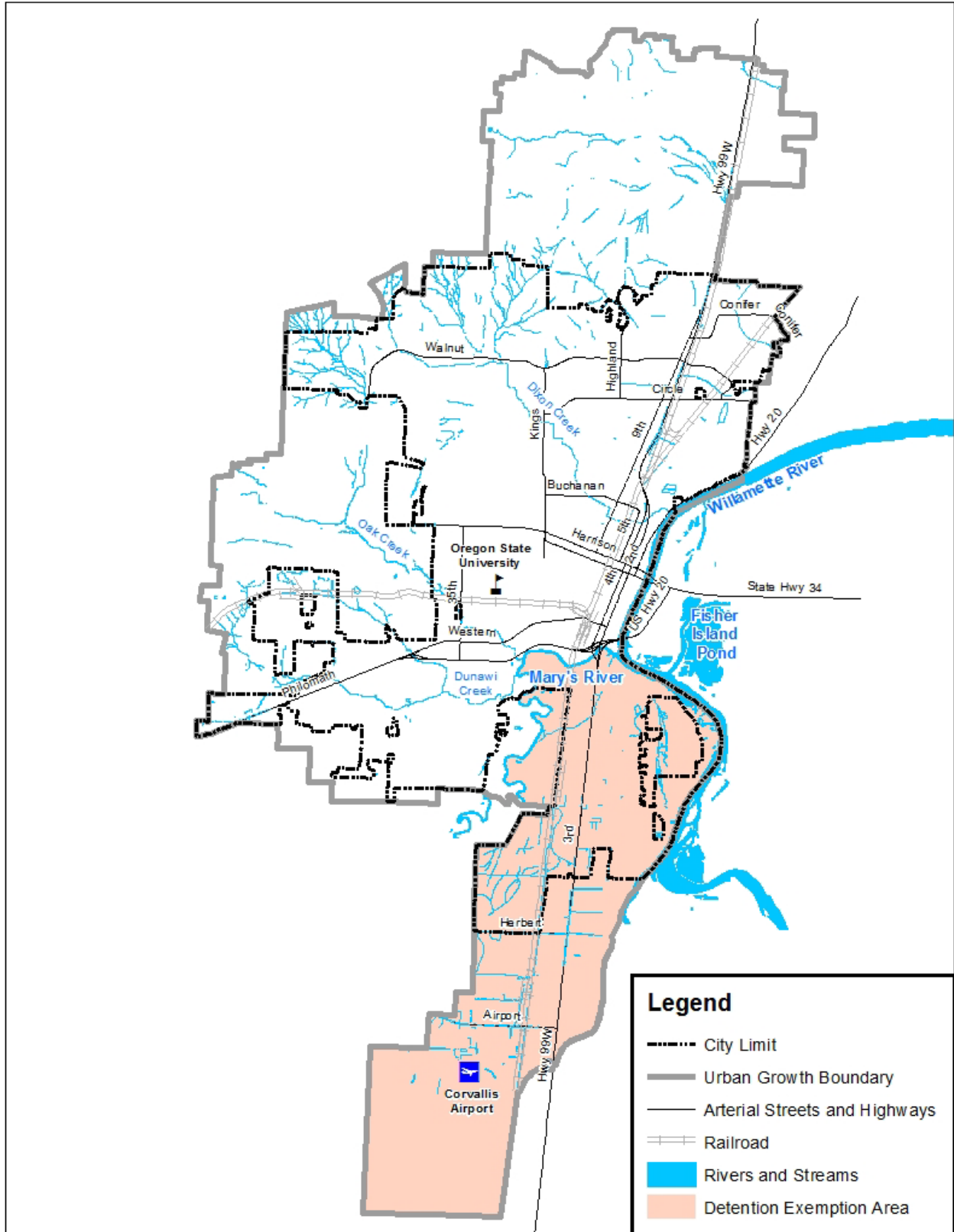


Figure 1-1. Detention Exemption Areas

5. The point of discharge for all stormwater may be a piped system, curb and gutter, or open channel as approved by the City. All outfalls to an existing or proposed stormwater facility, conveyance system, or drainageway shall be approved by the City.
6. When an approved point of discharge is located on an adjacent private property, the applicant shall be responsible to acquire all applicable downstream private and/or public stormwater easements.
7. In compliance with Oregon Drainage Law, development shall not adversely impact up or downstream properties. Stormwater runoff from a development shall be safely conveyed to prevent the uncontrolled or irresponsible discharge of stormwater onto adjoining public or private property.
8. The point of discharge for stormwater shall not be the City's sanitary sewerage system, except in existing combined sewer areas where a dedicated storm drain is not available.
9. When stormwater is discharged into a combined sewer system, separate storm and sewer laterals are required.
10. Infiltration shall not be allowed from stormwater facilities when discharging into a combined sewer system.
11. No project or development shall directly or indirectly discharge, to the public storm system, any quantity of stormwater, pollutant, substance, or wash water that will violate the discharger's permit (if one is issued), the City's NPDES MS4 permit, this policy, environmental laws, environmental regulations, or water quality standards.
12. Stormwater facilities at the City's Airport shall follow FAA requirements.

### **1.3.2 STORMWATER SITE PLANNING**

Effective use of the Corvallis Stormwater Design Standards requires developers to demonstrate an understanding of existing site conditions and potential impacts resulting from the proposed development. Elements of effective stormwater site planning shall be reflected in submittals to City staff throughout the design process, from land use approval to final design and permitting.

#### **1.3.2.1 SITE CONDITION ASSESSMENT**

Integration of existing site attributes and features into the stormwater management approach for a site is defined as the site condition assessment.

A site condition assessment is conducted prior to preliminary design in order to reduce or eliminate potential design conflicts as design progresses. It includes the optimization of design needs, stormwater management techniques, and sensitive area protection into a comprehensive stormwater management strategy for a site. The site condition assessment may include review of the following elements:

- Existing topography, including locations of steep slopes
- Soils and seasonal high groundwater conditions
- Infiltration testing results (if applicable, see Section 1.3.3)
- Existing hydrology, hydraulics (channels, pipes, and outfalls), and natural features (lakes, streams, creeks, wetlands, and drainageways) both on the site and immediately downstream

- Existing riparian corridors and riparian easements
- Existing land use and zoning restrictions and requirements
- Existing and proposed access points for all modes of transportation
- Public and private utilities on the site and surrounding areas

### **1.3.2.2 SITE PLANNING CONCEPTS**

During preliminary design, results of the site condition assessment may be used in conjunction with the following site planning concepts to reduce the impact of stormwater runoff from development. Effectively implementing these site planning concepts may reduce the number, size, and cost of stormwater facilities required:

- Preserve existing resources
- Minimize site disturbance
- Minimize soil compaction
- Minimize total and pollution-generating impervious surfaces

Site planning concepts should be reflected in the preliminary site design. Refinement of the preliminary site design for final design should maintain these concepts.

### **1.3.3 INFILTRATION TESTING AND USE OF INFILTRATION-BASED FACILITIES**

Infiltration-based facilities (i.e., bio-infiltration, porous pavement) not specifically referenced in these Standards are considered alternative facilities and design must be coordinated directly with the City.

Infiltration-based facilities are permissible in the city, and in most cases are preferred over standard water quality and/or detention facilities where native soil infiltration rates support their function and there are no expected adverse impacts to adjacent or downhill properties. Infiltration-based facilities shall not be allowed in areas with slopes over 10 percent.

Infiltration testing is required for development projects where infiltration-based facilities are proposed to manage some or all of the runoff generated from a site.

The City has approved two methods for performing an infiltration test, the Basic Test and the Professional Test. For sites with greater than 10,000 square feet of new or replaced impervious surface, or sites where infiltration-based facilities will be used to meet detention requirements, the Professional Test requirements apply. Sites with less than 10,000 square feet of impervious surface that are proposing infiltration-based facilities only for water quality treatment can follow either the Basic Test or Professional Test methodology. Specifications for both test procedures are included in Appendix D.

### **1.3.4 STORMWATER FACILITY DESIGN CONSIDERATIONS**

Stormwater management facilities include water quality treatment, detention, and conveyance systems. Selection of stormwater management facilities should consider site planning elements (see Section 1.3.2), runoff characteristics, and treatment and detention objectives.

Chapter 2 provides methods and guidelines for selection, sizing, and design of water quality facilities. Chapter 3 provides methods and guidelines for selection, sizing, and design of detention facilities. Appendix A includes design guidelines and analysis methods for piped and open-channel stormwater collection and conveyance systems.

Water quality and/or detention facilities defined in these Standards are not required if infiltration methods or an infiltration-based facility can demonstrate infiltration of the entire volume of runoff associated with the respective water quality and/or detention design storm.

### **1.3.5 SOURCE CONTROL**

Some site uses may be categorized as high risk for increased pollutant load discharges in stormwater runoff and required to implement additional source control practices or install additional water quality facilities (aside from those referenced in these Standards).

Coordination with the City during the land use process and building permit process will determine if a proposed site use will require additional source control or treatment measures.

### **1.3.6 DESIGN ALTERNATIVES**

Alternative materials, methods, and facility designs for stormwater management will be accepted only if the designer can demonstrate that the existing Standards are not appropriate for a given site or that the proposed alternative provides the same or greater level of stormwater management as defined in these Standards. Alternate materials, methods, or facilities not explicitly included in these Standards will be considered for approval through the modification process detailed in Section 1.5.

Alternate facilities must meet the water quality treatment goals outlined in Chapter 2 and/or the detention requirements outlined in Chapter 3. Alternate materials must meet listed structural stability requirements and provide the same or greater level of public safety and durability as the materials listed in these Standards. All requests will be evaluated on a case-by-case basis by the City Engineer, and approval of alternative materials and methods in one development proposal will not imply an approval under similar circumstances in another proposal.

### **1.3.7 STORMWATER EASEMENTS**

Public stormwater management facilities located outside of the public right-of-way shall require a stormwater easement or dedication as described in Chapter 4. The stormwater easement shall include access to the stormwater management facilities in order to accommodate maintenance of the facilities. The minimum width of an access easement is 15 feet. All-weather roads shall provide maintenance vehicle access to the facility and the control structure. The developer or property owner shall provide the City with all necessary documentation granting such easements. All off site easements shall be granted to the City prior to issuance of permits. All on site easements shall be granted to the City prior to warranty/acceptance of the facilities.

When any private stormwater management facility does not abut the public right-of-way, easements are required to allow City access to the facility.

Developments that discharge stormwater to private drainage systems, such as ditches, shall require downstream easements. All downstream easements need to be obtained prior to issuance of permits. If downstream easements cannot be obtained, the developer shall engineer solutions to minimize downstream impacts and the drainage system/facilities shall remain private (see Appendix A.2.5).

### **1.3.8 OPERATIONS AND MAINTENANCE**

Owners of all stormwater management facilities are required to comply with operations and maintenance (O&M) requirements for each stormwater management facility as described in Chapters 2 and 3 and listed in Appendix B. Additional details regarding maintenance obligations are outlined in Chapter 4.

### **1.3.9 DESIGN PROFESSIONAL**

All engineering plans, reports, or documents must be stamped and signed by a professional engineer registered in the State of Oregon. The engineer is responsible for reviewing any proposed improvements or modifications to the existing storm drain system with City staff prior to commencement of design work to determine any special requirements and whether the proposed design is permissible.

Approval of plans and issuance of permits by the City does not in any way relieve the engineer of his/her responsibility to meet all requirements of the City or other affected jurisdictions, or the obligation to protect the life, health, and property of the public. The design for any project must be revised or supplemented at any time it is determined or suspected by the City or the engineer of record that the full requirements of the City were not met.

Select submittals do not require the approval or stamp of a professional engineer. These include, but are not limited to, the Stormwater Facility Tracking Form and the design of planting plans.

## **1.4 ADMINISTRATIVE REQUIREMENTS AND JURISDICTION**

This section outlines jurisdiction, compliance with laws and regulations, and potential conflicts relating to these Standards.

### **1.4.1 JURISDICTION**

The City may promulgate new or amended policies pertaining to these Standards in accordance with any other rules and regulations issued by the City.

### **1.4.2 COMPLIANCE WITH LAWS**

Conformance with these Standards shall not be a substitute for, or eliminate the necessity of, conforming to all federal, state, and local laws, ordinances, rules, and regulations that are now, or in the future may be, in effect.

### **1.4.3 CONFLICTS**

Any provisions or limitations of these Standards and any regulation and order adopted pursuant hereto are suspended and supplemented by any applicable federal, state, or local requirements existing or adopted subsequent hereto that are more stringent than the provisions and limitations contained herein. Any provision of these Standards and policies adopted pursuant thereto that are more stringent than any applicable federal, state, or local requirement shall prevail and shall be the standard for compliance by all properties within the city boundary.

## 1.5 STORMWATER STANDARD MODIFICATION REQUEST

Modification to the adopted Standards may be requested. Requests for modification to the stormwater design Standards shall be submitted in writing to the City and include the following:

- The desired modification(s)
- The reason(s) for the request(s)
- A comparison between the specification(s) and standard(s) and the modification(s) for performance, function, maintainability, safety, etc.
- References to regional and/or national accepted standards, record of successful use by other agencies, or other supportive information

It is the responsibility of the applicant to obtain all approvals from any federal, state, or local entity that has authority over or is responsible for permitting of the activities before proceeding with an approved modification.

The City may allow a modification to the adopted Standards when the use thereof does not compromise public safety, environmental protection, or the intent of the Standards and any one of the following conditions are met:

- The standard is deemed not applicable for the particular application
- Topography or other geographic conditions impose an environmental or safety concern and an equivalent alternative exists that can accomplish the same design intent as provided in these Standards
- A minor change to the standard is required to address a specific design or construction problem that, if not enacted, will result in an undue hardship
- An alternative stormwater management facility is selected that meets performance criteria and design objectives outlined in these Standards
- The proposed modification is in the public interest and requirements for safety, function, appearance, and maintainability based on sound engineering and technical judgment being fully met
- The financial viability of meeting the requirements of these Standards is not in itself an adequate justification for granting a modification of the Standards



# STORMWATER FACILITY TRACKING FORM

Water Quality and Detention Impervious Area Thresholds

Water Quality and Detention Facility Selection

Name of applicant \_\_\_\_\_ Date \_\_\_\_\_

Project name \_\_\_\_\_

Site address \_\_\_\_\_

Section/township/range/tax lot  
(add additional sheets as necessary) \_\_\_\_\_

Land use zoning \_\_\_\_\_

Total site area (ac or sf) \_\_\_\_\_

Pre-developed Impervious Area (ac or sf) \_\_\_\_\_

**Development Review Category:**

- Public stormwater facility(ies) through PIPC Permit
- Private stormwater facility(ies) through Development Services

**Final Stormwater Discharge Point (check all that apply):**

- Public Conveyance System
- Private Conveyance System
- Willamette River       Marys River       Dixon Creek       Dunawi Creek       Oak Creek
- Jackson/Frazier/ Village Green Creeks       Other (specify) \_\_\_\_\_

**Describe Proposed Development Activity:**

**Development Review Notes (City use only):**



**Impervious Area Threshold Calculations and Facility Selection**

**Detention**

<p><b>Total Post-Developed Site Impervious Surface</b></p> <p><i>Include all existing, new, and replaced impervious surface such as sidewalk, parking lots, roadways (asphalt/concrete/porous pavement), rooftops, gravel surfaces, driveways, etc.</i></p>	<p>_____ SF</p> <p>If greater than or equal to 25,000 sf, a detention facility may be needed. Proceed to the next step.</p> <p>If less than 25,000 sf, detention is not needed.</p>
<p><b>(1) Total New Impervious Surface</b></p> <p><i>Include new impervious surface only. Exclude porous pavement. Exclude each level of a multi-tiered parking structure aside from the footprint.</i></p>	<p>_____ SF</p> <p>If greater than or equal to 25,000 sf, a detention facility is needed.</p> <p>If greater than or equal to 10,000 sf, a detention facility may be needed. Proceed to Steps 2 through 4.</p>
<p><b>(2) Total Replaced Impervious</b></p> <p><i>Include existing impervious surface removed and replaced with development.</i></p>	<p>_____ SF</p>
<p><b>(3) Total Removed Impervious Surface</b></p> <p><i>Reflects existing impervious surface removed and not replaced that is associated with the substantial improvement or replacement of structures.</i></p>	<p>_____ SF</p>
<p><b>(4) = (1 + 2 – 3) Total New and Redeveloped Impervious Area Subject to Detention Requirements</b></p>	<p>_____ SF</p> <p>If greater than or equal to 10,000 sf, a detention facility is needed.</p>
<p><b>Will runoff from offsite areas discharge to the site and to the proposed detention facility?</b></p> <p><i>Offsite flow may be treated as “flow through” in sizing detention facilities</i></p>	<p><input type="checkbox"/> Yes, expected offsite flow rates:</p> <p>2-yr _____</p> <p>5-yr _____</p> <p>10-yr _____</p> <p><input type="checkbox"/> No</p>
<p><b>Proposed detention facility, check all that apply:</b></p> <p><input type="checkbox"/> Detention pond    <input type="checkbox"/> Detention tank    <input type="checkbox"/> Detention vault    <input type="checkbox"/> Alternative facility (specify): _____</p> <p><input type="checkbox"/> Project is exempt from detention due to discharge location (<i>refer to Corvallis Stormwater Design Standards for detention area exemptions – Section 1.2.3.2</i>)</p>	







## **2. WATER QUALITY FACILITY SELECTION AND DESIGN**

This chapter presents the City approved methods, criteria, and details for analysis and design of water quality facilities for projects that exceed the development thresholds described in Section 1.2. In many cases, water quality facilities must be used in conjunction with detention facilities (see Chapter 3) to meet the minimum stormwater management requirements.

### **2.1 OVERVIEW**

Urban development creates a wide range of stormwater management-related problems, including higher flow rates and increased water pollution. Stormwater runoff collects and conveys a variety of pollutants, including nutrients, suspended solids, organic matter, bacteria, hydrocarbons, trace metals, pesticides, and trash and debris as it travels through the drainage system and discharges to receiving waters.

Water quality facilities constructed in developed areas will help to lessen the negative impacts associated with increased urban development, including impacts to natural habitat and receiving waters.

### **2.2 WATER QUALITY REQUIREMENTS**

All new development and redevelopment projects that meet or exceed the impervious area thresholds defined in Section 1.2 are required to construct water quality facilities to reduce contaminants entering the storm collection and surface water systems.

Water quality facilities shall be designed to remove 70 percent of the total suspended solids (TSS) entering the facility during the water quality design storm. Water quality facilities referenced in this chapter meet this performance standard.

Alternative facilities not referenced in this chapter may be proposed with written documentation provided by the Design Engineer confirming that the performance standard can be achieved. Alternative facilities are subject to approval from the City Engineer (See Section 1.3.6.)

Alternative facilities may include surface infiltration facilities, provided that the Design Engineer can demonstrate that the proposed facility has capacity to infiltrate the full water quality design storm (see Section 1.3.3.). Facilities that incorporate subsurface infiltration of stormwater may be classified as Underground Injection Control (UIC) facilities that require additional permitting from the Oregon DEQ.

#### **2.2.1 WATER QUALITY FACILITY CONTRIBUTING AREA**

Water quality requirements are dependent on the amount of impervious area and pollution-generating surfaces proposed on site. Impervious area reduction techniques, such as retaining vegetation and open space, clustering buildings, the use of porous pavements, and reducing impervious area footprints, may be used in the planning stage to help mitigate stormwater runoff and reduce the size of required water quality facilities.

Water quality facilities must be sized to treat runoff from the pollution-generating impervious areas of the site and from any non-pollution-generating impervious areas that are hydraulically connected to pollution-generating surfaces (e.g., sidewalks that slope toward the roadway). Applicants shall complete and attach the Stormwater Facility

Tracking Form (see Chapter 1) to document pollution-generating impervious areas that are proposed for the site.

Pollution-generating impervious surfaces include all roadways, parking lots, and galvanized rooftop areas existing and proposed for the site with the following exceptions:

- Areas of porous pavement may be exempt from water quality treatment, provided that runoff generated from the areas of porous pavement is conveyed in a separate pipe system to bypass the water quality treatment system.
- Non-galvanized rooftop areas are exempt from water quality treatment, provided that the roof runoff is fully infiltrated onsite or captured and bypassed around the water quality facility, given it is not considered to be a pollution-generating impervious surface.

Note that detention requirements may still apply to areas of non-galvanized roofs (see Chapter 1 for detention exemptions).

Regardless of land coverage, water quality facilities must be sized for the total land area conveyed to the facility, so non-pollution-generating surfaces must either be hydraulically isolated and conveyed in separate conveyance systems from those carrying runoff to water quality facilities or water quality facilities must be sized to address these flows.

## **2.2.2 FACILITY SELECTION**

The following types of water quality treatment facilities can be used to provide water quality treatment in Corvallis:

- Biofiltration Swales (basic and continuous)
- Filter Strips (basic and narrow)
- Wet Pond or Combined Detention and Wet Pond
- Stormwater Wetland
- StormFilters
- Alternative water quality treatment facilities, if approved through the City's alternative facility process outlined in Section 1.3.6.

The use of infiltration facilities is recommended where soil and slope conditions permit the use of this type of facility and the facilities do not have an adverse impact to adjacent or downhill properties. Use of an infiltration facility is considered an alternative facility that will require infiltration testing (see Appendix D) and coordination with the City for approval. See Section 2.2.3 regarding a minimum infiltration rate.

To select the most appropriate water quality facility, applicants may use Table 2-1 as a quick reference to match appropriate water quality facility types with common design objectives, land use, and site constraints.

**Table 2-1. Water Quality Facility Design Site Constraints**

Water Quality Facilities	Site Constraints and Opportunities				
	Public right-of-way	Private property	Can be used on steep slopes	Can incorporate infiltration	Can apply toward landscaping requirements
Biofiltration Swale: Basic	X	X	X <sup>c</sup>		X
Biofiltration Swale: Continuous	X	X	X <sup>c</sup>		X
Biofiltration Swale: Wet	X	X	X <sup>c</sup>		X
Filter Strip: Basic	X	X	X <sup>c</sup>		X
Filter Strip: Narrow	X	X	X <sup>c</sup>		X
Wet pond	X	X	X <sup>c</sup>	X	X
Combined Detention and Wet pond	X	X	X <sup>c</sup>	X	X
Stormwater Wetland	X	X			X
StormFilter <sup>b</sup>	X	X	X		
Infiltration Facility <sup>a</sup>		X		X	X

- a. Use of an infiltration facility is considered an alternative facility that will require infiltration testing and coordination with the City for approval.
- b. Use of a StormFilter as a public facility shall be approved by the City Engineer on a case by cases basis due to site constraints.
- c. These facilities may be considered for steep slopes with the use of liners. See Section 2.3.1.

### 2.2.3 FACILITY SITING

Water quality facilities shall be located on the development site and as close to the pollution-generating areas as practical. Water quality facilities shall generally be installed upstream of detention facilities. However, if calculations are provided to support the facility sizing, some water quality facilities may be located downstream of detention facilities. Water quality facilities that require dispersed flows, such as filter strips, will seldom be practical downstream of detention facilities. Combination water quality and detention facilities are not allowed, with the exception of the combined detention and wet pond facility (see Section 2.3.4.2).

Water quality facilities shall be located outside the 10-year floodplain.

Water quality facilities within the regulated riparian corridor shall be located outside of the applicable riparian easement area unless it is deemed necessary by the City Engineer. The riparian easement area is identified in Corvallis Land Development Code (LDC) and shall apply regardless of whether an easement has been granted. The impacted area within the riparian corridor shall be re-vegetated consistent with LDC Chapter 4.13: Riparian Corridor and Wetland Provisions.

Water quality facilities designed for infiltration must be located on a site that has a minimum infiltration rate of 0.5 inch per hour. A geotechnical evaluation is required if water quality facilities are proposed on areas where slopes exceed 15 percent. Water quality facilities with an infiltration component shall not be allowed in areas with slopes over 10 percent unless the facility is fully lined (see Section 2.3.1).

Setback requirements for water quality facilities are described in Section 2.3.1.

## 2.2.4 SIZING CRITERIA

Water quality facilities shall be designed to remove 70 percent of TSS entering the facility during a water quality design storm.

When water quality facilities are located upstream (prior to) a detention facility, the water quality design storm shall be a storm event equivalent to two-thirds of the 2-year, 24-hour design storm. In Corvallis, this equates to a water quality design storm of 1.6 inches over 24 hours based on the standard Natural Resources Conservation Service (NRCS) Type 1A rainfall distribution.

Calculation of the water quality design flow for the water quality design storm shall be based on a hydrograph method. The NRCS TR-55 or TR-20 or the Santa Barbara Urban Hydrograph Method (SBUH) are the recommended hydrologic calculation methods. Coefficients and curve numbers used in the calculations shall be consistent with the Oregon Department of Transportation (ODOT) Hydraulics Manual. The use of alternative hydrograph methods may be allowed but requires pre-approval by the City.

If water quality facilities are located downstream of a detention facility, the water quality design flow shall be the full 2-year release rate from the detention facility. Note that flow-based water quality facilities may be smaller when located downstream of detention because the detention facility routing sequence stores peaks within the pond and releases them at a slow rate. However, the facility should be expected to collect similar levels of pollutants to those in a facility located upstream of detention and these pollutant levels should be accounted for when establishing maintenance schedules and inspections.

Additional facility sizing criteria for individual water quality facilities are included in Section 2.3 below.

## 2.3 FACILITY DESIGN CRITERIA AND SPECIFICATIONS

This section presents water quality facility-specific design criteria and should be used in conjunction with the facility design drawings in Appendix B.

General design criteria that apply to all water quality facilities are outlined in Section 2.3.1. Facility-specific analysis and design criteria for biofiltration swales (basic, continuous, and wet), filter strips (basic and narrow), wet ponds, stormwater wetlands, and StormFilters are included in Sections 2.3.2 through 2.3.6.

### 2.3.1 GENERAL DESIGN CRITERIA

The following general design criteria apply to all water quality treatment facilities.

#### **Peak Flow**

Water quality facilities must be designed to safely pass, without damage to the facility, flows in excess of the water quality design storm up to the 100-year, 24-hour event. For some facilities, a bypass system will be required.

#### **High Flow Bypass**

Most water quality facilities may be designed as flow-through, or online, systems with flows above the water quality design flow or volume simply passing through the facility untreated. However, it is sometimes desirable to restrict flows to water quality treatment facilities and bypass the remaining higher flows around them (offline facilities). This can be accomplished by splitting flows in excess of the water quality design flow upstream of

the facility and diverting higher flows to a bypass pipe or channel. The bypass typically enters a detention facility or discharges to the downstream receiving drainage system, depending on detention requirements. In most cases, it is a designer's choice whether water quality facilities are designed as online or offline. See Section 2.4.1 for design criteria for flow splitters.

### **Tracts and Setbacks**

- Water quality facilities to be maintained by the City shall be located within the public right-of-way, easements, or in tracts dedicated to the City.
- Water quality facilities shall maintain a standard 5-foot setback from the property line/ tract and a 5-foot setback from the top or toe of slopes. Exceptions can be made by the City Engineer. If the LDC requires different setback requirements based on the development type and/or application, the larger setback distance shall be used.
- Setback distances shall consider the need for maintenance access and maneuverability.

### **Side Slopes and Embankments**

Side slopes for water quality facilities should not exceed a slope of 3 units horizontal to 1 unit vertical (3H:1V). Moderately undulating slopes are acceptable and can provide a more natural setting for the facility. In general, gentle side slopes improve the aesthetic attributes of the facility and enhance safety.

- For public facilities, at least 25 percent of the facility perimeter shall have interior sides no steeper than 3H:1V, even if fenced, to minimize safety risks. Access to the side slopes shall be provided for maintenance. For private facilities, the same is recommended rather than required.
- Interior side slopes may be retaining walls, provided that the design is prepared and stamped by a professional engineer licensed in the State of Oregon. A fence shall be provided along the top of the wall.
- Exterior side slopes for public or private facilities shall not be steeper than 2H:1V unless confirmed stable by a geotechnical engineer.
- Water quality facilities with embankments that impound water must comply with Oregon State dam safety regulations (Oregon Administrative Rules [OAR] 690-020-0000 to 0200, Oregon Revised Statutes [ORS] 537.109 to 420 and ORS 540.340 to 540.545). These regulations are administered by the Oregon Department of Water Resources (OWRD). Statutory dams are defined as any dam that is 10 feet or higher and stores more than 9.2 acre feet of water. Statutory dams require design by a registered professional engineer and approval from OWRD.

### **Fencing**

- *Public Facilities:* If the water quality facility will have a design water depth deeper than 2 feet and the interior side slopes are steeper than 3H:1V, fencing is required. Fencing is not required if the design water depth is less than 2 feet.
- If required, fencing shall be placed at or above the overflow water surface. The specific fencing requirements given in Chapter 3 for detention ponds (see Section 3.3.2) also apply to water quality facilities.
- *Private Facilities:* The fencing requirements of these Standards are recommended rather than required. However, the site must still comply with any fencing requirements in other codes or regulations.

### Facility Liners

When a facility liner is required, the liner shall be made of an impermeable geotextile liner as determined by a geotechnical engineer. Geotextile material properties shall conform to ODOT standard specification 02320.

## 2.3.2 BIOFILTRATION SWALES

A biofiltration swale is an open, gently sloped, vegetated channel designed for treatment of stormwater. The primary pollutant removal mechanisms are filtration and sedimentation by the grass and vegetation and the adhesion of pollutants to the grass and thatch media. These flow-through biofiltration swales generally are not effective in the removal of dissolved pollutants.

A biofiltration swale is designed so that water will flow evenly across the entire width of a densely vegetated surface area. A biofiltration swale may be designed for treatment and conveyance of onsite stormwater flow, which can reduce development costs by eliminating the need for separate structural conveyance systems.

Biofiltration swales should be aligned to avoid sharp bends where erosion of the swale side slope can occur. However, gradual meandering bends in the swale are desirable for aesthetic purposes and to promote slower flow.

This section presents the methods of analysis and design criteria for three types of biofiltration swales: basic, wet, and continuous inflow.

### 2.3.2.1 BASIC BIOFILTRATION SWALES

An effective biofiltration swale achieves uniform sheet flow over and through a densely vegetated area for a specified residence time of several minutes. Basic design requirements for achieving proper flow conditions through a biofiltration swale are described below. Appendix B includes a typical detail for a basic biofiltration swale.

#### Applications and Limitations

Biofiltration swales are best applied on a relatively small scale (generally for less than 5 acres of contributing impervious surface). They work well along roadways, driveways, and parking lots. Swales are more costly to apply in situations where the swale channel would be deep; in deep swales, self-shading can inhibit the necessary grass growth, resulting in poor pollutant removal performance. Some specific considerations for biofiltration swale applications are as follows:

- A biofiltration swale shall not be located in a shaded area. For healthy grass growth, a swale should receive a minimum of 6 hours of sunlight daily during the summer months throughout the length of the swale.
- To maintain healthy grass growth, a swale must be dry between storms. It shall not receive continuous base flows (such as seepage from a hill slope throughout the winter) or be located in a high groundwater area, because saturated soil conditions will kill grass. If these conditions are likely to occur, consider installing a low-flow drain to remove base flows.
- Modifying an existing drainage ditch to create an engineered biofiltration swale may be difficult because of physical constraints and because ditches often serve as conveyance for flows from larger offsite areas.



## Methods of Analysis

Biofiltration swale sizing is based on several variables, including the peak water quality design flow, longitudinal slope, vegetation height, bottom width, side slope, required hydraulic residence time (i.e., the time required for flow to travel the full length of the swale), and design flow depth. The steps for sizing are as follows:

### Step 1: Calculate design flows

The water quality design flow ( $Q_{wq}$ ) is defined in Section 2.4 depending on if the swale will be placed upstream or downstream of a detention facility.

### Step 2: Calculate swale bottom width

Assume a water quality flow depth of 2 inches (0.17 foot). For shallow flow depths in swales, channel side slopes are ignored in the calculation of bottom width. Use the following equation (a simplified form of Manning's formula) to estimate the swale bottom width:

$$b = \frac{Q_{wq} n_{wq}}{1.49 y^{1.67} s^{0.5}}$$

where

- $b$  = bottom width of swale (ft)
- $Q_{wq}$  = water quality design flow (cfs)
- $n_{wq}$  = Manning's roughness coefficient for shallow flow conditions = 0.20 (unitless)
- $y$  = design flow depth (ft)
- $s$  = longitudinal slope (along direction of flow) (ft/ft)

### Step 3: Adjust width and recalculate water quality flow depth

If the calculated bottom width is between 2 and 10 feet, proceed to Step 4. If the calculated bottom width is less than 2 feet, increase the width to 2 feet and recalculate the design water quality flow depth ( $y$ ) using the following equation:

$$y = \left( \frac{Q_{wq} n_{wq}}{1.49 s^{0.5} b} \right)^{0.6}$$

where  $Q_{wq}$ ,  $n_{wq}$ , and  $s$  are the same values as used in Equation (6-2), but  $b = 2$  feet.

If the calculated bottom width exceeds 10 feet, then one of the following steps is necessary to reduce the design bottom width:

- Increase the longitudinal slope  $s$  to a maximum of 6 feet in 100 feet (0.06 foot vertical per 1 foot horizontal).
- Increase the water quality design flow depth,  $y$ , to a maximum of 4 inches (0.333 foot).
- Place a divider length-wise through the swale length to create two parallel channels and provide a flow spreader (see Section 2.4.2). The swale bottom width can be up to 16 feet wide when a divider is used.

### Step 4: Determine design flow velocity

To calculate the water quality design flow velocity ( $V_{wq}$ ) through the swale, use the flow continuity equation:

$$V_{wq} = \frac{Q_{wq}}{A_{wq}}$$

where  $V_{wq}$  = design flow velocity (fps)  
 $A_{wq}$  =  $by + Zy^2$  = cross-sectional area (sf) of flow at design depth  
 $Z$  = side slope length per unit height (e.g.,  $Z = 3$  if side slopes are 3H:1V)

If the water quality design flow velocity exceeds 1 foot per second, go back to Step 2 and modify one or more of the design parameters (longitudinal slope, bottom width, or flow depth) to reduce the design flow velocity to 1 foot per second or less.

#### Step 5: Calculate swale length

Use the following equation to determine the necessary swale length to achieve a hydraulic residence time of at least 9 minutes (540 seconds):

$$L = 540V_{wq}$$

where  $L$  = minimum allowable swale length (ft)  
 $V_{wq}$  = design flow velocity (fps)

If the swale length is calculated to be less than 100 feet, increase the length to a minimum of 100 feet, leaving the bottom width unchanged.

#### Step 6: Adjust swale layout to fit on site

If the swale length calculated in Step 5 is too long for the site, the length may be reduced (to a minimum of 100 feet) by increasing the bottom width up to a maximum of 16 feet and adjusting the length based on maintaining an equivalent top area of the swale. Note: Although bottom widths may be increased to reduce length, bottom width cannot be reduced because Manning's depth-velocity-flow rate relationships would not be preserved.

Recalculate water quality design flow velocity according to Step 4, using the revised swale geometry. Revise the design as necessary if the design flow velocity exceeds 1 foot per second or the residence time drops below 9 minutes.

#### Step 7: Provide conveyance capacity for flows higher than $Q_{wq}$

(If a high-flow bypass is provided, this step is not needed.) Use Manning's equation as shown below to verify that the swale can convey the 100-year peak flow. The roughness coefficient shall be selected to reflect the deeper flow conditions with less resistance provided by grass during these high-flow events.

$$Q = \frac{1.49}{n} AR^{0.67} s^{0.5}$$

where  $Q$  = flow rate (cfs)  
 $n$  = Manning's roughness coefficient (unitless)  
 $A$  = cross-sectional area of flow (sf)  
 $R$  = hydraulic radius (ft) = area divided by wetted perimeter  
 $s$  = longitudinal slope (ft/ft)

The 100-year peak flow velocity ( $V_{100} = Q_{100}/A_{100}$ ) based on the 100-year flow depth must be less than 3.0 feet per second. If  $V_{100}$  exceeds 3.0 feet per second, increase the bottom width or flatten the longitudinal slope and revise calculations accordingly.

**Swale Geometry**

1. Swale bottom width shall be between 2 and 16 feet.
  - a. Minimum bottom width is 2 feet to allow for ease of mowing.
  - b. If the bottom width exceeds 10 feet, a length-wise divider shall be provided. The divider shall extend from the flow spreader at the inlet for at least three-quarters of the swale length.
  - c. Maximum bottom width is 16 feet, excluding the width of the divider.
2. The longitudinal slope (along the direction of flow) shall be no less than 1 percent and no more than 6 percent, subject to the following provisions.
  - a. If the longitudinal slope is less than 1.5 percent, underdrains must be provided.
  - b. If the longitudinal slope exceeds 6 percent, check dams with vertical drops of 12 inches or less shall be provided to achieve a bottom slope of 6 percent or less between the drop sections.
3. The swale shall be flat in cross section (perpendicular to the flow direction) to promote even flow across the whole width of the swale.
4. The minimum swale length shall be 100 feet; no maximum length is set.
5. The swale treatment area (below the water quality design water depth) shall be trapezoidal in cross-section. Side slopes within the treatment area shall not be steeper than 2H:1V, though 3H:1V or flatter is preferred.
6. Side slopes above the treatment area may be steeper than 3H:1V, subject to the following provisions:
  - a. Side slopes between 1H:1V and 2H:1V shall be reinforced with erosion control netting or matting during construction.
  - b. Interior slopes steeper than 1H:1V shall be constructed as a rockery or structural retaining wall<sup>1</sup> to prevent the swale slope from sloughing. To ensure that adequate sunlight reaches the swale bottom, only one wall can be taller than 2 feet. If possible, the higher wall should be on the northern or eastern side of the swale to maximize the amount of light reaching the swale bottom.
7. Curved swales are encouraged for aesthetic reasons, but curves must be gentle to prevent erosion and allow for vehicle access to remove sediment.

**Water Depth and Base Flow**

1. Swales that will be frequently mowed, such as those in commercial or landscaped areas, shall have a design water depth of no more than 2 inches (0.17 feet) under the water quality design flow conditions.
2. Swales that will not be frequently mowed, such as those along roadsides or in rural areas, shall have a design water depth of no more than 4 inches (0.33 foot) under the water quality design flow conditions.
3. If a swale will receive base flows because of seeps and springs, then a low-flow drain shall be provided. Low-flow drains are narrow surface drains filled with pea gravel that run length-wise through the swale to bleed off base flows; they should

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<sup>1</sup> Soil bioengineering techniques may be used as an alternative to a rockery or structural retaining wall.

not be confused with underdrains. In general, base flows less than 0.01 cubic foot per second (cfs) per acre can be handled with a low-flow drain.

4. If a low-flow drain is used, it shall extend the entire length of the swale. The drain shall be a minimum of 6 inches deep, and its width shall be no greater than 5 percent of the calculated swale bottom width. If an anchored plate or concrete sump is used for flow spreading at the swale inlet, the plate or sump wall shall have a v-notch (maximum top width = 5% of swale width) or holes to allow preferential exit of low flows into the drain. See Figure B.1.D for low-flow drain specifications and details.

#### **Flow Velocity, Energy Dissipation, and Flow Spreading**

1. The maximum flow velocity through the swale under the water quality design flow conditions shall not exceed 1.0 foot per second.
2. The maximum flow velocity through the swale under the peak 100-year flow conditions shall not exceed 3.0 feet per second.
3. A flow spreader shall be used at the inlet of a swale to dissipate energy and spread runoff evenly across the swale bottom.
4. If check dams are used, a flow spreader shall be provided at the toe of each vertical drop. The spreader must span the width of the swale.
5. If a swale discharges flows to a slope rather than to a piped system or confined channel, an energy dissipater shall be provided at the swale outlet. See Appendix A for energy dissipater design requirements.

#### **Underdrains**

1. An underdrain is required if the longitudinal slope of the swale is less than 1.5 percent.
2. Underdrains must be made of perforated polyvinyl chloride (PVC) perforated pipe (SDR 35), laid parallel to the swale bottom and backfilled and bedded as shown in Figure B.1.C.
3. For public facilities, the underdrain pipe must be 6 inches or greater in diameter.
4. Six inches of clean drain rock (5/8-inch minus) must be above the top of the pipe.
5. The drain rock must be wrapped in geotextile. Geotextile material properties shall conform to ODOT standard specification 02320.
6. The underdrain must drain freely to an acceptable discharge point.

#### **Swale Divider**

1. A divider is required if the swale bottom width exceeds 10 feet.
2. Dividers shall be constructed of a firm material that will resist weathering and not erode, such as treated lumber, concrete, plastic, or compacted soil seeded with grass. Selection of divider material shall take into consideration swale maintenance, especially mowing.
3. The divider shall have a minimum height of 1 inch higher than the water quality design water depth.
4. Side slopes of earthen berms used as dividers shall be no steeper than 2H:1V.
5. Materials other than earth (e.g., treated lumber, recycled plastic lumber, concrete, etc.) shall be embedded to a depth sufficient to be stable.

### Access and Access Roads

For public swales, an access road shall be provided to the swale inlet and along one side of the swale according to the schedule shown in Table 2-2. See also the access requirements in Section 3.3.2. Note: City streets and paved parking areas adjacent to the top of slope may be counted as access.

**Table 2-2. Requirements for Biofiltration Swale Access Road**

Swale Bottom Area, L x w (sf) <sup>a</sup>	Access Road Length
200 to 1,000	1/2 swale length L
1000 to 1,600	2/3 swale length L
Over 1,600	Entire swale length L

a. The swale area used for computing access road length may be the bottom area.

### Planting and Soil Amendments

See Appendix C for planting requirements for biofiltration swales.

### Construction Considerations

- If a biofiltration swale is put into operation before all construction in the drainage area of the swale is complete, the swale must be cleaned of sediment and reseeded prior to acceptance by the City. The City will not release securities if swales are not restored and vigorous grass growth is not established.
- It is preferable to provide good erosion control before runoff enters a biofiltration swale. Swales are designed to handle only modest sediment loads from stabilized sites.
- Biofiltration swales are best constructed by leveling the bottom after excavating, and after the soil is amended. A single-width pass with a front-end loader produces a better result than a multiple-width pass.

### Maintenance Considerations

The design criteria outlined above incorporate maintenance concerns into swale design.

Maintenance requirements for biofiltration swales are detailed in Appendix B. Typical biofiltration swale maintenance includes routine mowing, sediment and debris removal, and repair of eroded or scoured channel sections as summarized below.

1. Grass should be mowed to maintain an average grass height between 4 and 9 inches, depending on the site situation. Monthly mowing is needed from May through September to maintain grass vigor. If a swale is not mowed at least annually, trees and brush will invade the swale and inhibit grass growth, compromising the swale's performance for water quality treatment.
2. Grass clippings should be removed from the swale and composted onsite or disposed of properly offsite.
3. Sediment deposited at the head of the swale should be removed if grass growth is being inhibited for more than 10 percent of the swale length or if the sediment is blocking the even spreading or entry of water to the rest of the swale. Annual sediment removal and spot reseeded will probably be necessary.
4. If flow channelization or erosion has occurred, the swale should be regraded to produce a flat bottom width, and then reseeded as necessary. If the channel results from constant base flow, it may be better to install a low-flow drain rather than to regrade.

5. For swales with underdrains, vehicular access to the swale bottom (other than grass mowing equipment) should be avoided because the drainpipe cannot support vehicle weight. Consideration should be given to providing wheel strips in the swale bottom if access is needed.

### **2.3.2.2 WET BIOFILTRATION SWALES**

A wet biofiltration swale is a variation of a basic biofiltration swale for use where the longitudinal slope is slight, water tables are high, or continuous low base flow is likely to result in saturated soil conditions. Where saturation exceeds about 2 weeks, typical grasses will die. Thus, vegetation specifically adapted to saturated soil conditions is needed. Different vegetation in turn requires modification of several of the design parameters for the basic biofiltration swale detailed in Section 2.3.2.1.

#### **Applications and Limitations**

Wet biofiltration swales are applied where a basic biofiltration swale is desired but not allowed or advisable because of one of the following conditions exists:

- Saturated soil conditions are likely because of seeps or base flows on the project site.
- Longitudinal slopes are slight (generally less than 2 percent).

#### **Methods of Analysis**

Same as for basic biofiltration swales.

#### **Swale Geometry**

Same as specified for basic biofiltration swales (see Section 2.3.2.1) except for the following modifications:

- The maximum bottom width may be increased to 25 feet, but a length-to-width ratio of 5:1 must be provided. No longitudinal dividing berm is needed. Note: The minimum swale length is still 100 feet.
- If longitudinal slopes are greater than 2 percent, the wet swale must be stepped so that the slope within the stepped sections averages 2 percent. Steps may be made of retaining walls, log check dams, or short riprap sections. No underdrain or low-flow drain is required.

Curved swales are allowed and the application of criteria for maintenance access road curves are not required.

#### **High-Flow Bypass**

A high-flow bypass is required for flows greater than the water quality design flow to protect wetland vegetation from damage. Unlike grass, wetland vegetation will not quickly regain an upright attitude after being laid down by high flows. New growth, usually from the base of the plant, often taking several weeks, is required to regain its upright form. The bypass may be an open channel parallel to the wet biofiltration swale.

#### **Water Depth and Base Flow**

Same as for basic biofiltration swales, except the design water depth shall be 4 inches or less for all wetland vegetation selections, and no underdrains or low-flow drains are required.

#### **Flow Velocity, Energy Dissipation, and Flow Spreading**

Same as for basic biofiltration swales, except no flow spreader is needed.

**Access**

Same as for basic biofiltration swales except access is only required to the inflow and the outflow of the swale; access along the length of the swale is not required. Frequent mowing or harvesting is not desirable. In addition, wetland plants are fairly resilient to sediment-induced changes in water depth, so the need for access should be infrequent.

**Soil Amendment**

Same as for basic biofiltration swales.

**Planting Requirements**

See Appendix C for planting requirements for wet biofiltration swales.

**Construction Considerations**

Same as for basic biofiltration swales.

**Maintenance Considerations**

Same as for basic biofiltration swales, except mowing of wetland vegetation is not required. However, harvesting of very dense vegetation may be desirable in the fall after plant die-back to prevent the sloughing of excess organic material into receiving waters. Many native *Juncus* species remain green throughout the winter; therefore, fall harvesting of *Juncus* species is not recommended.

**2.3.2.3 CONTINUOUS INFLOW BIOFILTRATION SWALES**

A continuous inflow biofiltration swale shall be used in situations where water enters a swale continuously along the side slope or at multiple points along the swale. The basic biofiltration swale design (see Section 2.3.2.1) is modified by increasing swale length to achieve the required average residence time. All other design criteria shall be the same as the basic biofiltration swale. Appendix B includes a typical detail for a continuous-inflow biofiltration swale.

**Applications and Limitations**

A continuous inflow biofiltration swale is used when inflows are not concentrated, such as locations along the shoulder of a road without curbs. This water quality facility may also be used where frequent, small point flows enter a swale, such as through curb inlet ports spaced at intervals along a road, or from a parking lot with frequent curb cuts. In general, no inlet port should carry more than about 10 percent of the flow.

A continuous inflow swale is not appropriate for situations where significant lateral flows enter a swale at one location downstream from the head of the swale. In this situation, the swale width and length must be recalculated from the point where the significant lateral flows enter the swale to the discharge point in order to provide adequate treatment for the concentrated flow.

Other applications and limitations described for the basic biofiltration swale apply to the continuous inflow biofiltration swale.

**Methods of Analysis**

The method of analysis for continuous inflow biofiltration swales is the same as that for basic biofiltration swales except for the following clarification of Step 1 and modification to Step 5:

**Step 1:** The water quality design flow may be variable to reflect the increase in flows along the swale length. If only a single design flow is used, the flow at the outlet shall be used.

**Step 5:** Double the hydraulic residence time so that it is a minimum of 18 minutes (1,080 seconds).

$$L = 1080V_{wq}$$

where  $L$  = minimum allowable swale length (ft)  
 $V_{wq}$  = design flow velocity calculated in Step 3 (fps).

*Note: Although bottom widths may be increased to reduce length, bottom width cannot be reduced because Manning's depth-velocity-flow rate relationships would not be preserved.*

### Design Criteria

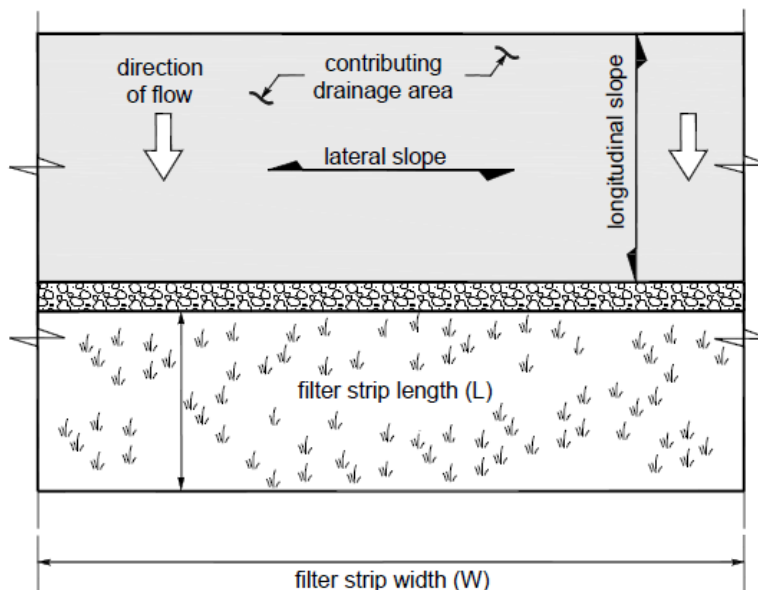
All other design, construction, and maintenance criteria shall be the same as for basic biofiltration swales (see Section 2.3.2.1).

### 2.3.3 FILTER STRIPS

A filter strip is a grassy slope located adjacent and parallel to an impervious area such as a parking lot, driveway, or roadway. A filter strip is graded to maintain sheet flow of stormwater runoff over the entire width of the strip. A filter strip removes pollutants primarily by means of filtration and sedimentation by the grass and vegetation and the adhesion of pollutants to the grass and thatch media. Pollutants can also be adsorbed by the underlying soil when infiltration occurs, but the extent of infiltration depends on the type of soil, density of the grass, and slope of the strip.

Filter strip design applications are based on the expectation that water will flow fairly evenly across the width and length of the strip area. Thus, paved areas without underground stormwater collection systems, gutters, or other runoff control features are good candidates for filter strips.

As shown in Figure 2-1, filter strip *length* is defined as the length of the flow path through the strip and filter strip *width* is typically the same as the extent of pavement along the upstream edge of the strip.



**Figure 2-1. Typical Filter Strip Terminology**



This section presents the methods of analysis and design criteria for two types of filter strips: basic and narrow area.

### 2.3.3.1 BASIC FILTER STRIPS

The basic filter strip is designed for uniform sheet flow under all runoff flow conditions. To achieve proper flow conditions, the following basic design requirements apply. Appendix B includes a typical detail for a basic filter strip.

#### Applications and Limitations

Basic filter strips are applicable for parking lots, driveways, and roads where space is available, where grassy slopes already exist, or where a slope can be incorporated easily into the landscape design for a project site. Basic filter strips are preferred to narrow area filter strips when space allows.

Basic filter strips are suitable for areas that meet the following conditions:

- Stormwater runoff from the area requiring treatment is uniformly distributed along the top of the entire filter strip.
- The flow path draining to the filter strip does not exceed 150 feet. Runoff flows traveling greater distances tend to concentrate before entering the filter strip.
- The lateral slope of the drainage area contributing flows to the filter strip (parallel to the edge of pavement) is less than 2 percent.
- The longitudinal slope of the contributing drainage area (parallel to the direction of flow entering the filter strip) is less than 5 percent. Contributing drainage areas with slopes steeper than 5 percent must provide energy dissipation and flow-spreading mechanisms up-slope of the upper edge of the filter strip.
- Filter strips shall not be located in shaded areas, because filter strips require exposure to sunlight to ensure healthy grass growth.

#### Methods of Analysis

The procedure for sizing a basic filter strip relies on Manning's equation to calculate select design variables. It is recognized that there are problems in this application<sup>2</sup>. The filter strip sizing method will be modified as new research results become available.

##### Step 1: Calculate design flow

Determine the water quality design flow ( $Q_{wq}$ ) according to Section 2.2.4).

##### Step 2: Calculate design flow depth

The water quality design flow depth is calculated based on the width of the filter strip (see Figure 2-1) and the longitudinal slope of the filter strip (parallel to the direction of flow) using a form of Manning's equation as follows:

$$d_f = \left( \frac{Q_{wq} n_{wg}}{1.49 W_s^{0.5}} \right)^{0.6}$$

<sup>2</sup> Ree, W.O., F.L. Wimberley, and F.R. Crow. 1977. Manning n and the overland flow equation. Transactions of the American Society of Agricultural Engineers 20 (89).

where  $Q_{wq}$  = water quality design flow (cfs)  
 $n_{wq}$  = Manning's roughness coefficient (either 0.35 or 0.45; see the criteria under "Filter Strip Geometry and Flow Resistance," p. 6-62)  
 $W$  = width of filter strip perpendicular to the direction of flow (ft) ( $\cong$  length of impervious surface contributing flow)  
 $d_f$  = design depth of flow (ft), which is also assumed to be the hydraulic radius (maximum 1 inch, or 0.083 feet; see the criteria under "Water Depth and Velocity," p. 6-62)  
 $s$  = longitudinal slope of filter strip parallel to the direction of flow (ft/ft) (averaged over the width of the filter strip; all portions averaged must also meet the slope design criteria).

If the calculated flow depth exceeds 1 inch (0.083 foot), the design flow rate routed through the strip must be reduced or the filter strip geometry must be adjusted.

### Step 3: Calculate design flow velocity through filter strip

The water quality design flow velocity ( $V_{wq}$ ) is calculated using the following equation:

$$V_{wq} = \frac{Q_{wq}}{Wd_f}$$

where  $V_{wq}$  = design flow velocity (fps)  
 $W$  = strip width (ft) (parallel to the edge of pavement)  
 $d_f$  = water depth (ft)

If  $V_{wq}$  exceeds 0.5 foot per second, reduce the longitudinal slope of the strip or select a different water quality facility.

### Step 4: Calculate required length of filter strip

Determine the required length ( $L$ ) of the filter strip to achieve a desired hydraulic residence time of at least 9 minutes (540 seconds) using the following equation:

$$L = 540V_{wq}$$

where  $L$  = filter strip length (ft)  
 $V_{wq}$  = design flow velocity from **Step 3** (fps)

### Filter Strip Geometry

1. The lateral slope of a strip (parallel to the edge of pavement, perpendicular to the direction of flow) shall be less than 2 percent.
2. The minimum longitudinal slope of a filter strip (along the direction of flow) shall be 1 percent.
3. The maximum allowable filter strip slope is 20 percent. If the slope exceeds 20 percent, the filter strip must be stepped down the slope so that the treatment areas between drop sections do not have a longitudinal slope greater than 20 percent. Drop sections must be provided with erosion protection at the base and flow spreaders to re-spread flows. Vertical drops along the slope must not exceed 12 inches in height. If this is not possible, a different water quality facility must be selected.
4. The ground surface at the upper edge of a filter strip (adjacent to the contributing drainage area) shall be at least 1 inch lower than the edge of the impervious area contributing flows.

5. Manning's roughness coefficient ( $n$ ) for flow depth calculations shall be 0.35. An exception to this requirement may be made for situations where the filter strip will be mowed weekly in the growing season to consistently provide a grass height of less than 4 inches; in this case, the value of  $n$  may be set to 0.45. Note: In filter strip design, a larger  $n$  value results in a smaller strip size.
6. Curbs should be avoided, if possible, at the down-slope edge of the contributing area. If curbing is needed, through-curb ports shall be provided.
7. If parking lot wheel stops are necessary, individual wheel stops should have gaps for water to pass through.

#### **Water Depth and Velocity**

1. The maximum depth of flow through a filter strip for the water quality design flow shall be 1.0 inch.
2. The maximum allowable flow velocity for the water quality design flow  $V_{wq}$  shall be 0.5 foot per second.

#### **Flow Spreading and Energy Dissipation**

1. A flow spreader shall be installed at the edge of the pavement to uniformly distribute the flow along the entire width of the filter strip.
2. At a minimum, a gravel flow spreader (gravel-filled trench) shall be placed between the impervious area contributing flows and the filter strip, and meet the following requirements:
  - a. The gravel flow spreader shall be a minimum of 6 inches deep and shall be 18 inches wide for every 50 feet of contributing flow path.
  - b. The gravel shall be a minimum of 1 inch below the pavement surface to allow sediment from the paved surface to be accommodated without blocking drainage onto the strip.
  - c. For contributing flow paths of less than 50 feet, the spreader width may be reduced to 12 inches.
  - d. Where the ground surface is not level, the gravel spreader must be installed so that the bottom of the gravel trench and the outlet lip are level.
  - e. Along roadways, gravel flow spreaders must meet the specification for shoulder ballast given ODOT/American Public Works Association (APWA) Standard Specifications for Road, Bridge, and Municipal Construction. The ballast shall be compacted to 90 percent standard proctor.
3. Other flow spreader designs (see Section 2.4.2) may be used. For filter strip applications, the notched curb spreader and through-curb port spreaders shall not be used without also adding a gravel spreader to better ensure that water sheet-flows onto the strip.
4. Energy dissipaters are needed in a filter strip if sudden slope drops occur, such as locations where flows in a filter strip pass over a rockery or retaining wall aligned perpendicular to the direction of flow.

#### **Access**

Access shall be provided at the upper edge of a filter strip to enable maintenance of the flow spreader throughout the strip width and allow access for mowing equipment.

### **Soil Amendment and Planting Requirements**

See Appendix C for landscaping requirements for basic filter strips.

### **Construction Considerations**

1. If a filter strip is put into operation before all construction in the drainage area is complete, the strip must be cleaned of sediment and reseeded prior to acceptance by the City. The City will not release securities if the filter strip is not restored and vigorous grass growth is not established.
2. It is preferable to provide erosion control before construction-phase sediment enters the filter strip. Filter strips are designed to handle only modest sediment loads without frequent maintenance.

### **Maintenance Considerations**

Maintenance considerations, including mowing frequency and sediment removal, are similar to those for biofiltration swales (see Section 2.3.2).

### **2.3.3.2 NARROW AREA FILTER STRIPS**

This section describes a filter strip design<sup>3</sup> for impervious areas with flow paths of 30 feet or less and a simplified method of analysis as detailed below. All other design criteria for basic filter strips shall apply to narrow area filter strips. Appendix B includes a typical detail for a narrow area filter strip.

#### **Applications and Limitations**

The basic filter strip design is preferred to the narrow area filter strip design and shall be used in most applications, where space is available. The narrow area filter strip shall be applied for roadside applications with limited right-of-way space that constricts the filter strip sizing.

Narrow area filter strips are suitable for areas that meet the following conditions:

- Stormwater runoff from the area requiring treatment is uniformly distributed along the top of the entire filter strip.
- The flow path draining to the filter strip does not exceed 30 feet.
- The lateral slope of the drainage area contributing flows to the filter strip (parallel to the edge of pavement) is less than 2 percent.
- The longitudinal slope of the contributing drainage area (parallel to the direction of flow entering the filter strip) is less than 5 percent. Contributing drainage areas with slopes steeper than 5 percent must provide energy dissipation and flow-spreading mechanisms up-slope of the upper edge of the filter strip.

Filter strips shall not be located in shaded areas, because filter strips require exposure to sunlight to ensure healthy grass growth.

#### **Methods of Analysis**

The sizing of a narrow area filter strip is based on the length of the flow path draining to the filter strip and the longitudinal slope of the filter strip itself (parallel to the flow path).

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<sup>3</sup> This narrow area filter strip design method is included here because technical limitations exist in the basic design method that result in filter strips that are proportionately longer as the contributing drainage becomes narrower (a result that is counterintuitive). Research by several parties is under way to evaluate filter strip design parameters. This research may lead to more stringent design requirements that would supersede the design criteria presented here.

**Step 1: Determine the length of the flow path draining to filter strip**

Determine the length of the flow path from the contributing area. Normally this is the same as the width of the paved area, but if the area is sloped, the flow path may be longer than the width of the impervious area. See Figure 2-1 for filter strip terminology.

**Step 2: Determine the average longitudinal slope of the filter strip**

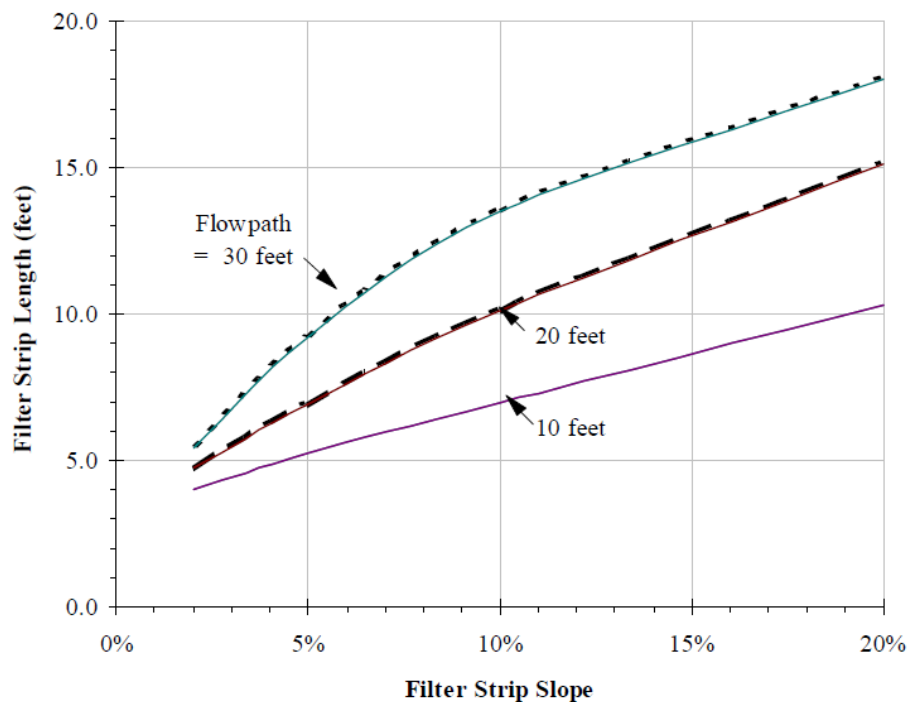
Calculate the longitudinal slope of the filter strip (along the direction of flow), averaged over the total width of the filter strip. The minimum slope is 2 percent. If the slope is less than 2 percent, use 2 percent for sizing purposes. The maximum allowable filter strip slope is 20 percent.

**Step 3: Determine the required length of the filter strip.**

Select the appropriate narrow area filter strip length for the flow path length and filter strip longitudinal slope (Steps 1 and 2 above) from the graph in Figure 2-2.<sup>4</sup> The narrow area filter strip must be designed to provide this minimum length, L, along the entire stretch of pavement draining into it.

**To use the graph:** Find the length of the flow path on one of the curves (interpolate between curves as necessary). Move along the curve to the point where the design longitudinal slope of the filter strip (x-axis) is directly below. Read the filter strip length on the y-axis that corresponds to the intersection point.

**Example:** If the length of the flow path through a parking strip is 20 feet and the filter strip will be at 5 percent longitudinal slope, move along the middle curve until it intercepts the 5% grid from the x-axis. The required filter strip length is 7 feet (read from the y-axis).



Note: minimum allowable filter strip length is 4 feet

**Figure 2-2. Narrow Filter Strip Sizing Guidelines**

<sup>4</sup> The filter strip length requirements reflected in Figure 2-2 are scaled from dimensions of biofiltration swale treatment areas for the same slope and flow rate conditions.

## 2.3.4 WET POND/COMBINED DETENTION AND WET POND

A wet pond is a constructed stormwater pond that retains a permanent pool of water (a “wet pool”) at least during the wet season. The volume of the wet pool is related to the effectiveness of the pond in settling particulate pollutants.

A wet pond requires a larger area than a biofiltration swale or a sand filter, but it can be integrated to the contours of a site fairly easily. In till soils, the wet pond holds a permanent pool of water that provides an attractive aesthetic feature. In more porous soils, wet ponds may still be used, but water seepage from unlined cells could result in a dry pond, particularly in the summer months. Lining with impervious material is one way to deal with this situation.

Wet ponds may be single-purpose facilities, providing only water quality treatment, or they may be combined with a detention pond to also provide detention. If combined, the wet pond can often be stacked under the detention pond with little further loss of development area.

This section presents the methods of analysis and design criteria for wet ponds and combined detention and wet ponds.

### 2.3.4.1 WET POND

Wet ponds treat water both by sedimentation and by biological uptake from algae and microorganisms. Wet ponds can remove some dissolved pollutants such as soluble phosphorus by this uptake mechanism. Figure B.3.A shows a typical detail for a wet pond.

#### Applications and Limitations

Wet ponds work best when the water already in the pond is moved out en masse by incoming flows, a phenomenon called plug flow. Because treatment works on this displacement principle, the dead storage pool of wet ponds may be provided below the groundwater level without interfering unduly with treatment effectiveness. However, if combined with a detention function, the live storage must be above the seasonal high groundwater level.

#### Methods of Analysis

The primary design factor that determines a wet pond’s particulate removal efficiency is the volume of the wet pool in relation to the volume of stormwater runoff from the mean annual storm.<sup>5</sup> The larger the wet pond volume is in relation to the volume of runoff, the greater the potential is for pollutant removal.

Wet ponds designed using the methods below are expected to meet the water quality treatment goal of 70 percent TSS removal. The actual performance of a wet pond may vary, however, because of a number of factors, including design features, maintenance frequency, storm characteristics, pond algae dynamics, and waterfowl use.

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<sup>5</sup> The mean annual storm is a statistically derived rainfall event defined by the U.S. Environmental Protection Agency in “Results of the Nationwide Urban Runoff Program,” 1986. It is defined as the annual rainfall divided by the number of storm events in the year. The NURP studies refer to pond sizing using a  $V_b/V_r$  ratio: the ratio of the pond volume  $V_b$  to the volume of runoff from the mean annual storm  $V_r$ . This is equivalent to using a volume factor  $f$  times  $V_r$ .

**Step 1: Identify required volume factor (f).**

A basic wet pond requires a volume factor of 3.

**Step 2: Determine rainfall (R) for the mean annual storm**

In Corvallis, the mean annual storm is 0.61" inches.

**Step 3: Calculate runoff from the mean annual storm ( $V_r$ ) for the developed site**

To determine  $V_r$ , each portion of the wet pond tributary area is assigned to one of four cover types, each having a different runoff coefficient: impervious surface, till grass, till forest, or outwash.

- *Impervious surface* is a compacted surface, such as pavement, gravel, soil, or other hard surfaces, as well as open water bodies.
- *Till grass* is post-development grass or landscaped area and onsite forested land on Type C or D soils that are not permanently in critical area buffers or covenants.
- *Till forest* is all permanent onsite forest and/or shrub cover, located on Type C or D soils, that retains the natural understory vegetation and forest duff, irrespective of age, if densities are sufficient to ensure at least 80 percent canopy cover within 5 years. To be counted in this category, forest must be protected as permanent open space.
- *Outwash* is soil that infiltrates well and, as a result, produces small amounts of runoff. SCS hydrologic soil groups classified as outwash soils for this application include all A and B soils.

$$V_r = (0.9A_i + 0.25A_{tg} + 0.10A_{tf} + 0.01A_o) \times (R)$$

where  $V_r$  = volume of runoff from mean annual storm (cf)  
 $A_i$  = area of impervious surface (sf)  
 $A_{tg}$  = area of till soil covered with grass (sf)  
 $A_{tf}$  = area of till soil covered with forest (sf)  
 $A_o$  = area of outwash soil covered with grass or forest (sf)  
 $R$  = rainfall from mean annual storm (ft)

**Step 4: Calculate wet pond volume ( $V_b$ )**

Use the results of the previous steps to calculate the required wet pond volume according to the following equation:

$$V_b = fV_r$$

where  $V_b$  = wet pool volume (cf)  
 $f$  = volume factor from Step 1  
 $V_r$  = runoff volume (cf) from Step 3

**Step 5: Determine wet pool dimensions**

Determine the wet pool dimensions to hold between 25 and 35 percent of the wet pond volume. See "Wet Pond Geometry" below for additional design criteria.

**Step 6: Design pond outlet pipe and determine primary overflow water surface**

The design criteria for wet ponds call for a pond outlet pipe to be placed on a reverse grade from the pond's wet pool elevation to the outlet structure. Use the culvert sizing guidelines in Appendix A to size the pond outlet pipe sufficient to pass the water quality design flow (Qwq).

**Wet Pool Geometry**

1. The wet pool shall be divided into two cells separated by a baffle or berm<sup>6</sup> to promote plug flow. The first cell shall contain between 25 and 35 percent of the total wet pool volume. The baffle or berm volume shall not count as part of the total wet pool volume.
2. Wet ponds with wet pool volumes less than or equal to 4,000 cubic feet (cf) may be single-celled (i.e., no baffle or berm is required).
3. Wet ponds with a length-to-width ratio greater than 4:1 may be single-celled and no divider berm is required.
4. Sediment storage shall be provided in the first cell. Sediment storage shall be accounted for in the wet pool volume and assumed to be a minimum of 1 foot deep.
5. The minimum depth of the first cell shall be 4 feet, exclusive of sediment storage requirements. The depth of the first cell may be greater than the depth of the second cell. If the wet pool is a single cell, the volume equivalent to the first cell shall have a minimum depth of 4 feet, exclusive of sediment storage requirements.
6. The maximum depth of each cell shall not exceed 8 feet (exclusive of sediment storage in the first cell). Pool depths of 3 feet or shallower (second cell) shall be planted with emergent wetland vegetation (see planting requirements).
7. Inlets and outlets shall be placed to maximize the flow path and prevent short-circuiting. Ideally there should be only one inlet. Design features that encourage plug flow and avoid dead zones include:
  - a. Dissipating energy at the inlet
  - b. Providing a large length-to-width ratio
  - c. Providing a broad surface for water exchange across cells rather than a constricted area
  - d. Maximizing the flow path between inlet and outlet, including the vertical path, to increase residence time
8. The ratio of flow path length to width from the inlet to the outlet shall be at least 3H:1V. The flow path length is defined as the distance from the inlet to the outlet, as measured at mid-depth.
9. All inlets shall enter the first cell. If there are multiple inlets, the length-to-width ratio shall be based on the average flow path length for all inlets.

**Berms, Baffles, and Slopes**

1. A berm or baffle shall extend across the full width of the wet pool and tie into the wet pond side slopes. If the berm embankments are greater than 4 feet in height, the berm must be constructed by excavating a key equal to 50 percent of the embankment cross-sectional height and width. This requirement may be waived if recommended by a geotechnical engineer for specific site conditions.<sup>7</sup>

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<sup>6</sup> As used here, the term “baffle” means a vertical divider placed across the entire width of the pond, stopping short of the pond bottom. A berm is a vertical divider typically built up from the bottom or, if in a vault, connecting all the way to the bottom.

<sup>7</sup> The geotechnical analysis must address situations in which one of the two cells is empty while the other remains full of water. These situations can occur, for example, during pump down of either cell for sediment removal, or when water from the second unlined cell percolates into the ground.



2. The top of the berm shall extend to the water quality design water surface or be 1 foot below the water quality design water surface. If at the water quality design water surface, berm side slopes must be 3H:1V. Berm side slopes may be steeper (up to 2:1) if the berm is submerged 1 foot. Submerging the berm is intended to enhance safety by discouraging pedestrian access when side slopes are steeper than 3H:1V.
3. If vegetation is not established on the berm, erosion control measures shall be used to prevent erosion of the berm back-slope when the pond is initially filled.
4. The interior berm or baffle may be a retaining wall provided that the design is prepared and stamped by a civil engineer licensed in the State of Oregon. If a baffle or retaining wall is used, it shall be submerged 1 foot below the design water surface to discourage access by pedestrians.
5. Criteria for wet pond side slopes and fencing are given in Section 2.3.1.
6. Berm embankments shall be the same as those for detention ponds (see Section 3.2).
7. Internal berms to lengthen the flow path or allow the inlet and outlet to be at the same side of the pond may be used if site constraints prevent the standard configuration. Internal berms must extend to the 2-year water elevation, a minimum of 10 feet must be between the berms, and a distance equal to the width between the internal berms must be provided between the internal berm and the pond side at the point that the flow turns around the berm.

#### **Inlet and Outlet**

1. To dissipate energy of incoming flow, the inlet to the wet pond shall be submerged with the inlet pipe invert a minimum of 2 feet from the pond bottom (not including sediment storage). The top of the inlet pipe shall be submerged at least 1 foot.
2. To provide for trapping of oil and floatables, the pond outlet pipe (as opposed to the outlet control structure) shall be back-sloped or have a turn-down elbow, and extend 1 foot below the water quality design water surface. A floating outlet, set to draw water from 1 foot below the water surface, is also acceptable if vandalism concerns are adequately addressed.
3. The pond outlet pipe shall be sized, at a minimum, to pass the water quality design flow. The invert of the outlet pipe sets the water quality design water surface elevation.
4. An outlet control structure shall be provided. Either a Type 2 catch basin with a grated opening (jailhouse window) or a manhole with a cone grate (birdcage) may be used, consistent with the requirements for detention ponds (see Section 3.3.2). No sump is required in the outlet structure for wet ponds not providing detention storage. The outlet structure receives flow from the pond outlet pipe. The grate or birdcage openings provide an overflow route should the pond outlet pipe become clogged.
5. The bottom of the grate opening in the outlet control structure shall be set at or above the height needed to pass the water quality design flow through the pond outlet pipe. The grate invert elevation sets the overflow water surface elevation.
6. The grated opening shall be sized to pass the 100-year design flow.

7. An emergency spillway shall be provided and designed according to the requirements for detention ponds (see Section 3.3.2).
8. A gravity drain for maintenance shall be provided if grade allows, allowing the first cell to be drained to the second cell when the first cell is pumped dry for cleaning.
  - a. The drain invert shall be at least 18 inches above the pond bottom to prevent highly sediment-laden water from escaping the pond when drained for maintenance.
  - b. The drain shall be at least 8 inches (minimum) diameter and shall be controlled by a valve. Use of a shear gate is allowed only at the inlet end of a pipe located within an approved structure. Intent: Shear gates often leak if water pressure pushes on the side of the gate opposite the seal. The gate should be situated so that water pressure pushes toward the seal.
9. All metal parts shall be corrosion-resistant. Galvanized materials are discouraged where substitutes are available.

#### **Access and Setbacks**

1. Wet ponds and combined wet pond and detention ponds shall be located in a dedicated public right-of-way only on a case-by-case basis.
2. Access and maintenance roads shall be provided and designed according to the requirements for detention ponds (see Chapter 3).
3. If the dividing berm is also used for access, it must be built to sustain loads of up to 80,000 pounds.

#### **Planting Requirements**

See Appendix C for landscaping requirements for wet ponds.

#### **Recommended Design Features**

1. For wetpool depths in excess of 6 feet, it is recommended that some form of recirculation be provided in the summer, such as a fountain or aerator, to prevent stagnation and low dissolved oxygen conditions. A special use permit is needed for a pump or fountain in a County maintained pond.
2. A tear-drop shape, with the inlet at the narrow end, rather than a rectangular pond is preferred since it minimizes dead zones caused by corners.
3. A small amount of base flow is desirable to maintain circulation and reduce the potential for low oxygen conditions during late summer.
4. Stormwater tracts may be credited to meet recreational space requirements.
5. The following design features should be incorporated to enhance aesthetics where possible:
  - a) Provide side slopes that are sufficiently gentle to avoid the need for fencing (3:1 or flatter).
  - b) Create flat areas overlooking or adjoining the pond for picnic tables or seating that can be used by residents. Walking or jogging trails around the pond are easily integrated into site design.
  - c) Include fountains or integrated waterfall features for privately maintained facilities.

- d) Provide visual enhancement with clusters of trees and shrubs. In most pond areas, it is important to amend the soil before planting since ponds are typically placed well below the native soil horizon in very poor soils.
- e) Orient the pond length along the direction of prevailing summer winds (typically west or southwest) to enhance wind mixing.

#### **Construction Considerations**

If a wet pond is put into operation before all construction in the drainage area of the pond is complete, the wet pond must be cleaned of accumulated sediment after construction and prior to acceptance by the City. The City will not release securities if wet ponds are not cleaned of sediment.

#### **Maintenance Considerations**

1. The pond should be inspected annually. Floating debris and accumulated petroleum products should be removed as needed, but at least annually.
2. Nearby vegetation should be trimmed as necessary to keep the pond free of leaves and to maintain the aesthetic appearance of the area. Slope areas that have become bare should be revegetated and eroded areas should be regraded prior to being revegetated.
3. Sediment should be removed when the minimum 1 foot of sediment has accumulated and resulted in a loss of more than 6 inches of wet pool design depth. Sediments should be tested for toxicants in compliance with current disposal requirements if land uses in the catchment include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed.
4. Water drained or pumped from private ponds prior to maintenance shall be per a plan approved by Development Services.
5. Pumping rates should be slow enough so that downstream channel erosion problems do not develop.

### **2.3.4.2 COMBINED DETENTION AND WET POND**

Combined detention and water quality wet pool facilities have the appearance of a detention facility but contain a permanent pool of water as well. The following design procedures and requirements cover differences in the design of the standalone wet pond water quality facility when combined with detention storage.

This section presents design criteria for the wet pond portion of the facility. The detention portion of the facility shall meet the design criteria set forth in Chapter 3 for detention ponds. Figures B.4.A and B.4.B show typical details for combined detention and wet pond facilities.

#### **Applications and Limitations**

Combined detention and wet pond facilities are very efficient for sites that have water quality and detention requirements. The wet pond may often be placed beneath the detention facility without increasing the facility surface area. The live storage component of the facility should be provided above the seasonal high water table.

The basis for pollutant removal in this combined facility is the same as with a standalone wet pond facility. However, in this combined facility, the live storage creates fluctuating water levels, added turbulence, and unique challenges for plant growth and aesthetics.

For design purposes, the water quality benefits of extra live storage volume offsets the negative effects of increased turbulence in the facility.

### **Methods of Analysis**

The methods of analysis for combined detention and wet ponds are identical to those outlined independently for wet ponds and detention ponds. Follow the procedure specified in Section 2.3.4.1 to determine the required wet pond volume. Then follow the standard procedure specified in Section 3.3.2 to size the detention portion of the pond.

### **Combined Detention and Wet Pond Geometry**

The “Wet Pond Geometry” criteria shall apply with the following modifications:

1. The wet pool, wet pond, and sediment storage volumes shall not be included in the required detention volume.
2. The minimum sediment storage depth in the first cell is 1 foot. The 6 inches of sediment storage required for detention ponds do not need to be added to this, but 6 inches of sediment storage must be added to the second cell to comply with the detention sediment storage requirement.

### **Berms, Baffles, and Slopes**

These requirements are the same as those for wet ponds.

### **Inlet and Outlet**

The “Inlet and Outlet” criteria for wet ponds shall apply with the following modifications:

1. A sump must be provided in the outlet structure of combined detention and wet ponds.
2. The detention flow restrictor and its outlet pipe shall be designed according to the requirements for detention ponds.

### **Access and Setbacks**

These requirements are the same as those for wet ponds.

### **Planting Requirements**

These requirements are the same as those for wet ponds.

## **2.3.5 STORMWATER WETLAND**

Stormwater wetlands are shallow constructed ponds that are designed to treat stormwater through the biological processes associated with emergent aquatic plants. Stormwater treatment wetlands are used to capture and transform pollutants, similar to wet ponds. Like wet ponds, over time sediment will accumulate and require removal. Additionally, vegetation must be harvested and replaced to maintain treatment capacity. Sediment and vegetation removal activities should be conducted and timed appropriately, as they may affect wildlife habitat.

Stormwater wetlands are different from mitigation wetlands, which are constructed to replace or mitigate impacts when natural wetlands are filled or impacted by development. Wetlands created to mitigate disturbance impacts, such as filling, shall not also be used as stormwater treatment facilities.

In general, stormwater wetlands perform well to remove sediment, metals, and pollutants that bind to humic or organic acids. Phosphorus removal in stormwater wetlands is highly variable.

This section presents the methods of analysis and design criteria for stormwater wetlands. Appendix B shows a typical stormwater wetland detail.

### **Applications and Limitations**

When used for stormwater treatment, stormwater wetlands employ some of the same design features as wet ponds. However, instead of sedimentation being the dominant treatment process, pollutant removal mediated by aquatic vegetation and the microbiological community associated with that vegetation becomes the dominant treatment process. Thus when designing wetlands, water volume is not the dominant design criterion. Rather, factors that affect plant vigor and biomass are the primary concerns.

### **Methods of Analysis**

Stormwater wetlands designed and constructed using the criteria below are expected to meet the water quality treatment goals of 70 percent TSS removal.

#### **Steps 1 through 5:**

Determine the volume of a basic wet pond. Follow Steps 1 through 5 for wet ponds. The volume of a basic wet pond is used as a template for sizing the stormwater wetland.

#### **Step 6:**

Calculate the surface area of the stormwater wetland by using the volume from Step 5 and dividing by an average water depth of 3 feet.

#### **Step 7:**

Determine the presettling cell volume. The presettling cell shall contain a volume equal to the volume of runoff from the mean annual storm ( $V_r$ ).

#### **Step 8:**

Determine the surface area of the presettling cell of the stormwater wetland. Use the presettling cell volume determined in Step 7, and the actual depth designed for the presettling cell (see "Wetland Geometry" below for presettling cell depths).

#### **Step 9:**

Determine the total surface area of the wetland cell. Subtract the surface area of the presettling cell (Step 8) from the total surface area (Step 6).

#### **Step 10:**

Determine the water depth distribution in the second cell according to the design guidelines under "Wetland Geometry" below. *Note: This will result in a facility that holds less volume than that determined in Step 5 above.* This is acceptable.

### **Wetland Geometry**

1. Stormwater wetlands shall consist of two cells, a presettling cell and a wetland cell. The depth of the presettling cell shall be between 4 feet (minimum) and 8 feet (maximum).
2. One additional foot of sediment storage shall be provided in the presettling cell.
3. The wetland cell shall have an average water depth of about 1.5 feet (plus or minus 3 inches).
4. The top of the berm separating the two cells shall be designed either to the water quality design water surface elevation or submerged 1 foot below the water quality design water surface elevation, as with wet ponds. If the top of the berm is at the water quality design water surface elevation, the berm side slopes shall be no

steeper than 3H:1V. If the top of the berm is submerged 1 foot, the upstream side slope may be up to 2H:1V.<sup>8</sup>

5. The berm shall be shaped such that its downstream side gradually slopes to form the second shallow wetland cell (see the “Option A” section view in Appendix B, Figure B.5.A). Alternatively, the second cell may be graded naturalistically with the specified range of depths intermixed throughout the second cell (see “Option B” in Figure B.5.B). A distribution of depths shall be provided in the wetland cell depending on whether the dividing berm is at the water surface or submerged (see Table 2-3). The maximum depth is 2.5 feet in either design configuration.

**Table 2-3. Distribution of Depths in Wetland Cell**

Dividing berm at WQ design water surface		Dividing berm submerged 1 foot	
Depth range (ft)	Percent	Depth range (ft)	Percent
0.1 to 1	25	1 to 1.5	40
1 to 2	55	1.5 to 2	40
2 to 2.5	20	2 to 2.5	20

### Lining Requirements

In infiltrative soils, a facility liner may be needed in one or both cells to maintain plant communities. Many wetland plants can adapt to periods of summer drought, so a limited drought period is allowed in the second cell. To determine whether a liner is required, determine whether the following conditions will be met:

- The second cell must retain water for at least 10 months of the year
- The first cell must retain at least 3 feet of water year-round

If a facility liner is used, a minimum of 18 inches (3 feet preferred) of native soil amended with good topsoil or compost (one part compost mixed with three parts native soil) must be placed over the liner to prevent damage to the liner during planting.

### Inlet and Outlet

These requirements are the same as those for wet ponds but with the added requirement that spill control (such as a pollution control manhole or other structure with a spill control valve that can be manually operated in the event of a spill) be provided prior to discharge of runoff from pollution-generating impervious surface into the stormwater wetland.

### Access and Setbacks

1. Access and maintenance roads shall be provided and designed according to the requirements for detention ponds. Access and maintenance roads shall extend to both the wetland inlet and outlet structures. An access ramp (steepest allowed is 7H:1V) shall be provided to the bottom of the first cell unless all portions of the cell can be reached and sediment loaded from the top of the wetland side slopes.
2. If the dividing berm is also used for access, it must be built to sustain loads of up to 80,000 pounds.

<sup>8</sup> If the berm is at the water surface, then for safety reasons, its slope must be no greater than 3H:1V, just as the pond banks must be 3H:1V if the pond is not fenced. A steeper slope (2H:1V rather than 3H:1V) is allowed if the berm is submerged in 1 foot of water. If submerged, the berm is not considered accessible, and the steeper slope is allowed.

### Planting Requirements

The wetland cell shall be planted with emergent wetland plants following the recommendations given in Appendix C or the recommendations of a wetland specialist. Cattails (*Typha latifolia*) are not allowed.

### Construction and Maintenance Considerations

Construction and maintenance considerations are the same as those for wet ponds.

Construction of the naturalistic alternative (Option B, Figure B.5.B) can be easily done by first excavating the entire area to the 1.5-foot average depth. Then soil subsequently excavated to form deeper areas can be deposited to raise other areas until the distribution of depths indicated in the design is achieved.

## 2.3.6 STORMFILTERS

The Contech StormFilter® (StormFilter), or approved equal, is a flow-through stormwater filtration system comprising a vault, manhole, or catch basin that houses siphon activated, media-filled cartridges. As stormwater fills the vault, stormwater radially filters through the media to the center of each cartridge, and treated stormwater is collected and discharged through underdrain collection pipes.

This section presents the methods of analysis and design criteria for Appendix B; Figure B.6 shows a schematic representation of a StormFilter.

### Applications and Limitations

StormFilters, or an approved equal, can be designed to treat specific pollutants based on the filter media selected and installed in the cartridges. Table 2-4 provides general guidelines to aid in the selection of the appropriate filter media. Applicants shall consult manufacturer design guidelines and the City to ensure appropriate media selection.

**Table 2-4. StormFilter Media Selection**

Pollutants	StormFilter Media <sup>a</sup>		
	PhosphoSorb	Perlite	Compost (CSF)
Sediments	X	X	X
Oil and Grease	X	X	X
Soluble Metals	X		X
Organics			X
Nutrients	X	X	X
Total Phosphorus	X		

a. Indicated media are the most effective for the associated pollutant type. ZPG™ media, a proprietary blend of zeolite, perlite, and GAC is also available from Contech and provides an alternative where the CSF media is not recommended.

### Methods of Analysis

StormFilter, or an approved equal, sizing may be based on the water quality design flow rate (if designed upstream of detention) or a mass loading method (commonly used if designed downstream of detention).

Contech Stormwater Solutions (CSS) provides technical design assistance and can aid in accurate sizing and configuration of the StormFilter system. Designers should coordinate with CSS personnel to configure a StormFilter based on the design water quality flow provided and specific site characteristics. The water quality design flow shall be calculated as described in Section 2.2.4. An accurate description of land use and

potential sediment and pollutant loading sources shall also be provided to CSS personnel, who will consider these factors in sizing. The specific sizing methodologies are described below.

The StormFilter shall be sized using both the flow-based and mass-based methods as described in the *Product Design Manual Version 4.1* (April 2006), or the most current version, and the designer shall select the result yielding the larger number of cartridges.

#### **Design Criteria**

1. Vaults used for a StormFilter, or an approved equal, shall conform to the “Materials” and “Structural Stability” requirements specified for detention vaults (see Section 3.3.2.2).
2. Several vault sizes and system configurations are available for the StormFilter. Catch basins (on a case by case basis), manhole, and precast vault configurations are acceptable. Vault configurations shall be designed with an inlet bay to provide pretreatment and solids removal. The details of cartridge configuration and maximum number of cartridges allowed in each size vault are available from the manufacturer.
3. StormFilter systems, or an approved equal, shall be installed in such a manner that the flows exceeding the peak flow bypass capacity of the system are bypassed around the facility (i.e., the facility is configured offline).
4. StormFilters shall be designed based on the calculated water quality flow rate and the associated number of cartridges required to treat the water quality flow rate. Cartridge design (cartridge design flow rate and height) shall be in accordance with manufacturer’s design guidelines.

#### **Access Requirements**

1. Requirements for access roads, right-of-way, and setbacks shall be the same as those for detention vaults.
2. Access must be provided to allow for removal and replacement of the filter cartridges. Typical access details are available from the manufacturer. Access configurations shall be approved by the City.
3. Access to the inflow and outlet cells must also be provided.
4. Ladder access is required when vault height exceeds 4 feet.
5. Locking lids shall be provided as specified for detention (see Section 3.3.4).
6. If removable panels are not used, corner ventilation pipes shall be provided, and the minimum internal height and width and maximum depth shall be met.

#### **Construction Considerations**

Installation of a StormFilter, or an approved equal, shall follow the manufacturer’s recommended procedures.

If a StormFilter is put into operation before all construction in the contributing drainage area is complete, the StormFilter must be cleaned of accumulated sediment after construction and, if applicable, new cartridges shall be installed prior to acceptance by the City. The City will not release warranty securities if StormFilters are not cleaned of sediment and new cartridges installed at the end of the two-year warranty period.



### **Maintenance Requirements**

Maintenance needs vary from site to site based on the type of land use activity, implementation of source controls, and weather conditions. The StormFilter, or an approved equal, shall be inspected quarterly or at a frequency recommended by the supplier. Inspection and maintenance shall include the following:

1. The O&M instructions from the manufacturer shall be kept along with an inspection and maintenance log. The maintenance log shall be available for review by City inspectors upon request.
2. Routine maintenance shall include inspecting for debris, vegetation, and sediment accumulation; flushing the underdrain; and removing or replacing media.
3. Maintenance is required when 1/4 inch of sediment has accumulated on the top of the cartridge hood, or 2 inches of sediment have accumulated on the floor. If the cartridges are in standing water more than 24 hours after rainfall has occurred, maintenance is required. The inspector should make sure that the cartridges are not submerged because of backwater conditions caused by high groundwater, plugged pipes, or high hydraulic grade lines.
4. Media shall be disposed of in accordance with applicable solid waste regulations.

## **2.4 WATER QUALITY CONTROL STRUCTURES**

Water quality control structures include flow splitters and flow spreaders. Flow splitters are typically used to bypass high flows away from or around a water quality treatment facility. Flow spreaders are used to uniformly spread flows across the inflow portion of a water quality facility. Design requirements for each are included below.

### **2.4.1 FLOW SPLITTERS**

Most water quality facilities may be designed as flow-through, or on-line, systems with flows above the water quality design flow or volume simply passing through the facility untreated. However, it is sometimes desirable to restrict flows to water quality treatment facilities and bypass the remaining higher flows around them (off-line facilities). This can be accomplished by splitting flows in excess of the water quality design flow upstream of the facility and diverting higher flows to a bypass pipe or channel. The bypass typically enters a detention facility or the downstream receiving drainage system, depending on detention requirements. In most cases, it is a designer's choice whether WQ facilities are designed as on-line or off-line. Flow splitters are typically catch basins or vaults with concrete baffles. In place of baffles, the splitter mechanism may be a half tee section with a solid top and an orifice in the bottom of the tee section. A full tee option may also be used (see "Design Criteria" below). Two possible design options for flow splitters are shown in Appendix B, Figure B.8.A and Figure B.8.B. Other equivalent designs that achieve the result of splitting low flows, up to the water quality design flow, into the water quality facility and divert higher flows around the facility are also acceptable.

A crucial factor in designing flow splitters is to ensure that low flows are delivered to the treatment facility up to the water quality design flow rate. Above this rate, additional flows are diverted to the bypass system with minimal increase in head at the flow splitter structure to avoid surcharging the water quality facility under high flow conditions.

### Methods of Analysis

Flow splitters may be modeled using level-pool routing (or equivalent) with a two-outlet reservoir. The stage/discharge relationship of the outflow pipes should account for backwater effects, where applicable. Orifices and weirs shall be analyzed following the control structure guidelines in Section 3.3.5. Weirs should be analyzed as sharp-crested weirs.

### Design Criteria

1. A flow splitter shall be designed to deliver the required water quality design flow rate specified in Section 2.2.4 to the water quality facility.
2. The top of the weir shall be located at the water surface for the design flow. Remaining flows enter the bypass line.
3. The maximum head shall be minimized for flow in excess of the water quality design flow. Specifically, flow to the water quality facility at the 100-year water surface shall not increase the design water quality flow by more than 10 percent.
4. Either design shown in Appendix B, Figure B.8.A and Figure B.8.B, shall be used. Equivalent designs are also acceptable.
5. Special applications, such as for use in roads, may require the use of a modified flow splitter. The baffle wall may be fitted with a notch and adjustable weir plate to proportion runoff volumes other than high flows.
6. For ponding facilities, backwater effects must be included in designing the height of the standpipe in the catch basin.
7. Ladder or step and handhold access shall be designed as a manhole safety ladder per City standard detail or ODOT standard detail RD337. If the weir wall is higher than 36 inches, two ladders, one to each side of the wall, are required.

### Material Requirements

1. The splitter baffle shall be installed in a standard manhole (see City standard detail 203).
2. The baffle wall shall be made of reinforced concrete or another suitable material resistant to corrosion, and have a minimum 4-inch thickness. The minimum clearance between the top of the baffle wall and the bottom of the catch basin cover shall be 4 feet; otherwise, dual access points shall be provided.
3. All metal parts shall be corrosion-resistant. Examples of preferred materials include aluminum, stainless steel, and plastic. Zinc and galvanized materials are discouraged because of aquatic toxicity. Painting metal parts shall not be allowed because of poor longevity.

## 2.4.2 FLOW SPREADERS

Flow spreaders function to uniformly spread flows across the inflow portion of water quality facilities (e.g., biofiltration swale or filter strip). Five flow spreader options are presented in this section:

- Anchored plate (Option A)
- Concrete sump box (Option B)
- Notched curb spreader (Option C)

- Through-curb ports (Option D)
- Interrupted curbing (Option E)

Options A through C may be used for spreading flows that are concentrated. Any one of these options may be used when spreading is required by the facility design criteria.

Options A through C may also be used for non-concentrated flows, and in some cases must be used, such as to correct for moderate grade changes along a filter strip.

Options D and E are only for flows that are already non-concentrated when they enter a filter strip or continuous-inflow biofiltration swale. Other flow spreader options are possible with approval from the City.

#### **General Design Criteria**

1. Where flow enters the flow spreader through a pipe, it is recommended that the pipe be submerged to the extent practical to dissipate energy as much as possible.
2. For higher-velocity inflows (greater than 5 cfs for the 100-year storm), a Type 1 catch basin should be positioned in the spreader, and the inflow pipe should enter the catch basin with flows exiting through the top grate. The top of the grate should be lower than the level spreader plate or, if a notched spreader is used, lower than the bottom of the V-notches.

#### **Option A: Anchored Plate (B.7.A)**

1. An anchored plate flow spreader shall be preceded by a sump having a minimum depth of 8 inches and minimum width of 24 inches. If not otherwise stabilized, the sump area shall be lined to reduce erosion and to provide energy dissipation.
2. The top surface of the flow spreader plate shall be level, projecting a minimum of 2 inches above the ground surface of the water quality facility, or V-notched with notches 6 to 10 inches on center and 1 to 6 inches deep (use shallower notches with closer spacing). Alternative designs are allowed.
3. A flow spreader plate shall extend horizontally beyond the bottom width of the facility to prevent water from eroding the side slope. The horizontal extent should be such that the bank is protected for all flows up to the 100-year flow or the maximum flow that will enter the water quality facility.
4. Flow spreader plates shall be securely fixed in place.
5. Flow spreader plates may be made of wood, metal, fiberglass-reinforced plastic, or other durable material. If wood is used, pressure-treated 4-by-10-inch lumber or landscape timbers are acceptable.
6. Anchor posts shall be 4-inch-square concrete, tubular stainless steel, or other material that is resistant to decay.

#### **Option B: Concrete Sump Box (B.7.B)**

1. The wall of the downstream side of a rectangular concrete sump box shall extend a minimum of 2 inches above the treatment bed. This serves as a weir to spread the flows uniformly across the bed.
2. The downstream wall of a sump box shall have “wing walls” at both ends. Side walls and returns shall be slightly higher than the weir so that erosion of the side slope is minimized.

3. Concrete for a sump box may be either cast-in-place or precast, but the bottom of the sump shall be reinforced with wire mesh for cast-in-place sumps.
4. Sump boxes shall be placed over bases that consists of 4 inches of crushed rock, 5/8-inch minus to help ensure that the sump remains level.

**Option C: Notched Curb Spreader (B.7.C)**

Notched curb spreader sections shall be made of extruded concrete laid side by side and level. Typically five “teeth” per 4-foot section provide good spacing. The space between adjacent “teeth” forms a V-notch.

**Option D: Through-Curb Ports (B.7.D)**

Non-concentrated flows from paved areas entering filter strips or continuous-inflow biofiltration swales may use curb ports or interrupted curbs (Option E) to allow flows to enter the strip or swale. Curb ports use fabricated openings that allow concrete curbing to be poured or extruded while still providing an opening through the curb to admit water to the water quality facility.

Openings in the curb shall be at regular intervals but at least every 6 feet (minimum). The width of each curb port opening shall be a minimum of 11 inches. Approximately 15 percent or more of the curb section length should be in open ports, and no port should discharge more than about 10 percent of the flow. Splash blocks or splash pads are required at each opening. Typical dimensions are 2-foot by 2-foot, based on a standard curb port opening of 12 inches.

**Option E: Interrupted Curb (No Figure)**

Interrupted curbs are sections of curb placed to have gaps spaced at regular intervals along the total width (or length, depending on facility) of the treatment area. At a minimum, gaps shall be every 6 feet to allow distribution of flows into the treatment facility before they become too concentrated. The opening shall be a minimum of 11 inches. As a general rule, no opening should discharge more than 10 percent of the overall flow entering the facility.

### **3. DETENTION FACILITY SELECTION AND DESIGN**

This chapter presents the City-approved methods, criteria, and details for analysis and design of detention facilities for projects that exceed the development thresholds described in Section 1.2. In many cases, detention facilities must be used in conjunction with water quality facilities (see Chapter 2) to meet the minimum stormwater management requirements.

#### **3.1 OVERVIEW**

Urbanization and past stormwater management practices have impacted the city's streams, wetlands, and riparian areas. Increased development has expanded the quantity of impervious areas, which directly affects stormwater runoff volumes and velocities. Increased stormwater runoff volumes and higher runoff velocities may alter the stream channels, resulting in streambed and streambank erosion. In addition, piped collection systems and culverts may become capacity-limited as new development generates increased stormwater flow and can alter the timing and duration with which flow discharges to a receiving water body. Detention and other types of stormwater management techniques will help to prevent further impacts and avoid exacerbating these problems.

#### **3.2 DETENTION REQUIREMENTS**

All new development and redevelopment projects that meet or exceed the detention thresholds defined in Section 1.2 are required to construct detention facilities to reduce the risk of downstream flooding and help maintain or restore the condition of receiving waters.

Detention facilities shall be designed to match pre-development peak flows as outlined in Section 3.2.4 and designed to encourage infiltration by maximizing the soil to water contact area. Detention facilities that are required or proposed to infiltrate shall have the bottom of the facility located above the maximum wet season water table.

Alternative facilities not referenced in this chapter may be proposed with written documentation provided by the Design Engineer confirming that the detention requirements can be achieved. Alternative facilities are subject to approval from the City Engineer. See Section 1.3.6.

The use of infiltration facilities is recommended where soil and slope conditions permit the use of this type of facility and the facilities do not have an adverse impact to adjacent or downhill properties. If an alternative facility utilizing infiltration is proposed, disposal of the equivalent runoff volume from the 10-year, 24-hour design storm via surface infiltration would meet the detention requirement of this section. Infiltration facilities require documentation of the infiltration capacity of the native soils onsite (see Section 1.3.3) and calculations supporting full disposal of the runoff volume associated with the 10-year, 24-hour design storm. Subsurface infiltration of stormwater may be considered a UIC and require additional permitting from Oregon DEQ.

##### **3.2.1 DETENTION CONTRIBUTING AREA**

Detention requirements are dependent on the amount of total site impervious area and the amount of new and replaced impervious surface proposed for a site. Impervious area reduction techniques, such as retaining vegetation and open space, clustering buildings,

removing existing impervious surfaces (not associated with the development activity), and reducing impervious footprint area, may be used in the planning stage to help mitigate stormwater runoff and reduce the size of the required detention facilities.

Detention facilities shall be sized to manage runoff from all new and replaced impervious areas of the site. Applicants shall complete and attach the Stormwater Facility Tracking Form (see Chapter 1) to document the proposed total new and redeveloped impervious area proposed for a site.

### 3.2.2 FACILITY SELECTION

Detention facilities shall be limited to a single facility, rather than a series of smaller facilities, whenever possible. Only combined detention and wet ponds (Section 2.3.4.2) may be designed as a combined facility. All other detention and water quality facilities shall be separate, and designed to operate in series.

The following types of detention facilities can be used to meet these standards:

- Detention pond
- Detention tank or vault
- Alternative proposed detention/retention system, if approved through the City's design alternative process outlined in Section 1.3.6.

Detention facilities shall be designed to encourage infiltration by maximizing the soil to water contact area. Underdrains are discouraged in areas of high groundwater. See Appendix B.

To select the most appropriate detention facility, applicants may use Table 3-1 as a quick reference to match detention facility types with common design objectives, land use, and site constraints.

**Table 3-1. Detention Facility Design Site Constraints**

Water quality facilities	Site constraints and opportunities					
	Public right-of-way	Private property	Can be used on steep slopes	Can incorporate infiltration	Can apply toward landscaping requirements	Other
Detention pond	X	X		X	X	
Detention tank or vault		X	X	X <sup>b</sup>		
Infiltration facility <sup>a</sup>		X		X	X	

a. Use of an infiltration facility is considered an alternative facility that will require infiltration testing and coordination with the City for approval.

b. Perforated facilities may be used to achieve required infiltration with detention tanks and vaults.

### 3.2.3 FACILITY SITING

Detention facilities shall be located on the development site or in a tract with a dedicated easement. To the extent possible, the City encourages the use of detention ponds that serve more than one development. A facility that serves more than one development will be referred to as a regional facility. Regional facilities can be more effective in maximizing the development area, reducing the overall maintenance requirement, and minimizing the overall construction costs while enhancing water quality of the stormwater runoff.

Detention facilities shall be located outside of the 10-year floodplain.

Detention facilities within the regulated riparian corridor shall be located outside of the applicable riparian easement area unless it is deemed necessary by the City Engineer. The riparian easement area is identified in Corvallis LDC 4.13.70 and this standard shall apply regardless of whether an easement has been granted. The impacted area within the riparian corridor shall be re-vegetated consistent with Sections 4.13.50.d.1 and 4.13.50.d.2 of Chapter 4.13: Riparian Corridor and Wetland Provisions.

Parking areas should not be used as detention facilities except for larger storm events. Up to 6 inches of water depth is allowed to be detained in parking areas for storm events larger than the 10-year, 24-hour design storm.

A geotechnical evaluation is required if detention facilities are proposed in areas where slopes exceed 15 percent. Detention facilities with an infiltration component shall not be allowed in areas with slopes over 10 percent.

Setback requirements for individual detention facilities are described in Section 3.3.

### 3.2.4 SIZING CRITERIA

Detention facilities shall be designed so that the peak flow rates from post-development conditions shall be less than or equal to the peak flow rates from pre-development conditions for the 2-year, 5-year, and 10-year, 24-hour design storm based on the standard NRCS Type 1A rainfall distribution. Pre-developed conditions for all redeveloped impervious area shall assume a runoff pattern based on good condition grass and the corresponding native hydrologic soil group. Pre-developed conditions for all new impervious area shall assume the current land use condition and native hydrologic soil group.

For redevelopment projects, flows from existing developed areas (impervious surface, landscaped areas, etc. that are not being replaced) that are routed through the detention facility may be treated as “flow-through” flows. Those areas shall be modeled as the current development land use. No additional detention for those areas is required.

An analytical model capable of performing hydrograph method peak flow and volume calculations and level-pool routing (or equivalent) detention calculation must be used to determine the peak flow rates and volumes, and to size the proposed detention facilities. The NRCS TR-55, TR-20, or SBUH are recommended hydrologic calculation methods. Coefficients and curve numbers used in the calculations shall be consistent with the ODOT Hydraulics Manual. The use of alternative hydrograph methods may be allowed but requires preapproval by the City.

Table 3-2 shows the 24-hour design storm depths for the City of Corvallis.

**Table 3-2. City of Corvallis 24-hour Design Storms**

Recurrence interval, years	24-hour total precipitation, inches
2	2.55
5	2.91
10	3.64
25	4.00
100	4.73

Source: Corvallis Storm Water Master Plan

### 3.3 FACILITY DESIGN CRITERIA AND SPECIFICATIONS

This section presents the detention facility-specific design criteria and should be used in conjunction with the facility design drawings in Appendix B.

Detention facilities provide for the temporary storage of increased surface water runoff resulting from development. General design criteria that apply to all detention facilities are outlined in Section 3.3.1. Facility-specific analysis and design criteria for detention ponds, underground detention (tanks and vaults), and control structures are included in Sections 3.3.2 through 3.3.4.

#### 3.3.1 GENERAL DESIGN CRITERIA

The following general design criteria apply to all detention facilities.

##### Flow-through Systems

Detention facilities must be designed as flow-through systems. Flow must enter through a conveyance system that is separated from the facility control structure and outflow conveyance system. Maximizing the distance between the inlet and outlet is encouraged to promote sedimentation.

An exception may be made for parking lot storage, in which a back-up (backflow) system can be designed for a maximum of 6 inches of storage for storm events that exceed the 10-year, 24-hour design storm.

##### Peak Flow

1. Detention facilities must be designed to safely pass, without damage to the facility, flows up to the 100-year, 24-hour event. Examples of overflow systems to convey peak flow are included with each facility type below.

##### Tracts and Setbacks

Guidelines related to tracts and setbacks for detention facilities are as follows:

1. Detention ponds shall be located in dedicated public right-of-way only on a case-by-case basis.
2. Detention facilities to be maintained by the City shall be in an easement or tract dedicated to the City (see Section 1.3.7). Any easement or tract not abutting public right-of-way will require a 15-foot-wide extension of the easement or tract to an acceptable maintenance access location.
3. A setback of 5 feet from the toe of the exterior slope, retaining walls, and rockeries to the tract or property line is required for City-maintained ponds and recommended for privately maintained ponds.
4. The tract or property line on a detention pond cut slope shall be set back 5 feet from the emergency overflow water surface.
5. Setbacks to tract/easement lines for tanks and vaults shall be 5 feet; adjacent building setback lines shall be 10 feet. For privately owned and maintained vaults, building foundations may serve as one or more of the vault walls.

#### 3.3.2 DETENTION PONDS

Open ponds are the most desirable detention facilities for controlling runoff from developed areas. The design criteria in this section are for detention ponds. However,



many of the criteria also apply to water quality wet ponds and combined detention/wet ponds.

Standard details for detention ponds are shown in Appendix B, Figure B.9.A. Control structure guidelines are included in Section 3.3.4 and shown in Appendix B, B.12.A, B.12.B, and B.12.C.

### **Methods of Analysis**

The volume and outflow design for detention ponds shall be in accordance with the sizing criteria defined in Section 3.2.4. Control structures and restrictor orifice structure design shall comply with Section 3.3.4. *Note: The design water surface elevation is the highest elevation that occurs in order to meet the required outflow performance for the pond.*

### **Detention Pond General Design Criteria**

1. Pond bottoms shall be level and be located a minimum of 0.5 foot below the inlet and outlet to provide sediment storage.
2. A geotechnical analysis and report may be required if the detention pond is located on slopes over 15 percent, or if located within 200 feet of the top of a steep slope hazard area or landslide hazard area.
3. The live storage area of all detention ponds must be above the seasonal high groundwater level.
4. Detention ponds may occasionally be sited on soils that will provide infiltration as a primary or secondary pond outflow. Projects that propose detention ponds with infiltration as an outflow must conduct infiltration testing according to Appendix D.

### **Side Slopes**

1. For facilities to be maintained by the City, interior side slopes up to the emergency overflow water surface shall be no steeper than 3H:1V unless a fence is provided. See Section 2.3.1 for side slope requirements for internal berms in combined ponds and wet ponds.
2. Exterior side slopes shall be no steeper than 2H:1V unless analyzed for stability by a geotechnical engineer.
3. Pond walls may be vertical retaining walls, provided that: (a) they are constructed of reinforced concrete per the structural stability requirements in Section 3.3.3, (b) a fence is provided along the top of the wall, (c) at least 25 percent of the pond perimeter will be a vegetated soil slope not steeper than 3H:1V, and (d) the design is stamped by a licensed structural engineer.
4. For privately owned and maintained facilities, the entire pond perimeter may be retaining walls, and building foundations may serve as one or more of the pond walls.

### **Embankments**

1. Pond berm embankments higher than 6 feet shall require design by a geotechnical engineer.
2. For berm embankments 6 feet or less, the minimum top width shall be 6 feet, or as recommended by a geotechnical engineer.

3. Pond berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical engineer), free of loose surface soil materials, roots, and other organic debris.
4. Pond berm embankments greater than 4 feet in height must be constructed by excavating a key equal to 50 percent of the berm embankment cross-sectional height and width. This requirement may be waived if specifically recommended by a geotechnical engineer.
5. The berm embankment shall be constructed of soil placed in 6-inch lifts compacted to at least 95 percent of maximum dry density, within 2 percentage points of the optimum moisture content, modified proctor method ASTM D1557. Density tests shall be performed for each lift to confirm compliance with this specification. The soil used for construction shall have the following soil characteristics: a minimum of 20 percent silt and clay, a maximum of 60 percent sand, a maximum of 60 percent silt and clay, with nominal gravel and cobble content. Note: In general, excavated glacial till is well suited for berm embankment material.
6. Anti-seepage collars must be placed on outflow pipes in berm embankments impounding water greater than 8 feet in depth at the design water surface.
7. Detention facilities with embankments that impound water must comply with Oregon State dam safety regulations (Oregon Administrative Rules [OAR] 690-020-0000 to 0200, Oregon Revised Statutes [ORS] 537.109 to 420 and ORS 540.340 to 540.545). These regulations are administered by the Oregon Department of Water Resources (OWRD). Statutory dams are defined as any dam that is 10 feet or higher and stores more than 9.2 acre feet of water. Statutory dams require design by a registered professional engineer and approval from OWRD.

#### **Overflow**

1. In all ponds a primary overflow must be provided (usually a riser pipe within the control structure; see Section 3.3.4) to bypass the 100-year, 24-hour developed peak flow over or around the restrictor system. This assumes that the facility will be full because of plugged orifices or high inflows; the primary overflow is intended to protect against breaching of a pond embankment. The design must provide controlled discharge directly into the downstream conveyance system or another acceptable discharge point.
2. A secondary inlet to the control structure must be provided in ponds as additional protection against overtopping should the inlet pipe to the control structure become plugged. A grated opening (“jailhouse window”) in the control structure manhole functions as a weir (see Appendix B, Figure B.11) when used as a secondary inlet. Note: The maximum circumferential length of this opening shall not exceed one-half the control structure circumference. The “birdcage” overflow structure as shown in Appendix B, Figure B.9.C, may also be used as a secondary inlet.

#### **Emergency Overflow Spillway**

1. In addition to the general overflow requirements, ponds must have an emergency overflow spillway sized to pass the 100-year, 24-hour developed peak flow in the event of total control structure failure (e.g., blockage of the control structure outlet pipe) or extreme inflows. Emergency overflow spillways are intended to control the location of pond overtopping and direct overflows back into the downstream conveyance system or other acceptable discharge point.



### Access Requirements

1. Maintenance access road(s) shall be provided to the control structure and other drainage structures associated with the pond (e.g., inlet, emergency overflow, or bypass structures). Manhole and catch basin lids must be in or at the edge of the access road and at least 3 feet from a property line. Rims shall be set at the access road grade.
2. An access ramp is required for removal of sediment with a trackhoe and truck. The ramp must extend to the pond bottom if the pond bottom is greater than 1,500 square feet (measured without the ramp). If the pond bottom is less than 1,500 square feet (measured without the ramp), the access ramp may end at an elevation 4 feet above the pond bottom, provided that the pond side slopes are 3H:1V or flatter.
3. The internal berm of a wet pond or combined detention and wet pond may be used for access if it meets the above requirements and is designed to support a loaded truck, considering the berm is normally submerged and saturated.
4. Access roads shall meet the following design criteria:
  - a. Maximum grade shall be 15 percent for asphalt paving and 12 percent for gravel or modular grid paving.
  - b. Outside turning radius shall be 40 feet, minimum.
  - c. Fence gates shall be located only on straight sections of road.
  - d. Access roads shall be 15 feet in width on curves and 12 feet on straight sections.
  - e. A paved apron shall be provided where access roads connect to paved public roadways. The apron shall be consistent with City standard driveway details.
5. Access roads shall be constructed with an asphalt, concrete, or gravel surface, or modular grid pavement. Access roads must conform to City road design and construction standards for residential minor access streets. Modular grid pavement shall meet manufacturer's specifications.
6. All control structures shall have round, solid locking lids per ODOT standard detail RD356.
7. Access shall be limited by a double-posted gate designed in accordance with ODOT standard detail RD815.

### Fencing

1. A fence is required at the emergency overflow water surface elevation, or higher, where a pond interior side slope is steeper than 3H:1V, or where the impoundment is a wall greater than 24 inches in height. The fence need only be constructed for those slopes steeper than 3H:1V. The intent is to discourage access to portions of a pond where steep side slopes increase the potential for slipping into the pond, and to guide those who have fallen into a pond to side slopes that are flat enough to allow for easy escape.
2. For privately owned and maintained facilities, fences are recommended, but not required, for slopes steeper than 3H:1V. Note, however, that other regulations such as the City adopted building codes may require fencing of vertical walls. Fence

material and construction specifications outlined below do not apply to private facilities.

3. Fences shall be 6 feet in height. The fence may be a minimum of 4 feet in height if the depth of the impoundment (measured from the lowest elevation in the bottom of the impoundment up to the emergency overflow water surface) is 5 feet or less. For example designs, see ODOT standard detail RD815.
4. Access road gates shall be 16 feet in width, consisting of two swinging sections 8 feet in width. Additional vehicular access gates may be required as needed to facilitate maintenance access.
5. Pedestrian access gates (if needed) shall be 4 feet in width.
6. For fences to be maintained by the City, chain link fencing is required. Fence posts and rails shall conform to ODOT standard detail RD815.
7. Wood fences are allowed in subdivisions where the fence will be maintained by homeowners' associations or adjacent lot owners. Fence maintenance requirements shall be a condition of subdivision approval, and a statement detailing maintenance responsibilities and requirements must be recorded with the plat.
8. Wood fences shall have pressure-treated posts (ground contact rated) either set in 24-inch-deep concrete footings or attached to footings by galvanized brackets. Rails and fence boards shall be cedar or pressure-treated fir or hemlock.

#### **Seeps and Springs**

Intermittent seeps along cut slopes are typically fed by a shallow groundwater source (interflow) flowing along a relatively impermeable soil stratum. These flows are storm-driven and should discontinue after a few weeks of dry weather. More continuous seeps and springs that extend through longer dry periods are likely from a deeper groundwater source. When continuous flows are intercepted and directed through detention facilities, adjustments to the approved facility design may be required to account for the additional base flow.

#### **Planting and Landscaping**

See Appendix C for landscaping requirements for detention ponds.

### **3.3.3 UNDERGROUND DETENTION (TANK)**

Detention tanks are underground storage facilities typically constructed with large-diameter corrugated metal pipe (CMP). Standard detention tank details are shown in Appendix B, Figures B.10.A, and B.10.B. Control structure guidelines are provided in Section 3.3.5 and details are included in Appendix B, Figures B.12.A, B.12.B, and B.12.C.

#### **Methods of Analysis**

The storage volume and outflow design for underground detention systems shall be in accordance with the sizing criteria defined in Section 3.2.4. Detention structures and restrictor orifice structure design shall comply with Section 3.3.4. Please note that the design water surface elevation is the highest elevation that occurs in order to meet the required outflow performance for the pond.

**Design Criteria**

1. Tanks shall be designed as flow-through systems with manholes in line to promote sediment removal and facilitate maintenance. Tanks may be designed as backup systems if preceded by water quality facilities because little sediment should reach the inlet/control structure and low head losses can be expected because of the proximity of the inlet/control structure to the tank.
2. The detention tank bottom shall be located 0.5 foot below the inlet and outlet to provide dead storage for sediment.
3. The minimum pipe diameter allowed for a detention tank is 36 inches.
4. Tanks larger than 36 inches may be connected to each adjoining structure with a short section (2-foot maximum length) of 36-inch-minimum diameter pipe.
5. Control and access manholes shall have additional ladder rungs to allow ready access to all tank access pipes when the catch basin sump is filled with water.

**Overflow**

In all tanks, a primary overflow (usually a riser pipe within the control structure; see Section 3.3.4) must be provided to bypass the 100-year, 24-hour, developed peak flow over or around the restrictor system. This assumes that the facility will be full because of plugged orifices or high inflows; the primary overflow is intended to protect against overflows of the upstream conveyance system. The design must provide controlled discharge directly into the downstream conveyance system or another acceptable discharge point.

**Materials**

Pipe material, joints, and protective treatment for tanks shall be in accordance with ODOT or APWA standard specifications.

**Structural Stability**

1. Detention tanks shall meet structural requirements for overburden support and traffic loading if appropriate. H-20 live loads must be accommodated for tanks lying under parking areas and access roads.
2. Metal tank end plates must be designed for structural stability at maximum hydrostatic loading conditions. Flat end plates generally require thicker-gauge material than the pipe and/or require reinforcing ribs.
3. Tanks shall be placed on stable, well-consolidated native material with suitable bedding. Backfill shall be placed and compacted in accordance with the pipe specifications in Appendix A. Tanks made of LCPE require inspection for deformation prior to installation as well as continuous inspection of backfilling to 1 foot above the top of the tank. Tanks shall not be allowed in fill slopes, unless analyzed in a geotechnical report for stability and constructibility.

**Buoyancy**

In moderately pervious soils where seasonal groundwater may induce flotation, buoyancy tendencies must be balanced either by ballasting with backfill or concrete backfill, providing concrete anchors, increasing the total weight, or providing subsurface drains to permanently lower the groundwater table. Calculations must be submitted to the City in conjunction with other stormwater calculations concurrent with permit submittal that demonstrate stability and size ballast (as applicable).

**Access Requirements**

1. The maximum depth from finished grade to tank invert shall be 20 feet.
2. Access openings shall be positioned a maximum of 50 feet from any location within the tank.
3. All tank access openings shall have round, solid locking lids per ODOT standard detail RD356.
4. Thirty-six-inch minimum diameter CMP riser-type manholes (Appendix B, Figure B.10.B) of the same gauge as the tank material may be used for access along the length of the tank and at the upstream terminus of the tank if a backup system. The top slab is separated (1-inch minimum gap) from the top of the riser to allow for deflections from vehicle loadings without damaging the riser tank.
5. All tank access openings must be readily accessible by maintenance vehicles.
6. Access roads are required to all detention tank control structures and risers. The access roads shall be designed and constructed as specified for detention ponds.

**3.3.4 UNDERGROUND DETENTION (VAULT)**

Detention vaults are box-shaped underground storage facilities typically constructed with reinforced concrete. A standard detention vault detail is shown in Appendix B, Figure B.11. Control structure guidelines are provided in Section 3.3.4 and details are included in Appendix B, Figures B.12.A, B.12.B, and B.12.C.

**Methods of Analysis**

The storage volume and outflow design for underground detention systems shall be in accordance with the sizing criteria defined in Section 3.2.4. Detention structures and restrictor orifice structure design shall comply with Section 3.3.4. Please note that the design water surface elevation is the highest elevation that occurs in order to meet the required outflow performance for the pond.

**Design Criteria**

1. Detention vaults shall be designed as flow-through systems with bottoms level (longitudinally) or sloped toward the inlet to facilitate sediment removal. The distance between the inlet and outlet shall be maximized (as feasible).
2. The detention vault bottom shall slope at least 5 percent from each side toward the center, forming a broad "V" to facilitate sediment removal.
  - a. More than one "V" may be used to minimize vault depth.
  - b. The vault bottom may be flat if removable panels are provided over the entire vault. Removable panels shall be at grade, have stainless-steel lifting eyes, and weigh no more than 5 tons per panel.
3. The invert elevation of the outlet shall be elevated above the bottom of the vault to provide an average 6 inches of sediment storage over the entire bottom. The outlet must also be elevated a minimum of 2 feet above the orifice to retain oil within the vault.
4. The outflow system and restrictor device shall be designed according to the applicable requirements specified for control structures in Section 3.3.4.

**Overflow**

In all vaults, a primary overflow must be provided (usually a riser pipe within the control structure; see Section 3.3.4) to bypass the 100-year, 24-hour, developed peak flow over or around the restrictor system. This assumes that the facility will be full because of plugged orifices or high inflows; the primary overflow is intended to protect against overflows of the upstream conveyance system. The design must provide controlled discharge directly into the downstream conveyance system or another acceptable discharge point.

**Materials**

Minimum 3,000-pound per square inch (psi) structural reinforced concrete must be used for all detention vaults. All construction joints must be provided with water stops.

**Structural Stability**

1. Detention vaults shall meet structural requirements for overburden support and traffic loading if appropriate. H-20 live loads must be accommodated for tanks and vaults lying under parking areas and access roads.
2. Metal tank end plates must be designed for structural stability at maximum hydrostatic loading conditions. Flat end plates generally require thicker-gauge material than the pipe and/or require reinforcing ribs.
3. Structural designs for vaults must be stamped by a licensed structural engineer. Vaults shall be placed on stable, well-consolidated native material with suitable bedding. Vaults shall not be allowed in fill slopes, unless analyzed in a geotechnical report for stability and constructibility.

**Buoyancy**

In moderately pervious soils where seasonal groundwater may induce flotation, buoyancy tendencies must be balanced either by ballasting with backfill or concrete backfill, providing concrete anchors, increasing the total weight, or providing subsurface drains to permanently lower the groundwater table. Calculations must be submitted to the City in conjunction with other stormwater calculations concurrent with permit submittal that demonstrate stability and size ballast (as applicable).

**Access Requirements for Vaults**

1. Access consisting of a frame and locking cover shall be provided over the inlet pipe and outlet structure (see ODOT standard detail RD356). Access openings shall be positioned a maximum of 50 feet from any location within the vault; additional access points may be required on large vaults. If more than one "V" is provided in the vault floor, access to each "V" must be provided.
2. For vaults with greater than 1,250 square feet of floor area, a 5-by-10-foot removable, locking panel shall be provided. Alternatively, a separate access vault may be provided as shown in Appendix B, Figure B.11.
3. For vaults under roadways, the removable panel must be located outside the travel lanes. Spacing of manhole covers shall be 12 feet, measured on center, to facilitate removal of sediment. Ladders and hand-holds need only be provided at the outlet pipe and inlet pipe, and as needed to meet Occupational Safety and Health Administration (OSHA) confined-space requirements. Vaults providing manhole access at 12-foot spacing need not provide corner ventilation pipes as specified in Item 10 below.



4. All access openings, except those covered by removable panels, shall have round, solid locking lids per ODOT standard detail RD356. For raised openings where the depth from the iron cover to the top of the vault exceeds 24 inches, an access structure equivalent to a standard manhole shall be used (see City Standard Detail 203). The opening in the vault lid need not exceed 24 inches in diameter.
5. Vaults with widths 10 feet or less must have removable lids.
6. The maximum depth from finished grade to the vault invert shall be 20 feet.
7. Internal structural walls of large vaults shall be provided with openings sufficient for maintenance access between cells. The openings shall be sized and situated to allow access to the maintenance “V” in the vault floor.
8. The minimum internal height shall be 7 feet from the highest point of the vault floor (not sump), and the minimum width shall be 4 feet.
9. Exceptions:
  - Concrete vaults may be a minimum 3 feet in height and width if used as tanks with access manholes at each end, and if the width is no larger than the height.
  - The minimum internal height requirement may be waived for any areas covered by removable panels.
10. Ventilation pipes (minimum 12-inch diameter or equivalent) shall be provided in all four corners of vaults to allow for artificial ventilation prior to entry of maintenance personnel into the vault.

### **3.3.5 CONTROL STRUCTURE DESIGN CRITERIA**

Control structures are catch basins or manholes with a restrictor device for controlling outflow from a facility to meet the desired performance requirements. The restrictor device is typically a tee section with an orifice plate welded to the bottom (called a “FROP-T”). To meet performance requirements, one or more elbow sections with orifice plates may need to be mounted on the side of the tee section. The restrictor device may also be a weir section sized to meet performance requirements or to provide peak flow or overflow conveyance.

#### **3.3.5.1 TYPES AND APPLICATIONS**

There are two general types of control structure designs: multiple-orifice restrictors and riser and weir restrictors. The applications and analysis methods of each are described below. Standard control structure details are shown in Appendix B, Figures B.12.A. through B.12.C.

The following applications and design criteria must be considered when choosing a control structure design:

1. Most control structures will use a combination of orifices and weirs to match pre-developed peak flows and to best utilize detention storage volume. Several orifices may be located at the same elevation if necessary to meet performance requirements.
2. Minimum orifice diameter is 0.25 inch. Note: In some instances, a 0.25-inch bottom orifice may be too large to meet target release rates, even with minimal head. In these cases, the live storage depth may be retained at 3 feet (which may result in flows higher than pre-developed rates).

3. Orifices shall be constructed on a tee section as shown in Figure B.12.A or on a baffle as shown in Appendix B, B.12.B.
4. In some cases, performance requirements may require the top orifice/elbow to be located too high on the riser to be physically constructed (e.g., a 13-inch-diameter orifice positioned 0.5 foot from the top of the riser). In these cases, a notch weir in the riser pipe may be used to meet performance requirements.
5. Consideration shall be given to the backwater effect of water surface elevations in the downstream conveyance system. High tailwater elevations may affect performance of the restrictor system and reduce live storage volumes.
6. A combined orifice and riser (or weir) system may be used to meet performance requirements in conjunction with the riser and weir restrictor design; however, the design must still provide for primary overflow of the developed 100-year peak flow assuming all orifices are plugged.
7. Properly designed weirs may be used as flow restrictors. However, they are more often used to provide primary overflow of the developed 100-year peak flow discharging to the detention facility.
8. An access road to the control structure is required for inspection and maintenance, and shall be designed and constructed as specified for detention ponds.
9. Manhole and catch basin lids for control structures shall be locking, and rim elevations shall match proposed finish grade.

### 3.3.5.2 ANALYSIS METHODS

This section presents the methods and equations for design of control structure restrictor devices. Included are details for the design of orifices, rectangular sharp-crested weirs, V-notch weirs, sutro weirs, and overflow risers. In most cases, design and analysis calculations will include a combination of equations to establish the stage-storage relationships for a particular control structure.

#### Orifices

Flow through orifice plates in the standard tee section or turn-down elbow may be approximated by the general equation:

$$Q = CA\sqrt{2gh}$$

where

- Q = flow (cfs)
- C = coefficient of discharge (0.62 for plate orifice)
- A = area of orifice (sf)
- h = hydraulic head (ft)
- g = gravity ([32.2 ft/sec]<sup>2</sup>)

Figure 3-2 illustrates a simplified application of the orifice equation, assuming a water surface at the top of the riser and that the 2-year water surface represents the head in the outlet pipe.

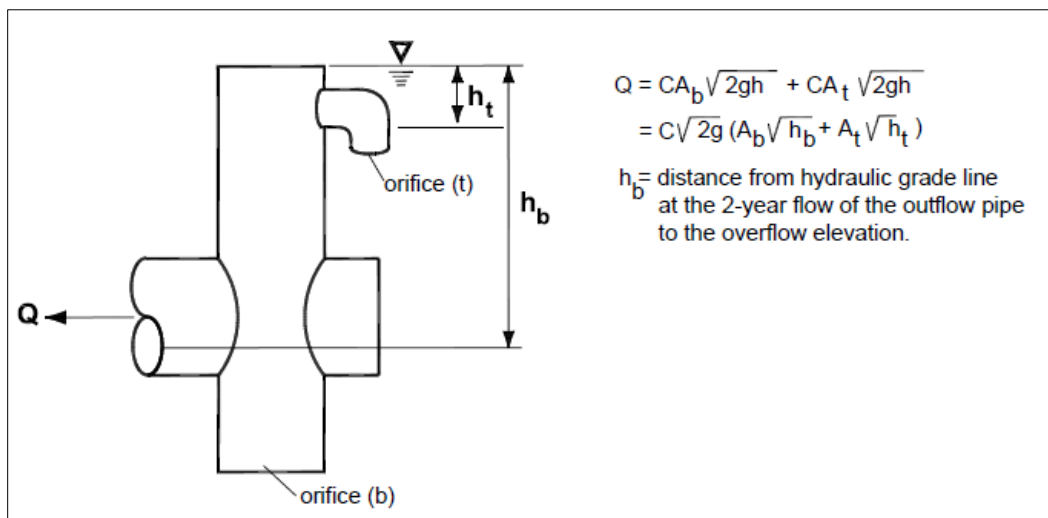


Figure 3-2. Typical Orifice Dimensions

The diameter of the orifice is calculated from the flow. The orifice equation is often useful when expressed as the orifice diameter in inches:

$$d = \sqrt{\frac{36.88Q}{\sqrt{h}}}$$

where      d = orifice diameter (inches)  
               Q = flow (cfs)  
               h = hydraulic head (ft)

### Rectangular, Sharp-Crested Weir

The rectangular, sharp-crested weir design shown in Figure 3-3 may be analyzed using standard weir equations for the fully contracted condition.

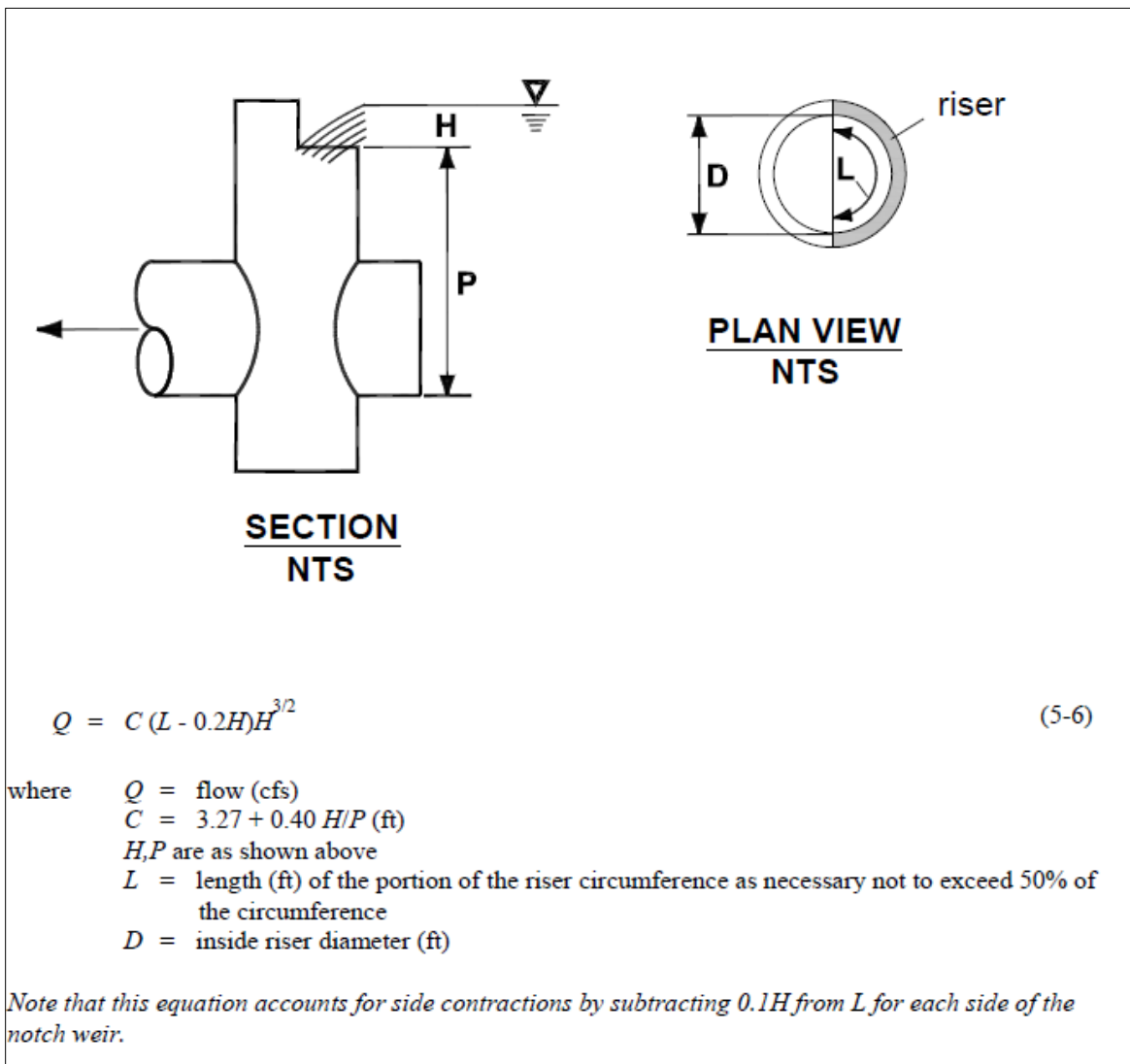


Figure 3-3. Typical Rectangular, Sharp-Crested Weir Dimensions

### V-Notch, Sharp-Crested Weir

V-notch weirs, as shown in Figure 3-4, may be analyzed using standard equations for the fully contracted condition.

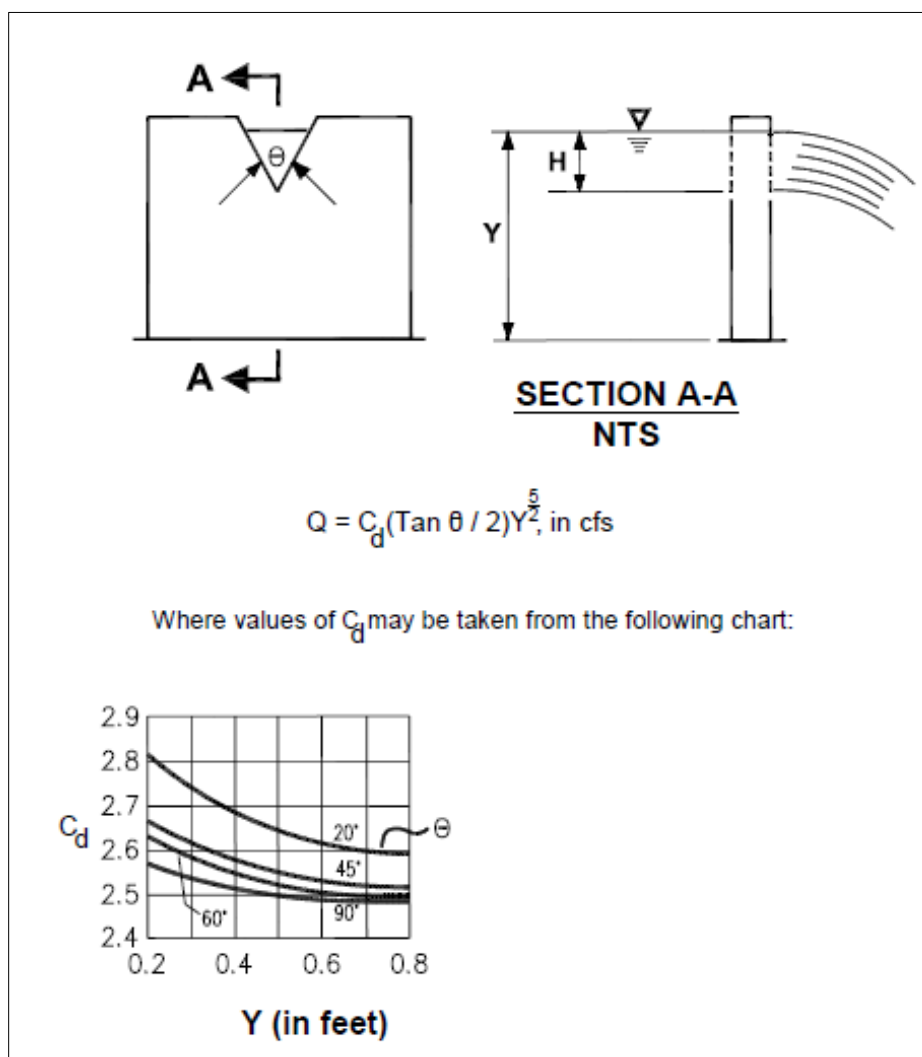


Figure 3-4. Typical V-notch, Sharp-Crested Weir Dimensions

### Proportional or Sutro Weir

Sutro weirs are designed so that the discharge is proportional to the total head. This design may be useful in some cases to meet performance requirements. The sutro weir consists of a rectangular section joined to a curved portion that provides proportionality for all heads above the line A-B (see Figure 3-5). The weir may be symmetrical or non-symmetrical.

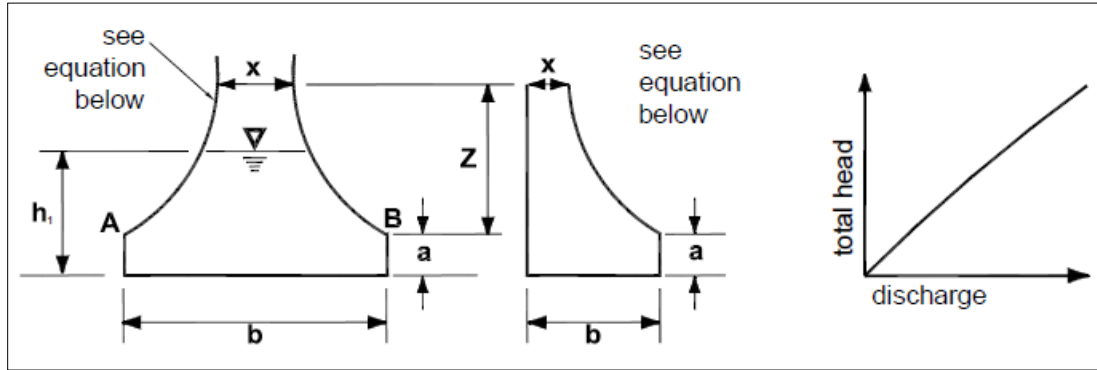


Figure 3-5. Typical Sutro Weir Dimensions

For this type of weir, the curved portion is defined by the following equation (calculated in radians):

$$\frac{x}{b} = 1 - \frac{2}{\pi} \tan^{-1} \sqrt{\frac{Z}{a}}$$

where  $a$ ,  $b$ ,  $x$ , and  $Z$  are as shown in Figure 3-5. The head-discharge relationship is:

$$Q = C_d b \sqrt{2ag} \left( h_1 - \frac{a}{3} \right)$$

Values of  $C_d$  for both symmetrical and non-symmetrical sutro weirs are summarized in Table 3-3.

*Note: When  $b > 1.50$  or  $a > 0.30$  use  $C_d = 0.6$ .*

**Table 3-3. Values of  $C_d$  for Sutro Weirs**

<b><math>C_d</math> values, symmetrical</b>					
<b>a (ft)</b>	<b>b (ft)</b>				
	<b>0.50</b>	<b>0.75</b>	<b>1.0</b>	<b>1.25</b>	<b>1.50</b>
<b>0.02</b>	<b>0.608</b>	<b>0.613</b>	<b>0.617</b>	<b>0.6185</b>	<b>0.619</b>
<b>0.05</b>	<b>0.606</b>	<b>0.611</b>	<b>0.615</b>	<b>0.617</b>	<b>0.6175</b>
<b>0.10</b>	<b>0.603</b>	<b>0.608</b>	<b>0.612</b>	<b>0.6135</b>	<b>0.614</b>
<b>0.15</b>	<b>0.601</b>	<b>0.6055</b>	<b>0.610</b>	<b>0.6115</b>	<b>0.612</b>
<b>0.20</b>	<b>0.599</b>	<b>0.604</b>	<b>0.608</b>	<b>0.6095</b>	<b>0.610</b>
<b>0.25</b>	<b>0.598</b>	<b>0.6025</b>	<b>0.6055</b>	<b>0.608</b>	<b>0.6085</b>
<b>0.30</b>	<b>0.597</b>	<b>0.602</b>	<b>0.605</b>	<b>0.6075</b>	<b>0.608</b>
<b><math>C_d</math>, values, non-symmetrical</b>					
<b>a (ft)</b>	<b>b (ft)</b>				
	<b>0.50</b>	<b>0.75</b>	<b>1.0</b>	<b>1.25</b>	<b>1.50</b>
<b>0.02</b>	<b>0.614</b>	<b>0.619</b>	<b>0.623</b>	<b>0.6245</b>	<b>0.625</b>
<b>0.05</b>	<b>0.612</b>	<b>0.617</b>	<b>0.621</b>	<b>0.623</b>	<b>0.6235</b>
<b>0.10</b>	<b>0.609</b>	<b>0.614</b>	<b>0.618</b>	<b>0.6195</b>	<b>0.620</b>
<b>0.15</b>	<b>0.607</b>	<b>0.6115</b>	<b>0.616</b>	<b>0.6175</b>	<b>0.618</b>
<b>0.20</b>	<b>0.605</b>	<b>0.610</b>	<b>0.614</b>	<b>0.6155</b>	<b>0.615</b>
<b>0.25</b>	<b>0.604</b>	<b>0.6085</b>	<b>0.6125</b>	<b>0.614</b>	<b>0.6145</b>
<b>0.30</b>	<b>0.603</b>	<b>0.608</b>	<b>0.612</b>	<b>0.6135</b>	<b>0.614</b>

**Riser Overflow**

The nomograph in Figure 3-6 may be used to determine the head (in feet) above a riser of given diameter and for a given flow (usually the 100-year peak flow for developed conditions).

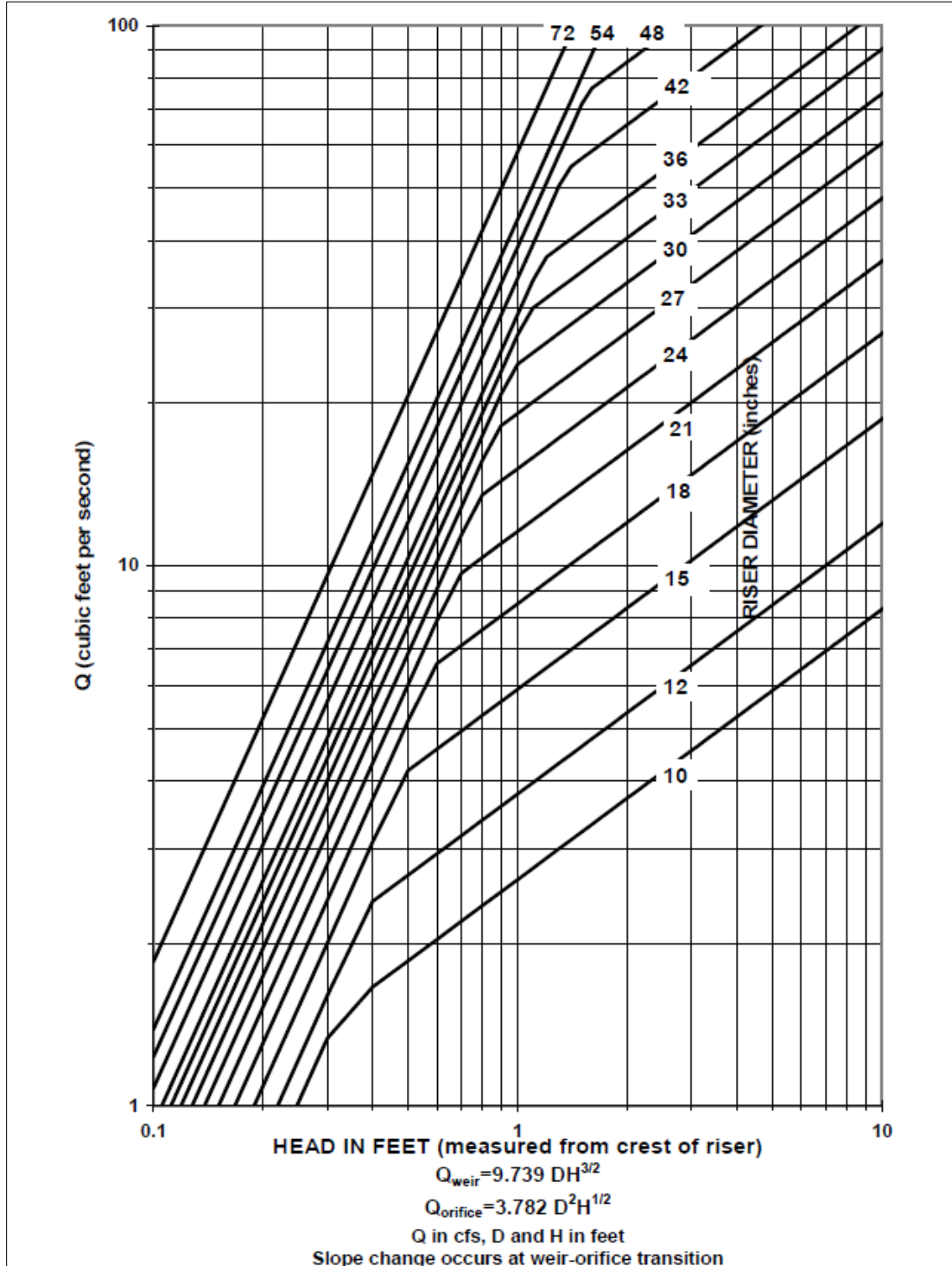


Figure 3-6. Riser Inflow Curves



## 4. OPERATIONS AND MAINTENANCE

Operation and maintenance of stormwater management facilities is required to ensure desired performance and long-term functionality and minimize the potential for system flooding and pollutant discharge.

### 4.1 OPERATIONS AND MAINTENANCE REQUIREMENTS

The O&M requirements in this chapter apply to all stormwater management facilities constructed in conjunction with these Standards including those installed on private property and those within a public utility easement, dedicated tract, or the public right-of-way.

Maintenance of all stormwater facilities shall be conducted to the same standards regardless of the organization or entity that has accepted responsibility for the maintenance.

Maintenance activities, including routine inspections, restorative maintenance, and facility rehabilitation, are required to ensure the long-term function and effectiveness of stormwater management facilities and infrastructure. Initial site planning must incorporate provisions for adequate access and space to perform maintenance activities for all stormwater management facilities.

Two categories of stormwater management facilities are described below as related to maintenance responsibility:

- **Privately owned and maintained:** These are stormwater facilities that benefit one owner or group of owners with shared responsibility. They generally include multi-family residential, commercial, and industrial types of developments. They generally do not include facilities associated with residential subdivisions, as those facilities are required to be located within the public right-of-way, easement, or dedicated tract for public maintenance (see Section 1.3.7).
- Privately owned and maintained stormwater facilities require a maintenance agreement recorded with the title and approved by the City that references the Stormwater Facilities Operation and Maintenance Plan (O&M Plan), outlining necessary maintenance to be performed at the owner's expense.
- **Publicly owned and maintained:** These include regional stormwater management facilities that benefit the public in general and any facility located within the public right-of-way, public property, or a tract/easement dedicated to the City.
- Publicly owned facilities may be constructed by the City, or they may be constructed as a public improvement by private contract (PIPC), with maintenance responsibilities transferred to the City following the 2-year maintenance warranty period (see Section 4.2).

#### 4.1.1 PRIVATELY OWNED AND MAINTAINED

Stormwater management facilities to be privately maintained shall address the following requirements:

##### **O&M Plan**

All stormwater management facilities to be maintained privately require an O&M plan that is reviewed and approved as part of the land development submittal. Details for completing the O&M Plan are included in Section 4.3.

**Maintenance Agreement**

A maintenance agreement must be approved by the City and recorded into the land record prior to permit issuance. A sample maintenance agreement for private facilities is available from the City. The O&M Plan, including description of scheduled inspection frequencies and regular maintenance activities, shall be referenced in the maintenance agreement.

**Access Easement**

The maintenance agreement requires access rights for the City, or its contractor or agent, to inspect the facility and ensure that it is maintained in proper working condition. This includes the right to enter a property when the City has a reasonable basis to believe that a violation of City standards and/or rules and regulations is occurring or has occurred, and to perform maintenance if the facility is found to have the potential to have a negative impact on public facilities or water quality. The access easement shall be included in the maintenance agreement, as approved by the City and recorded at the County Recorder's office.

**Annual Inspection and Maintenance**

Annual inspections are to be conducted by the facility owner (or designated representative) to document maintenance and repair needs and ensure compliance with the requirements of these Standards. Maintenance needs may include the following: removal of silt, litter, and other debris from all catch basins, inlets, and drainage pipes; grass cutting and vegetation removal (this should be manual removal and not include the use of pesticides); and necessary replacement of water quality vegetation. Any maintenance needs identified must be addressed by the responsible party in a timely manner in accordance with the O&M Plan.

**Records of Maintenance Activity**

Facility owners shall keep records of all inspections, maintenance activity, and repairs, and shall retain the records for at least 3 years. Copies of maintenance records shall be made available to the City upon request.

**City Inspection of Stormwater Management Facilities**

Inspections may be conducted by the City at any time, including but not limited to routine inspections, random inspections, inspections based on complaints or other notice of possible violations, inspections related to environmental permits, and joint inspections with other agencies done under environmental or safety laws. Inspections may include, but are not limited to, review of maintenance and repair records; sampling discharges, surface water, groundwater, or material/water in stormwater management facilities; and facility condition evaluations.

**Failure to Comply**

In the event that the private stormwater management facility becomes a danger to public safety or public health, the City shall notify the facility owner in writing. Upon receipt of the written notice, the owner shall have 30 days (in accordance with the maintenance agreement) to conduct maintenance and repair of the facility in an approved manner.

If an owner fails or refuses to meet the requirements of the maintenance agreement, the City, after reasonable notice, may perform maintenance in conjunction with these Standards to return the facility to proper working condition. The City shall charge the owner of the facility 200 percent of the actual time and materials cost incurred from the City-performed maintenance.

**Modifications to the O&M Plan**

If it is determined that the O&M Plan requires substantial modification to maintain the functionality of the facility, then modifications to the O&M Plan shall be submitted to the City for review and approval. The approved, modified O&M Plan shall be referenced in the maintenance agreement.

The inspection and maintenance frequency may be increased at any time to ensure proper functioning of the stormwater management facility. Increasing inspection and/or maintenance frequency does not require City review or approval.

**4.1.2 PUBLICLY OWNED AND MAINTAINED**

Stormwater facilities to be maintained by the City (including those installed as a PIPC) shall address the requirements outlined below.

**O&M Plan**

All stormwater facilities installed as a PIPC require an O&M Plan that is reviewed and approved with the PIPC permit. The O&M Plan shall identify the City as the responsible party for inspection and maintenance following the 2-year maintenance warranty period (see Section 4.2). Stormwater facilities designed and constructed by the City shall have an O&M Plan on file for City reference. Details for completing the O&M Plan are included in Section 4.3.

**Modifications to the O&M Plan**

Following the 2-year maintenance warranty period, at the City's discretion, the applicant may be required to prepare a modified O&M Plan if it is determined that the initial O&M Plan is not adequate to maintain the functionality of the facility. Modifications to the O&M Plan shall be submitted to the City for review and approval prior to the release of the Warranty Security (see Section 4.2).

**Tract Dedication and Easements**

All stormwater management facilities installed as a PIPC require the facility to be located within the public right-of-way, public property, or a tract/easement dedicated to the City. The process for submittal of dedications and easements associated with a PIPC permit are outlined in the PIPC Manual. The right-of-way dedication and easement forms for PIPC facilities are available from the City.

**4.2 MAINTENANCE, WARRANTY PERIOD, AND SECURITY**

Stormwater management facilities installed as a public facility through the PIPC permit process are subject to a 2-year maintenance and warranty period. The City requires the applicant of a PIPC permit to submit the Stormwater Facility Agreement and warranty security equal to 20 percent of the total cost of construction of the stormwater facilities or \$5,000, whichever is greater. The Stormwater Facility Agreement and Warranty Security forms are available from the City and included in the PIPC Permit Procedure Manual.

The Stormwater Facility Agreement and Warranty Security ensures that the owner/applicant agrees to maintain, repair, replace, and be responsible for damage to the stormwater facility for a period of 2 years following the date the City deems the improvements to be complete. During the 2-year warranty period, the applicant is responsible for all maintenance and documentation requirements outlined within the O&M Plan. Prior to the completion of the warranty period, the City will require all

maintenance records and documents to be reviewed and deficiencies addressed prior to the transfer of maintenance responsibilities. All facilities shall be cleaned and in good operating condition (i.e., replaced cartridges, replaced vegetation, etc.) prior to the completion of the warranty period. Upon default, the City may perform the remaining work or remedy violations and draw upon the Warranty Security.

### **4.3 STORMWATER FACILITY O&M PLAN**

O&M Plans are required to provide guidance to those who are responsible for the long-term inspection and maintenance of the facility. Specifically, O&M Plans describe the: regular maintenance schedule for the facility and conditions requiring additional maintenance actions to properly maintain, repair, modify, or reconstruct (if necessary) the facility.

The facility details and maintenance specifications in Appendix B can be used as a basis to create the O&M Plan. If an alternative facility is proposed, the design engineer shall create the facility details, maintenance specifications, and inspection checklist needed for the O&M Plan.

The following elements shall be included in an O&M Plan:

1. Introduction and general information
  - a. Facility type, project name if applicable, and permit number that the facility was constructed under.
  - b. Name and contact information for the responsible organization or individual.
  - c. Written narrative describing the site, drainage areas, and intended function of the facility. If applicable, include a list of interrelated or connected stormwater management facilities and description of how the facilities are connected.
2. Inspection and maintenance activity summary
  - a. Written narrative describing normal operating procedures.
  - b. Required inspection frequency.
  - c. Inspection checklist that outlines the minimum standards and conditions that trigger maintenance actions.
  - d. Required maintenance activities by applicable facility component and schedule.
3. O&M Plan responsibility
  - a. Person(s) or organization(s) responsible for inspections of stormwater management facilities.
  - b. Current and future (if applicable) funding source for maintenance.
4. Attachments
  - a. Site plan with the location of the facility/facilities, sources of runoff entering each facility, and ultimate stormwater disposal point.
  - b. Facility detail sheet(s) from the construction drawings.

# **APPENDICES**

- A CONVEYANCE SYSTEM DESIGN**
- B STORMWATER FACILITY DETAILS AND MAINTENANCE GUIDELINES**
- C PLANTING GUIDELINES FOR VEGETATED FACILITIES**
- D INFILTRATION TESTING PROCEDURES**



## **Appendix A: Conveyance System Design**

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## **A. CONVEYANCE SYSTEM DESIGN**

Stormwater conveyance system design is an integral component of overall stormwater management planning. Stormwater conveyance systems are used to minimize potential hazards to life (public safety), hazards to property (flooding), and hazards to habitat (water quality). Acceptable conveyance system design must maintain compatibility and minimize interference with existing drainage patterns; control onsite and downstream flooding of property, structures, and roadways; and minimize the potential degrading environmental impacts of stormwater runoff.

This chapter includes guidelines as well as specific requirements for the design of both open-channel and closed-conduit stormwater conveyance systems.

### **A.1 GENERAL CONDITIONS**

The following are the general conveyance system design guidelines:

1. In parking lots, access roads, and other newly developed or redeveloped impervious surface accessible to vehicles with a contributing drainage area of 1,000 square feet (sf) or greater, take one of the following actions:
  - a. Install catch basins and an onsite collection system to direct stormwater to the nearest public stormwater system or open drainage channel unless such facility is deemed to be too far away by the City Engineer
  - b. If approved by the City Engineer, sheet flow stormwater to an approved, onsite stormwater management facility
2. Parking lots, access roads, and other newly developed or redeveloped impervious surface accessible to vehicles with a contributing drainage area of 1,000 sf shall not sheet flow to the public right-of-way without approval from the City Engineer. Such discharge shall not be allowed across a public sidewalk area.
3. Public conveyance systems shall be designed as gravity systems to carry the design storm under no pressure flow (see Section A.3.2.3) and without the use of stormwater pumps. Private conveyance systems may be designed with use of stormwater pumps on a case-by-case basis as described in Section A.8. In select conditions, a backwater analysis may be required as described in Section A.3.2.4.
4. A development that connects to the public stormwater system shall provide connection points to allow all future development on uphill adjacent parcels to be served by the stormwater system as the natural drainage patterns and future planning concerns dictate.
5. The City's Public Works Standards and Specifications shall be adhered to for materials, workmanship, fittings and installation, and other applicable aspects of stormwater conveyance design and installation.
6. Conveyance systems shall be designed and constructed in compliance with requirements of all applicable federal, state, and local agencies. Written authorization of approval from other agencies may be required at the discretion of the City.
7. Conveyance systems shall be designed and constructed in accordance with floodplain management policies and regulations and other National Flood Insurance Program requirements and as determined by the City.

8. A separate stormwater conveyance system may be required to accept and convey upstream offsite stormwater runoff through the site. See Section A.2.3 for offsite upstream conveyance requirements.
9. Conveyance systems shall be designed and constructed to minimize downstream damage and erosion and to protect existing natural resources to the maximum extent practicable.

## **A.2 DESIGN CONSIDERATIONS**

Stormwater conveyance systems shall be designed to intercept and convey stormwater runoff efficiently. The stormwater conveyance system should complement the site design and stormwater management facilities in order to mitigate the impacts of urban development.

### **A.2.1 POINT OF DISCHARGE**

Design of a stormwater conveyance system requires one or more acceptable points of discharge to be identified. The following considerations and/or limitations shall be taken into account when establishing the point(s) of discharge:

- Points of discharge shall be located at an existing natural or constructed drainage outlet or outlets.
- Runoff shall not be allowed to flow over adjacent public or private property at a rate, volume, or location materially different from that which existed before development occurred.
- Runoff must be discharged in a manner that will not cause adverse impacts to downstream properties or previously constructed stormwater systems.
- If the point of discharge is an open drainage channel, then adequate velocity dissipation and/or additional channel protection shall be required to prevent erosion and/or alteration to the existing downstream channel.
- Any connection to an existing (public or private) downstream stormwater conveyance system shall be approved by the City. The means and methods of connecting or extending a piped conveyance system will be consistent with City standards and/or other standards required by agencies that have the authority to regulate the connection.
- If private property must be crossed to reach an approved point of discharge, the developer is responsible to acquire and record a downstream easement from the private property owner. Receipt of the downstream easement shall follow the procedure identified in Section A.2.5. The downstream easement must meet City approval.

#### **OnSite Conveyance**

Onsite conveyance shall be provided for all stormwater runoff from parking lots, access roads, and other new or redeveloped impervious surface accessible to vehicles with a contributing drainage area of 1,000 sf or greater. The following onsite conveyance system considerations shall be incorporated into the overall stormwater conveyance design.

Open-channel conveyance systems may be preferred over closed conduits where feasible, especially where they might provide opportunities for water quality treatment, wildlife habitat improvement, or emergency overland flood relief routes.

The onsite stormwater conveyance system shall be designed to minimize the likelihood of nuisance flooding or damage to neighboring and downstream properties.

An overland emergency flow path must be identified and/or designed to accommodate the 100-year flow event without risk of injury or property damage. The emergency flow shall not be allowed to flow through or inundate an existing building.

The property owner is responsible for controlling and conveying flow from springs and groundwater that surface during construction and within the applicable warranty period of the stormwater management facility.

## **A.2.2 OFFSITE CONVEYANCE**

Conveyance systems shall be designed to convey upstream offsite drainage through or around the project site using an integrated approach that plans for future development impacts.

The onsite conveyance system and stormwater facilities shall be designed to convey, treat, and control the additional flows from the upstream offsite drainage basin(s). Stormwater conveyance system sizing for upstream offsite stormwater runoff shall assume ultimate buildout and/or maximum zoning density for the contributing offsite area.

As an alternative, the upstream, offsite stormwater runoff may be conveyed through the project site in a separated stormwater conveyance system and not mixed with the onsite stormwater. This approach may be approved on a case-by-case basis by the City Engineer.

## **A.2.3 DOWNSTREAM ANALYSIS**

Stormwater discharge from a project site shall not adversely affect the safety and/or flooding potential of adjacent or downstream property owners.

A written downstream analysis shall document existing conditions and demonstrate adequate conveyance capacity of the natural and/or constructed drainage system downstream of the project site. The downstream analysis shall be submitted with construction drawings and associated design calculations and analysis.

The following requirements shall be followed when preparing a downstream analysis:

- The downstream analysis shall extend to the distance where the project site contributes less than 15 percent of the cumulative tributary drainage area or 1,500 feet downstream from the approved point of discharge, whichever is greater. In capacity-constrained areas, the City may extend the distance of the required downstream analysis.
- If the downstream analysis crosses into the jurisdictional boundary of another agency or municipality with stormwater management responsibilities, that agency or municipality must be notified and given the opportunity to review and comment on the analysis.

If the downstream stormwater conveyance system shows that property may be adversely affected by proposed stormwater release rates, the applicant may take either of the following actions:

1. Correct and/or improve downstream drainage conditions to provide adequate capacity for the proposed stormwater release. This approach may be used for public or private downstream stormwater conveyance systems.

2. Provide additional onsite control measures to reduce stormwater contribution to the downstream system. This approach may be used only for private downstream stormwater conveyance systems.

Obtaining necessary easements, design approval, and authorization from all affected property owners and/or regulating agencies for construction of any proposed downstream improvements shall be the responsibility of the developer. See Section A.2.5 for procedures for obtaining a downstream easement.

Note that a downstream analysis is required event when the project is located in an area that is exempt from detention.

#### **A.2.4 DOWNSTREAM EASEMENTS**

Where no public conveyance system exists at the adjacent, down gradient property line and the discharge was previously un-concentrated or significantly lower concentrated flow, the following procedure shall be followed to obtain an offsite stormwater easement to the downstream stormwater system. Information referenced below shall be submitted with the easement and/or during the permit process.

1. Applicants Shall Describe the Existing Drainage Situation. A physical description of drainage features from the development site downstream to the first existing public facility should be provided. Information on the presence or absence of a defined channel, the extent of the presence of water in the system, the type of vegetation and its tolerance for hydrological changes, the type of land uses being employed, groundwater characteristics, and any other relevant physical characteristic should be provided. A known hydrological change caused by development is an increase in dry season flows due to irrigation and/or intercepted groundwater.

A discussion of the existing drainage legal situation should also be provided. A list of downstream property owners and any known storm drainage easements or other access rights should be provided. Any previous disputes should be documented.

2. Applicants Shall Make a Good Faith Effort to Obtain Easement(s). Written and personal contact should be made with affected downstream property owners and documentation furnished to the City. If objections are raised, resolution alternatives, including offering compensation, should be considered. Physical improvements to the drainage system could be considered. Benefits associated with an established public drainage system in the area could be discussed. Existing drainage problems should be considered for potential resolution.
3. If it is demonstrated that downstream easements cannot be obtained as described above, the following requirements shall apply:
  - The applicant shall engineer solutions to minimize downstream impacts. Features such as detention, infiltration, water conserving landscaping (no automatic irrigation systems), minimization of impervious area, commitments to low impact weed and pest control, water quality treatment, or other applicable solutions should be considered. These solutions shall be prepared by a registered professional engineer and conform as closely as possible to criteria contained in this Manual.
  - Any drainage facility installed under this process without easements shall remain private in perpetuity.
  - The applicant shall provide an indemnification and hold harmless agreement acceptable to the City Attorney's Office protecting the City of Corvallis, its officers,

employees, volunteers and agents against any drainage related action, claim for injury or damage and all loss, liability, cost or expense, including court costs and attorney fees, growing out of or resulting directly or indirectly from construction, installation, operation and maintenance of the land division and subsequent development. This indemnification shall be a covenant running with the land, and shall be binding upon the Owner and Owner's heirs, executors, administrators, successors, assigns, lessees, sub-lessees, tenants, and sub-tenants forever.

- The applicant's attorney shall provide a written legal opinion that the proposed approach is consistent with Oregon water law.
- On a case-by-case basis, City staff may present the Corvallis City Council with a recommendation to pursue condemnation of the public drainage easements. It is expected that this would be an unusual situation based on a demonstrated high degree of public benefit and/or risk.

### **A.3 DESIGN CRITERIA AND METHODS**

The following section describes accepted design criteria and methods for analyzing the capacity of stormwater conveyance systems. It is the responsibility of the project design engineer to determine the appropriate method of analysis in determining the capacity of the proposed conveyance system. In conjunction with stormwater management facility calculations and analysis, calculation documentation shall be submitted to show that the proposed conveyance system has been designed in accordance with these Standards.

#### **A.3.1 DESIGN EVENT**

The conveyance system design events are based on the level of flood protection desired for a community, along with the cost of providing additional levels of protection.

Conveyance facilities shall be designed to convey and contain the peak flow from the specified design events below without surcharge. The design events for manmade elements of the conveyance system are as follows, including storm sewer pipes, culverts, open channels, and outfall pipes:

- Catch basins and piped collection and conveyance, including storm sewer pipes, culverts, and outfall pipes: 10-year, 24-hour storm
- Ditches, swales, and open channels: 10-year, 24-hour storm
- Bridges and culverts that convey streams identified in the City's Stormwater Master Plan shall be sized for the 100-year, 24-hour storm event, consistent with the requirements of the Oregon Department of Transportation (ODOT) *Hydraulics Manual*.

The 10-year, 24-hour design event shall be supplemented with an overland conveyance component demonstrating the safe passage of the 100-year, 24-hour storm event. The overland components shall not be allowed to flow through or inundate existing buildings.

#### **A.3.2 DESIGN METHODOLOGY**

Conveyance system capacity shall be determined for most conveyance system components using the Rational Method. Specifically, the Rational Method shall be used to calculate contributing peak flow to existing and proposed conveyance systems from contributing areas of 25 acres or less and that have a time of concentration (Tc) of less than 100 minutes for a single calculation. For all other conditions, an approved hydrograph method (e.g., Santa Barbara Urban Hydrograph [SBUH], Natural Resources Conservation

Service [NRCS] Method, or Technical Release 55 [TR-55]), Stormwater Management Model (SWMM), or other standard methods as approved by the City shall be used to calculate contributing peak flow to conveyance system components.

Manning's equation generally shall be acceptable for determining pipe or open-channel capacity for drainageways with a contributing area of 50 acres or less. For larger drainage areas, backwater effects shall be included in determining capacity for a drainageway, typically using HEC-RAS or equivalent modeling software.

Contributing area and system capacity calculations shall reflect future growth potential of offsite or upstream areas as appropriate in conjunction with the City's Comprehensive Plan.

Additional guidance related to the specific design methods is provided below.

### A.3.2.1 RATIONAL METHOD

The Rational Method is most accurate for runoff estimates from small drainages with large amounts of impervious area. When using the Rational Method, refer to the ODOT *Hydraulics Manual* for calculation formulas and expanded tables of coefficients.

The following is the traditional Rational Method equation:

$$Q_R = CI_RA$$

where	$Q_R$ =	peak flow (cfs) for a storm of return frequency R
	C =	estimated runoff coefficient (ratio of rainfall that becomes runoff)
	$I_R$ =	peak rainfall intensity (inches/hour) for a storm of return frequency R
	A =	drainage subbasin area (acres)

When using the Rational Method, the following limitations shall apply:

1. Use the Rational Method only for predicting a conservative peak flow rate to be used in determining the required capacity for conveyance elements. The Rational Method shall not be used to size stormwater management facilities.
2. In computing the runoff coefficient, an area-weighted runoff coefficient should be calculated for drainage areas comprising multiple land covers and soil types, based on average runoff coefficients shown in Table A-1.
3. In computing  $T_c$ , for smaller basins, the largest and most significant component in the total  $T_c$  is the portion of the time devoted to sheet flow. For this reason, extreme care should be given to determining the true travel time for the sheet flow component of the  $T_c$ . In calculating the total  $T_c$ , the following limitations will apply:
  - a. The flow segment used for the sheet flow component shall not extend for more than 300 feet. The use of a distance of less than 200 feet on a pre-developed land use will require supporting documentation, such as photographs that show evidence of shallow concentrated flow at the point of transition.
  - b. For segments of the  $T_c$  route that flow through closed conveyance facilities, such as pipes and culverts, use standard hydraulics formulas for establishing velocity and travel time.
  - c. For segments of the  $T_c$  route that flow through lakes or submerged wetlands, travel time is normally very short. The travel time can be determined using an appropriate storage routing technique, or it can be assumed to be zero.
  - d. The minimum total  $T_c$  used in the runoff calculations shall be 5 minutes.

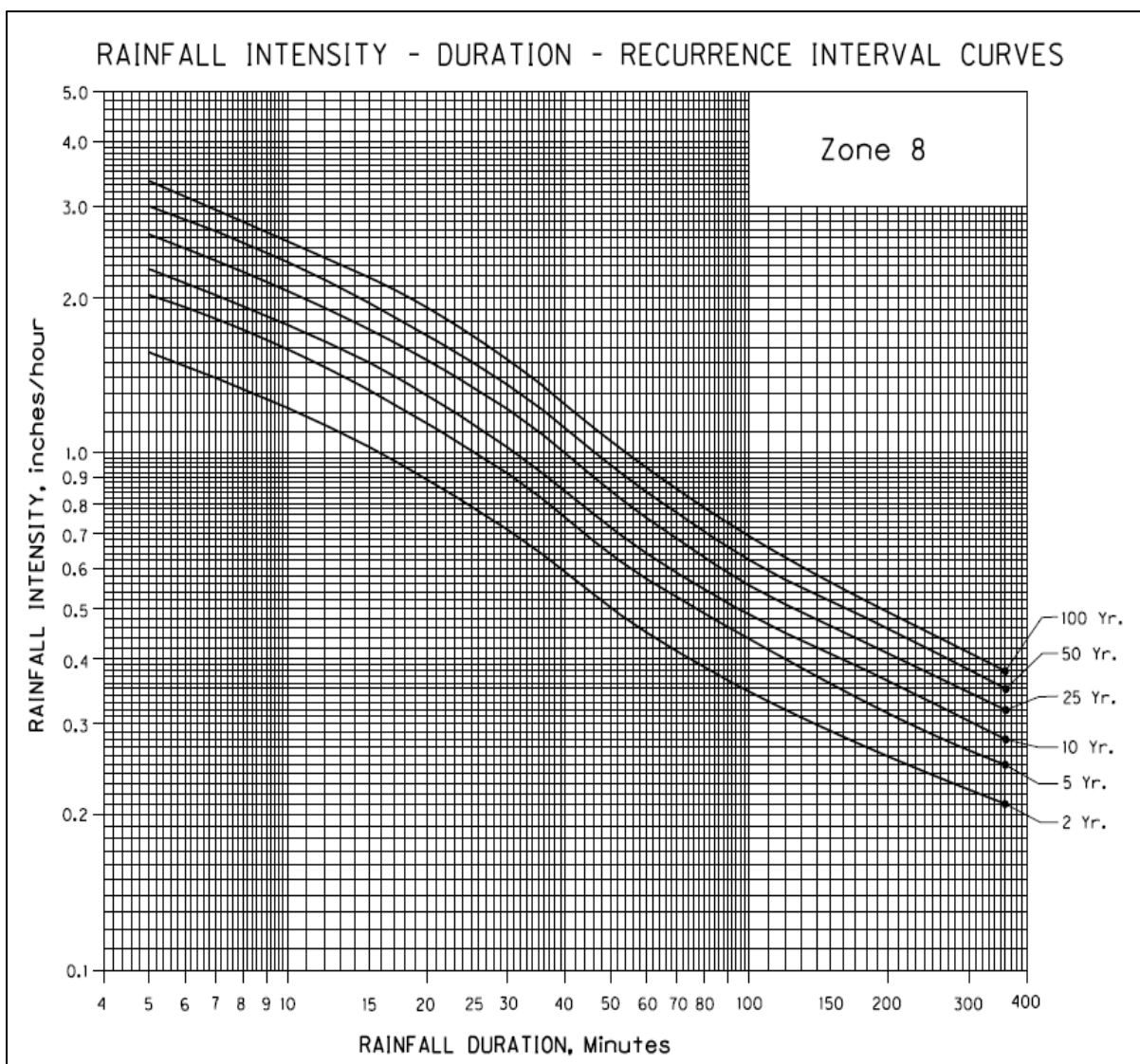
- e. The rainfall intensity (I) should be based on the ODOT rainfall intensity frequency curve from Zone 8 shown in Figure A-1.

**TABLE A-1: Rational Method Runoff Coefficients**

General Land Covers		Single Family Residential Areas <sup>a</sup>	
Land Cover	C	Land Cover Density	C
Dense forest	0.10	0.20 DU/Ac (1 unit per 5 ac.)	0.17
Light forest	0.15	0.40 DU/Ac (1 unit per 2.5 ac.)	0.20
Pasture	0.20	0.80 DU/Ac (1 unit per 1.25 ac.)	0.27
Lawns	0.25	1.00 DU/Ac	0.30
Playgrounds	0.30	1.50 DU/Ac	0.33
Gravel areas	0.80	2.00 DU/Ac	0.36
Pavement and roofs	0.90	2.50 DU/Ac	0.39
Open water (pond, lakes, wetlands)	1.00	3.00 DU/Ac	0.42
		3.50 DU/Ac	0.45
		4.00 DU/Ac	0.48
		4.50 DU/Ac	0.51
		5.00 DU/Ac	0.54
		5.50 DU/Ac	0.57
		6.00 DU/Ac	0.60

a. Based on average 2,500 square feet per lot of impervious coverage.

For combinations of land covers, an area-weighted composite coefficient ( $C_c$ ) should be computed for each drainage basin based on the equation:  $C_c = [(C_1 \times A_1) + (C_2 \times A_2) + \dots + (C_n \times A_n)] / A_t$ , where  $A_t = (A_1 + A_2 + \dots + A_n)$ , the total drainage basin area.



**Figure A-1: Intensity-duration-frequency curve for use in the rational method**

(Source: ODOT)

### A.3.2.2 HYDROGRAPH METHOD

When using SBUH, TR-55, or the SWMM method to calculate runoff estimates, the calculations shall have the following limitations:

1. The rainfall distribution to be used for hydrograph methods shall be the standard NRCS Type 1A rainfall distribution and 24-hour precipitation. Table A-2 provides the design storms for use in the conveyance calculations.
2. Curve numbers shall be derived from the NRCS runoff curve numbers contained in TR-55 *Urban Hydrology for Small Watersheds* as referenced in Tables A-3 and A-4.
3. Soil types shall be derived from the NRCS Soil Survey for Benton County.
4. A maximum overland distance for sheet flow used in calculations shall be 300 feet.
5. The minimum time of concentration shall be 5 minutes.



**TABLE A-2: 24-Hour Rainfall Depths In Corvallis**

Recurrence Interval, years	24-hour Depth, inches
10	3.64
100	4.73

Source: Corvallis Storm Water Master Plan.

**TABLE A-3: Runoff Curve Numbers for Urban Areas**

Cover Descriptions	Average % Impervious Area	Curve Numbers for Hydrologic Soil Group			
		A	B	C	D
<b>Cover Type and Hydrologic Condition</b>					
<b>Open space (lawns, parks, golf courses, cemeteries, etc.)</b>					
• Poor condition (grass cover <50%)		68	79	86	89
• Fair condition (grass cover 50% to 75%)		49	69	79	84
• Good condition (grass cover > 75%)		39	61	74	80
<b>Impervious areas</b>					
• Paved parking lots, roofs, driveways, etc.		98	98	98	98
<b>Streets and roads</b>					
• Paved: curbs and stone sewers (excluding right-of-way)		98	98	98	98
• Paved: open ditches (including right-of-way)		83	89	92	93
• Gravel (including right-of-way)		76	85	89	91
• Dirt (including right-of-way)		72	82	87	89
<b>Urban districts</b>					
• Commercial and business	85	89	92	94	95
• Industrial	72	81	88	91	93
<b>Residential districts by average lot size</b>					
• 1/8 acre or less (town houses)	65	77	85	90	92
• 1/4 acre	38	61	75	83	87
• 1/3 acre	30	57	72	81	86
• 1/2 acre	25	54	70	80	85
• 1 acre	20	51	68	79	84
• 2 acres	12	46	65	77	82

Source: Soil Conservation Service, *Urban Hydrology for Small Watersheds*, Technical Release 55, pp. 2.5–2.8, June 1986.

TABLE A-4: Runoff Curve Numbers for Other Agricultural Areas

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover Type	Hydrologic Condition	A	B	C	D
<b>Pasture, grassland, or range-continuous forage for grazing</b> <ul style="list-style-type: none"> <li>&lt;50% ground cover or heavily grazed with no mulch</li> <li>50 to 75% ground cover and not heavily grazed</li> <li>&gt;75% ground cover and lightly or only occasionally grazed</li> </ul>	poor	68	79	86	89
	fair	49	69	79	84
	good	39	61	74	80
<b>Meadow (continuous grass, protected from grazing and generally mowed for hay)</b>	–	30	58	71	78
<b>Brush-weed-grass mixture with brush as the major element</b> <ul style="list-style-type: none"> <li>&lt;50% ground cover</li> <li>50 to 75% ground cover</li> <li>&gt;75% ground cover</li> </ul>	poor	48	67	77	83
	fair	35	56	70	77
	good	30	48	65	73
<b>Woods-grass combination (orchard or tree farm)</b>	poor	57	73	82	86
	fair	43	65	76	82
	good	32	58	72	79
<b>Woods:</b> <ul style="list-style-type: none"> <li>Forest litter, small trees, and brush are destroyed by heavy grazing or regular browsing.</li> <li>Woods are grazed but not burned, and some forest litter covers the soil.</li> <li>Woods are protected from grazing, and litter and brush adequately cover the soil.</li> </ul>	poor	45	66	77	83
	fair	36	60	73	79
	good	30	55	70	77

Source: Soil Conservation Service, *Urban Hydrology for Small Watersheds, Technical Release 55*, pp. 2.5–2.8, June 1986.

### A.3.2.3 NO SURCHARGE FLOW CAPACITY ANALYSIS

Storm drains that are designed to operate at full or partially full conditions during the design storm are considered to be operating at non-pressure or no surcharge flow.

The capacity of pipe systems and open channels, for no surcharge flow conditions, can often be estimated using Manning's equation. Manning's equation for steady uniform flow is as follows:

#### Manning's Equation

$$Q = \left(\frac{1.486}{n}\right) AR^{2/3} S^{1/2}$$

or

$$V = \left(\frac{1.486}{n}\right) R^{2/3} S^{1/2}$$

where: Q = flow in cubic feet per second (cfs)  
n = coefficient of roughness (Manning's n)  
A = cross sectional area of flow in square feet  
V = Velocity, fps  
R = hydraulic radius in feet = A/WP

(WP = wetted perimeter = length, in feet, of the wetted contact between a flow of water and its containing channel, measured at right angles to the direction of flow)

S = hydraulic slope (or hydraulic grade line) in feet per foot

Typical values for the hydraulic roughness coefficient (Manning's  $n$ ) for conduits and channels can be found in Tables A-5 and A-6. Refer to the ODOT *Hydraulics Manual* for additional hydraulic roughness values.

This conveyance system capacity estimate using the Manning equation is acceptable for final design purposes if the conveyance system does not have tailwater influence (such as discharge into a partially full detention basin) or abrupt changes in channel cross-section or slope that might cause non-uniform flow. Manning's equation does not take into account entrance, exit, bend, and junction losses within catch basins or manholes.

**TABLE A-5: Normal Range Hydraulic Roughness Coefficient (Manning's  $n$ ) for Conduits**

Type of Pipe Material	Manning's $n$ (normal)
Concrete	0.013
Ductile iron	0.012
Corrugated metal (CMP): annular - 2-2/3" x 1/2"	0.024
CMP: annular - 3" x 1"	0.027
CMP: annular - 6" x 2"	0.032
CMP: helical - 2-2/3" x 1/2"	
12-inch diameter	0.013
18-inch diameter	0.015
24-inch diameter	0.017
36-inch diameter	0.021
48-inch diameter	0.023
60-inch diameter and larger	0.024
Corrugated high-density polyethylene (CPEP): single wall	0.024
CPEP: smooth wall	0.012
Spiral rib metal	0.011
Polyvinyl chloride (PVC)	0.011
High-density polyethylene (HDPE): butt fused	0.009

*These  $n$  values are the "normal" range hydraulic roughness coefficient values for use in the analysis of conduits. Refer to the ODOT Hydraulics Manual for additional reference values.*

TABLE A-6: Normal Range Hydraulic Roughness Coefficient (Manning's n) for Channels

Type of Channel	
Constructed	Natural
<p><b>A. Earth, straight and uniform</b></p> <p>1. Clean, recently completed..... 0.018</p> <p>2. Clean, after weathering..... 0.022</p> <p>3. Gravel, uniform section, clean..... 0.025</p> <p>4. With short grass, few weeds ..... 0.027</p> <p><b>B. Earth, winding and sluggish</b></p> <p>1. No vegetation ..... 0.025</p> <p>2. Grass, some weeds ..... 0.030</p> <p>3. Dense weeds or aquatic plants in deep channels ..... 0.035</p> <p>4. Earth bottom and rubble sides ..... 0.030</p> <p>5. Stony bottom and weedy banks ..... 0.035</p> <p>6. Cobble bottom and clean sides ..... 0.040</p> <p><b>C. Rock cuts</b></p> <p>1. Smooth and uniform ..... 0.035</p> <p>2. Jagged and irregular ..... 0.040</p> <p><b>D. Channels not maintained, weeds and brush uncut</b></p> <p>1. Dense weeds, high as flow depth..... 0.080</p> <p>2. Clean bottom, brush on sides..... 0.050</p> <p>3. Clean bottom, brush on sides, highest stage of flow ..... 0.070</p> <p>4. Dense brush, high stage..... 0.100</p>	<p><b>A. Minor streams (top width at flood stage less than 100 feet)</b></p> <p>1. Streams on plain</p> <p>a. Clean, straight, full stage, no rifts or deep pools ..... 0.030</p> <p>b. Same as above, but more stones and weeds..... 0.035</p> <p>c. Clean, winding, some pools and shoals ..... 0.040</p> <p>d. Same as above, but some weeds and stones ..... 0.045</p> <p>e. Same as above, lower stages, irregular slopes and sections with more ineffective flow area ..... 0.048</p> <p>f. Same as d, but more stones ..... 0.050</p> <p>g. Sluggish reaches, weedy, deep pools ..... 0.070</p> <p>h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush ..... 0.100</p> <p>2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages</p> <p>a. Bottom: gravels, cobbles, and few boulders ..... 0.040</p> <p>b. Bottom: cobbles with large boulders ..... 0.050</p> <p><b>B. Floodplains</b></p> <p>1. Pasture, no brush</p> <p>a. Short grass..... 0.030</p> <p>b. High grass ..... 0.035</p> <p>2. Cultivated areas</p> <p>a. No crop ..... 0.030</p> <p>b. Mature row crops..... 0.035</p> <p>3. Brush</p> <p>a. Scattered brush, heavy weeds ..... 0.050</p> <p>b. Light brush and trees ..... 0.050</p> <p>c. Medium to dense brush ..... 0.070</p> <p>4. Trees</p> <p>a. Dense willows, straight ..... 0.150</p> <p>b. Cleared land with tree stumps, no sprouts ..... 0.040</p> <p>c. Cleared land with tree stumps, heavy growth of sprouts..... 0.060</p> <p>d. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches ..... 0.100</p> <p>e. Same as above, but with flood stage reaching branches ..... 0.120</p>

The n values listed above are the "normal" range hydraulic coefficient values for use in the analysis of open channels. For conservative design of channel capacity the "maximum" values listed in the ODOT Hydraulics Manual should be considered. For channel bank stability calculations, the "minimum" values listed in the ODOT Hydraulics Manual should be considered.

#### **A.3.2.4 BACKWATER ANALYSIS**

A backwater analysis shall be conducted for the following circumstances:

1. Where uniform flow is not expected or where sudden losses within the system may cause surcharging of water
2. A discharge into a tailwater condition, such as a partially full stormwater detention pond or into a partially full channel
3. Culvert entrances
4. Ditch inlet location where backwater effect could cross a property line
5. Other locations as determined by the City Engineer

The backwater analysis shall be to a point where no surcharge flow at the design storm flow rate is re-established.

When a backwater condition exists, the storm drain system shall be designed to convey and contain at least the peak runoff from the 10-year design storm.

Structures for proposed pipe systems must be designed to provide a minimum of 1 foot of freeboard between the hydraulic grade line (HGL) and the top of the stormwater structure and appurtenances or finish grade above the pipe during the design flow. The HGL is defined by the elevations to which water will rise in small vertical pipes, located at various locations along the flow path. In a no surcharge flow condition, the hydraulic slope can be assumed to be parallel with the flow line slope.

Surcharge in pipe systems shall not be allowed under any circumstance if it will cause flooding in portions of a structure, including below crawl spaces and basements.

### **A.4 PIPE DESIGN**

Pipe systems are composed of more than one run of pipe and include at least one junction type of structure such as a catch basin or manhole. The following sections describe design criteria for pipe systems.

#### **A.4.1 MINIMUM REQUIREMENTS**

Pipe systems shall be designed to meet the following minimum requirements:

1. The minimum pipe diameter for public storm drain mains is 12 inches. The minimum pipe diameter for storm pipe leading from curb inlets or catch basins to mains is 10 inches.
2. Private pipes sizes should be consistent with the Oregon Plumbing Specialty Code. The minimum pipe diameter for storm drain mains located on private development is 10 inches, unless detailed calculations are provided to warrant a smaller pipe size and the City Engineer approves the application. An exception to this is for the public portion of storm sewer service laterals which serve an individual house or a small commercial property. These laterals may be a minimum of 6 inches in diameter or as approved by the City.
3. Pipe diameter shall not decrease in size as the pipe moves downstream, regardless of the slope provided on the pipe.
4. All storm pipe shall be designed at a grade that will produce a mean velocity, when flowing full or half-full, of at least 2 feet per second (fps).

5. Storm pipe greater than or equal to a 20 percent slope shall be secured by anchor walls (see ODOT standard detail RD332). Concrete pipe shall not be used when slopes exceed 20 percent due to the potential for joint displacement from differential settlement.
6. Debris grates shall be installed at all inlets where an open channel discharges to a piped drainage system. Additionally, debris grates are required at all outlets of piped systems.

#### **A.4.2 PIPE MATERIAL**

The pipe materials approved for use in public pipe systems and culverts shall conform to the City's Standard Construction Specifications. The City Engineer may adopt or approve other pipe materials or specifications due to technology developments.

#### **A.4.3 PIPE COVER**

Pipe cover, as measured from the bottom of roadway subgrade, shall meet the following minimum requirements. Pipe cover that is less than the stated minimums may be permitted on a case-by-case basis, as approved by the City Engineer.

- Minimum cover of 2 feet is required.
- PVC and HDPE shall require a 2-foot minimum cover in any public roadway area.
- If Class 52 ductile iron pipe, C900, or Class V concrete pipe is used, the cover may be reduced to 1 foot.
- In areas of relatively flat terrain, the project engineer must show that sufficient depth is provided at the boundary of the development to properly drain the remainder of the upstream basin area tributary to the site.
- The Oregon Plumbing Specialty Code (OPSC) typically requires 1-foot minimum cover on private property where the system will be privately maintained.

#### **A.4.4 ALIGNMENT AND LOCATION**

Pipe alignment and location shall follow the following guidelines:

1. All pipe lengths and slopes shown on construction plans shall be based on measurements from center of structure to center of structure.
2. The maximum pipe length is 400 feet between access structures.
3. Storm drains shall be laid on a straight alignment.
4. At a structure, a change in the horizontal alignment of the pipe and associated flow path greater than 45 degrees is undesirable. Changes in the horizontal alignment of the pipe and associated flow path greater than 90 degrees will not be allowed.
5. A minimum separation distance from other utility pipes and conduits shall conform to City Standard Detail 202, unless otherwise specified by the purveyor of the utility in question. The separation shall be measured from the outside edge of the pipe. If there is less than 12 inches of separation, a concrete cap is required.
6. Where storm pipe is designed parallel to other utility pipe or conduit lines, the vertical location of the storm pipe shall be located in a manner that will permit future connections and avoid conflicts with parallel utilities without abrupt changes in vertical grade.

7. Stormwater conveyance system connections shall follow the following guidelines:
  - a. For all piped public stormwater conveyance systems, excluding roof drains and foundation drains, connections may be made only at a manhole. A single point of connection shall be established. Tees, wyes, saddles, or other types of connections to the public stormwater conveyance system shall not be permitted.
  - b. Lateral or side pipe connections within the right-of-way shall not exceed half the diameter of the mainline and cannot exceed 6 inches in diameter. For larger connections, a structure for maintenance access is required.
  - c. Laterals or side pipes shall connect to the main storm pipe in such a manner that all flows enter the manhole pointed downstream.
  - d. Connection of a private stormwater conveyance system to a combination sewer requires specific approval by the City Engineer. The connection shall be made only at a manhole.

#### **A.4.5 INLETS**

Stormwater conveyance system inlets shall follow the following guidelines:

##### **Location**

Inlet structures are required at the following locations, but in no case shall they be spaced farther apart than 400 feet:

- At the ends of all dead-end streets with a descending grade
- At intermediate locations so that the maximum gutter flow during the 10-year design storm does not exceed the shoulder width plus 2 feet of the travel lane
- At all sag points (low points) in vertical curves
- Within 20 feet, measured on the uphill side, of pedestrian ramps
- Inlet structures shall not be located where they will interfere with a pedestrian ramp

##### **Design Requirements**

Inlet structures shall conform to the following design requirements:

1. Catch basin inlet structures shall be constructed in accordance with the City's Standard Details.
2. Inlet structures may be used as junctions, in lieu of manholes only on a case-by-case basis as approved by the City Engineer.
3. Ditch and/or area inlets shall be required to intercept existing flows.

#### **A.4.6 STRUCTURES**

Manhole structures shall meet the following requirements:

1. Manholes shall be required at, but not limited to, the following locations:
  - Changes in vertical grade or horizontal alignment of storm drain pipes.
  - Change in size of storm drain pipes.
  - Uppermost extent of storm pipe not opened (daylighted) to receive ditch or other open conveyance flows. Cleanouts may be allowed in this application on a case-by-case basis.

- Pipe junctions where the depth from rim to invert exceeds 4 feet or where the pipe is 18 inches in diameter or greater.
2. Manholes shall conform to the City's Standard Details.
  3. Where minimum vertical distance is proposed between inlet and outlet pipes in a manhole (or inlet structure serving as a junction structure), pipes must be aligned vertically by one of the following criteria, in order of preference:
    - Match pipe crowns
    - Match 80 percent diameter of pipes
    - Perform backwater analysis
  4. Standard depth manhole rim frames shall be installed in all paved street locations.
  5. Manhole rims not located in pavement areas, and not located in the pavement section of a paved road, shall be set 6 inches above finished grade. Covers shall be bolted down with a minimum of two stainless-steel bolts per the City's Standard Detail 203.

## **A.5 OPEN CHANNEL DESIGN**

The following section describes accepted criteria and methods for designing open-channel conveyance systems, such as swales and ditches.

### **A.5.1 GEOMETRY**

Open-channel geometry shall meet the following criteria:

1. Constructed open channels shall be sized to pass the design flows listed in Section A.3.1 without causing erosion.
2. Channel side slopes shall be no steeper than 2 horizontal to 1 vertical (2H:1V) for undisturbed ground (cuts), as well as for disturbed ground (embankments).
3. A low-flow channel, within the main channel, designed to carry 10 percent of the conveyance design storm, will be required for channels with a design flow of greater than 20 cubic feet per second (cfs). Side slopes for the low-flow channel shall not exceed 2H:1V and shall be stabilized with seeded matting or approved equivalent.
4. Curvilinear channel design shall have a 100-foot minimum radius. Tighter curves may be used if the City Engineer determines that sufficient erosion control has been incorporated into the design to maintain stable bank conditions following development.
5. Channels shall be designed to provide sufficient freeboard to avoid overtopping and flow into adjacent public roads. Channels shall be designed to have a minimum freeboard of 6 inches when the design discharge is 10 cfs or less and 1 foot when the design discharge is greater than 10 cfs. Extra freeboard may be required for curved segments of an open channel.

### **A.5.2 CHANNEL LINING AND PROTECTION**

Protection for open channels shall meet the following criteria:

1. Vegetation-lined channels shall be used whenever practicable. Rock-lined channels shall be used only where a vegetative lining will not provide adequate protection from erosion.



2. Channel protection shall be based on the minimum level of protection listed in Table A-7.
3. Where riprap protection is specified, riprap shall be placed over a woven geo-textile fabric.
4. No protruding pipes, culverts, or other structures that reduce or hinder the flow characteristics of the channel will be allowed. Channel connections shall be designed to prevent scouring. All pipe connections shall match side slopes and incorporate a headwall.
5. All channel sides and bottoms shall be seeded, sodded, or rock-lined immediately following excavation, regardless of mean flow velocity.

**TABLE A-7: Protection for New Channel Construction**

Velocity at Design Flow, fps		Required Protection	Thickness, feet	Minimum Height above Design Water Surface, feet
Greater than	Less than or Equal to			
0	5	Vegetation lining	Not applicable	0.5
5	8	Bioengineered lining	Not applicable	1
		ODOT Class 50 riprap <sup>a</sup>	1.5	
8	12	ODOT Class 200 riprap	2.5	2
12	20	Slope mattress, etc.	Varies	2
20		Designed by Professional Engineer		

a. The City may require ODOT Class 100 riprap on an as-needed basis.

### A.5.3 OPEN-CHANNEL LOCATIONS

When located on private property, new open-channel conveyance systems shall be located in drainageway easements and recorded on plat maps if plat maps are required with the following restrictions:

1. Property owner shall not alter the drainageway without approval of the City Engineering Division.
2. Property owner shall not place any structure or fence within the normal high water area of the open channel.
3. Property owner shall not introduce foreign material such as grass clippings within the high water area of the open channel.

### A.5.4 CHECK DAMS

Check dams are not recommended for use in conveyance channels because of the problems they pose for routine maintenance operations. However, check dams are recommended for use in temporary or permanent channels as an erosion and sedimentation control device and for stepping down channels to promote infiltration. Where check dams are proposed, they shall be spaced at maximum 2-foot elevation intervals.

## A.6 CULVERTS

Culverts, for the purposes of this manual, are single runs of pipe that are open at each end and do not have structures such as catch basins or manholes. Culverts designed for fish passage are governed by the Oregon Department of Fish and Wildlife and often require additional design considerations such as depth of flow and velocity that may differ considerably from the design requirements included herein. When conflicts exist, the applicant shall work with the City and the regulating agency to establish the appropriate design criteria.

### A.6.1 CULVERT DESIGN CRITERIA

Culvert design shall conform to the following requirements:

#### Material

The allowable culvert materials shall be the same as the allowable pipe materials listed in Section A.4.2.

#### Culvert Sizing

Minimum culvert diameters are as follows:

- For cross-culverts under public and private roadways: minimum 18 inches
- For all other roadway culverts, including driveway culverts: minimum 12 inches

#### Headwater

No surcharging (headwater) is allowed.

#### Minimum Cover

Minimum cover requirements, as measured from the bottom of the roadway subgrade, are as follows:

1. Under roads classified as collectors or higher: 2 feet.
2. If Class 52 ductile iron pipe is used, the cover may be reduced to 1 foot.
3. PVC and HDPE shall require a 2-foot minimum cover in any public roadway area.
4. Pipe covers of less than the above stated minimums may be permitted on a case-by-case basis. These may require a designed reinforced concrete cover that will distribute roadway use (traffic) forces to a foundation area to the sides of the pipe.
5. Reinforced concrete box (RCB) culverts with no cover requirement may be permitted on a case-by-case basis. Signed and sealed structural design calculations shall be submitted for review (this requirement may be waived for pre-cast RCB culverts with covers greater than 2 feet). In culverts with no cover, the clearance from the roadway surface to the reinforcing steel shall be no less than 3 inches and the 30-day concrete strength shall be no less than 4,500 pounds per square inch.

#### Headwalls/Endwalls

Concrete headwalls are required for all culverts. End protection shall conform to ODOT standard details RD316 to RD324. No plastic pipes shall be exposed.

## A.6.2 LAYOUT

Culvert layout shall conform to the following requirements:

1. No bends shall be permitted in culvert pipes.
2. The maximum culvert length without access structures is 300 feet.
3. The minimum separation distance from other utility pipes and conduits (as measured from the outside edge of pipe) shall conform to City Standard Detail 202, unless otherwise specified by the purveyor of the utility in question. The separation shall be measured from the outside edge of the pipe.
4. Culverts located within the structural street section shall be shown in plan and profile view in the design submittal.

## A.7 OUTFALLS

Outfalls from drainage facilities shall be designed with adequate energy dissipaters to minimize downstream damage and erosion. All outfalls with exit velocity exceeding 4 fps shall be examined with respect to soil type to ensure adequate erosion control. Where possible, the outfall shall be located below the 10 year water surface elevation of the receiving creek or channel.

Stormwater conveyance pipe shall enter a creek or open channel such that the flow path enters the creek or open channel in the direction of the flow and not more than 90 degrees. The outlet shall have a headwall and scour pad or riprap to prevent erosion of the existing bank or channel bottom. The size of the discharge pipe and the size of the creek or open channel being discharged to will govern which protective measures are required.

Engineered energy dissipaters, including but not limited to stilling basins, drop pools, hydraulic jump basins, baffled aprons, and bucket aprons, shall be designed using published references such as *Hydraulic Design of Energy Dissipaters for Culverts and Channels*, published by the Federal Highway Administration of the U.S. Department of Transportation, the ODOT *Hydraulics Manual*, and others. The design reference shall be cited in the stormwater management plan submittal.

Rock protection at outfalls shall be designed in accordance with information listed in Table A-8.

**TABLE A-8: Rock Protection at Outfalls**

Discharge Velocity at Design Flow, fps		Minimum Required Protection Dimensions				
Greater than	Less than or Equal to	Type	Thickness, feet	Width	Length (use greater of...)	Height over Crown, feet
0	5	ODOT Class 50 riprap <sup>a</sup>	1.5	Diameter + 6 feet	8 feet or 4 x diameter	1
5	10	ODOT Class 200 riprap	2.5	Diameter + 6 feet	12 feet or 4 x diameter	1
10		Engineered energy dissipater required				

a. The City may require ODOT Class 100 riprap on an as-needed basis.

## A.8 PRIVATE STORMWATER PUMPS

Private stormwater pumps will be permitted only after approval by the City Engineer. Any approved stormwater pumps must be designed according to the Oregon Plumbing Specialty Code.

## A.9 STORMWATER EASEMENTS

All public stormwater conveyance system components not located in streets or other rights-of-way shall be in an easement. Locating the public stormwater conveyance system in easements will be allowed only after all reasonable attempts to place the drains in the right-of-way have been exhausted (see procedure outlined in Section A.2.5). Provisions shall be made for vehicular access to manholes for preventive maintenance and emergency service.

Easements for the public stormwater conveyance system must meet the following criteria:

1. Minimum width of 15 feet.
2. All pipes must be located within the easement so that the outside edge of the pipe, is no closer than 5 feet from its adjacent easement boundary (roof and yard drain pipes shall be centered in the easement).
3. Open channels shall be located within the easement so that the water surface elevation at the top of freeboard is no closer than 5 feet from each easement boundary.
4. The City may require wider easements for storm mains, stormwater pipe greater than 10 feet deep, and areas with topographic constraints, such as steep slopes or sites where maintenance, repair, or replacement would require a wider easement. When wider easements are required, easement widths shall be increased in 5-foot increments.

Any private stormwater conveyance system components located offsite on adjacent private property shall also be located in easements (see procedure outlined in Section A.2.5).

Easements for private stormwater conveyance systems must meet the following criteria:

1. Minimum width of 15 feet, but private roof and yard drain systems may be located within 10-foot private storm easements.
2. All pipes must be located within the easement so that the outside edge of the pipe, or the top edge of the channel, is no closer than 5 feet from its adjacent easement boundary (roof and yard drain pipes shall be centered in the easement).
3. Open channels shall be located within the easement so that the water surface elevation at the top of freeboard is no closer than 5 feet from each easement boundary.
4. The City may require wider easements for private stormwater pipe greater than 10 feet deep and areas with topographic constraints, such as steep slopes or sites where maintenance, repair, or replacement would require a wider easement. When wider easements are required, easement widths shall be increased in 5-foot increments.

## **Appendix B: Stormwater Facility Details and Maintenance Guidelines**

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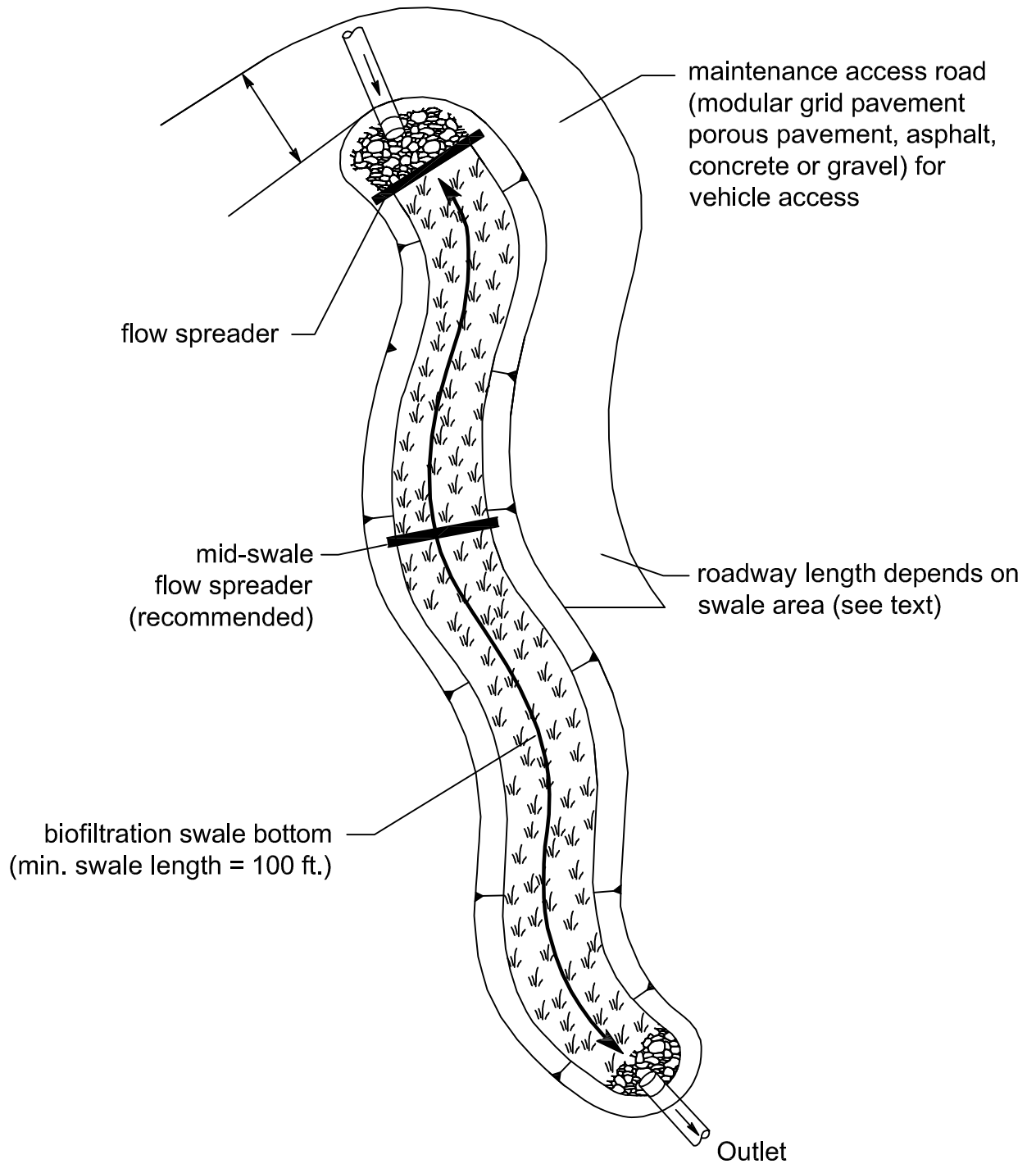
## **Water Quality Facilities**

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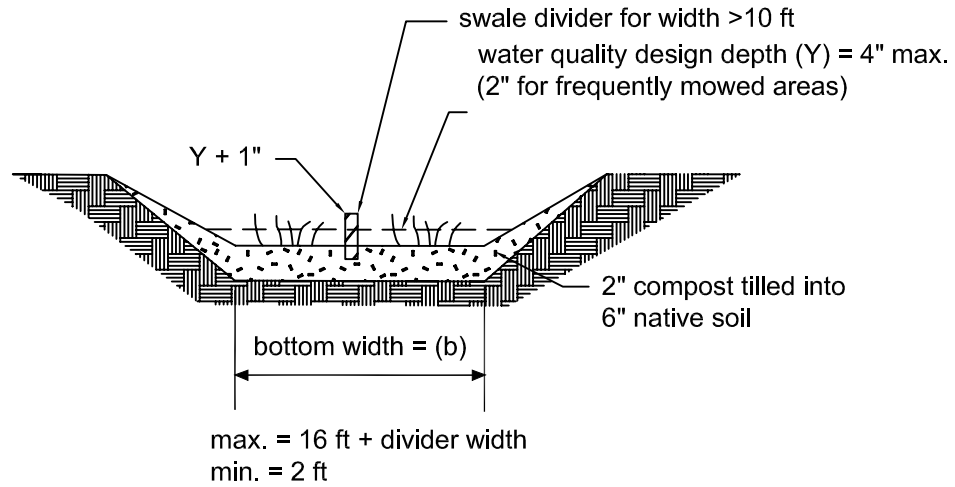
FIGURE B.1.A BIOFILTRATION SWALE SCHEMATIC



**NOTE:** Longitudinal slope 1-6%.  
Provide underdrain for slopes < 1.5%.

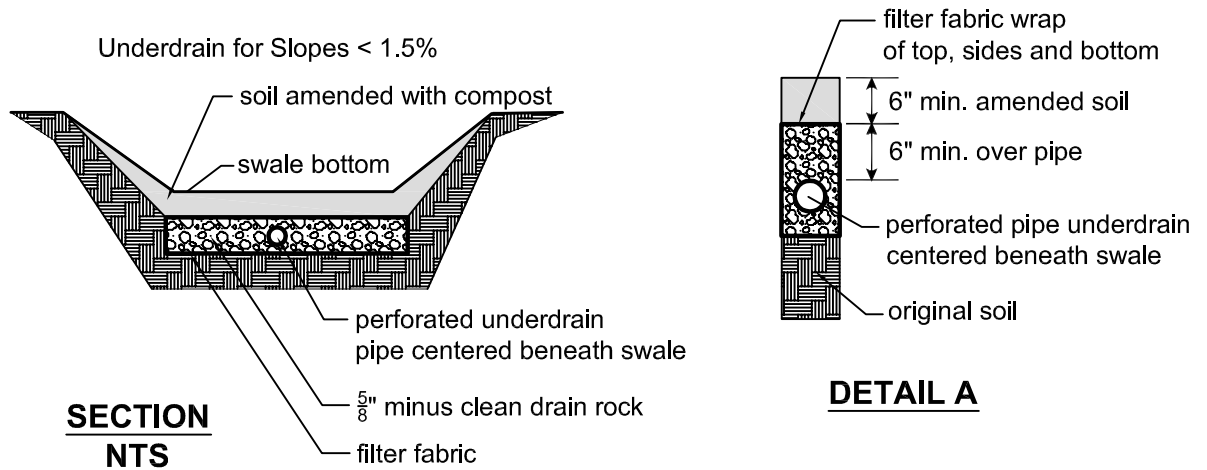
**PLAN  
NTS**

## FIGURE B.1.B BIOFILTRATION SWALE CROSS-SECTIONS



**TYPICAL SWALE SECTION**  
**NTS**

## FIGURE B.1.C BIOFILTRATION SWALE UNDERDRAIN DETAIL

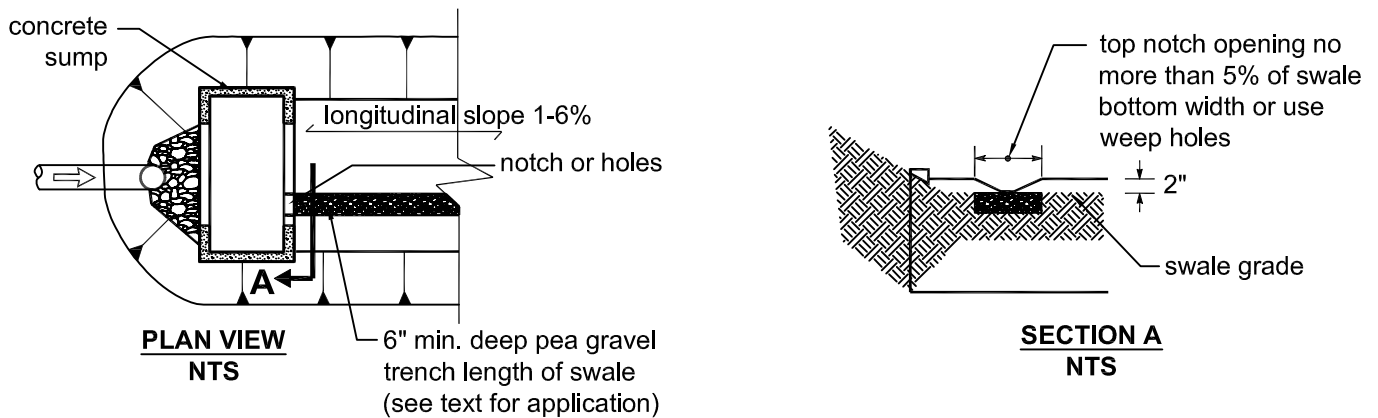


**SECTION**  
**NTS**

**DETAIL A**

**NOTE:** Underdrain must infiltrate or drain freely to an acceptable discharge point.

## FIGURE B.1.D BIOFILTRATION SWALE LOW-FLOW DRAIN



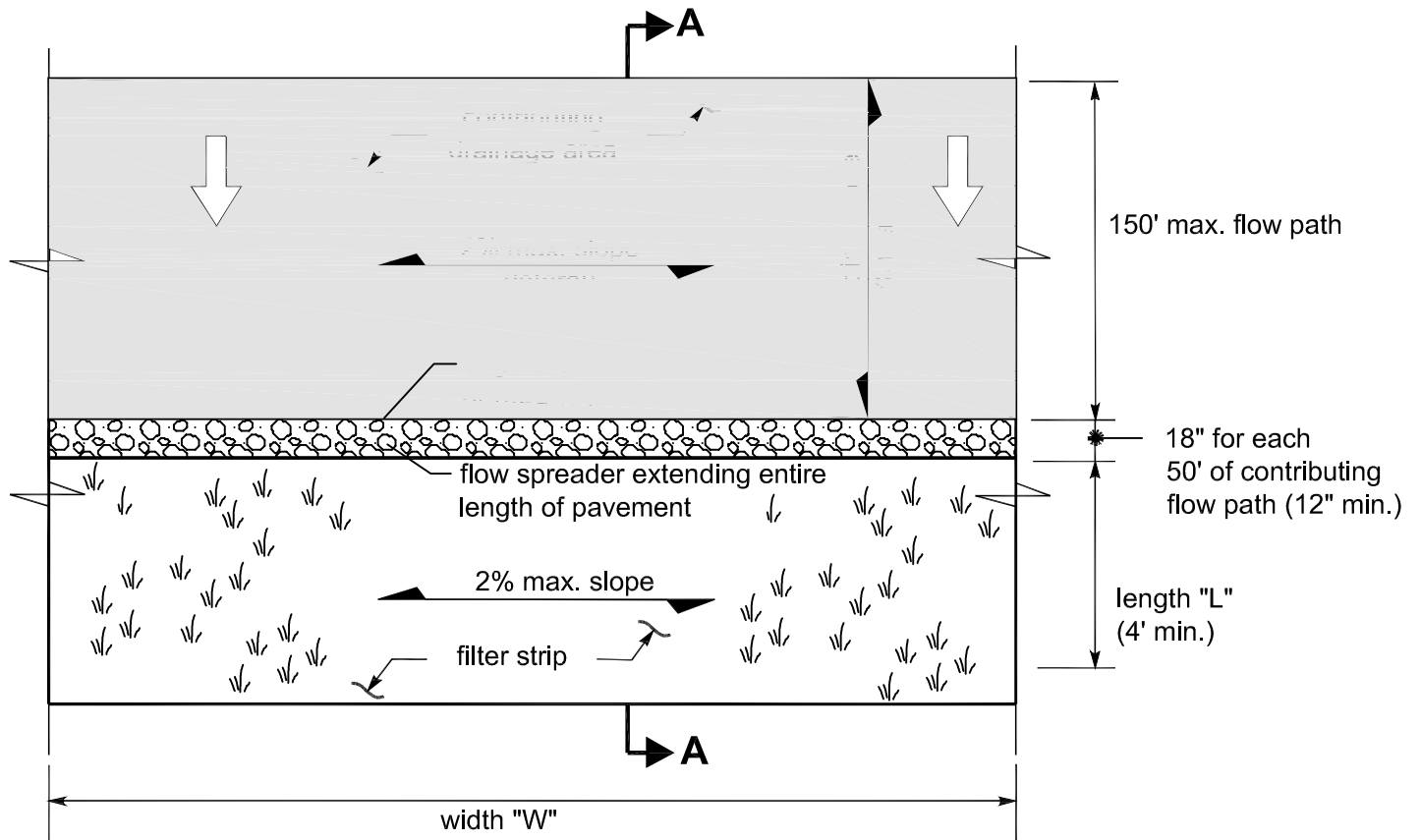
**PLAN VIEW**  
**NTS**

**SECTION A**  
**NTS**

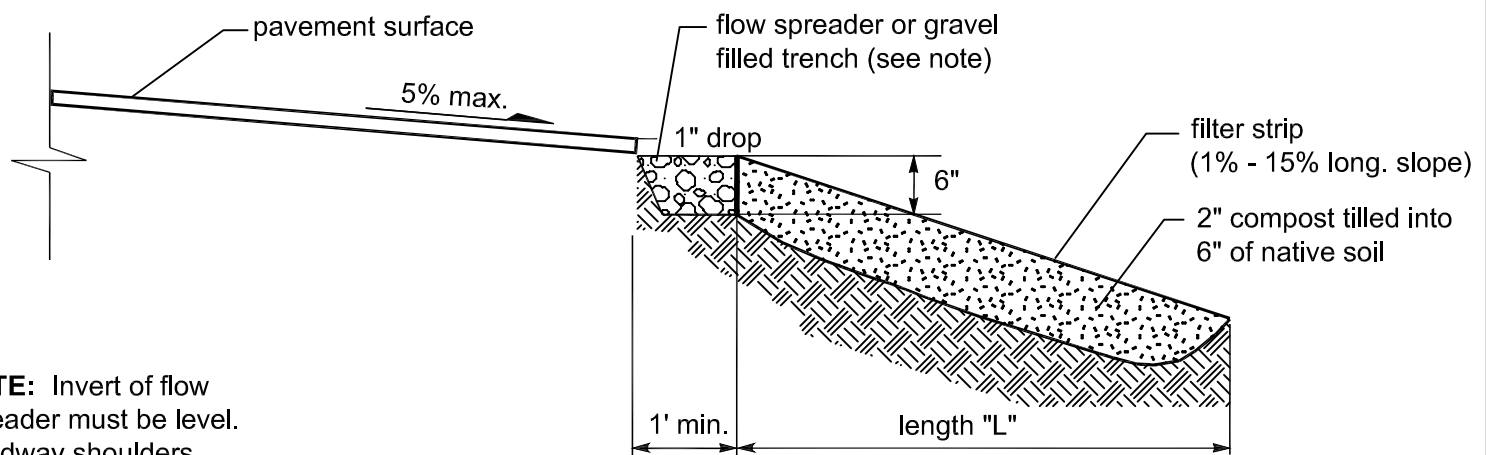
<b>BIOFILTRATION SWALE (BASIC, CONTINUOUS)</b>			
<b>Maintenance component</b>	<b>Defect or problem</b>	<b>Condition when maintenance is needed</b>	<b>Results expected when maintenance is performed</b>
Site	Trash and debris	Any trash and/or debris accumulated biofiltration swale at the site.	No trash or debris biofiltration swale at the site.
	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Bioswale section	Sediment accumulation	Sediment depth exceeds 2" in 10% of the biofiltration swale treatment area.	No sediment deposits in grass treatment area of the biofiltration swale.
		Sediment inhibits grass growth over 10% of the biofiltration swale length.	Grass growth not inhibited by sediment.
		Sediment inhibits even spreading of flow.	Flow spreads evenly through the biofiltration swale.
	Erosion/scouring	Eroded or scoured biofiltration swale bottom due to channelization or high flows.	No eroded or scoured areas in biofiltration swale. Cause of erosion or scour addressed.
	Poor vegetation coverage	Grass is sparse or bare or eroded patches occur in more than 10% of the biofiltration swale bottom.	Bioswale has no bare spots and grass is thick and healthy.
	Grass too tall	Grass is excessively tall (> 10"), grass is thin, or nuisance weeds and other vegetation have taken over.	Grass is between 3" and 4" tall, thick, and healthy. No clippings left in swale. No nuisance vegetation present.
	Excessive shade	Grass growth is poor because sunlight does not reach biofiltration swale.	Health grass growth or swale has converted to a wet biofiltration swale.
	Constant base flow	Continuous flow through the swale, even when it has been dry for weeks or an eroded, muddy channel has formed in the swale bottom.	Baseflow removed from swale by a low-flow pea-gravel drain or bypassed around the biofiltration swale.
	Standing water	Water pools in the biofiltration swale between storms or does not drain freely.	Biofiltration swale freely drains and there is no standing water in swale between storms.
	Channelization	Flow concentrates and erodes channel through biofiltration swale.	No flow channels in biofiltration swale.
Flow spreader	Concentrated flow	Flow from spreader not uniformly distributed across entire biofiltration swale width.	Flows are spread evenly over entire biofiltration swale width.
Inlet/outlet pipe	Sediment accumulation	Sediment filling 20% or more of the pipe.	Inlet/outlet pipes clear of sediment
	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	Damaged	Cracks wider than 1/2" at the joint of the inlet/outlet pipes or any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than 1/4" wide at the joint of the inlet/outlet pipe.

<b>BIOFILTRATION SWALE(WET)</b>			
<b>Maintenance component</b>	<b>Defect or problem</b>	<b>Condition when maintenance is needed</b>	<b>Results expected when maintenance is performed</b>
Site	Trash and debris	Any trash and/or debris accumulated at the site.	No trash or debris at the site.
	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Biofiltration swale section	Sediment accumulation	Sediment depth exceeds 2" in 10% of the biofiltration swale treatment area.	No sediment deposits in the treatment area of the biofiltration swale.
	Erosion/scouring	Eroded or scoured biofiltration swale bottom due to channelization or high flows.	No eroded or scoured areas in biofiltration swale. Cause of erosion or scour addressed.
	Water depth	Water not retained to a depth of about 4" during the wet season.	Water depth of 4" throughout biofiltration swale for most of the wet season.
	Vegetation ineffective	Vegetation sparse and does not provide adequate filtration or crowded out by very dense clumps of cattail or nuisance vegetation.	Wetland vegetation fully covers bottom of biofiltration swale and no cattails or nuisance vegetation present.
	Insufficient water	Wetland vegetation dies due to lack of water.	Wetland vegetation remains healthy (may require converting to grass lined biofiltration swale).
Flow spreader	Concentrated flow	Flow from spreader not uniformly distributed across entire swale width.	Flows are spread evenly over entire swale width.
Inlet/outlet pipe	Sediment accumulation	Sediment filling 20% or more of the pipe.	Inlet/outlet pipes clear of sediment
	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	Damaged	Cracks wider than 1/2" at the joint of the inlet/outlet pipes or any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than 1/4" wide at the joint of the inlet/outlet pipe.

FIGURE B.2 TYPICAL FILTER STRIP DETAILS



**PLAN VIEW**  
**NTS**

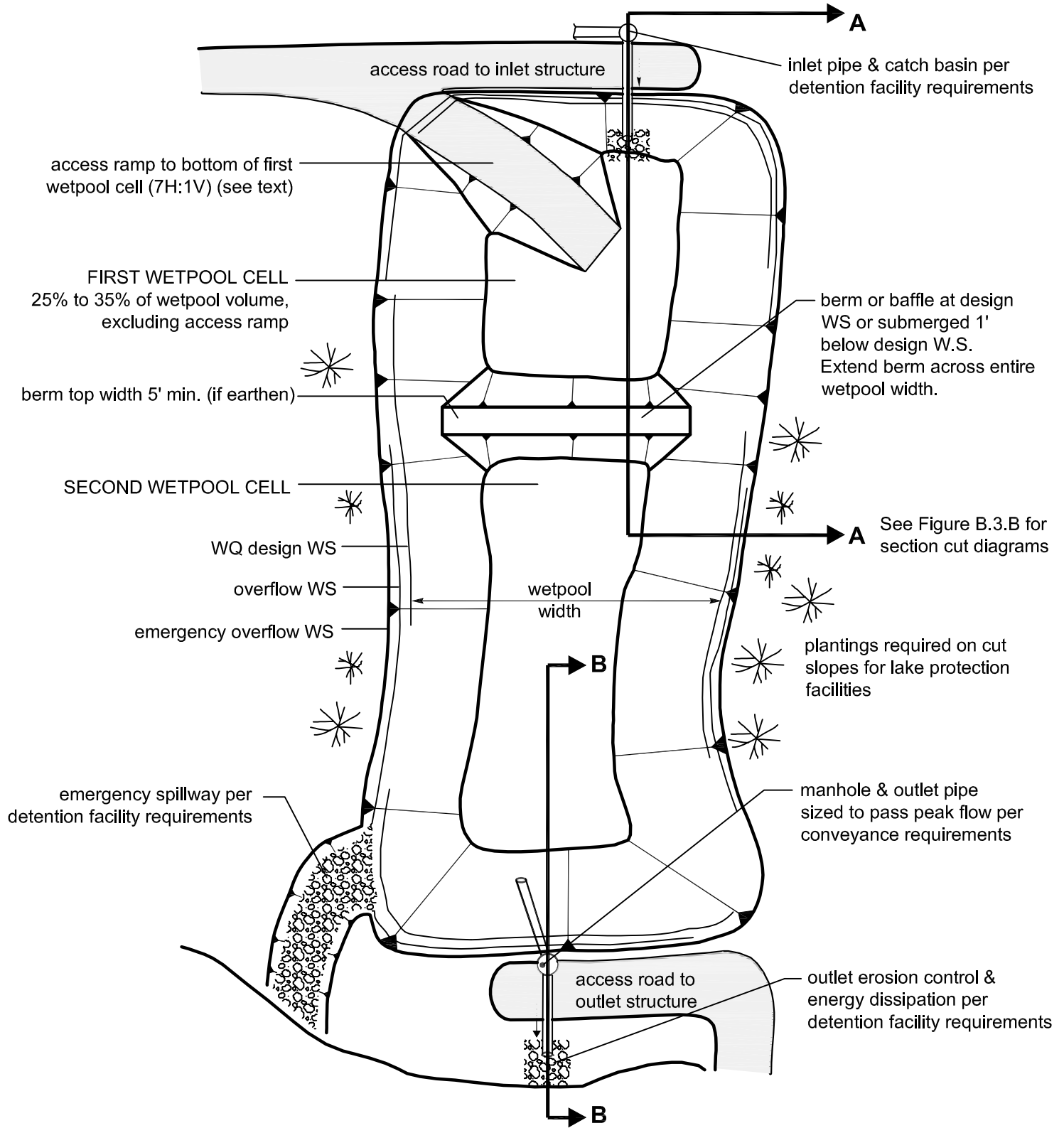


**NOTE:** Invert of flow spreader must be level. Roadway shoulders must use shoulder ballast.

**SECTION A-A**

<b>FILTER STRIP</b>			
<b>Maintenance component</b>	<b>Defect or problem</b>	<b>Condition when maintenance is needed</b>	<b>Results expected when maintenance is performed</b>
Site	Trash and debris	Any trash and debris accumulated on the filter strip site.	Filter strip site free of any trash or debris.
	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Grass strip	Sediment accumulation	Sediment accumulation on grass exceeds 2" depth.	No sediment deposits in treatment area.
	Erosion/scouring	Eroded or scoured filter strip bottom due to channelization or high flows.	No eroded or scoured areas in filter strip. Cause of erosion or scour addressed.
	Grass too tall	Grass excessively tall (>10"), grass is thin or nuisance weeds and other vegetation has taken over.	Grass is between 3" and 4" tall, thick, and healthy. No clippings left in filter strip. No nuisance vegetation present.
	Vegetation ineffective	Grass has died out, become excessively tall (>10") or nuisance vegetation is taking over.	Grass is healthy, <9" high and no nuisance vegetation present.
Flow spreader	Concentrated flow	Flow from spreader not uniformly distributed across entire filter strip width.	Flows are spread evenly over entire filter strip width.
Inlet/outlet pipe	Sediment accumulation	Sediment filling 20% or more of the pipe.	Inlet/outlet pipes clear of sediment.
	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	Damaged	Cracks wider than 1/2" at the joint of the inlet/outlet pipes or any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than 1/4" wide at the joint of the inlet/outlet pipe.

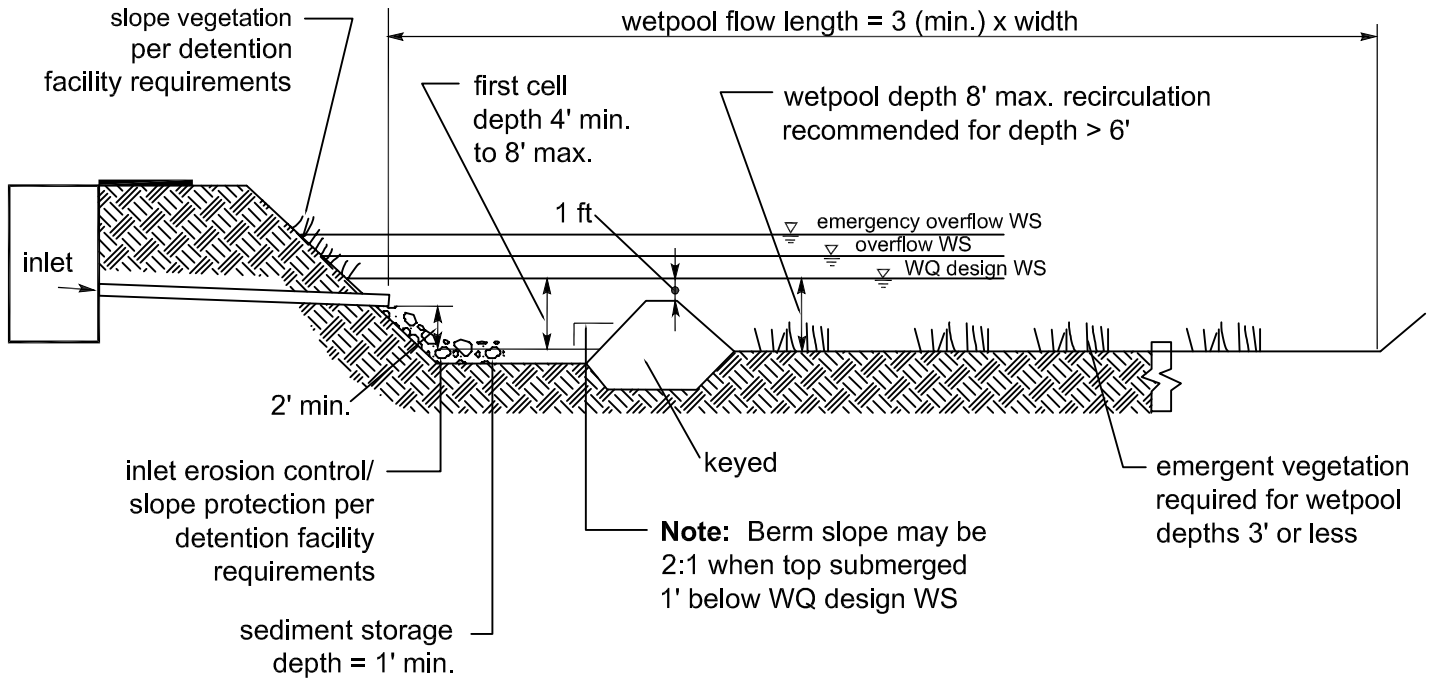
FIGURE B.3.A WETPOND



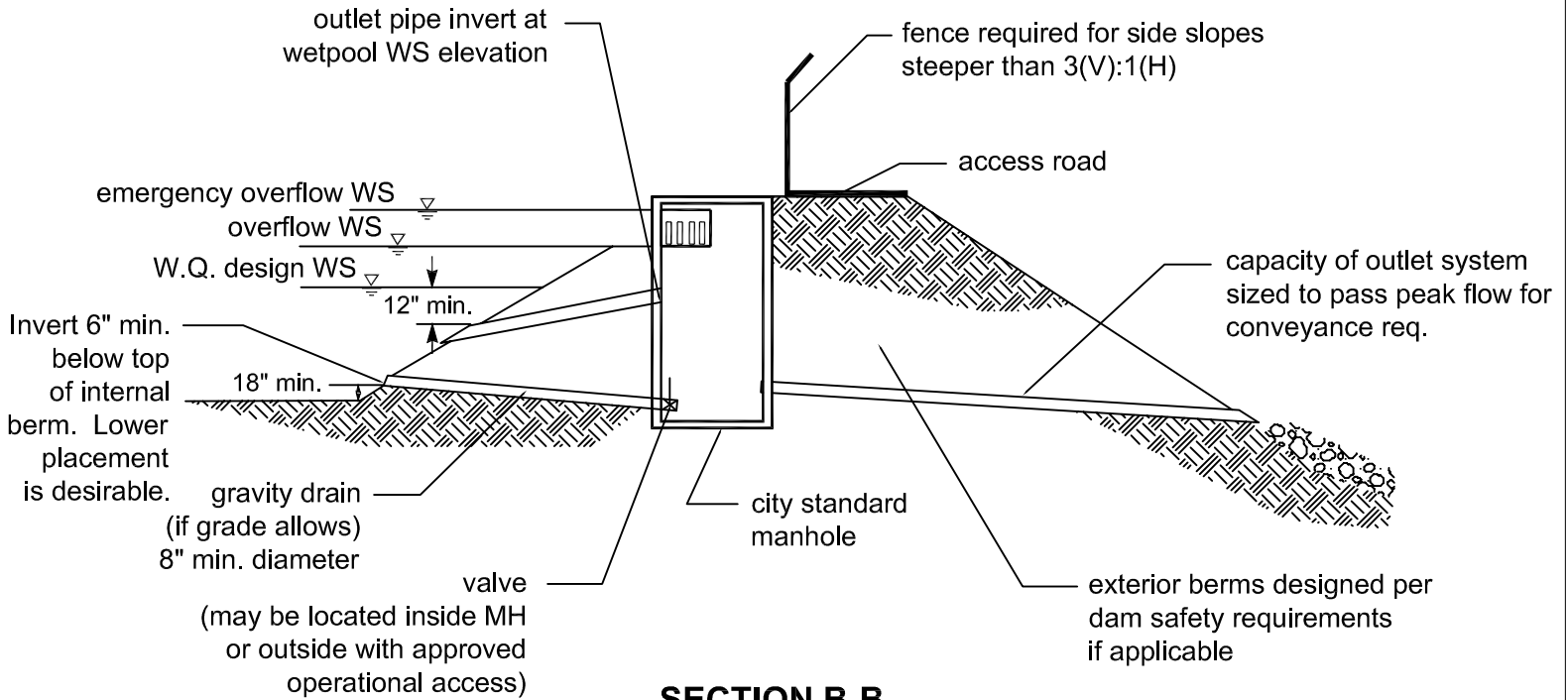
**NOTE:** Berm not required for ponds with length to width ratio 4:1 or if volume less than 4000 c.f.

**PLAN VIEW**  
**NTS**

FIGURE B.3.B WETPOND SECTIONS



SECTION A-A  
NTS



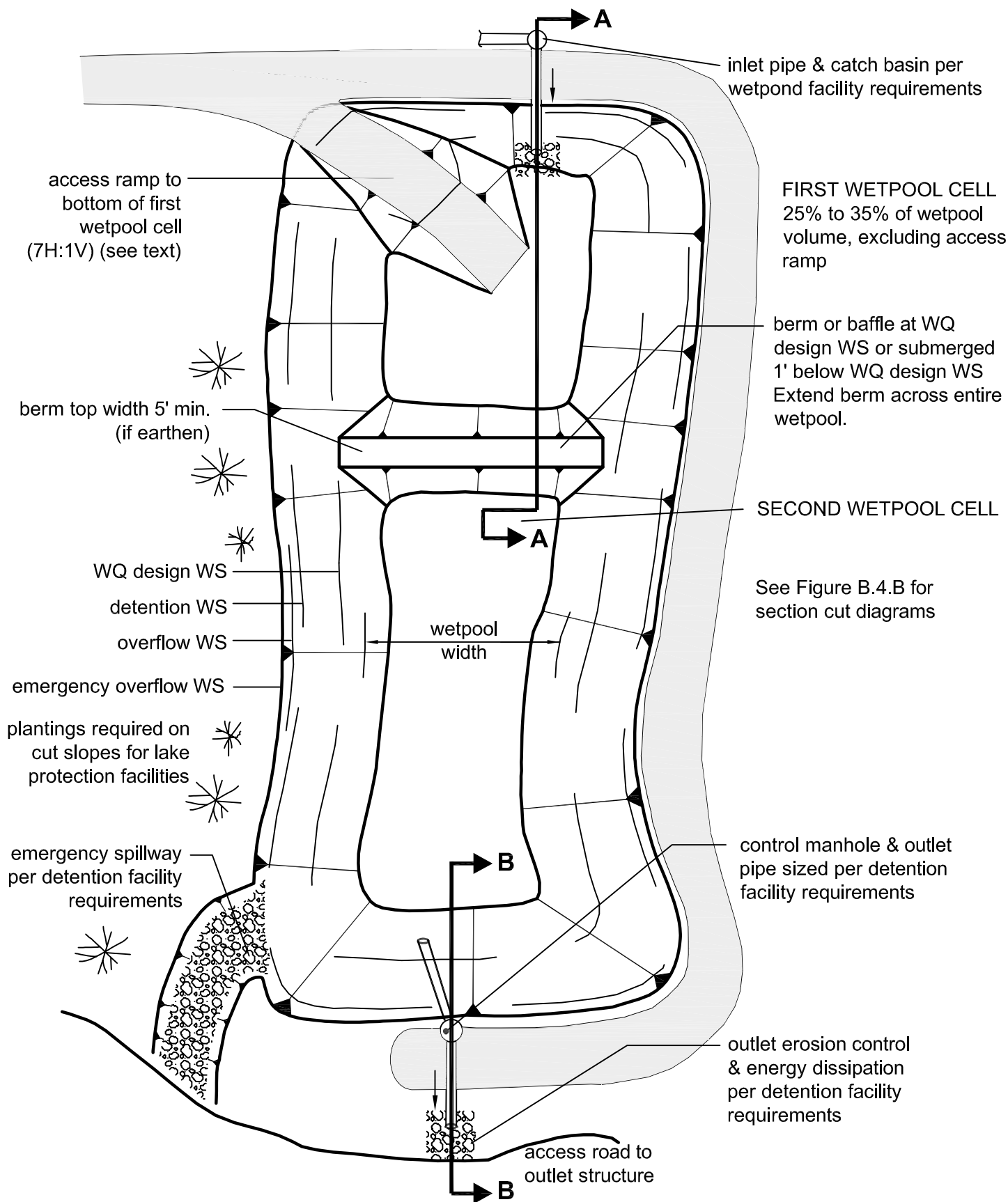
SECTION B-B  
NTS



<b>WETPOND</b>			
<b>Maintenance component</b>	<b>Defect or problem</b>	<b>Condition when maintenance is needed</b>	<b>Results expected when maintenance is performed</b>
Site	Trash and debris	Any trash and debris accumulated on the wetpond site.	Wetpond site free of any trash or debris.
	Noxious weeds	Any noxious or nuisance vegetation which may constitute a hazard to City personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where City personnel or the public might be.
	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	Grass/groundcover	Grass or groundcover exceeds 18" in height.	Grass or groundcover mowed to a height no greater than 6".
Side slopes of dam, berm, internal berm, or embankment	Rodent holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents removed or destroyed and dam or berm repaired.
	Tree growth	Tree growth threatens integrity of dams, berms, or slopes, does not allow maintenance access, or interferes with maintenance activity. If trees are not a threat to dam, berm, or embankment integrity, are not interfering with access or maintenance, or leaves do not cause a plugging problem, they do not need to be removed.	Trees do not hinder facility performance or maintenance activities
	Erosion	Eroded damage over 2" deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on compacted slope.	Slopes stabilized using appropriate erosion control measures. If erosion is occurring on compacted slope, a licensed civil engineer should be consulted to resolve source of erosion.
Top or side slopes of dam, berm, internal berm or embankment	Settlement	Any pan of a dam, berm, or embankment that has settled 4" lower than the design elevation.	Top or side slope restored to design dimensions. If settlement is significant, a licensed civil engineer should be consulted to determine the cause of the settlement.
	Irregular surface on internal berm	Top of berm not uniform and level.	Top of berm graded to design elevation.
Pond areas	Sediment accumulation (except first wetpool cell)	Accumulated sediment that exceeds 10% of the designed pond depth.	Sediment cleaned out to designed pond shape and depth.
	Sediment accumulation (first wetpool cell)	Sediment accumulations in pond bottom that exceeds the depth of sediment storage (1'+6").	Sediment storage contains no sediment.
	Liner damaged (if applicable)	Liner is visible or pond does not hold water as designed.	Liner repaired or replaced.
	Water level (first wet pool cell)	First cell empty and doesn't hold water.	Water retained in first cell for most of the year.
	Algae mats (first wetpool cell)	Algae mats developed over more than 10% of the water surface should be removed.	Algae mats removed (usually in the late summer before fall rains.)
Gravity drain	Inoperable valve	Valve will not open and close.	Valve opens and closes normally.
	Valve won't seal	Valve does not seal completely.	Valve completely seals closed.
Emergency overflow spillway	Tree growth	Tree growth impedes flow or threatens stability of spillway.	Trees removed.
	Rock missing	Only one layer of rock exists above native soil in area 5 square feet (ft <sup>2</sup> ) or larger, or any exposure of native soil at the top of the outflow path of spillway. Rip-rap on inside slopes need not be replaced.	Spillway restored to design standards.
Inlet/outlet pipe	Sediment accumulation	Sediment filling 20% or more of the pipe.	Inlet/outlet pipes clear of sediment.
	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	Damaged	Cracks wider than 1/2" at the joint of the inlet/outlet pipes or any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than 1/4" wide at the joint of the inlet/outlet pipe.



FIGURE B.4.A COMBINED DETENTION AND WETPOND



FIRST WETPOOL CELL  
25% to 35% of wetpool  
volume, excluding access  
ramp

berm or baffle at WQ  
design WS or submerged  
1' below WQ design WS  
Extend berm across entire  
wetpool.

SECOND WETPOOL CELL

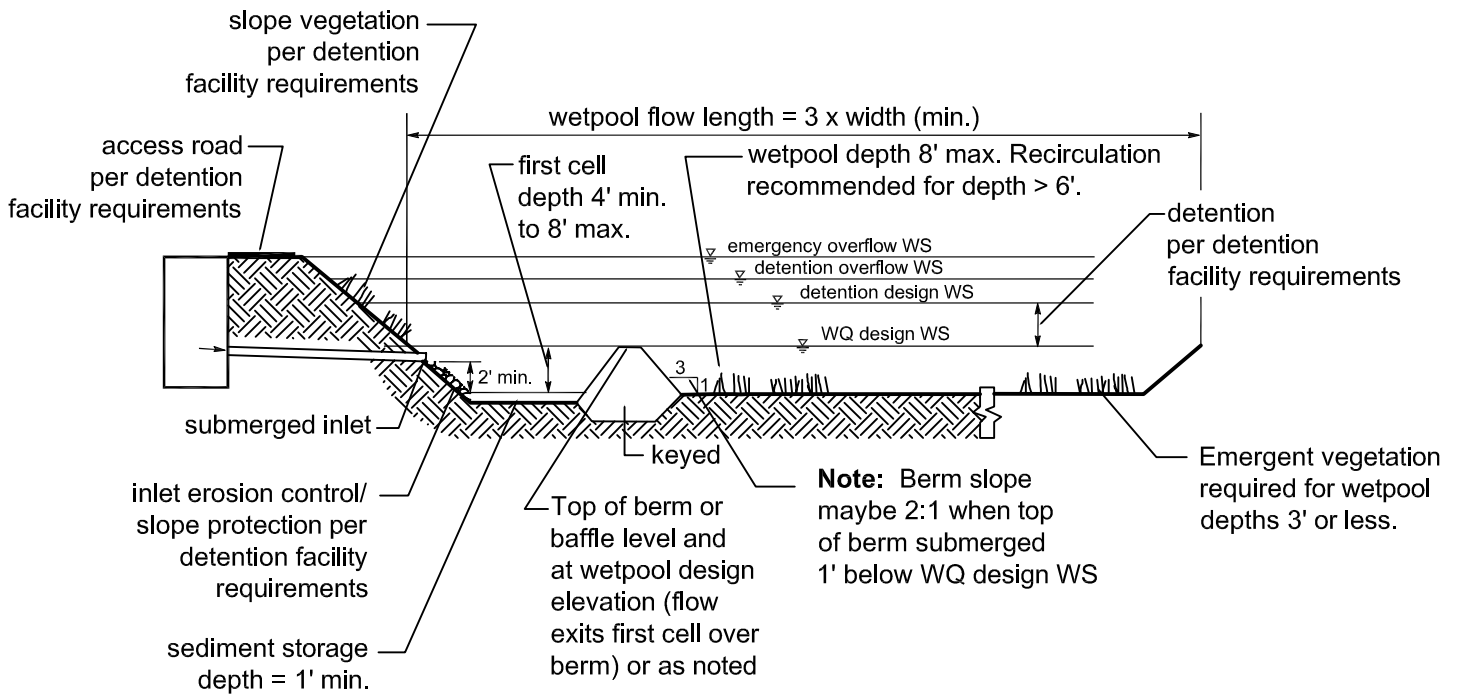
See Figure B.4.B for  
section cut diagrams

control manhole & outlet  
pipe sized per detention  
facility requirements

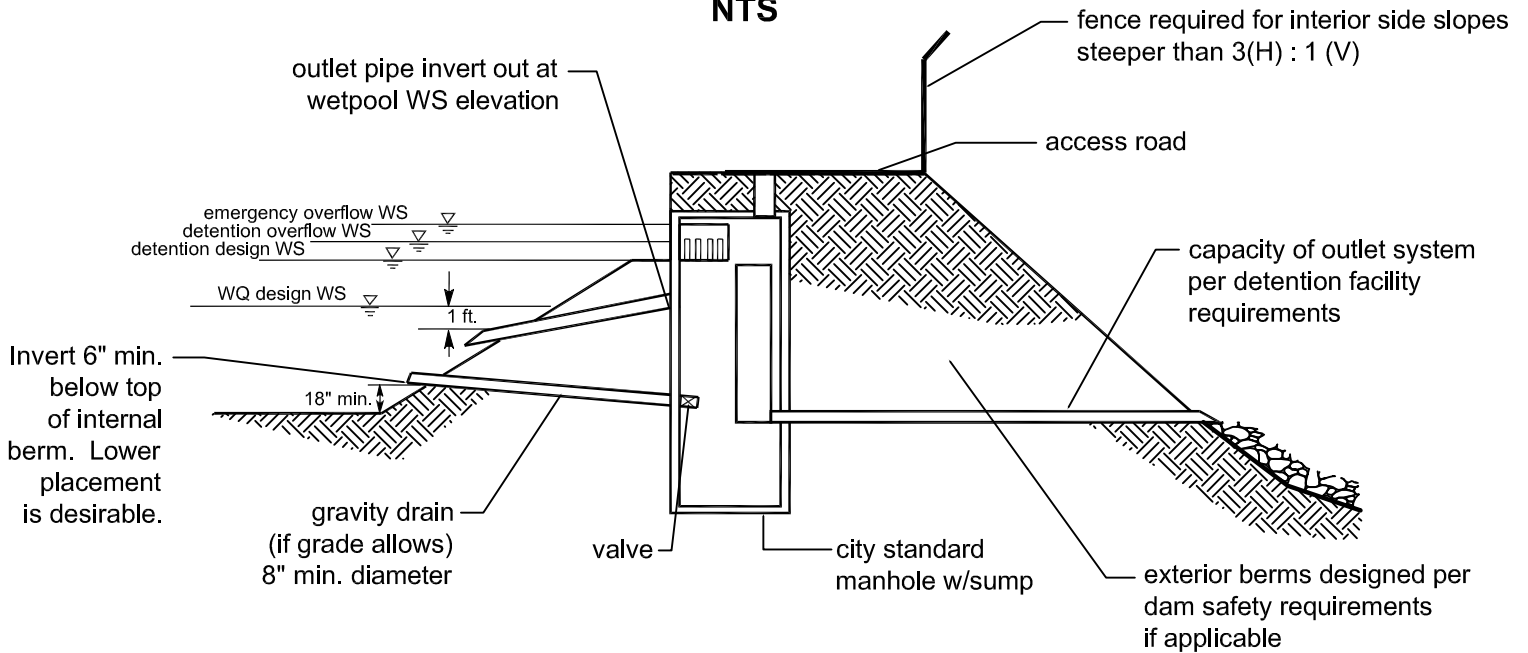
outlet erosion control  
& energy dissipation  
per detention facility  
requirements

**PLAN VIEW**  
**NTS**

FIGURE B.4.B COMBINED DETENTION AND WETPOND SECTIONS



**SECTION A-A**  
NTS



**SECTION B-B**  
NTS

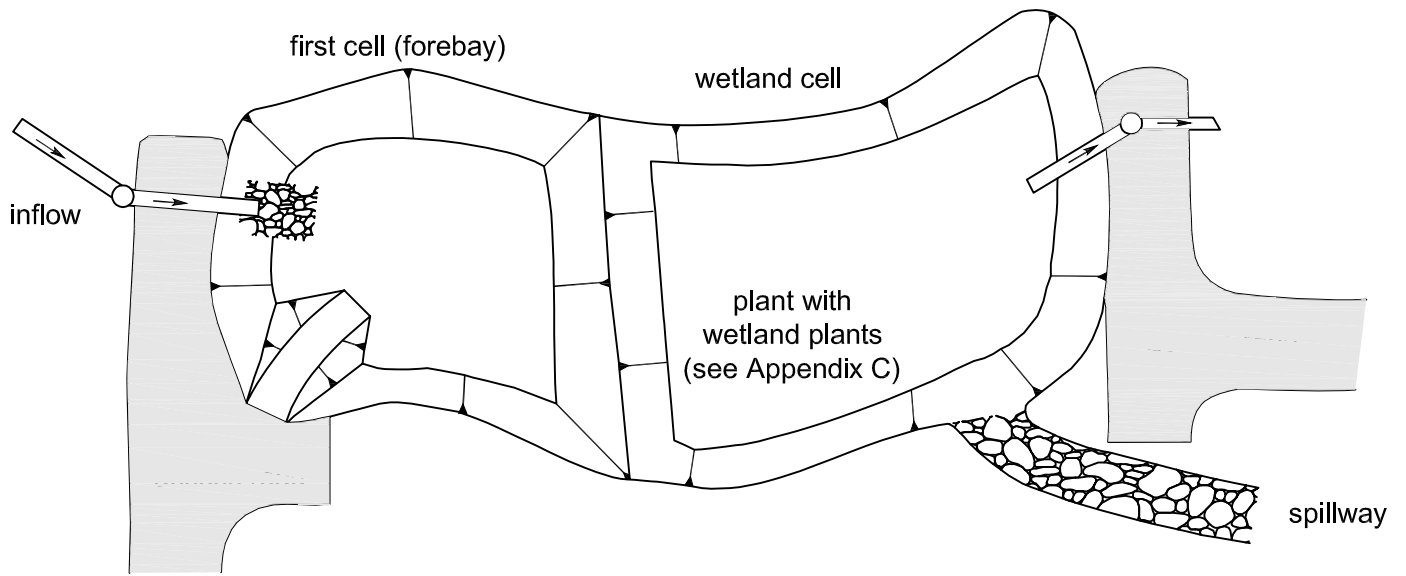
**COMBINED DETENTION AND WETPOND**

Maintenance requirements for a combined detention and wetpond should follow applicable maintenance guidelines for a detention pond and a wetpond. Refer to the detention pond and wetpond guidelines in this Appendix.

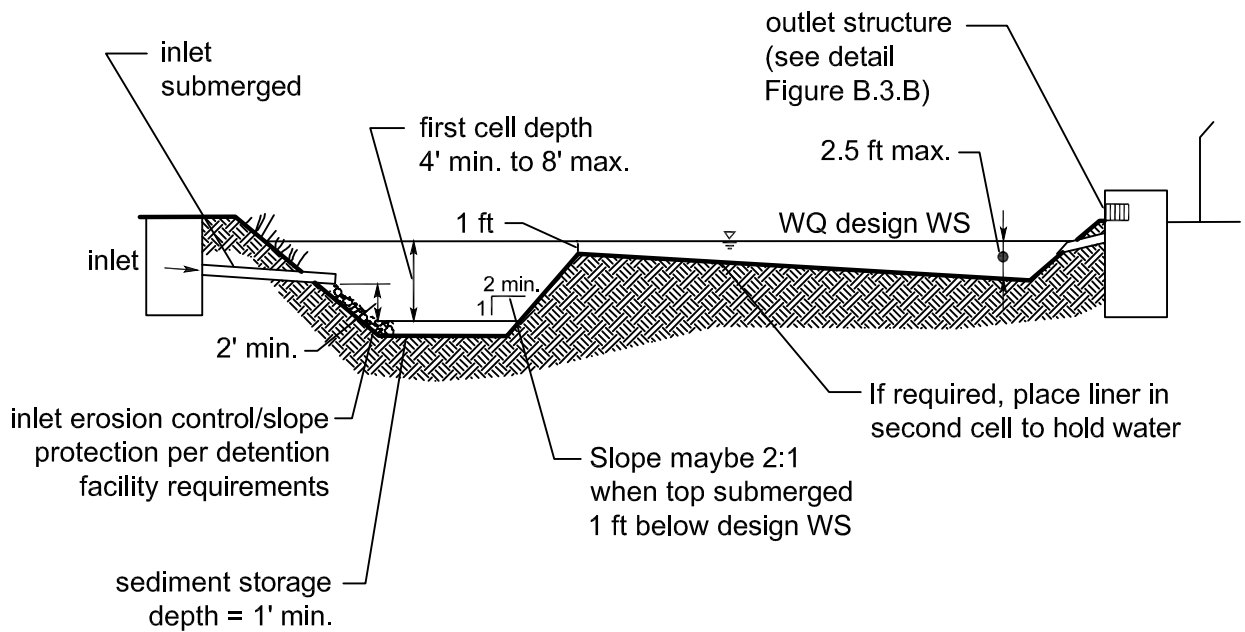
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FIGURE B.5.A STORMWATER WETLAND - OPTION A



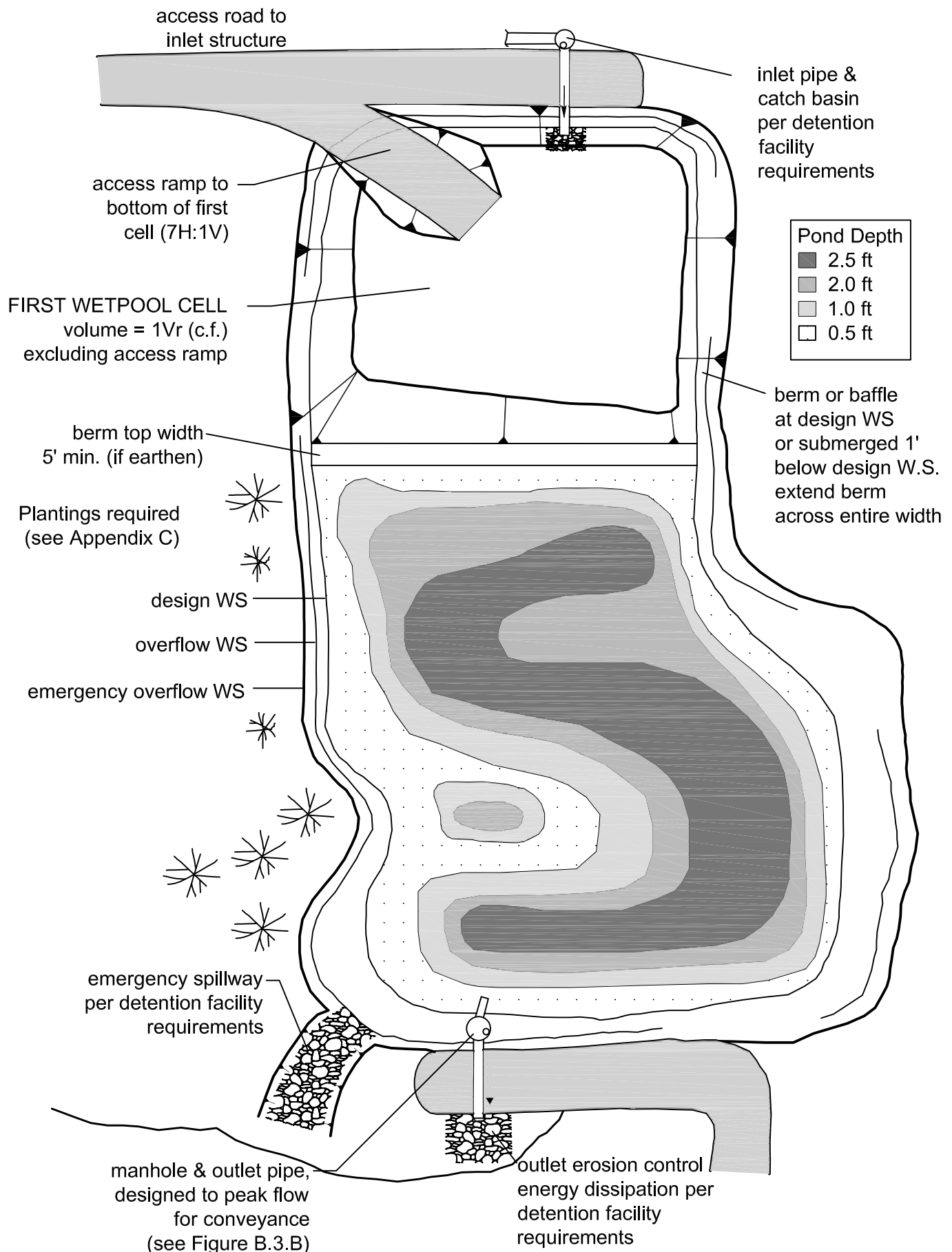
**PLAN VIEW Option A**  
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**SECTION VIEW Option A**  
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**Note:** See detention facility requirements for location and setback requirements.

**FIGURE B.5.B STORMWATER WETLAND - OPTION B**



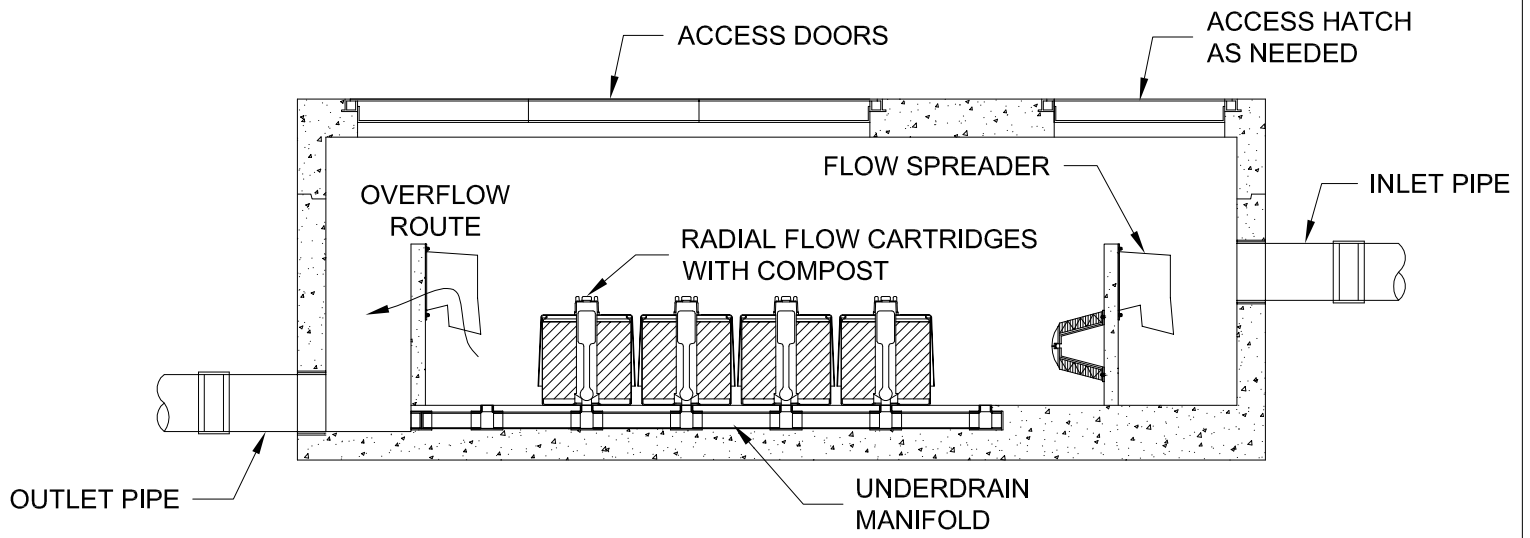
**PLAN VIEW Option B**  
**NTS**



<b>STORMWATER WETLAND</b>			
<b>Maintenance component</b>	<b>Defect or problem</b>	<b>Condition when maintenance is needed</b>	<b>Results expected when maintenance is performed</b>
Site	Trash and debris	Trash and debris accumulated on facility site.	Trash and debris removed from facility site.
	Noxious weeds	Any noxious or nuisance vegetation which may constitute a hazard to City personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where City personnel or the public might be.
	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	Grass/groundcover	Grass or groundcover exceeds 18" in height.	Grass or groundcover mowed to a height no greater than 6".
Side slopes of dam, berm, internal berm, or embankment	Rodent holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents removed or destroyed and dam or berm repaired.
	Tree growth	Tree growth threatens integrity of dams, berms, or slopes, does not allow maintenance access, or interferes with maintenance activity. If trees are not a threat to dam, berm, or embankment integrity or not interfering with access or maintenance, they do not need to be removed.	Trees do not hinder facility performance or maintenance activities.
	Erosion	Eroded damage over 2" deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted slope.	Slopes stabilized using appropriate erosion control measures. If erosion is occurring on compacted slope, a licensed civil engineer should be consulted to resolve source of erosion.
Top or side slopes of dam, berm, internal berm or embankment	Settlement	Any part of a dam, berm, or embankment that has settled 4" lower than the design elevation.	Top or slope restored to design dimensions. If settlement is significant, a licensed civil engineer should be consulted to determine the cause of the settlement.
	Irregular surface on internal berm	Top of berm not uniform	Top of berm graded to flat design elevation
Pond areas	Sediment accumulation (first cell/forebay)	Sedimentation accumulations in the first cell bottom that exceeds the depth of sediment storage (1 foot) plus 6".	Sediment storage contains no sediment.
	Sediment accumulation (wetland cell)	Accumulated sediment that exceeds 10% of the designed wetland cell depth.	Sediment cleaned out to designed shape and depth.
	Liner damaged (if applicable)	Liner is visible or does not hold water as designed.	Liner repaired or replaced.
	Water level(first cell/forebay)	Cell does not hold 3' of water year round.	3' of water retained year round.
	Water level (wetland cell)	Cell does not retain water for at least 10 months of the year or wetland plants are not surviving.	Water retained at least 10 months of the year or wetland plants are surviving.
	Algae mats (first cell/forebay)	Algae mats developed over more than 10% of the water surface should be removed.	Algae mats removed (usually in the late summer before fall rains.)
	Vegetation	Vegetation dead, dying, or overgrown (cattails) or not meeting original planting specifications.	Plants in wetland cell surviving and not interfering with wetland function.

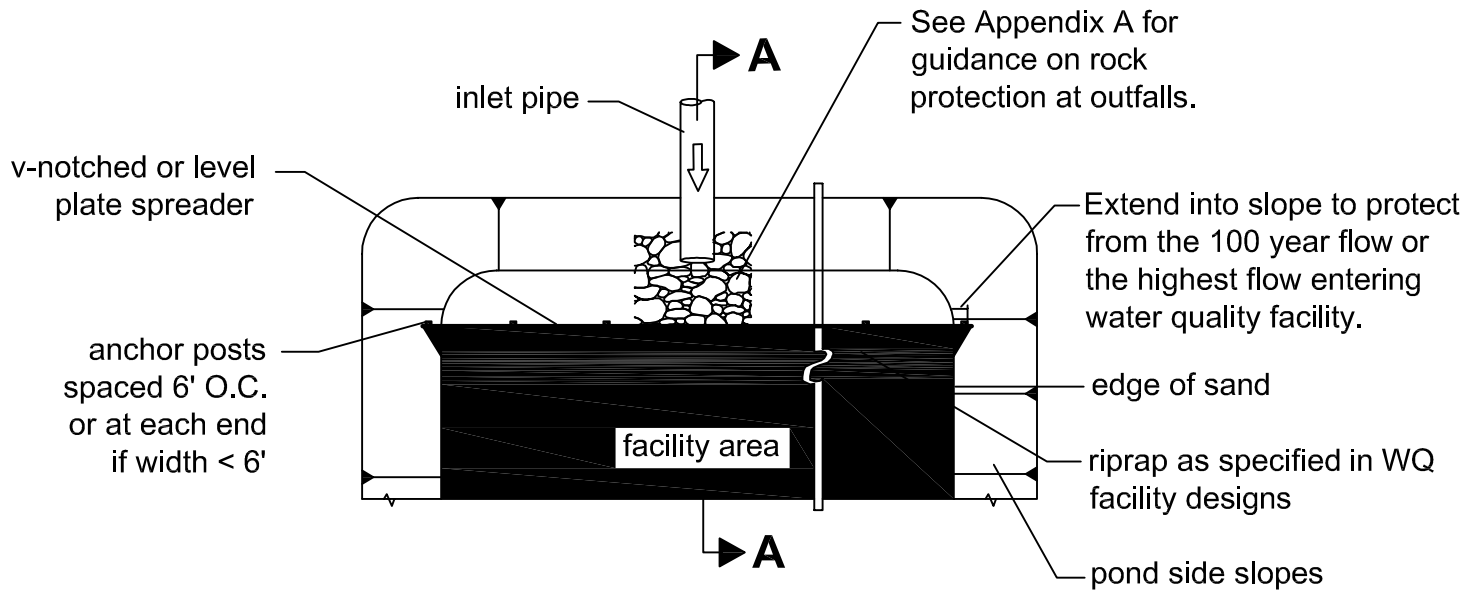
<b>STORMWATER WETLAND</b>			
<b>Maintenance component</b>	<b>Defect or problem</b>	<b>Condition when maintenance is needed</b>	<b>Results expected when maintenance is performed</b>
Gravity drain	Inoperable valve	Valve will not open and close	Valve opens and closes normally.
	Valve won't seal	Valve does not seal completely.	Valve completely seals closed.
Emergency overflow spillway	Tree growth	Tree growth impedes flow or threatens stability of spillway.	Trees removed.
	Rock missing	Only one layer of rock exists above native soil in area 5 ft <sup>2</sup> or larger, or any exposure of native soil at the top of out flow path of spillway. Rip-rap on inside slopes need not be replaced.	Spillway restored to design standards.
Inlet/outlet pipe	Sediment accumulation	Sediment filling 20% or more of the pipe.	Inlet/outlet pipes clear of sediment.
	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	Damaged	Cracks wider than ½" at the joint of the inlet/outlet pipes or any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼" wide at the joint of the inlet/outlet pipe.

FIGURE B.6 STORMFILTER SCHEMATIC

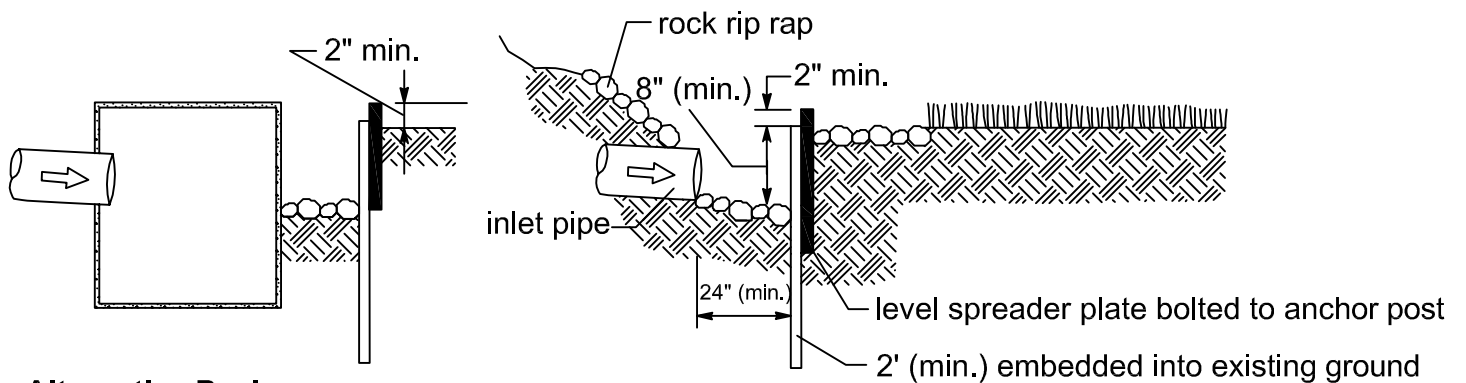


<b>STORMFILTER (CARTRIDGE TYPE)</b>			
Maintenance component	Defect or problem	Condition When Maintenance is Needed	Results expected when maintenance is performed
Site	Trash and debris	Any trash or debris which impairs the function of the facility.	Trash and debris removed from facility.
	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	Life cycle	System has not been inspected for 3 years.	Facility is re-inspected and any needed maintenance performed.
Vault treatment area	Sediment on vault floor	Greater than 4" of sediment.	Vault is free of sediment.
	Sediment on top of cartridges	Greater than ¼" of sediment.	Vault is free of sediment.
	Multiple scum lines above top of cartridges	Thick or multiple scum lines above top of cartridges. Probably due to plugged canisters or underdrain manifold.	Cause of plugging corrected, canisters replaced if necessary.
Vault structure	Damage to wall, frame, bottom, and/or top slab	Cracks wider than ½" and any evidence of soil particles entering through the cracks, or qualified inspection personnel determines the vault is not structurally sound.	Vault replaced or repaired to design specifications.
	Baffles damaged	Baffles corroding, cracking, warping, and/or showing signs of failure as determined by maintenance/inspection person.	Repair or replace baffles to specification.
Filter media	Standing water in vault	4" or greater of static water in the vault for more than 24 hours following a rain event and/or overflow occurs frequently. Probably due to plugged filter media, underdrain, or outlet pipe.	No standing water in vault 24 hours after a rain event.
	Short circuiting	Flows do not properly enter filter cartridges.	Flows go through filter media.
Underdrains and clean-outs	Sediment/debris	Underdrains or clean-outs partially plugged or filled with sediment and/or debris.	Underdrains and clean-outs free of sediment and debris.
Inlet/outlet pipe	Sediment accumulation	Sediment filling 20% or more of the pipe.	Inlet/outlet pipes clear of sediment.
	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non floatables).	No trash or debris in pipes.
	Damaged	Cracks wider than ½" at the joint of the inlet/outlet pipes or any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼" wide at the joint of the inlet/outlet pipe.
Access manhole	Cover/lid not in place	Cover/lid is missing or only partially in place. <b>Any open manhole requires immediate maintenance.</b>	Manhole access covered.
	Locking mechanism not working	Mechanism cannot be opened by one maintenance person proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.
	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs. of lift.	Cover/lid can be removed and reinstalled by one maintenance person.
	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.
Large access doors/plate	Damaged or difficult to open	Large access doors or plates cannot be opened/removed using normal equipment.	Replace or repair access door so it can be opened as designed.
	Gaps, doesn't cover completely	Large access doors not flat and/or access opening not completely covered.	Doors close flat and cover access opening completely.
	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate.	Lifting rings sufficient to lift or remove door or plate.

FIGURE B.7.A FLOW SPREADER OPTION A: ANCHORED PLATE



**PLAN VIEW**  
NTS

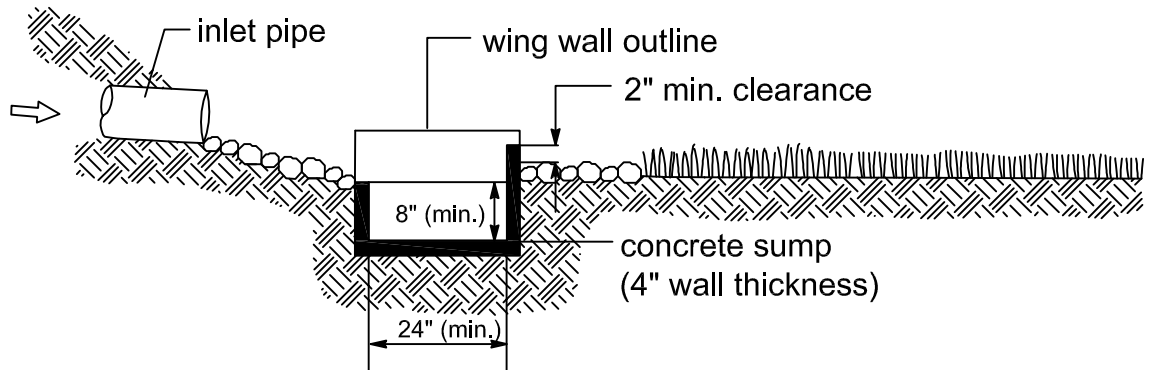
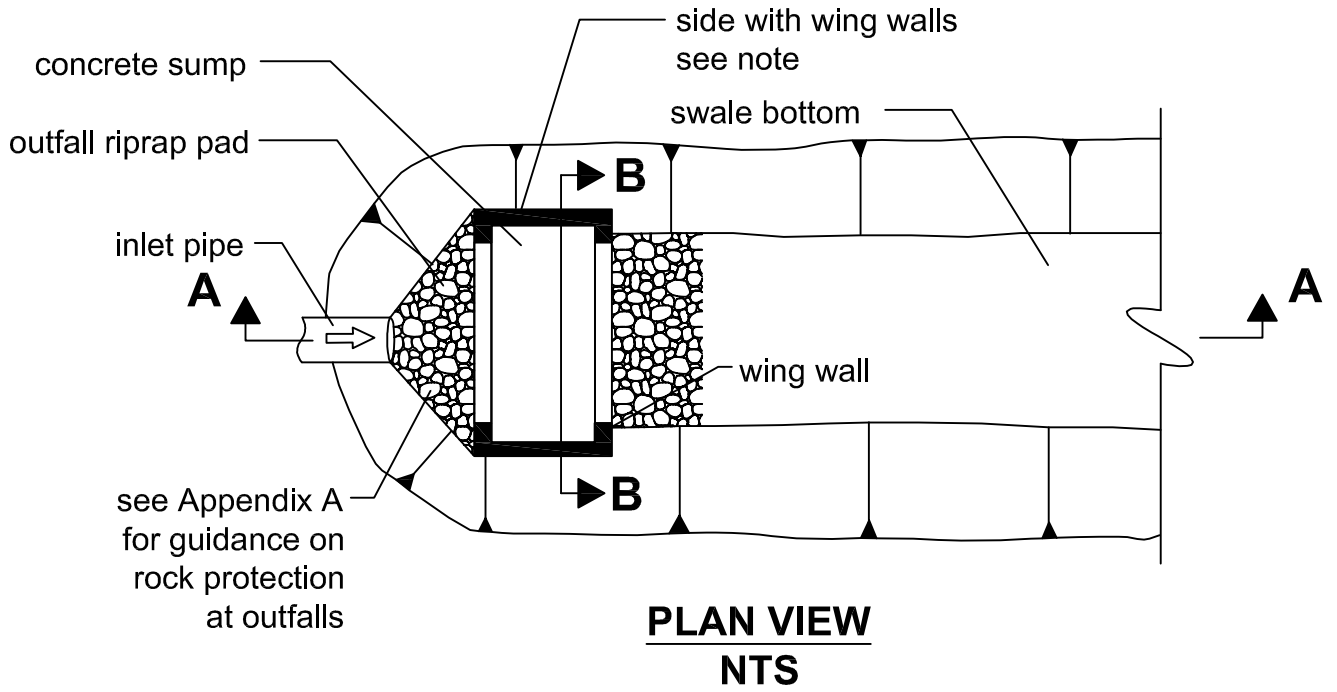


**SECTION A-A**  
NTS

**Alternative Design**

Catch basin recommended for higher flow situations (generally for inflow velocities of 5 fps or greater for 100 year storm).

FIGURE B.7.B FLOW SPREADER OPTION B: CONCRETE SUMP BOX



**Note:** Extend sides into slope. Height of side wall and wing walls must be sufficient to handle the 100-year flow or the highest flow entering the facility.

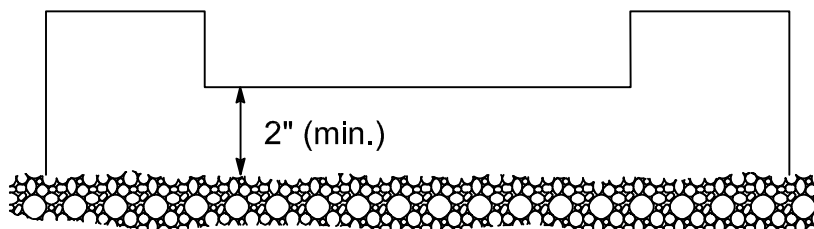
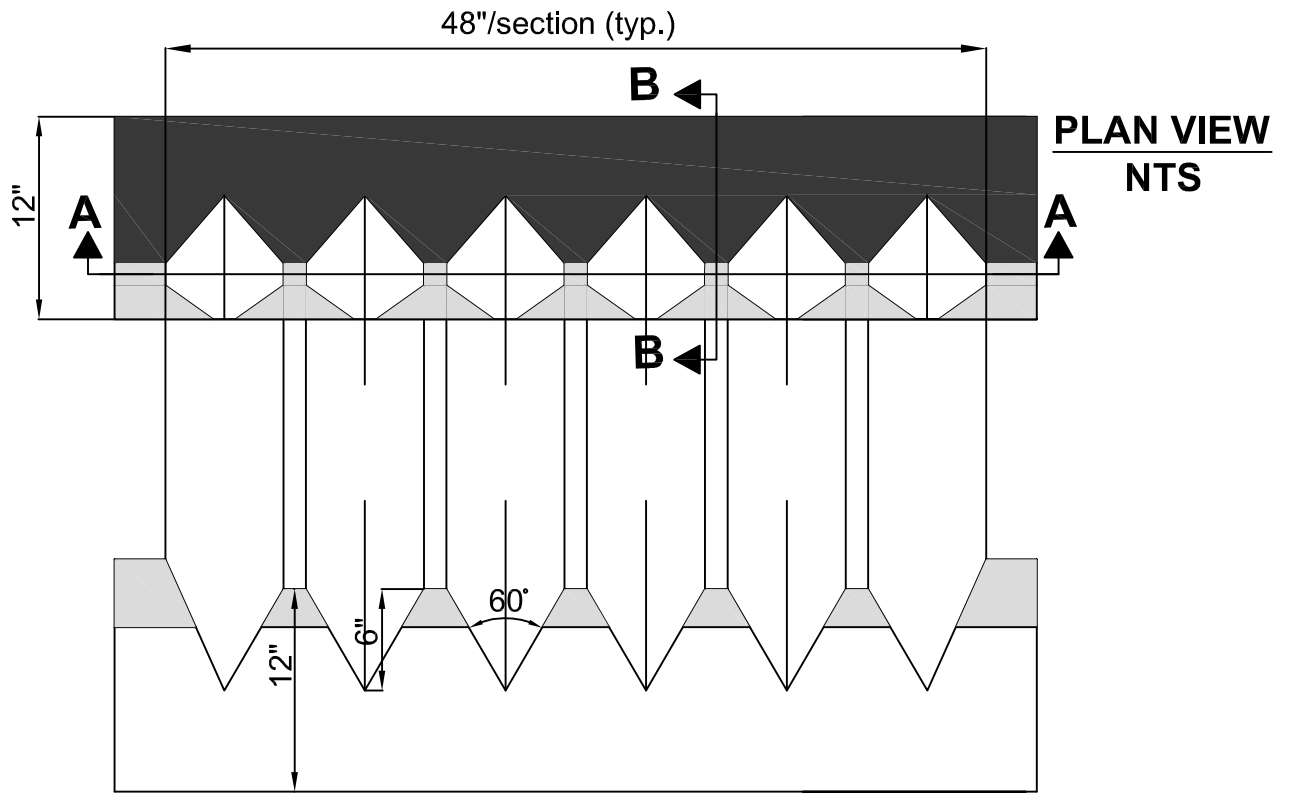
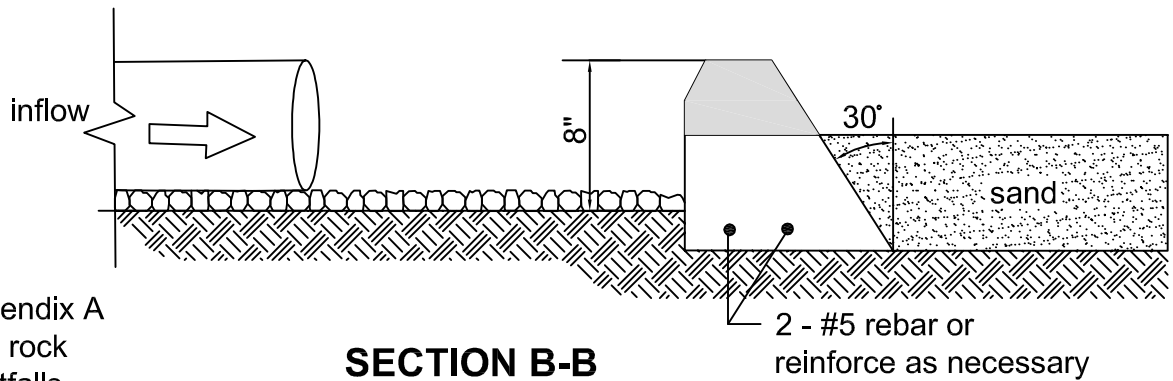


FIGURE B.7.C FLOW SPREADER OPTION C: NOTCHED CURB SPREADER



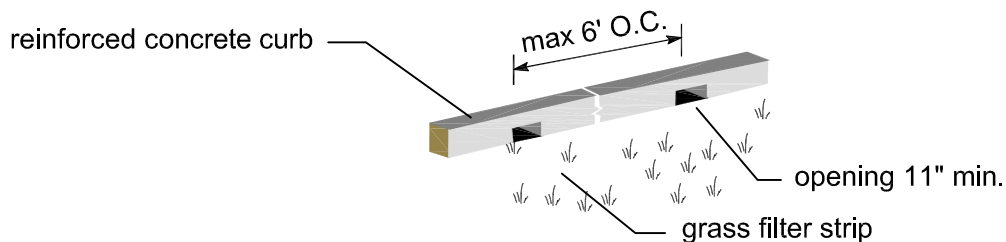
**FRONT VIEW A-A**  
NTS



**Note:** See Appendix A for guidance on rock protection at outfalls.

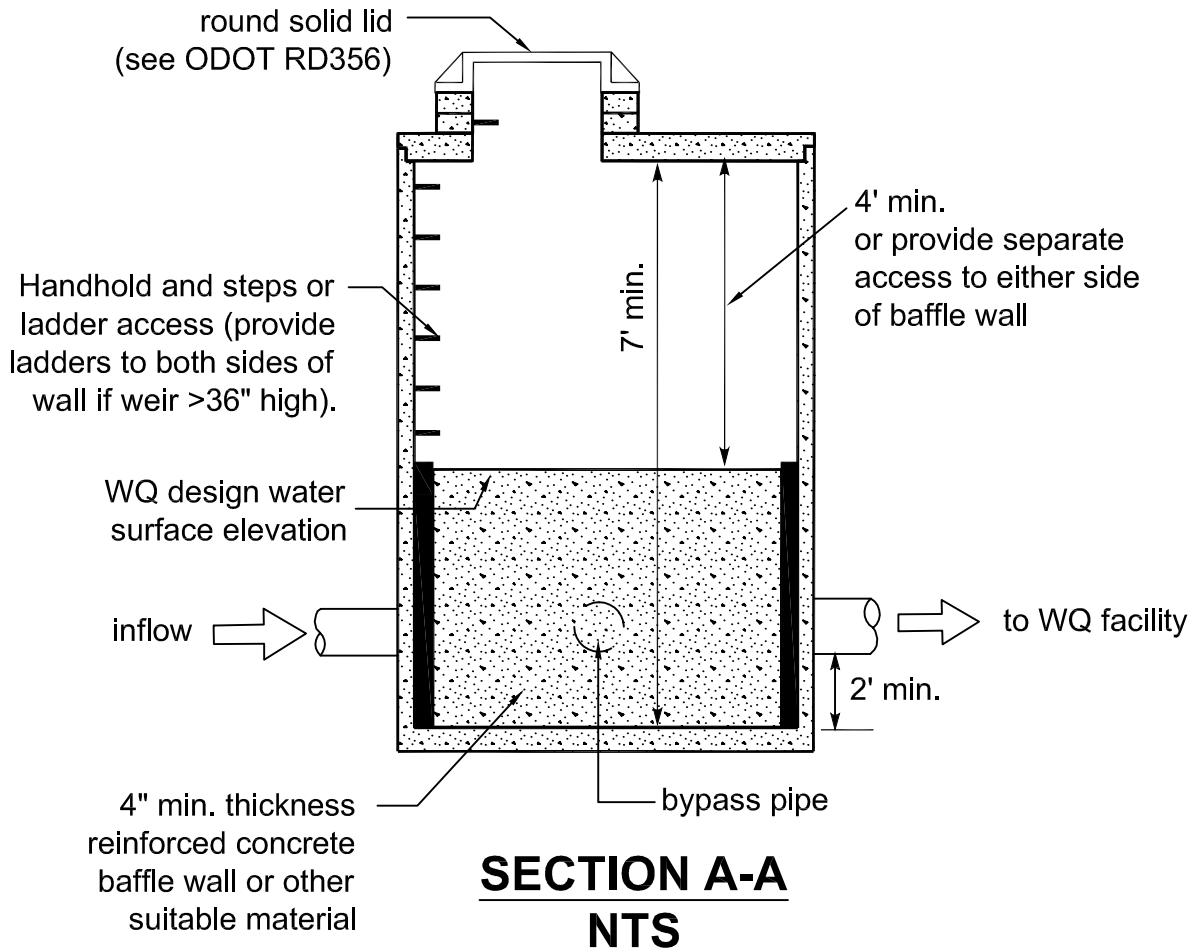
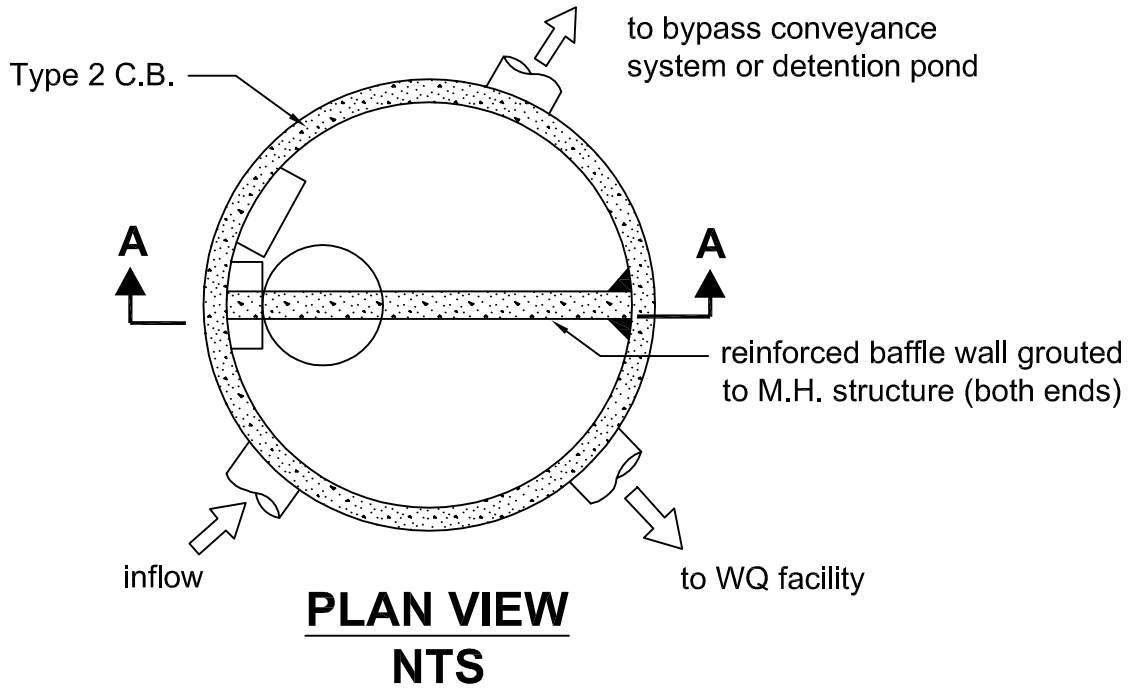
**SECTION B-B**  
NTS

FIGURE B.7.D FLOW SPREADER OPTION D: THROUGH-CURB PORT



**CURB PORT**  
NTS

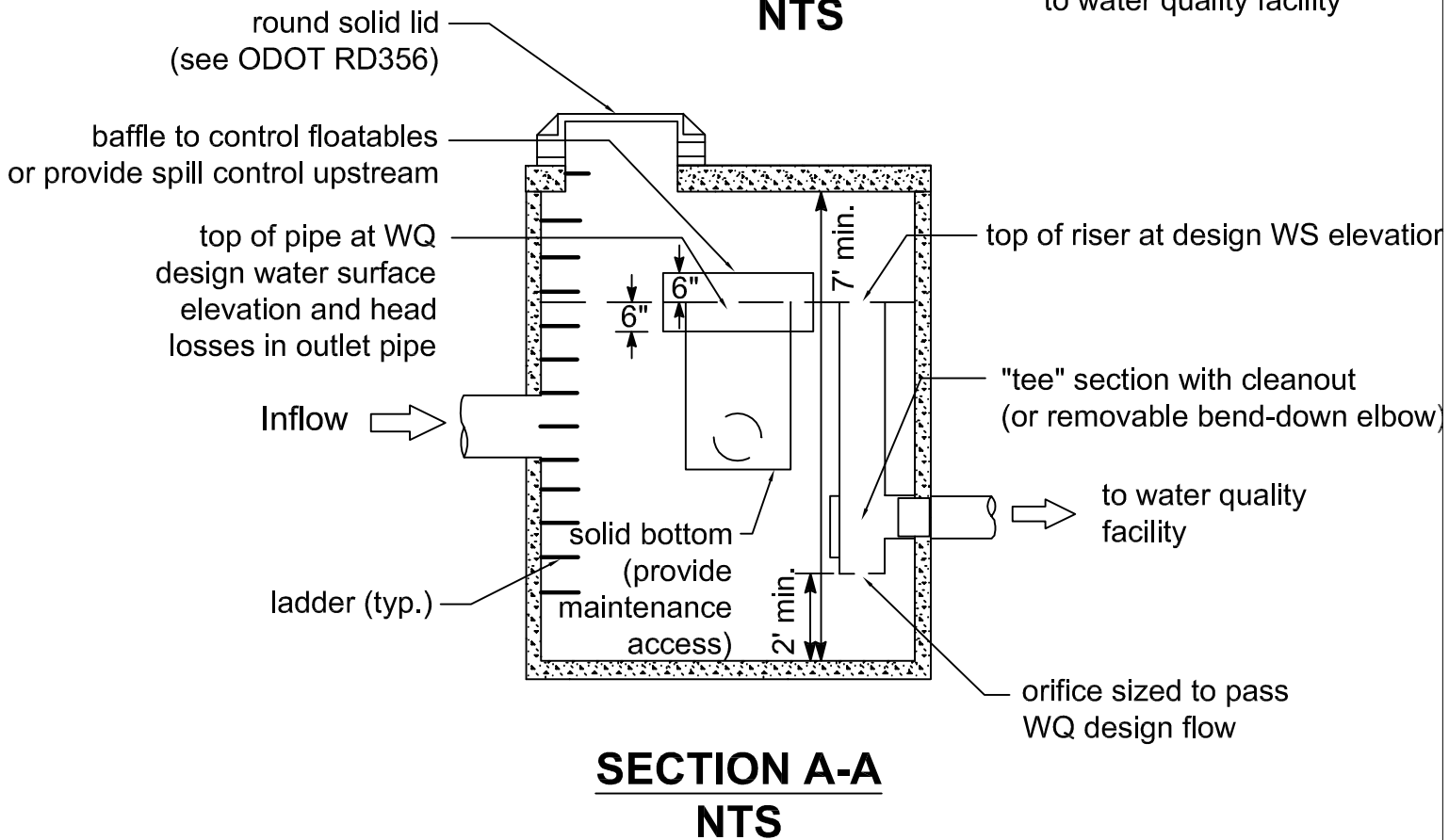
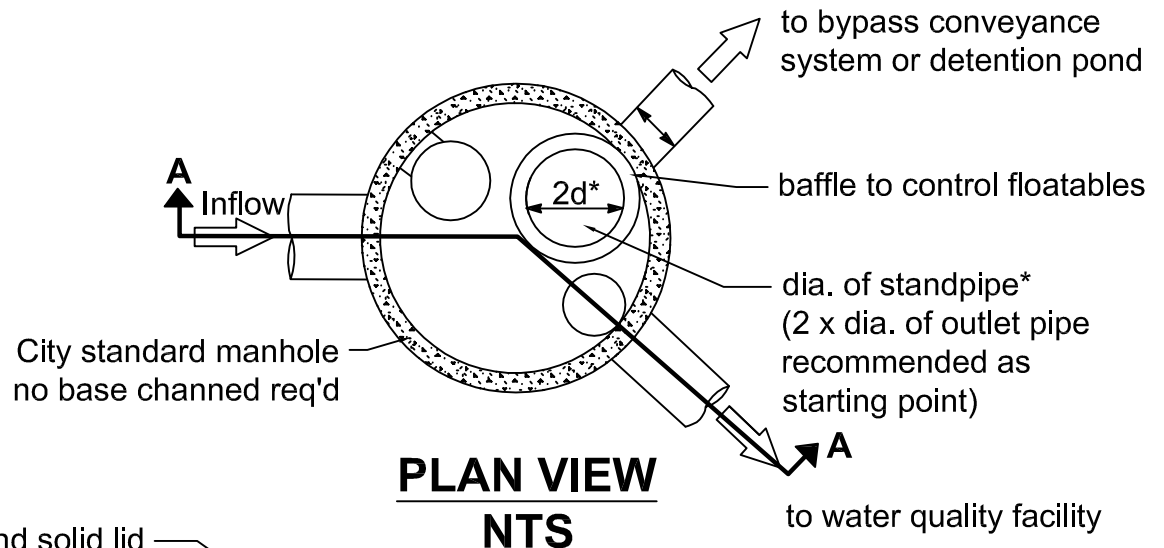
FIGURE B.8.A FLOW SPLITTER, OPTION A



**Note:** The water quality discharge pipe may require an orifice plate to be installed on the outlet to control the height of the design water surface (weir height). The design water surface should be set to provide a minimum headwater/diameter ratio of 2.0 on the outlet pipe.



FIGURE B.8.B FLOW SPLITTER, OPTION B



**\*NOTE:** Diameter (d) of standpipe should be large enough to minimize head above WQ design WS and to keep WQ design flows from increasing more than 10% during 100-year flows.

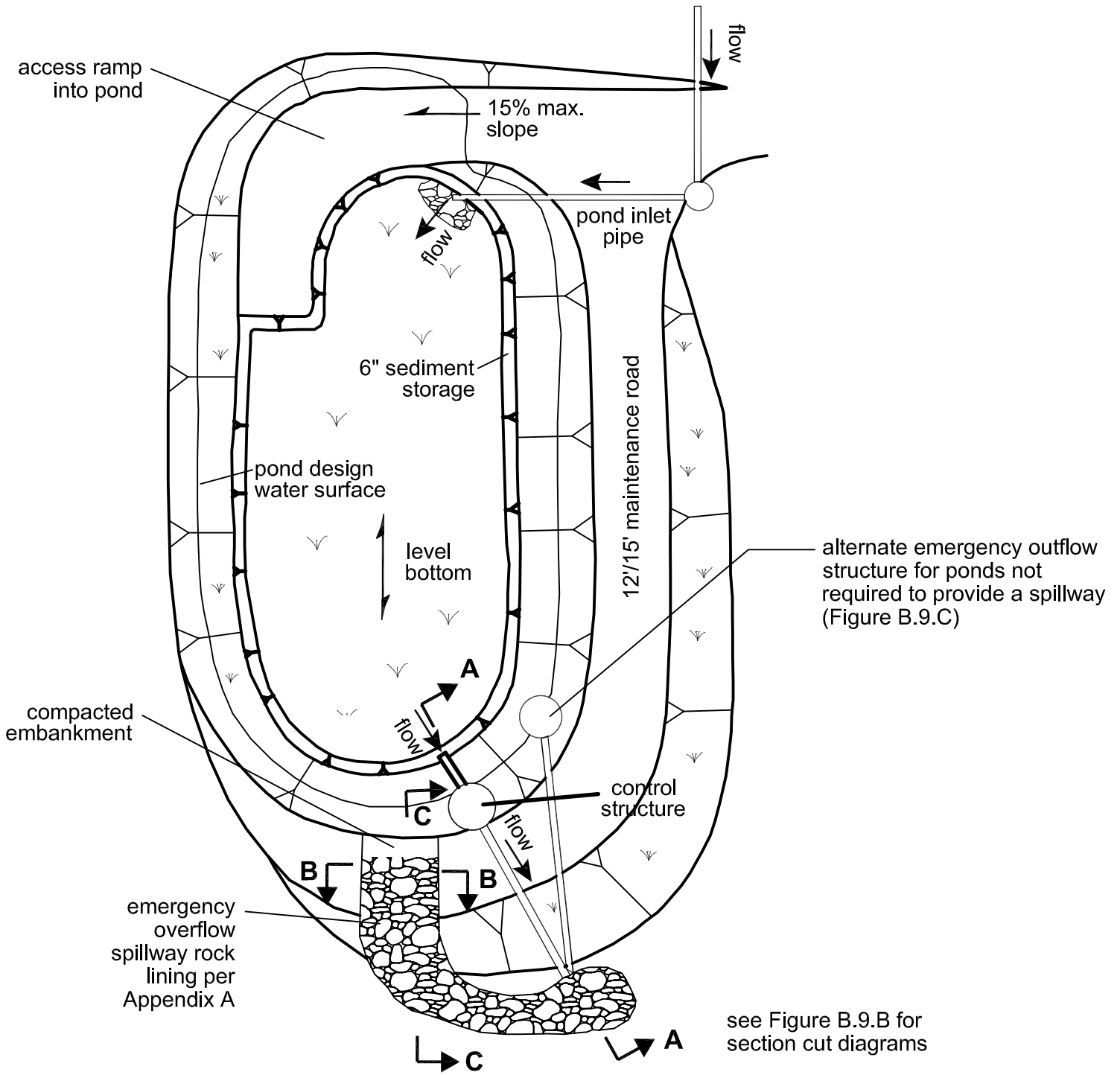


## **Detention Facilities**

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FIGURE B.9.A TYPICAL DETENTION POND

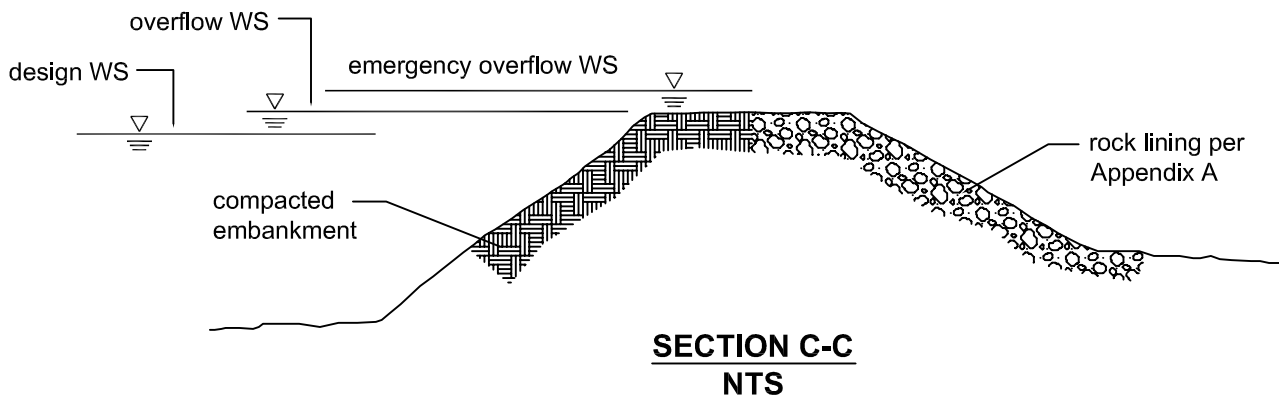
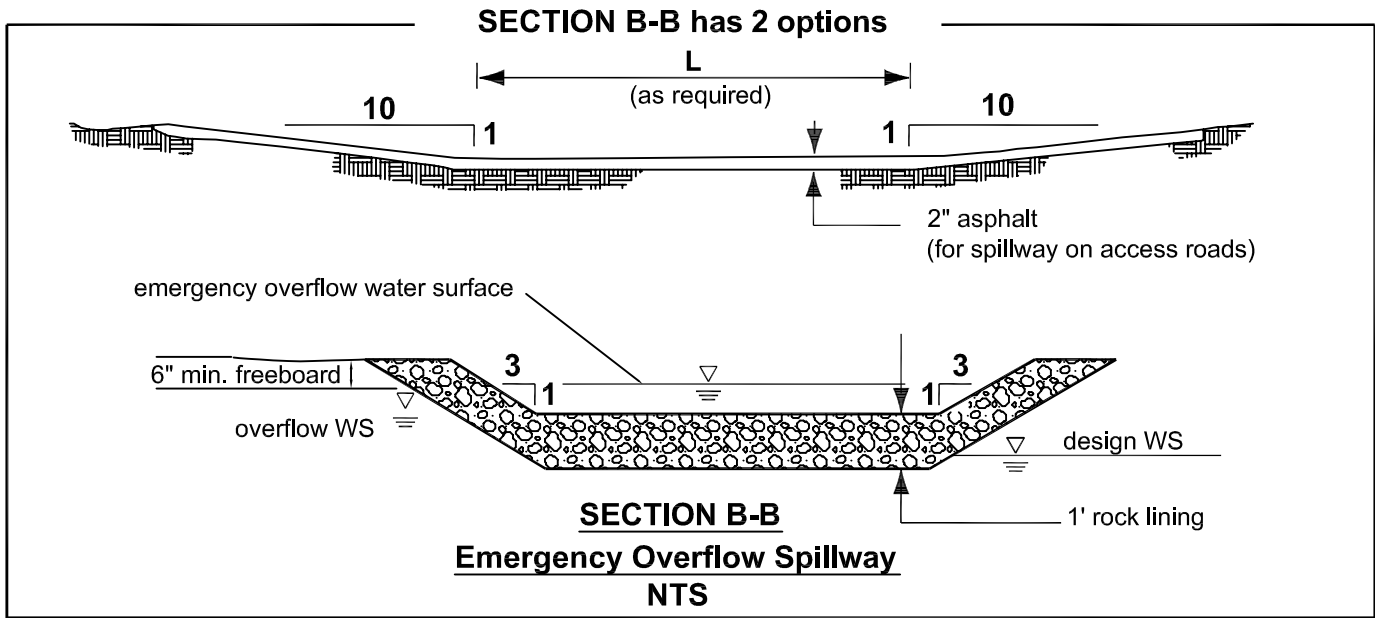
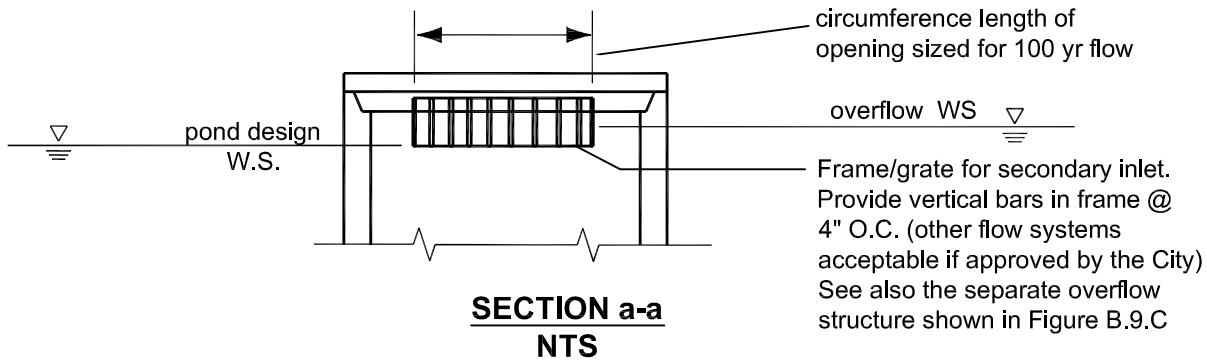
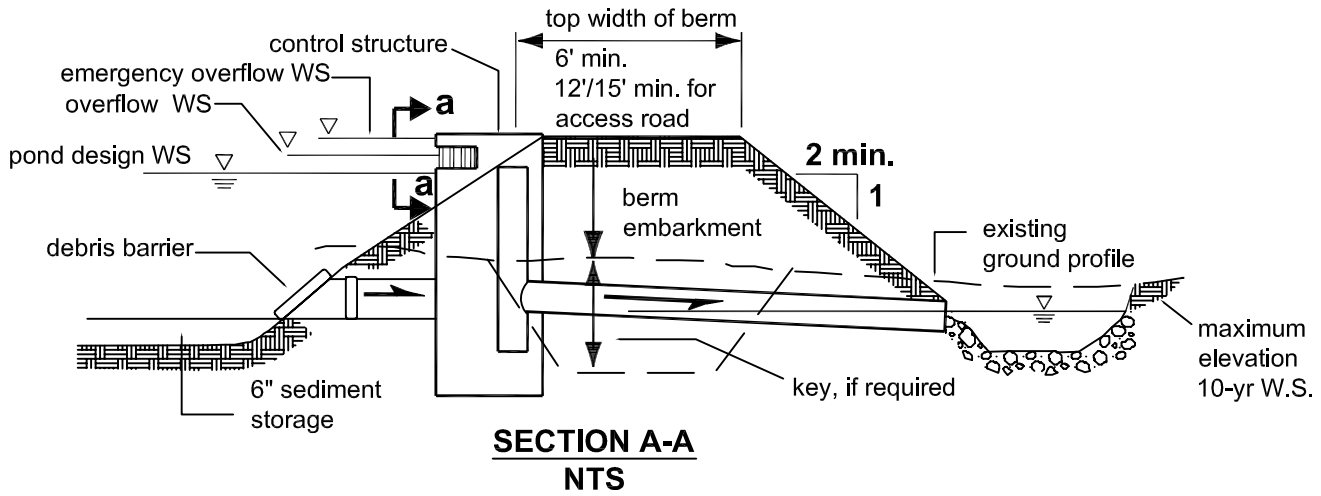


**NOTE:**

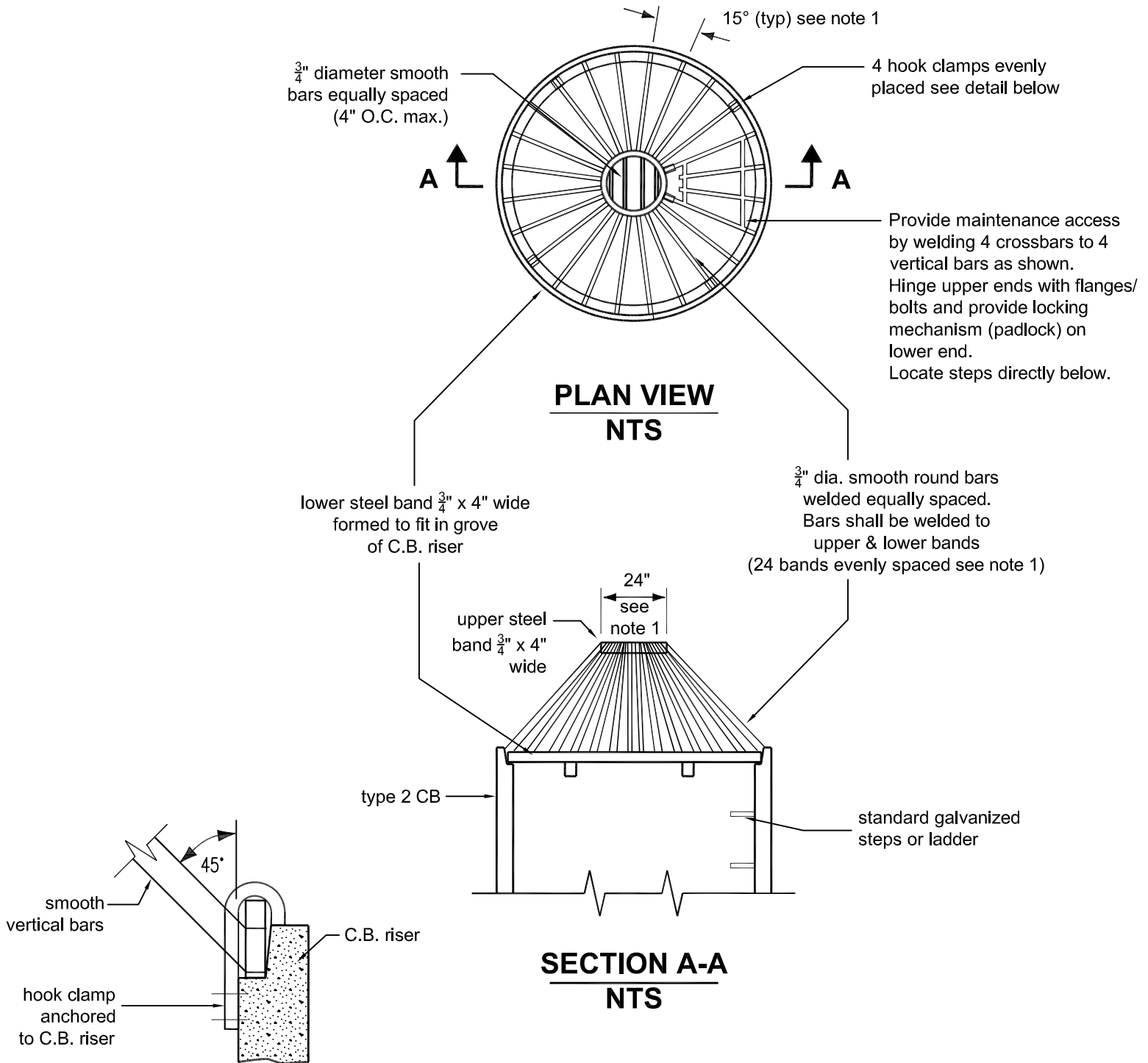
This detail is a schematic representation only. Actual configuration will vary depending on specific site constraints and applicable design criteria.

see Figure B.9.B for section cut diagrams

**FIGURE B.9.B TYPICAL DETENTION POND SECTIONS**



# FIGURE B.9.C OVERFLOW STRUCTURE



## DETAIL HOOK CLAMP

NTS

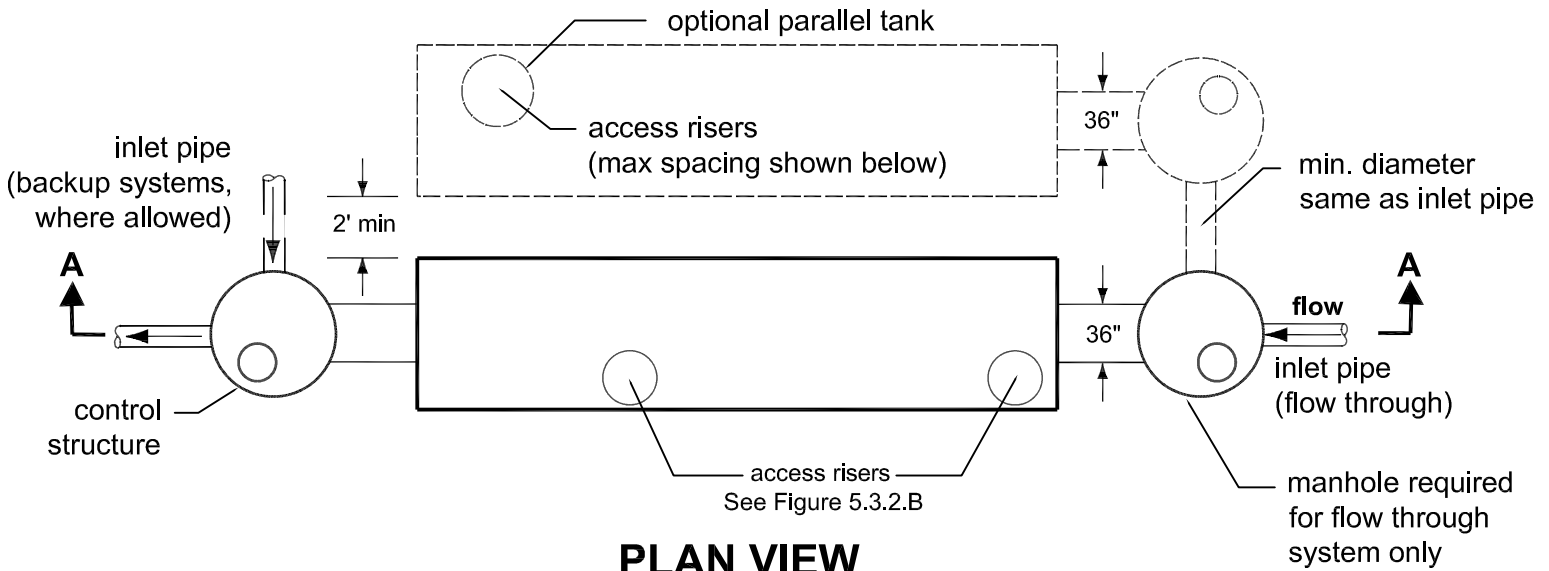
### NOTES:

1. Dimensions are for illustration on 54" diameter manhole base. For different diameter structures adjust to maintain 45° angle on "vertical" bars and 7" o.c. maximum spacing of bars around lower steel band.
2. Metal parts must be corrosion resistant; steel bars must be galvanized.
3. This debris barrier is also recommended for use on the inlet to roadway cross-culverts with high potential for debris collection (except on type 2 streams).

<b>DETENTION PONDS</b>			
<b>Maintenance component</b>	<b>Defect or problem</b>	<b>Conditions when maintenance is needed</b>	<b>Results expected when maintenance is performed</b>
Site	Trash and debris	Any trash and debris which exceed 1 cubic foot (ft <sup>3</sup> ) per 1,000 ft <sup>2</sup> (this is about equal to the amount of trash it would take to fill up one standard size office garbage can). In general, there should be no visual evidence of dumping.	Trash and debris cleared from site.
	Noxious weeds	Any noxious or nuisance vegetation which may constitute a hazard to City personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where City personnel or the public might be.
	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	Grass/ground cover	Grass or groundcover exceeds 18" in height.	Grass or groundcover mowed to a height no greater than 6".
Top or side slopes of dam, berm, or embankment	Rodent holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents removed or destroyed and dam or berm repaired.
	Tree growth	Tree growth threatens integrity of slopes, does not allow maintenance access, or interferes with maintenance activity. If trees are not a threat or not interfering with access or maintenance, they do not need to be removed.	Trees do not hinder facility performance or maintenance activities.
	Erosion	Eroded damage over 2" deep where cause of damage is present or where there is potential for continued erosion. Any erosion observed on a compacted slope.	Slopes stabilized using appropriate erosion control measures. If erosion is occurring on compacted slopes, a licensed civil engineer should be consulted to resolve source of erosion.
	Settlement	Any part of a dam, berm, or embankment that has settled 4" lower than the design elevation.	Top or slope restored to design dimensions. If settlement is significant, a licensed civil engineer should be consulted to determine the cause of the settlement.
Storage area	Sediment accumulation	Accumulated sediment that exceeds 10% of the designed pond depth.	Sediment cleaned out to designed pond shape and pond reseeded if necessary to control erosion.
	Liner damaged (if applicable)	Liner is visible or pond does not hold water as designed.	Liner repaired or replaced.
Inlet/outlet pipe	Sediment accumulation	Sediment filling 20% or more of the pipe.	Inlet/outlet pipes clear of sediment.
	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	Damaged	Cracks wider than ½" at the joint of the inlet/outlet pipes or any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼" wide at the joint of the inlet/outlet pipe.
Emergency overflow/spillway	Tree growth	Tree growth impedes flow or threatens stability of spillway.	Trees removed.
	Rock missing	Only one layer of rock exists above native soil in area 5 ft <sup>2</sup> or larger or any exposure of native soil on the spillway.	Spillway restored to design standards.



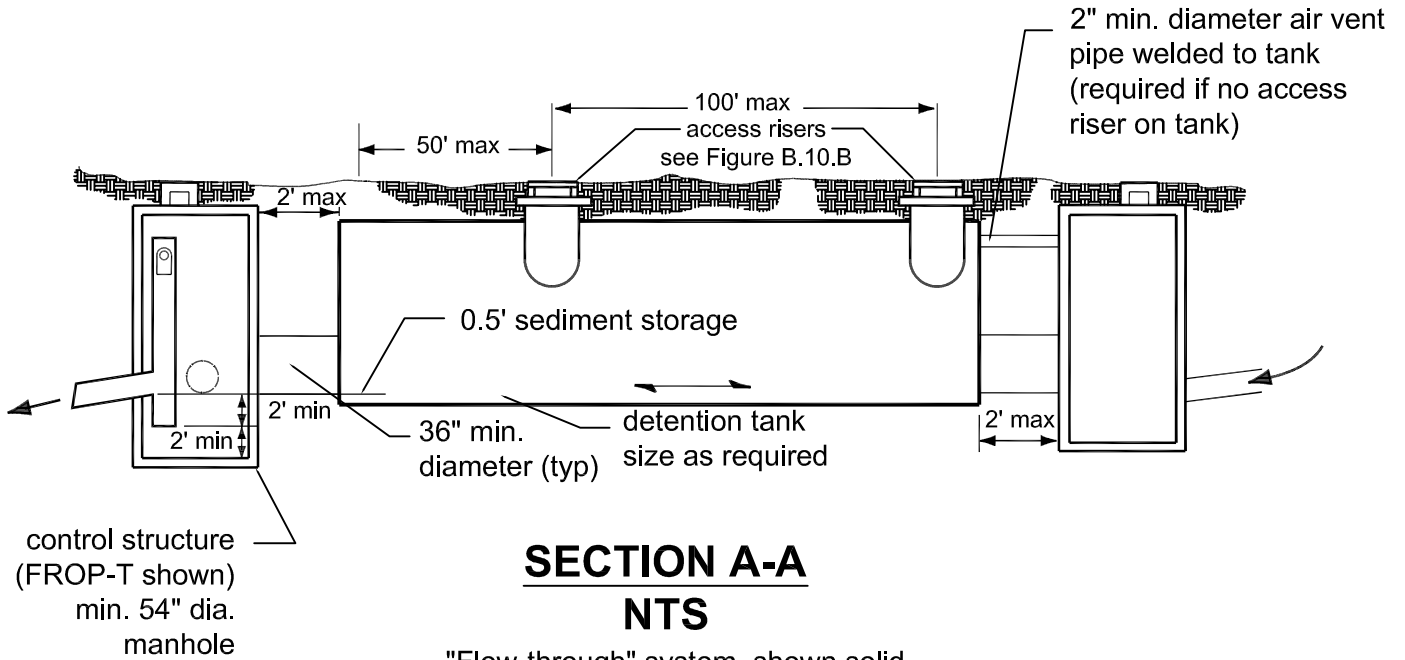
FIGURE B.10.A TYPICAL DETENTION TANK



**PLAN VIEW**

**NTS**

"Flow-through" system shown solid. Designs for "flow backup" system and parallel tanks shown dashed



**SECTION A-A**

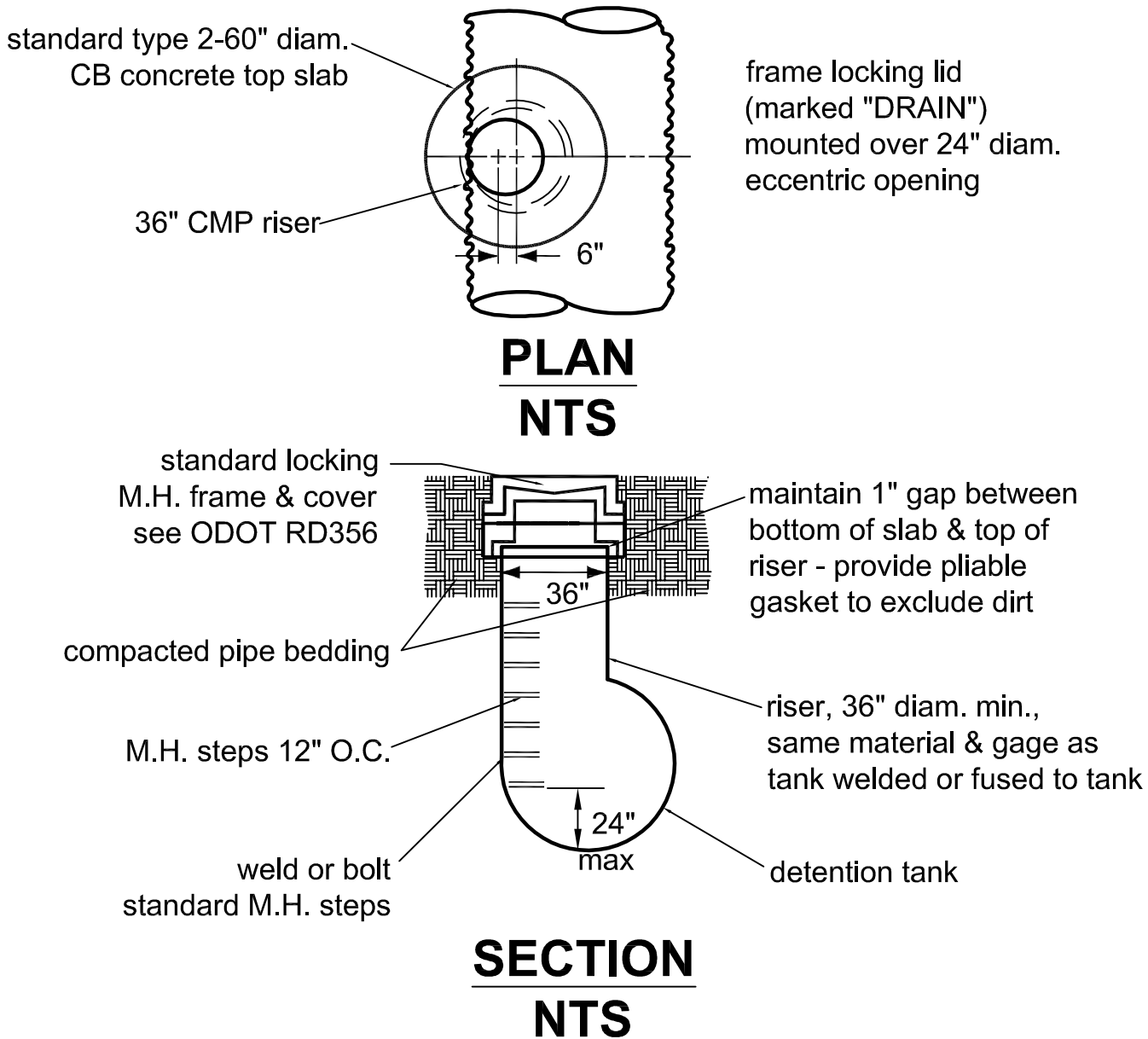
**NTS**

"Flow-through" system shown solid.

**NOTE:**

All metal parts corrosion resistant. Steel parts galvanized and asphalt coated (Treatment 1 or better)

FIGURE B.10.B DETENTION TANK ACCESS DETAIL

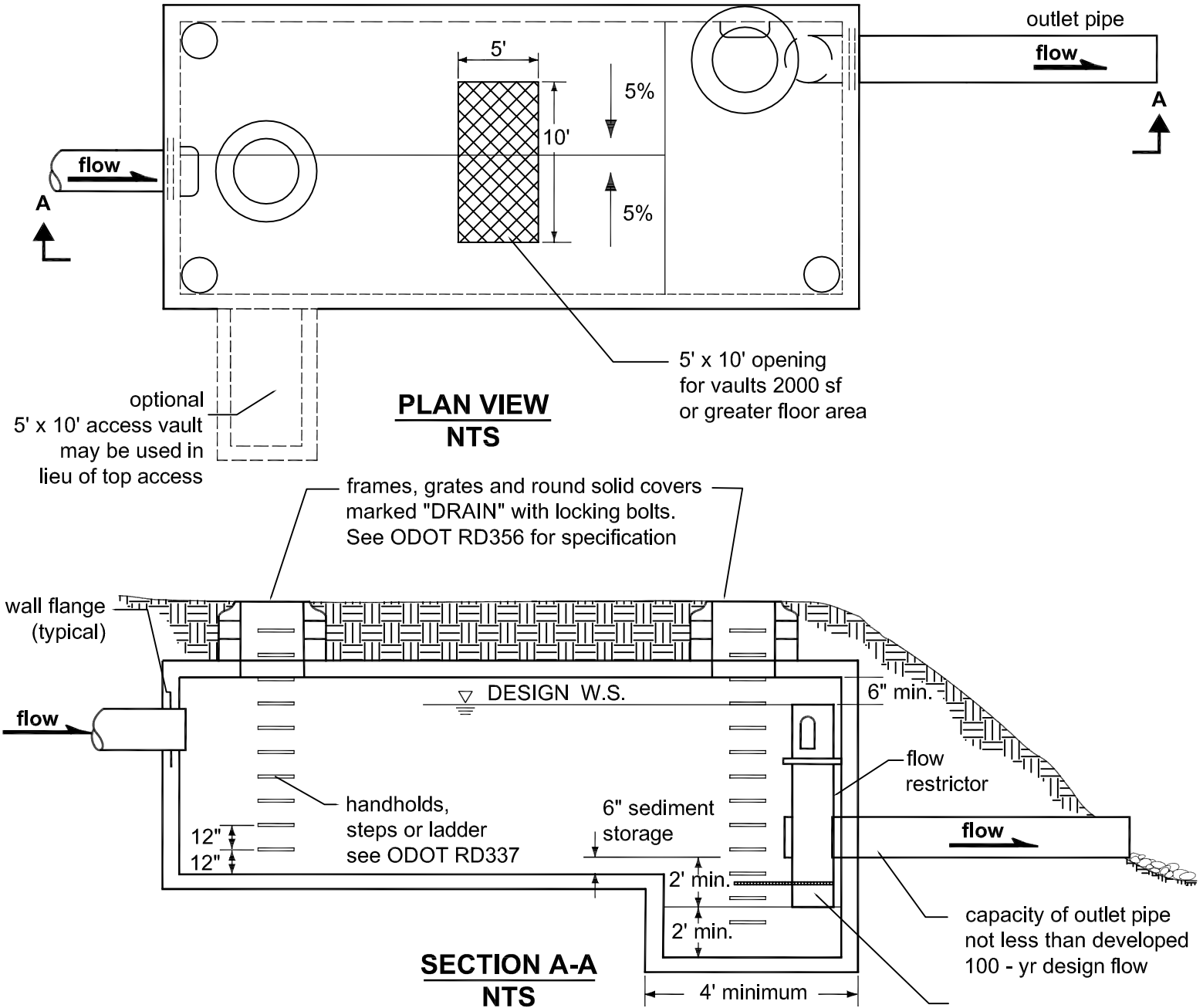


**NOTES:**

1. Use adjusting blocks as required to bring frame to guide.
2. All materials to be aluminum or galvanized and asphalt coated (Treatment 1 or better).
3. Must be located for access by maintenance vehicles.

FIGURE B.11 TYPICAL DETENTION VAULT

NOTE: All vault areas must be within 50' of an access point



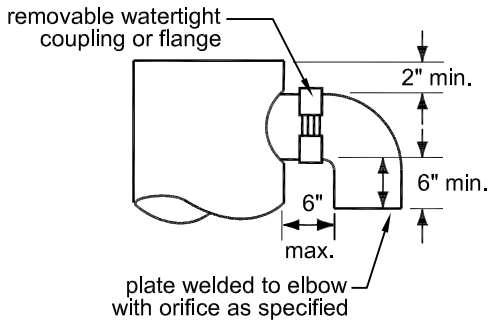
**NOTES:**

1. All metal parts must be corrosion resistant. Steel parts must be galvanized and asphalt coated (Treatment 1 or better).
2. Provide water stop at all cast-in-place construction joints. Precast vaults shall have approved rubber gasket system.
3. Vaults  $\leq 10'$  wide must use removable lids.
4. Prefabricated vault sections may require structural modifications to support 5' x 10' opening over main vault. Alternatively, access can be provided via a side vestibule as shown.

floor grate with 2' x 2' hinged access door (1" x  $\frac{1}{4}$ " galvanized metal bars)

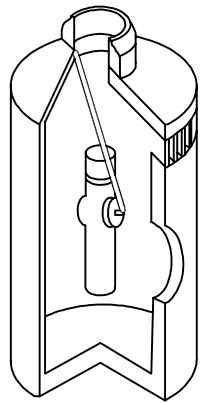
DETENTION TANKS AND VAULTS			
Maintenance component	Defect or problem	Conditions when maintenance is needed	Results expected when maintenance is performed
Site	Trash and debris	Any trash and debris which exceed 1 ft <sup>3</sup> per 1,000 ft <sup>2</sup> "(this is about equal to the amount of trash it would take to fill up one standard size office garbage can). In general, there should be no visual evidence of dumping.	Trash and debris cleared from site.
	Noxious weeds	Any noxious or nuisance vegetation which may constitute a hazard to City personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where City personnel or the public might be.
	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	Grass/groundcover	Grass or groundcover exceeds 18" in height.	Grass or groundcover mowed to a height no greater than 6".
Tank or vault storage area	Trash and debris	Any trash and debris accumulated in vault or tank (includes floatables and non-floatables).	No trash or debris in vault or tank.
	Sediment accumulation	Accumulated sediment depth exceeds 10% of the diameter of the storage area for ½ the length of a storage tank or vault or where any point depth exceeds 15% of diameter. <i>Example: 72" storage tank would require cleaning when sediment reaches depth of 7" for more than ½ the length of tank.</i>	All sediment removed from storage area.
Tank structure	Plugged air vent	Any blockage of the vent.	Tank or vault freely vents.
	Tank bent out of shape	Any part of tank/pipe is bent out of shape more than 10% of its design shape.	Tank repaired or replaced to design specifications.
	Gaps between sections, damaged joints or cracks or tears in wall	A gap wider than ½" at the joint of any tank sections or any evidence of soil particles entering the tank at a joint or through a wall.	No water or soil entering tank through joints or walls.
Vault structure	Damage to wall, frame, bottom, and/or top slab	Cracks wider than ½", any evidence of soil entering the structure through cracks or if qualified inspection personnel determines that the vault is not structurally sound.	Vault is sealed and structurally sound.
Inlet/outlet pipes	Sediment accumulation	Sediment filling 20% or more of the pipe.	Inlet/outlet pipes clear of sediment.
	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	Damaged	Cracks wider than ½" at the joint of the inlet/outlet pipes or any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼" wide at the joint of the inlet/outlet pipe.
Access manhole	Cover/lid not in place	Cover/lid is missing or only partially in place. <b>Any open manhole requires immediate maintenance.</b>	Manhole access covered.
	Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.
	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs. of lift.	Cover/lid can be removed and reinstalled by one maintenance person.
	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.
Large access doors/plate	Damaged or difficult to open	Large access doors or plates cannot be opened/removed using normal equipment.	Replace or repair access door so it can be opened as designed.
	Gaps, doesn't cover completely	Large access doors not flat and/or access opening not completely covered.	Doors close flat and covers access opening completely.
	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate.	Lifting rings sufficient to lift or remove door or plate.

FIGURE B.12.A FLOW RESTRICTOR (TEE)



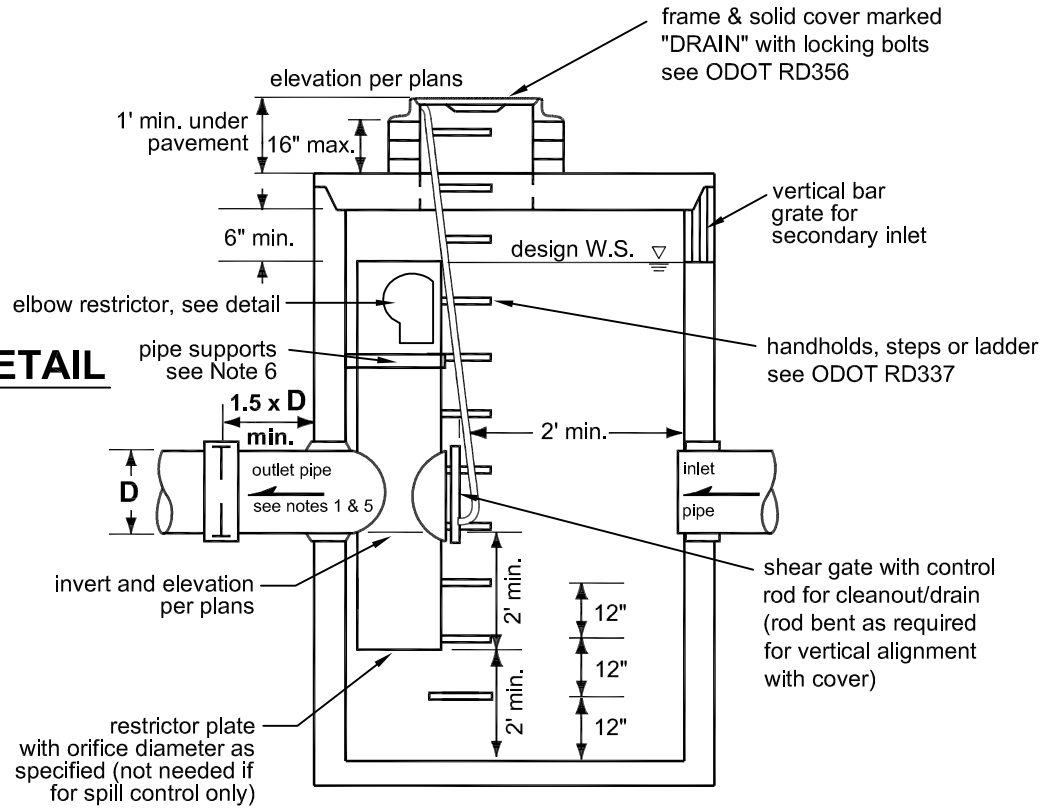
**ELBOW RESTRICTOR DETAIL**

**NTS**



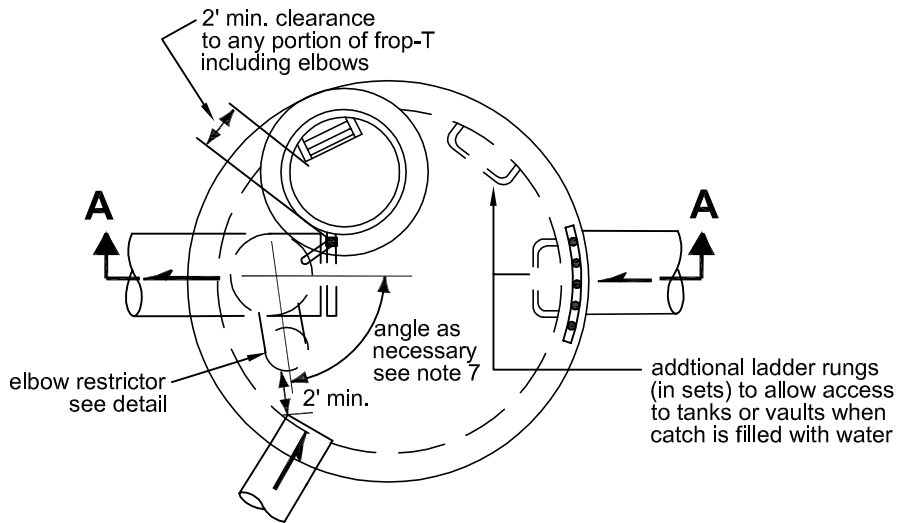
**ISOMETRIC**

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**SECTION A-A**

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**PLAN VIEW**

**NTS**

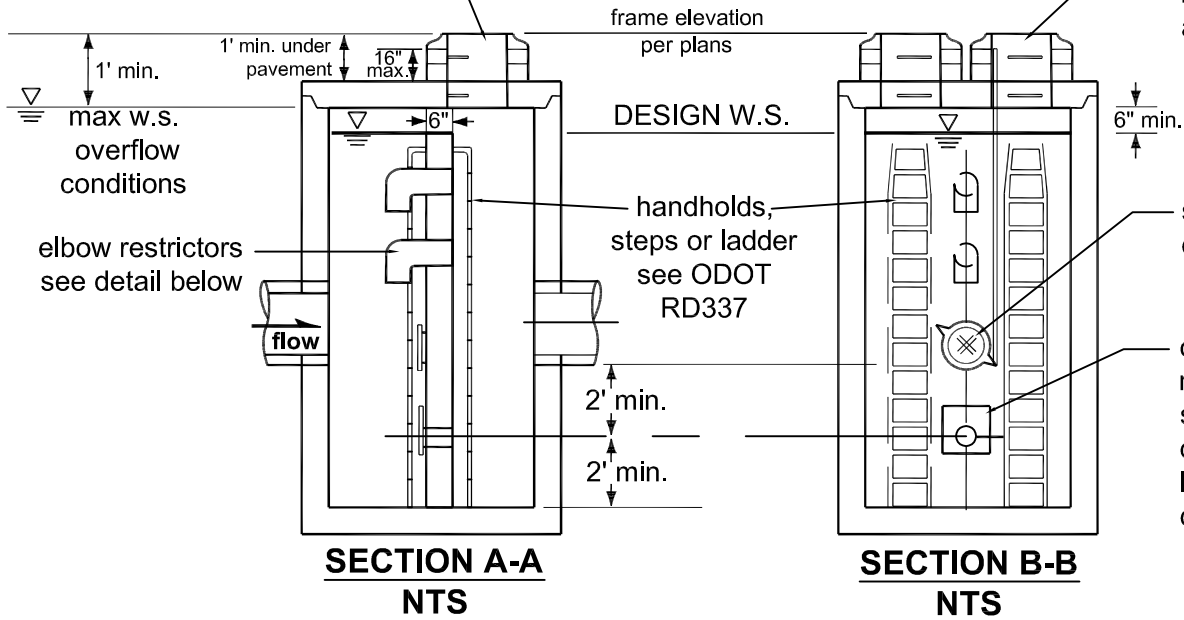
**NOTES:**

1. Use a minimum of a 54" diameter manhole.
2. Outlet Capacity: 100-Year developed peak flow.
3. Metal Parts: Corrosion resistant. Non-Galvanized parts preferred. Galvanized pipe parts to have asphalt treatment 1.
4. Frame and ladder or steps offset so:
  - A. Cleanout gate is visible from top.
  - B. Climb-down space is clear of riser and cleanout gate.
  - C. Frame is clear of curb.
5. If metal outlet pipe connects to cement concrete pipe: outlet pipe to have smooth O.D. equal to concrete pipe I.D. less  $\frac{1}{4}$ ".
6. Provide at least one 3" X .090 gage support bracket anchored to concrete wall. (maximum 3'-0" vertical spacing)
7. Locate elbow restrictor(s) as necessary to provide minimum clearance as shown.
8. Locate additional ladder rungs in structures used as access to tanks and vaults to allow access when catch basin is filled with water.
9. Tee shall be constructed of aluminum CMP or aluminized steel CMP meeting ODOT/APWA standards.

# FIGURE B.12.B FLOW RESTRICTOR (BAFFLE)

Frame and round solid cover marked "DRAIN" with locking bolts. See ODOT RD356.

attach shear gate control rod to support bracket on inside of access opening



elbow restrictors see detail below

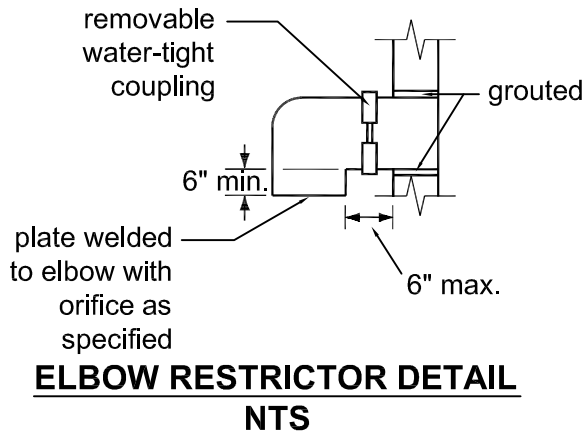
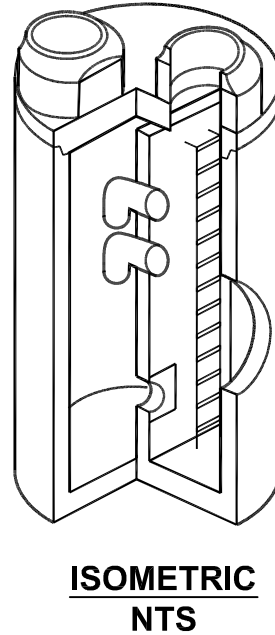
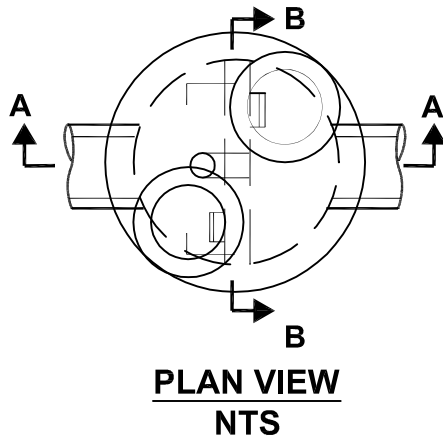
frame elevation per plans

DESIGN W.S.

handholds, steps or ladder see ODOT RD337

shear gate with control rod for drain

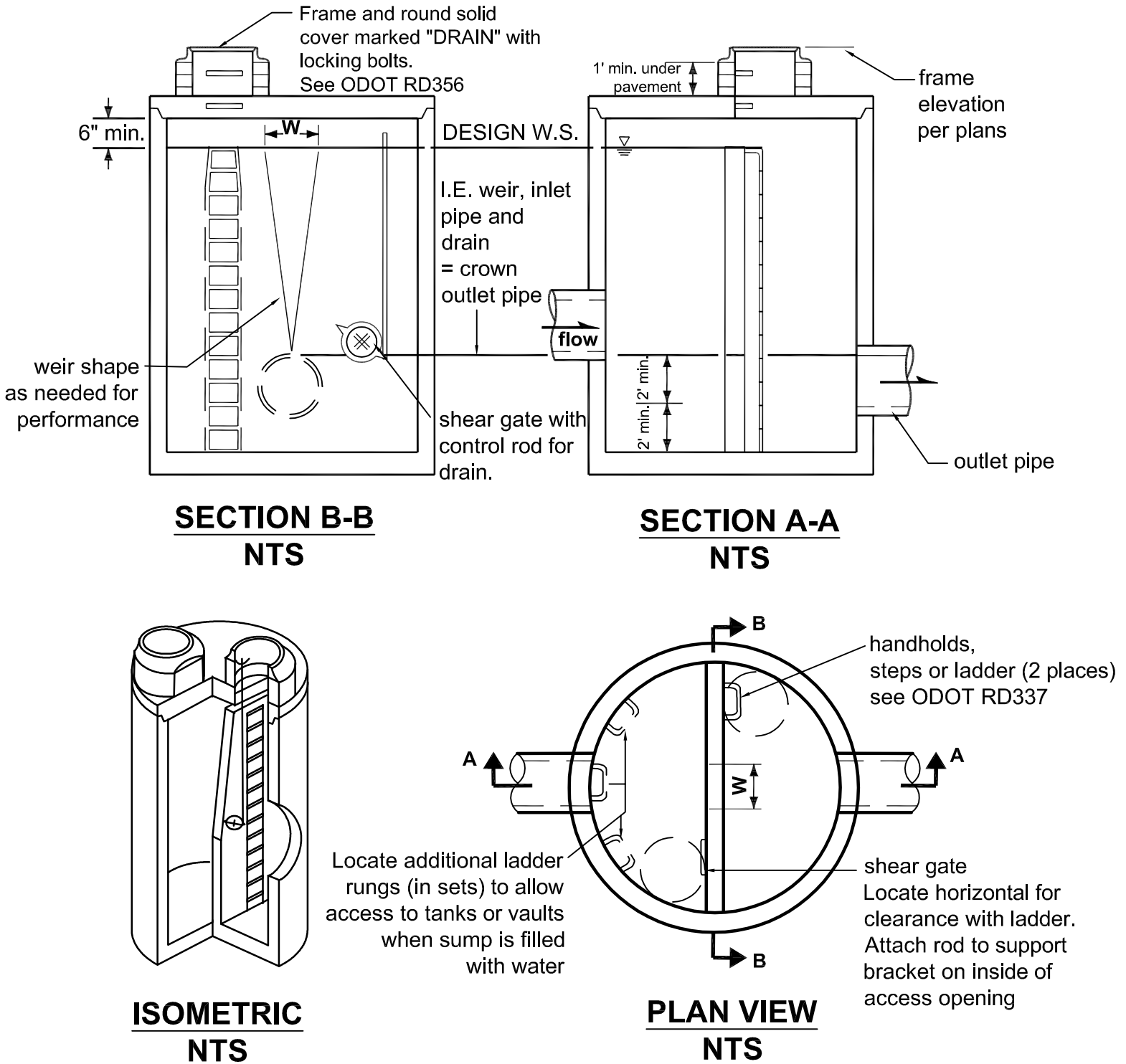
orifice plate 10 gage minimum galvanized steel with orifice diameter 1" minimum less than diameter of concrete hole



## NOTES:

- outlet capacity: 100 year developed peak flow
- metal parts: corrosion resistant steel parts galvanized and asphalt coated
- manhole: minimum 72" diameter to be constructed in accordance with city standards
- orifices: sized and located as required with lowest orifice a minimum of 2' from base

FIGURE B.12.C FLOW RESTRICTOR (WEIR)



**NOTES:**

- Outlet Capacity: 100-year developed peak flow.
- Metal Parts: corrosion resistant steel parts galvanized and asphalt coated.
- Manhole: type 2 Min. 72" diameter to be constructed in accordance with city standards.
- Baffle Wall: to be designed with concrete reinforcing as required.

<b>CONTROL STRUCTURES/FLOW RESTRICTORS</b>			
<b>Maintenance component</b>	<b>Defect or problem</b>	<b>Condition when maintenance is needed</b>	<b>Results expected when maintenance is performed</b>
Structure	Trash and debris	Trash or debris of more than ½ ft³ which is located immediately in front of structure opening or is blocking capacity of the structure by more than 10%.	No trash or debris blocking or potentially blocking entrance to structure.
		Trash or debris in the structure that exceeds one-third of the depth from the bottom of basin to invert of the lowest pipe into or out of the structure.	No trash or debris in the structure.
		Deposits of garbage exceeding 1 ft³ in volume.	No condition present which would attract or support the breeding of insects or rodents.
	Sediment	Sediment exceeds 60% of the depth from the bottom of the structure to the invert of the lowest pipe into or out of the structure or the bottom of the FROP-T section or is within 6" of the invert of the lowest pipe into or out of the structure or the bottom of the FROP-T section.	Sump of structure contains no sediment.
	Damage to frame and/or top slab	Corner of frame extends more than ¾" past curb face into the street (if applicable).	Frame is even with curb.
		Top slab has holes larger than 2 in² or cracks wider than ¼".	Top slab is free of holes and cracks.
		Frame not sitting flush on top slab (i.e., separation of more than ¾" of the frame from the top slab).	Frame is sitting flush on top slab.
	Cracks in walls or bottom	Cracks wider than ½" and longer than 3 feet, any evidence of soil particles entering structure through cracks, or maintenance person judges that structure is unsound.	Structure is sealed and structurally sound.
		Cracks wider than ½" and longer than 1' at the joint of any inlet/outlet pipe or any evidence of soil particles entering structure through cracks.	No cracks more than ¼" wide at the joint of inlet/outlet pipe.
	Settlement/misalignment	Structure has settled more than 1" or has rotated more than 2" out of alignment.	Structure replaced or repaired to design standards.
	Damaged pipe joints	Cracks wider than ½" at the joint of the inlet/outlet pipes or any evidence of soil entering the structure at the joint of the inlet/outlet pipes.	No cracks more than ¼" wide at the joint of inlet/outlet pipes.
	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	Ladder rungs missing or unsafe	Ladder is unsafe due to missing rungs misalignment, rust, cracks, or sharp edges.	Ladder meets design standards and allows maintenance person safe access.
FROP-T section	Damage	T section is not securely attached to structure wall and outlet pipe structure should support at least 1,000 lbs. of up or down pressure.	T section securely attached to wall and outlet pipe.
		Structure is not in upright position (allow up to 10% from plumb).	Structure in correct position.
		Connections to outlet pipe are not watertight or show signs of deteriorated grout.	Connections to outlet pipe are water tight; structure repaired or replaced and works as designed.
		Any holes-other than designed holes-in the structure.	Structure has no holes other than designed holes.



<b>CONTROL STRUCTURES/FLOW RESTRICTORS</b>			
<b>Maintenance component</b>	<b>Defect or problem</b>	<b>Condition when maintenance is needed</b>	<b>Results expected when maintenance is performed</b>
Cleanout gate	Damaged or missing	Cleanout gate is missing.	Replace cleanout gate.
		Cleanout gate is not watertight.	Gate is watertight and works as designed.
		Gate cannot be moved up and down by one maintenance person.	Gate moves up and down easily and is watertight.
		Chain/rod leading to gate is missing or damaged.	Chain is in place and works as designed.
Orifice plate	Damaged or missing	Control device is not working properly due to missing, out of place, or bent orifice plate.	Plate is in place and works as designed.
	Obstructions	Any trash, debris, sediment, or vegetation blocking the plate.	Plate is free of all obstructions and works as designed.
Overflow pipe	Obstructions	Any trash or debris blocking (or having the potential of blocking) the overflow pipe.	Pipe is free of all obstructions and works as designed.
	Deformed or damaged lip	Lip of overflow pipe is bent or deformed.	Overflow pipe does not allow overflow at an elevation lower than design
Inlet/outlet pipe	Sediment accumulation	Sediment filling 20% or more of the pipe.	Inlet/outlet pipes clear of sediment.
	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	Damaged	Cracks wider than ½" at the joint of the inlet/outlet pipes or any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼" wide at the joint of the inlet/outlet pipe.
Metal grates (if applicable)	Unsafe grate opening	Grate with opening wider than 7/8".	Grate opening meets design standards.
	Trash and debris	Trash and debris that is blocking more than 20% of grate surface.	Grate free of trash and debris.
	Damaged or missing	Grate missing or broken member(s) of the grate.	Grate is in place and meets design standards.
Manhole cover/lid	Cover/lid not in place	Cover/lid is missing or only partially in place. Any open structure requires urgent maintenance.	Cover/lid protects opening to structure.
	Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.
	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs. of lift.	Cover/lid can be removed and reinstalled by one maintenance person.



## **Appendix C: Planting Guidelines for Vegetated Facilities**

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## C. PLANTING GUIDELINES FOR VEGETATED FACILITIES

Plants play a critical role in the functionality and performance of vegetated stormwater facilities through a combination of physical and biological processes working in tandem. This appendix provides information on plant selection and design guidance for a variety of vegetated stormwater facilities.

### C.1 GENERAL GUIDELINES

The following general guidelines shall be considered when developing landscaping plans for projects with vegetated stormwater facilities.

**Native Plants.** Native plants, indigenous to the Pacific Northwest, are strongly recommended for vegetated stormwater facilities and should be used whenever suitable. Native cultivars are cultivated varieties of native plants that are bred for certain desired characteristics that make them different from their native counterparts. Native cultivars may be selected over a native plant if it is more suitable for certain conditions, such as densely urbanized applications.

**Plant Diversity.** Plant diversity can be created in vegetated stormwater facilities by selecting complementary vegetation to plant together, such as groundcovers, perennials, and shrubs. The structural variety of a diversified planting design can also improve site aesthetics. Plant selection should reflect this natural ordering of plantings, as well as mimicking a mixture of deciduous and evergreen materials.

**Planting Zones.** Planting zones for vegetated stormwater management facilities are categorized according to the degree of soil moisture that will be encountered at different points in the facility. Sloped, basin-like stormwater facilities such as wetponds have a moisture gradient that varies with the designed maximum water depth, the time it takes for a facility to drain after a storm event, and the steepness of the side slopes. These stormwater facilities typically include the following planting zones:

- Saturated (Zone S): standing or flowing water/nearly constant saturation; anaerobic soils
- Moist (Zone A): periodically saturated; anaerobic and/or aerobic soils
- Dry (Zones B): infrequent inundation/saturation, if any; aerobic soils

Planting conditions are more uniform for detention ponds, basic biofiltration swales and vegetated filter strips because of the relatively uniform and flat surface. The cross-sections in Figure C-1 and C-2 can be used to determine approximate planting zones for the vegetated stormwater facilities included in this manual.

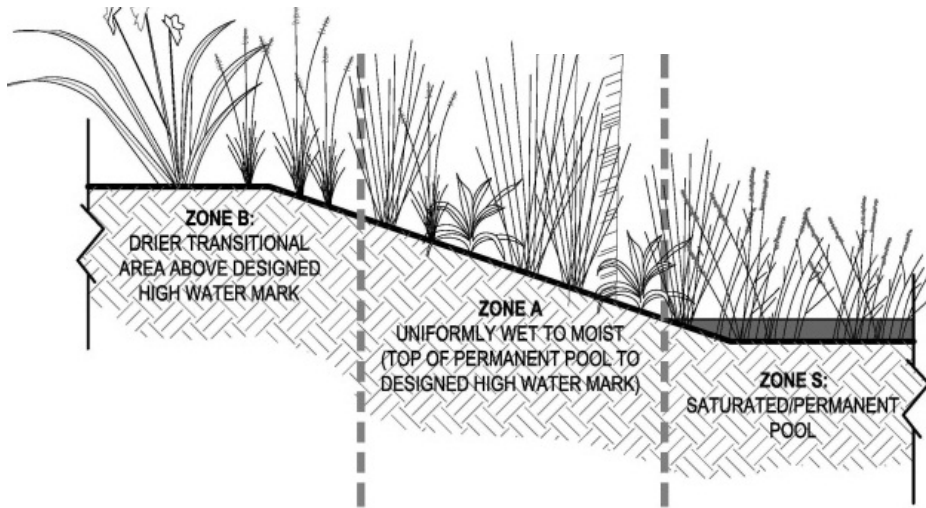


Figure C-1. Planting Zones for wet ponds, combined ponds, and wet biofiltration swales

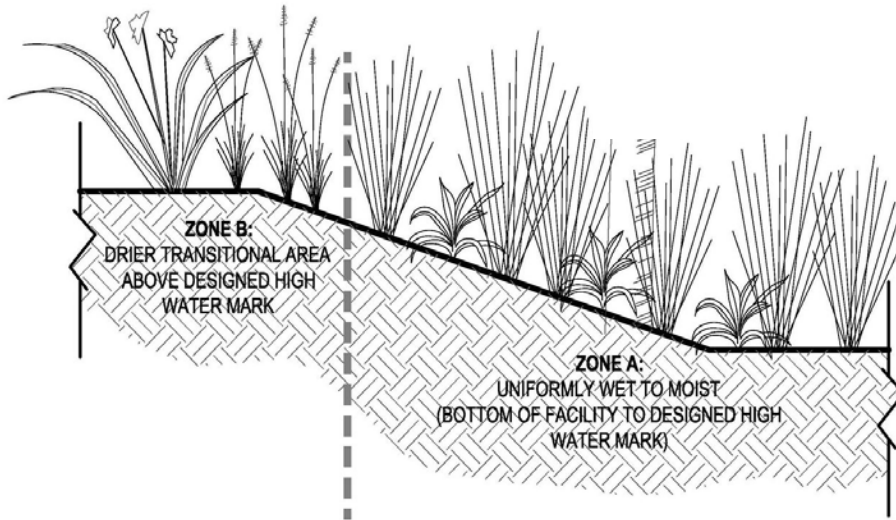


Figure C-2. Planting Zones for basic biofiltration swales, continuous biofiltration swales, detention ponds, and filter strips

## C.2 PLANT SELECTION AND DESIGN GUIDELINES

The success or failure of a stormwater management facility can often depend on the proper selection and location of plants. The following design guidelines apply to selecting and locating plants for private vegetated stormwater facilities.

Private facilities shall be vegetated using the plant lists in Table C-1 and/or the seed mixes in Table C-2. Public facilities shall be vegetated per the seed mixes detailed in Table C-2, unless otherwise approved by the City.

### C.2.1 PLANT LISTS

The plant list provided in Table C-1 should be referenced to select appropriate plants for private vegetated stormwater facilities. Use of plants not identified in Table C-1 must be approved by the City. Planting plans for private facilities must have a minimum of 50 percent evergreen plants and at least two species from the herbaceous and small shrubs/groundcover plant communities. Trees are not allowed in biofiltration swales, filter strips, or detention ponds and are not required or recommended in lined facilities.

**TABLE C-1: Approved Plant Lists for Vegetated Stormwater Facilities**

Plant Type	Plant Name <i>Botanical, common</i>	Potential Height	Size at Installation	Plant Spacing	# of Plants per 100 SF
<b>Saturated, Zone S</b>					
Herbaceous	<i>Carex obnupta</i> , Slough sedge	48"	4 inch	12 inch	115
	<i>Juncus ensifolius</i> , Dagger-leaf rush	10"			
	<i>Juncus patens</i> , Spreading rush	36"			
	<i>Scirpus microcarpus</i> , Small fruited bulrush	24"			
<b>Moist, Zone A</b>					
Herbaceous	<i>Camassia quamash</i> , Camas lily	24"	4 inch	12 inch	115
	<i>Carex obnupta</i> , Slough sedge	48"			
	<i>Deschampsia cespitosa</i> , Tufted hair grass	36"			
	<i>Elymus glaucus</i> , Blue wild rye	24"			
	<i>Juncus ensifolius</i> , Dagger-leaf rush	10"			
	<i>Juncus patens</i> , Spreading rush	36"			
	<i>Scirpus microcarpus</i> , Small fruited bulrush	24"			
	<i>Veronica liwanensis</i> , Speedwell	2"			
Small Shrub	<i>Cornus sericea 'Kelseyi'</i> , Kelsey dogwood	2'	1 gallon	2-3 feet	4
	<i>Mahonia aquifolium</i> , Oregon grape	5'			
	<i>Polystichum munitum</i> , Sword fern	2'			
	<i>Spiraea betulifolia</i> , Birchleaf spiraea	2'			
	<i>Smphoricarpus alba</i> , Snowberry	3'			
Large Shrub	<i>Holodiscus discolor</i> , Western serviceberry	6'	1 gallon	4 feet	3
	<i>Rosa nutkana</i> , Nootka rose	8'			
	<i>Omleria cerasiformis</i> , Indian plum	6'			
	<i>Ribes sanguineum</i> , Red flowering currant	8'			
	<i>Ceanothus velutinus</i> , Snowbrush	6'			

**TABLE C-1: Approved Plant Lists for Vegetated Stormwater Facilities**

Plant Type	Plant Name <i>Botanical, common</i>	Potential Height	Size at Installation	Plant Spacing	# of Plants per 100 SF
<b>Dry, Zone B</b>					
Herbaceous	<i>Camassia quamash</i> , Camas lily	24"	4 inch	12 inch	115
	<i>Elymus glaucus</i> , Blue wild rye	24"			
	<i>Juncus patens</i> , Spreading rush	36"			
Small Shrub	<i>Cornus sericea 'Kelseyi'</i> , Kelsey dogwood	2'	1 gallon	2-3 feet	4
	<i>Mahonia aquifolium</i> , Oregon grape	5'			
	<i>Polystichum munitum</i> , Sword fern	2'			
	<i>Spiraea betulifolia</i> , Birchleaf spiraea	2'			
	<i>Smphoricarpus alba</i> , Snowberry	3'			
Large Shrub	<i>Holodiscus discolor</i> , Western serviceberry	6'	1 gallon	4 feet	3
	<i>Rosa nutkana</i> , Nootka rose	6'			
	<i>Ribes sanguineum</i> , Red flowering currant	8'			
	<i>Spiraea douglasii</i> , Douglas spiraea	7'			
	<i>Ceanothus velutinus</i> , Snowbrush	6'			
Tree	<i>Acer circinatum</i> , Vine maple	15'	1 inch caliper	10-20feet	1
	<i>Acer rubrum</i> , Red maple	40'			
	<i>Cornus nuttallii</i> , Pacific dogwood	20'			

## C.2.2 SEED MIXTURES

The seed mixtures outlined in Table C-2 shall be used to vegetate public stormwater facilities and may be used to vegetate or supplement vegetation for private stormwater facilities. Seed mixtures are specified by zone.

Per the seed mixes identified in Table C-2, the recommended seeding rate is 1 lb per 1,000 square feet for seed applications in the Dry, Zone B and Moist, Zone A. The recommended seeding rate is 0.5 lb per 1,000 square feet for seed applications in the Saturated, Zone S.



TABLE C-2: Seed Mixture Specifications

<b>Saturated, Zone S</b>			
<b>Saturated Zone: Mix 1</b>	<b>Botanical Name</b>	<b>Common Name</b>	<b>% by Weight</b>
	Carex obnupta	Slough Sedge	27.00%
	Carex microptera	Smallwing Sedge	25.00%
	Carex stipata	Awlfruit Sedge	29.50%
	Eleocharis palustris	Common Spikerush	15.00%
	Scirpus microcarpus	Panicled Bulrush	3.00%
	Juncus tenuis	Poverty Rush	0.50%
<b>Moist, Zone A</b>			
<b>Moist Zone: Mix 1</b>	<b>Botanical Name</b>	<b>Common Name</b>	<b>% by Weight</b>
	Elymus glaucus	Blue Wildrye	46.00%
	Festuca rubra rubra	Native Red Fescue	38.00%
	Deschampsia cespitosa	Tufted Hairgrass	12.00%
	Glyceria occidentalis	Western Mannagrass	2.00%
	Beckmania syzigachne	American Sloughgrass	2.00%
<b>Moist Zone: Mix 2</b>	<b>Botanical Name</b>	<b>Common Name</b>	<b>% by Weight</b>
	Elymus glaucus	Blue Wildrye	50.00%
	Festuca rubra rubra	Native Red Fescue	15.00%
	Hordeum brachyantherum	Meadow Barley	10.00%
	Glyceria occidentalis	Western Mannagrass	10.00%
	Beckmania syzigachne	American Sloughgrass	10.00%
	Deschampsia cespitosa	Tufted Hairgrass	5.00%
<b>Moist Zone: Mix 3</b>	<b>Botanical Name</b>	<b>Common Name</b>	<b>% by Weight</b>
	Hordeum brachyantherum	Meadow Barley	35.00%
	Glyceria occidentalis	Western Mannagrass	20.00%
	Festuca rubra rubra	Native Red Fescue	20.00%
	Alopecurus genicaultius	Water Foxtail	13.00%
	Eleocharis palustris	Common Spikerush	5.00%
	Beckmania syzigachne	American Sloughgrass	4.00%
	Deschampsia cespitosa	Tufted Hairgrass	2.50%
Agrostis exerata	Spike Bentgrass	0.50%	
<b>Dry, Zone B and Upland Landscaping Areas</b>			
<b>Dry Zone: Mix 1</b>	<b>Botanical Name</b>	<b>Common Name</b>	<b>% by Weight</b>
	Hordeum brachyantherum	Meadow Barley	40.00%
	Bromus carinatus	California Brome	35.00%
	Festuca rubra rubra	Native Red Fescue	20.00%
	Deschampsia cespitosa	Tufted Hairgrass	3.00%
	Agrostis exerata	Spike Bentgrass	2.00%

### C.2.3 SOIL AMENDMENT

Two inches (minimum) of well-rotted compost shall be tilled into the entire treatment area of biofiltration swales, filter strips, and all planted areas (including grass) of wet ponds and detention ponds to amend the topsoil unless the soil already has an organic content of 1 percent or greater. This applies to both till soils and sandy soils. In very

coarse soils (gravels or courser), topsoil must be imported and amended to the required organic content.

1. Compost must be tilled into the underlying native soil to a depth of 6 inches to prevent the compost from being washed out and to avoid creating a defined layer of different soil types that can prevent downward percolation of water.
2. Compost shall not contain any sawdust, straw, green or under-composted organic matter, or toxic or otherwise harmful materials.
3. Compost shall not contain unsterilized manure because it can leach fecal coliform bacteria into receiving waters.

Soil in which trees or shrubs are planted may require additional enrichment or additional compost top-dressing. Consult a nurseryman, landscape professional, or arborist for site-specific recommendations.

#### **C.2.4 PLANTING RESTRICTIONS**

Unless approved by City staff, planting restrictions are as follows:

- Trees shall not be planted within 10 feet of a sanitary sewer, storm drainage, water line, fire hydrant, public utility service, utility pole, or retaining walls or within 20 feet of a street light. Deep-rooting trees and shrubs with roots that seek water (e.g., willow) are prohibited in the City.
- Large trees or shrubs shall not be planted on berms over 4 feet tall that impound water. Small trees or shrubs with fibrous root systems may be installed on berms that impound water and are less than 4 feet tall.
- Evergreen trees and trees that produce relatively little leaf-fall, such as Oregon ash, mimosa, or locust, are preferred. To prevent leaf drop into the water, large-leaf deciduous trees may not be planted where branches could extend over the 100-year water surface of wet ponds or detention ponds.
- Trees are not allowed in biofiltration swales, filter strips, or detention ponds and are not recommended in lined facilities.

#### **C.3 INSTALLATION AND PLANT ESTABLISHMENT**

The following guidelines shall apply to the installation, maintenance, and monitoring of vegetation to ensure establishment.

##### **Installation**

Recommended installation time frames are as follows. Planting or seeding outside these time frames may require additional measures to ensure survival.

- Containerized stock: February 1 through May 1 and October 1 through November 15
- Bare root stock: December 15 through April 15
- Seeding: March 15 through October 15

##### **Irrigation**

Unless site hydrology is currently adequate, a water-efficient irrigation system shall be applied for at least the first 2 years after construction of the facility, particularly during the dry summer months. The applicant may choose to provide irrigation by truck or installed irrigation system. When practicable, an onsite irrigation system is recommended

to maintain plant survivability. Temporary irrigation systems will require their own service meter and backflow prevention device.

Temporary irrigation systems must be fully removed before the City releases the warranty security for public facilities.

### **Maintenance**

Typical maintenance practices include:

- Check regularly for weeds. Remove weeds, non-native or invasive plants such as blackberries and ivy, and implement a weed control program as needed.
- Check mulch regularly to maintain uniform coverage. Many vegetated stormwater management facilities specify a mulch cover such as river rock to prevent erosion and moisture loss during dry periods.
- Replant bare patches as necessary to comply with the facility's coverage requirements and maintenance plan.

For a full list of maintenance practices for each type of vegetated stormwater management facility, see Appendix B.

### **Inspections and Monitoring**

Facility inspections are necessary throughout the growing season to assess the status of the plantings, irrigation, mulching, etc. and ensure successful plant establishment.

Successful plant establishment is defined as:

- All plants are surviving and have vigorous growth
- Plants are free of insects and disease
- Plants show signs of continuing health
- Plants have not reached permanent wilting point

### **Plant Replacement and Preservation**

Upon inspection, vegetation not in a healthy growing condition shall be noted and, as soon as seasonal conditions permit, shall be removed from the site and replaced with plants of the same species and size as originally specified.

For public facilities, at the end of the 2-year warranty period, all plants not in a healthy growing condition shall be removed from the site and seeded as originally specified. Prior to replacement, the cause of loss (wildlife damage, poor plant stock, etc.) shall be documented with a description of the corrective actions taken.

## **C.4 LANDSCAPE PLAN**

All vegetated stormwater management facilities shall have a Landscape Plan prepared, stamped, and signed by a Landscape Architect or Professional Engineer.

In addition to the typical plan information (north arrow, scale bar, property boundaries, project name, drawing date, name of designer, and property owner), the landscape plan and associated construction documents and specifications shall include:

1. Natural feature boundaries (if applicable). Temporary fencing shall be noted at buffer boundaries as well as at encroachment limits during construction.
2. Site preparation plan and specifications, including limits of clearing, existing plants and trees to be preserved, and methods for removal and control of invasive, non-

native species, and location and depth of topsoil and/or compost to be added to planting area.

3. Planting plan and specifications, including all of the following:
  - a. Planting table that documents the common name, scientific name, distribution (zone and spacing), condition, and size of plantings
  - b. Installation methods for plant materials
  - c. Mulching
  - d. Plant tagging for identification
  - e. Plant protection
  - f. Seeding mix, methods, rates, and areas
4. Irrigation plan and specifications, including identification of water source and maintenance of the system.
5. Maintenance schedule (see Section C.2.3 and Appendix B).
6. Access points for installation and maintenance including vehicle access if required.

## **Appendix D: Infiltration Testing Procedures**

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## **D. INFILTRATION TESTING**

The following sections provide the approved standard infiltration testing specifications. City staff reserve the right to require additional testing.

### **D.1 METHODS AND REQUIREMENTS**

To properly size and locate infiltration-based stormwater management facilities, it is necessary to characterize the soil infiltration conditions at the location of the proposed facility. All projects that require an infiltration-based stormwater management facility shall evaluate existing site conditions and determine if the site's infiltration rate is adequate to support the proposed stormwater management facility.

#### **D.1.1 APPLICABILITY**

Infiltration testing is required for all development projects that create more than 5,000 square feet of new or replaced impervious surface and are proposing the use of infiltration as a primary method of stormwater management (i.e., projects that will use infiltration swales, infiltration ponds, porous pavement, or other infiltration-based alternative facility not specifically referenced in this manual).

The City has approved two methods for performing an infiltration test, the Basic Test and the Professional Test method. For sites with greater than 10,000 square feet of new or replaced impervious surface or sites where infiltration-based stormwater management facilities will be used to meet detention requirements, the Professional Test requirements apply. Sites with less than 10,000 square feet of impervious surface that are proposing infiltration-based stormwater management facilities for water quality treatment only can follow either the Basic Test or Professional Test methodology.

#### **D.1.2 TESTING CRITERIA**

1. Testing shall be conducted or observed by a qualified professional. This professional may include a licensed Professional Engineer (PE), Registered Geologist (RG), or Certified Engineering Geologist (CEG) licensed in the state of Oregon.
2. The location and depth of the test shall correspond to the facility location and depth.
3. Infiltration testing should not be conducted in engineered or undocumented fill.
4. Boring logs shall be provided as supporting information with infiltration and depth to groundwater tests.

#### **D.1.3 DEPTH AND LOCATION OF REQUIRED TESTS**

Infiltration tests shall be performed at the base of the proposed facility.

If a confining layer, or soil with a greater percentage of fines, is observed during the subsurface investigation to be within 4 feet of the bottom of the planned infiltration system, the testing shall be conducted within that confining layer.

Tests shall be performed in the immediate vicinity of the proposed facility. Exceptions can be made to the test location if the qualified professional can support that the strata are consistent from the proposed facility to the test location.

For relatively deep stormwater facilities, a hollow-stem auger with an electronic measuring tape can be used if there is an adequate seal between the auger and the native soil.

#### D.1.4 MINIMUM NUMBER OF REQUIRED TESTS

The following standards shall be used to determine the minimum number of required infiltration testing locations:

- At least one test will be conducted for any proposed facility located in the public ROW or on a private street.
- One test will be conducted for every 100 lineal feet or 1,000 square feet of proposed infiltration facility.
- The total number of tests, as long as they meet the minimum requirement, is at the discretion of the qualified professional assessing the site, as well as the City.
- Where multiple types of facilities are used, it is likely that multiple tests will be necessary, because an infiltration test can test only a single soil stratum. It is highly recommended to conduct an infiltration test at each stratum used.

#### D.1.5 FACTORS OF SAFETY

Table D-1 lists the minimum required factors of safety applied to field-obtained infiltration rates for use in stormwater system design. To obtain the infiltration rate used in design, divide the infiltration rate measured in the field by the factor of safety. The factor of safety used in design should be chosen by collaboration between the geotechnical engineer or geologist overseeing the infiltration testing and the civil engineer designing the stormwater management facility. Determination of the factor of safety shall include consideration of project-specific conditions such as soil variability, testing methods, consequences of system failure, complexity of proposed construction, and other pertinent conditions. The maximum design infiltration rate is 20 inches per hour.

**Table D-1. Infiltration Rate Factors of Safety**

Test method	Minimum required factor of safety
Encased falling head	3
Open-pit (infiltration and falling head)	2
Double-ring infiltrometer	Public facilities: 1

## D.2 BASIC TEST: OPEN-PIT INFILTRATION

The intent of the Open-Pit Infiltration test is to determine whether the local infiltration rate is adequate (0.5 inch/hour or more). The Open Pit Infiltration test does not need to be conducted by a licensed professional, but it is recommended.

### D.2.1 BASIC TEST INSTRUCTIONS

1. The open-pit infiltration test should be conducted where the facility is proposed or within the direct vicinity.
2. Excavate a test hole to the depth of the bottom of the infiltration system, or otherwise to 4 feet. The test hole can be excavated with small excavation equipment or by hand using a shovel, auger, or posthole digger.



3. If a layer hard enough to prevent further excavation is encountered, or if noticeable moisture/water is encountered in the soil, stop and measure this depth from the surface and record it. Proceed with the test at this depth.
4. Fill the hole with water to a height of about 6 inches from the bottom of the hole (or to one-half the maximum depth of the proposed facility), and record the exact time. Check the water level at regular intervals (every 1 minute for fast-draining soils to every 10 minutes for slower-draining soils) for a minimum of 1 hour or until all of the water has infiltrated. Record the distance the water has dropped from the top edge of the hole.
5. Repeat this process two more times, for a total of three rounds of testing. These tests should be performed as close together as possible to portray the soil's ability to infiltrate at different levels of saturation accurately. The third test provides the best measure of the saturated infiltration rate.
6. For each test pit required, submit all three testing results with the date, duration, drop in water height, and conversion into inches per hour.
7. If the results of the Basic Test show an infiltration rate greater than 0.5 inch per hour, the applicant can proceed with facility design (where applicable). If the applicant would like to use an infiltration rate for design purposes, a Professional Test methodology shall be followed.

### **D.3 PROFESSIONAL TEST**

The Professional Test methods must be used for all public and private developments where the Basic Test is not applicable. The qualified professional must exercise judgment in the selection of the appropriate infiltration test method. The three available Professional Test methods to determine a design infiltration rate are:

- Open-pit falling head
- Encased falling head
- Double-ring infiltrometer

#### **D.3.1 OPEN-PIT FALLING HEAD PROCEDURE**

The open-pit falling head procedure is based on the U.S. Environmental Protection Agency (USEPA) Falling Head Percolation Test Procedure (Onsite Wastewater Treatment and Disposal Systems Design Manual, EPA/625/1-80-012, 1980). The test is performed in an open excavation and therefore is a test of the combination of vertical and lateral infiltration.

1. Excavate an approximately 2-by-2-foot-wide hole into the native soil to the elevation of the proposed facility bottom (see Figure D-1). The test can be conducted in a machine-excavated pit or a hand-dug pit using a shovel, posthole digger, or hand auger. If smooth auguring tools or a smooth excavation bucket is used, scratch the sides and bottom of the hole with a sharp-pointed instrument, and remove the loose material from the bottom of the test hole.
2. A 2-inch layer of coarse sand or fine gravel may be placed to protect the bottom from scour and sloughing.

3. Fill the hole with clean water a minimum of 1 foot above the soil to be tested, and maintain this depth of water for at least 4 hours (or overnight if clay soils are present) to presoak the native material.
4. Percolation rate measurements shall be made after 15 hours and no more than 30 hours after the soaking period begins. It is important that the soil be allowed to soak for a sufficiently long period of time to allow the soil to swell if accurate results are to be obtained. Any soil that sloughed into the hole during the soaking period shall be removed and the water level shall be adjusted to 6 inches above the added gravel (or 8 inches above the bottom of the hole).
5. In sandy soils with little or no clay, soaking is not necessary. If, after filling the hole twice with 12 inches of water, the water seeps completely away in less than 10 minutes, the test can proceed immediately.
6. The measurements should be made with reference to a fixed point. A lath placed in the test pit prior to filling or a sturdy beam across the top of the pit are convenient reference points. The tester and excavator should conduct all testing in accordance with Occupational Safety and Health Administration (OSHA) regulations.
7. Measure the water level to the nearest 0.01 foot (1/8 inch) at 10-minute intervals for a total period of 1 hour (or 20-minute intervals for 2 hours in slower soils) or until all of the water has drained. At no time during the test is the water level allowed to rise more than 6 inches above the sand or gravel.
8. Successive trials shall be run until the measured infiltration rate between two successive trials does not vary by more than 5 percent. At least three trials shall be conducted. After each trial, the water level is readjusted to the 12-inch level. Enter results into the Infiltration Test Data Table (see Figure D-2).
9. The results of the last water level drop are used to calculate the tested infiltration rate. The final rate shall be reported in inches per hour. See the calculation following Figure D-2.
10. For very rapidly draining soils, it may not be possible to maintain a water head above the bottom of the test pit. If the infiltration rate meets or exceeds the flow of water into the test pit, conduct the test in the following manner:
  - a. Approximate the area over which the water is infiltrating.
  - b. Using a water meter, bucket, or other device, measure the rate of water discharging into the test pit.
  - c. Calculate the infiltration rate by dividing the rate of discharge (cubic inches per hour) by the area over which it is infiltrating (square inches).
11. Upon completion of the testing, the excavation shall be backfilled.

### **D.3.2 ENCASED FALLING HEAD PROCEDURE**

The encased falling head procedure is based on a modification of the USEPA Falling Head Percolation Test Procedure (Onsite Wastewater Treatment and Disposal Systems Design Manual, EPA/625/1-80-012, 1980). The most significant modification is that this test is performed with a 6-inch casing that is embedded approximately 6 inches into the native soil. The goal of this field test is to evaluate the vertical infiltration rate through a 6-inch plug of soil, without allowing any lateral infiltration. The test is not appropriate in gravelly soils or in other soils where a good seal with the casing cannot be established.

1. Embed a solid 6-inch-diameter casing into the native soil at the elevation of the proposed facility bottom (see Figure D-1). Ensure that the embedment provides a good seal around the pipe casing so that percolation will be limited to the 6-inch plug of the material within the casing. This method can also be applied to testing within hollow-stem augers if the driller and tester are reasonably certain that a good seal has been achieved between the soil and auger.
2. A 2-inch layer of coarse sand or fine gravel may be placed to protect the bottom from scour and sloughing.
3. Fill the pipe with clean water a minimum of 1 foot above the soil to be tested, and maintain this depth for at least 4 hours (or overnight if clay soils are present) to presoak the native material.
  - a. Take percolation rate measurements after 15 hours and no more than 30 hours after the soaking period begins. It is important that the soil be allowed to soak for a sufficiently long period of time to allow the soil to swell to obtain accurate results. Any soil that sloughed into the hole during the soaking period shall be removed and the water level shall be adjusted to 6 inches above the added gravel (or 8 inches above the bottom of the hole).
  - b. In sandy soils with little or no clay, soaking is not necessary. If, after filling the hole twice with 12 inches of water, the water seeps completely away in less than 10 minutes, the test can proceed immediately.
4. To conduct the first trial of the test, fill the pipe to approximately 6 inches above the soil and measure the water level to the nearest 0.01 foot (1/8 inch). The level should be measured with a tape or other device with reference to a fixed point. The top of the pipe is often a convenient reference point. Record the exact time.
5. Measure the water level to the nearest 0.01 foot (1/8 inch) at 10-minute intervals for a total period of 1 hour (or 20-minute intervals for 2 hours in slower soils) or until all of the water has drained. The infiltration test is continued until the measured infiltration rate between two successive trials does not vary by more than 5 percent. At least three trials shall be conducted. After each trial, the water level is readjusted to the 6-inch level. Enter results into the Infiltration Rate Data Table (see Figure D-2). At no time during the test is the water level allowed to rise more than 6 inches above the gravel.
6. The result of the last water level drop is used to calculate the tested infiltration rate. The final rate shall be reported in inches per hour.
7. Upon completion of the testing, the casings shall be immediately pulled, and the test pit shall be backfilled.

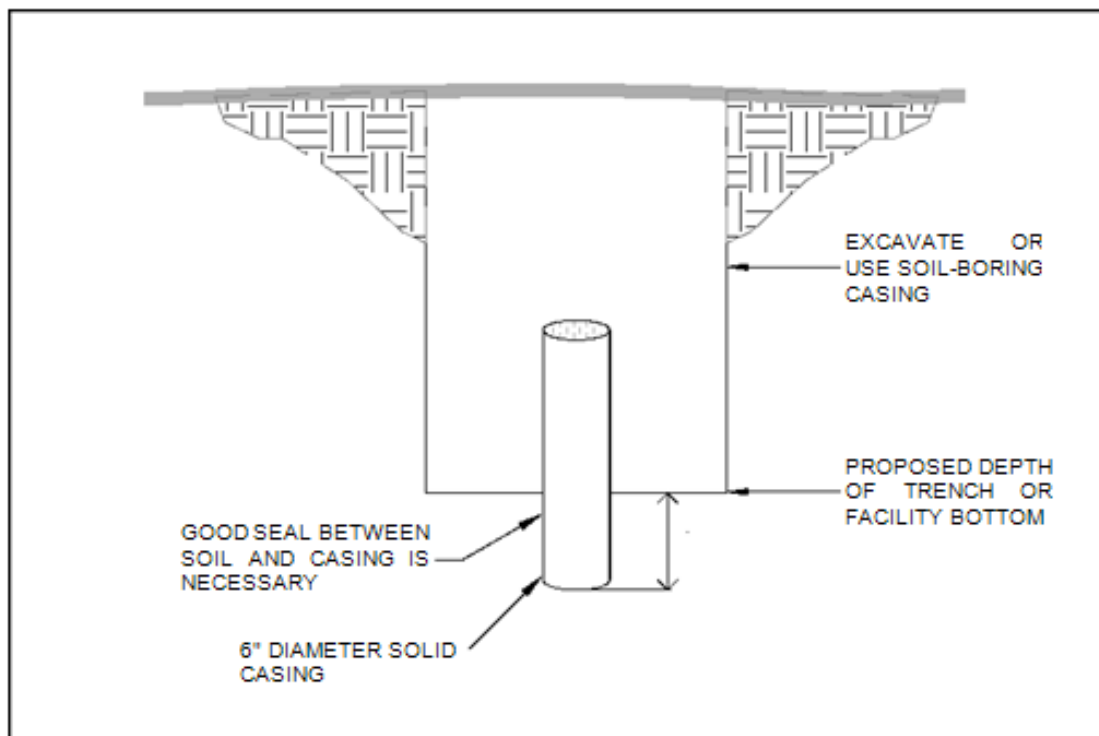


Figure D-1. Encased Falling Head Procedure

### D.3.3 DOUBLE-RING INFILTRMETER PROCEDURE

The double-ring infiltrometer test procedure shall conform with American Society for Testing and Materials (ASTM) 3385-94. The test is performed within two concentric casings embedded and sealed to the native soils. The outer ring maintains a volume of water to diminish the potential of lateral infiltration through the center casing. The volume of water added to the center ring to maintain a static water level is used to calculate the infiltration rate. The double-ring infiltrometer is appropriate only in soils where an adequate seal can be established.

The double-ring infiltrometer test may be difficult to perform where the tested soil strata are in a pit, because careful regulation of the static volumes is necessary.

## D.4 REPORTING REQUIREMENTS

All testing data shall be documented with the project submittals. The submittals shall adequately demonstrate that the proposed facilities (1) are appropriate to the assessment and characterization of the site, (2) will work, based on in situ infiltration tests, and (3) are sized appropriately, based on design infiltration rates.

The following information should be included in the infiltration testing documentation:

1. Infiltration results in inches per hour.
2. Location and depth of excavation. The excavation should be deep enough to verify that there is a 5-foot separation between the final depth of the facility (rock gallery) and the seasonal high groundwater or soil layer that could reduce the infiltration rate.

3. Summary and discussion of infiltration testing, including number of tests, amounts of water used in each test (inches, gallons, etc.), and time of each test. Testing is required to show that an accurate rate was achieved.
4. Discussion of how the test was performed:
  - a. Encased falling head: pipe type, embedment depth, size of pipe
  - b. Double-ring infiltrometer: pipe type, embedment depth, size of pipe
  - c. Open pit: size of area
5. Soil types with depth
6. Groundwater observations: seasonal high groundwater level estimation

Location:		Date:		Test Hole Number:	
Depth to bottom of hole:		Diameter of hole:		Test Method:	
Tester's Name: _____					
Tester's Company: _____ Tester's Contact Number: _____					
Depth, feet			Soil Texture		
Time	Time interval, minutes	Measurement, feet	Drop in water level, feet	Percolation rate, inches per hour	Remarks

**Figure D-2. Infiltration Test Data Table**

Calculation is performed for each water level drop  
 = (Drop in water level/Time interval) x conversion  
 = 0.055 ft/20 min x (12 in./ft) x (60 min/hr)  
 = 1.98 inches per hour

The design infiltration rate of two successive trials shall have a difference of 5% or less.

Figure D-3 shows an example of a completed infiltration test data table.

Location: Lot 105, Low Point Heights Subdivision		Date: 6/28/2010		Test Hole Number: 3	
Depth to bottom of hole: 57 inches		Diameter of hole: 0.5 foot		Test Method: Encased Falling Head	
Tester's Name: <u>C.J. Tester</u>					
Tester's Company: <u>Tester Company</u> Tester's Contact Number: <u>555-1212</u>					
Depth, feet			Soil Texture		
0-0.5			Black topsoil		
0.5-1.0			Brown SM		
1.0-2.2			Brown ML		
2.2-5.1			Brown CL		
Time	Time interval, minutes	Measurement, feet	Drop in water level, feet	Percolation rate, inches per hour	Remarks
9:00	0	3.75	-		Filled with 6"
9:20	20	3.83	0.08		
9:40	20	3.91	0.08	2.88	
10:00	20	3.98	0.07	2.52	
10:20	20	4.04	0.06	2.16	
10:40	20	4.11	0.07	2.52	
11:00	20	4.17	0.06	2.16	
11:20	20	4.225	0.055	1.98	
					Adjusted to 6" level for Trial 2

Figure D-3. Infiltration Test Data Table Example