CHAPTER 6 – WATER QUALITY TREATMENT DESIGN

Chapter Organization

6.1 INTRODUCTION

Water quality treatment facilities are designed to remove pollutants contained in stormwater runoff. The pollutants of concern include sand, silt, and other suspended solids; metals such as copper, lead and zinc; nutrients such as nitrogen and phosphorus; certain bacteria and viruses; and organics such as petroleum hydrocarbons and pesticides. Methods of pollutant removal include sedimentation/settling, filtration, plant uptake, ion exchange, adsorption, and organic and inorganic decomposition. Floatable pollutants such as oil and debris can be removed with separator structures.

Many treatment facilities, if designed correctly, can function as both a water quality treatment facility and a flow control facility. This chapter describes design criteria for water quality treatment and Chapter 7 provides design criteria for flow control.

All engineering work for water quality treatment facilities shall be performed by, or under the direction of, a professional engineer currently licensed in the State of Washington.

6.2 PROTECTION OF AQUIFER WATER QUALITY

The Spokane Valley-Rathdrum Prairie aquifer extends across an area of about 325 square miles and provides drinking water for more than 500,000 people. Most of the developed areas in the Spokane region and in North Idaho lie directly over the aquifer. The aquifer is designated by the U.S. EPA as a “sole source aquifer” because it is the only feasible source of drinking water available to the local community. The following sections describe state and local measures adopted to protect the quality of water in the aquifer.

6.2.1 AQUIFER SENSITIVE AREA

Groundwater recharge areas have critical impacts on aquifers used for potable water, as defined by WAC 365-190-030 (2). The City of Spokane is subject to regulations governing the Aquifer Sensitive Area (ASA), delineated in Figure 6-1. Under these regulations, any project within the City of Spokane is required to provide treatment for all stormwater runoff from pollution generating impervious surfaces. In urban areas, bio-infiltration swales are the expected BMP for providing basic treatment.

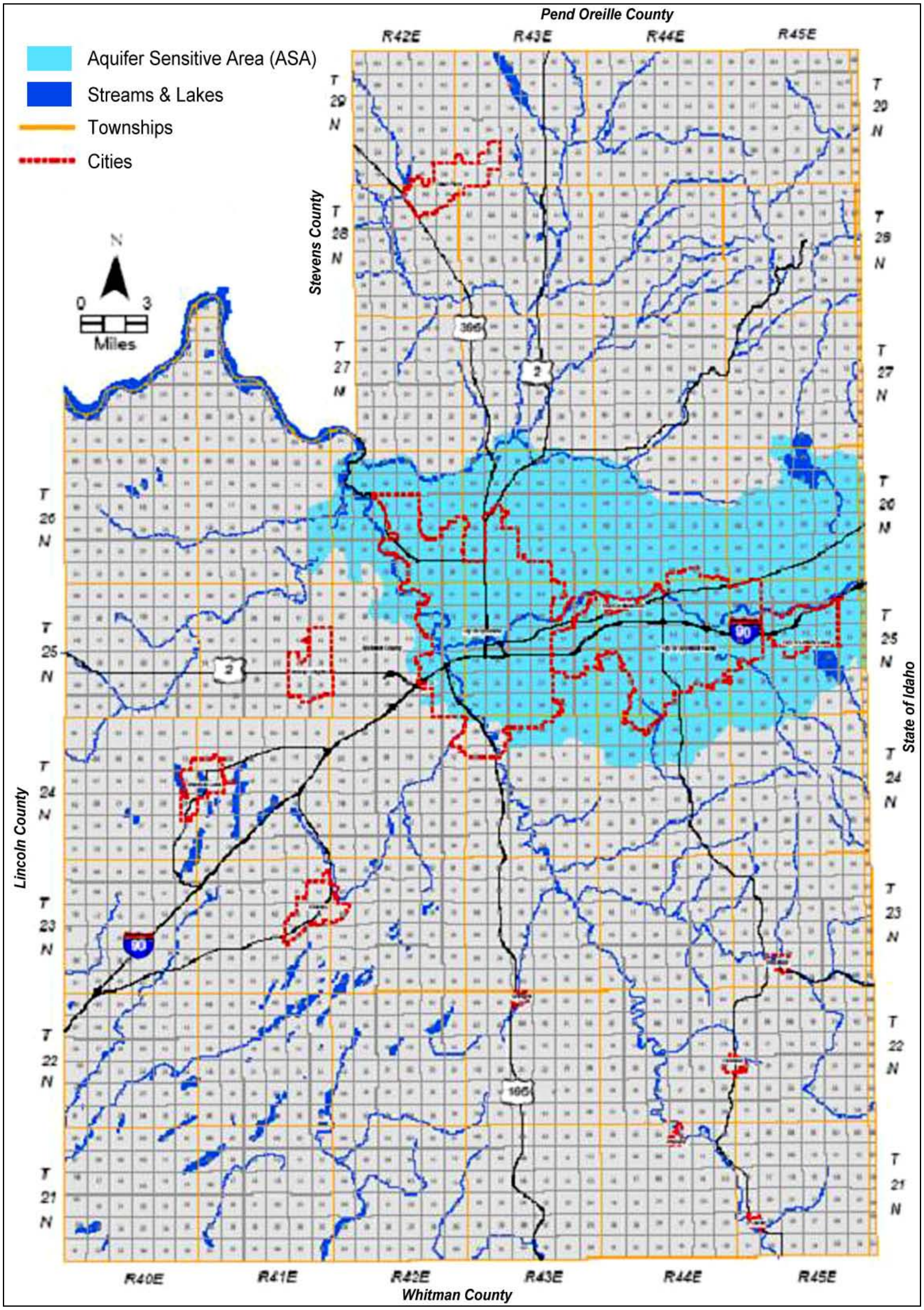


Figure 6-1 – Aquifer Sensitive Area (ASA)

6.2.2 CRITICAL AQUIFER RECHARGE AREAS

Spokane County and the City of Spokane Valley have designated the Critical Aquifer Recharge Areas (CARA) shown in Figure 6-2; this figure is also available on the Spokane County website:

- http://www.spokanecounty.org/BP/GISmaps/CARA/cara17.pdf

CARAs have prevailing geologic conditions associated with infiltration rates that create a high potential for contamination of groundwater resources, and they contribute significantly to the replenishment of groundwater.

The CARA resolution adopted by Spokane County requires that special consideration be given to stormwater runoff from areas with commercial and industrial development where chemical spills are more likely to occur. Specific potential problem areas include outdoor loading docks, fueling stations, and those activities involving toxic and hazardous materials handling.

For all land development in unincorporated areas of Spokane County and the City of Spokane Valley, the requirements of this regulation supersede those that govern the ASA. The incorporated areas of Spokane County, including the City of Spokane, are still subject to the requirements of the ASA. In addition, the entire Spokane region is subject to the Department of Ecology's Underground Injection Control (UIC) regulations (refer to Section 1.4.1).

Aquifer recharge areas are rated as having a high, moderate, or low susceptibility for contamination based on a scientific analysis of soils, hydraulic conductivity, annual rainfall, depth to the aquifer, vadose zone, and wellhead protection information. Wellhead protection areas approved by the Department of Health (DOH) and areas within a 1,000-foot radius of Group A and B wells without reported plans are treated as high susceptibility areas. Due to the numerous well-head capture zones found in Township 26 North, Range 43 East, and the difficulty associated with determining the exact "on-the-ground" locations of these protected zones on the CARA map, projects located within T26N, R43E are also subject to the requirements of high susceptibility areas (with the exception of the low susceptibility area located in the northeast corner of T26N, R43E).

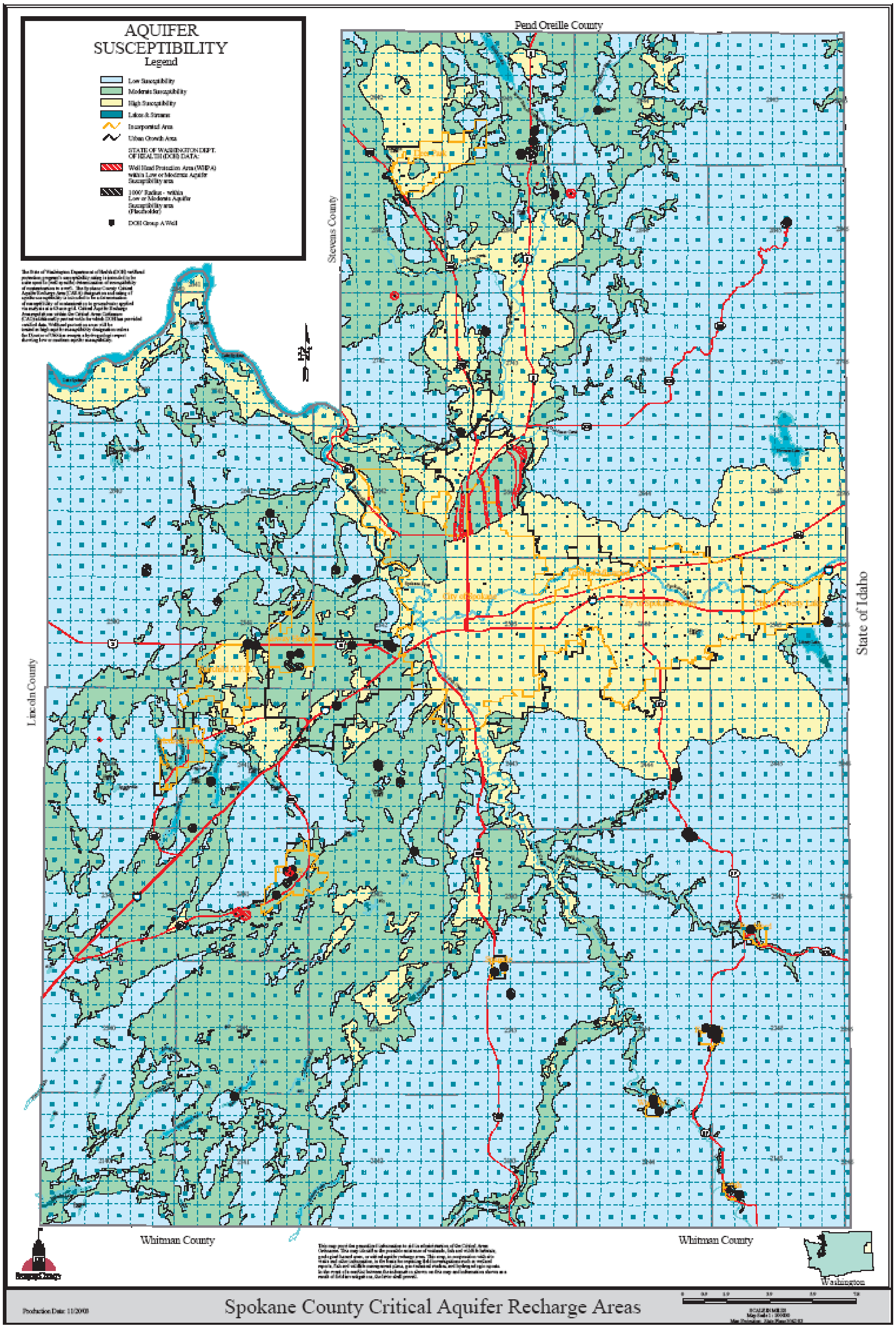


Figure 6-2 – Spokane County Critical Aquifer Recharge Areas

6.3 UIC FACILITIES

A UIC facility is a constructed subsurface infiltration system consisting of an assemblage of perforated pipes, drain tiles, or similar mechanisms intended to infiltrate fluids into the ground or a dug hole that is deeper than the largest surface dimension (WAC 173-218-030). Subsurface infiltration systems include drywells, pipe or French drains, drain fields, and similar devices that are designed to discharge stormwater directly into the ground. The following are not UIC facilities:

- Storm drain pipe systems that collect stormwater runoff and convey it to a disposal or treatment facility;
- Surface infiltration basins and flow dispersion stormwater infiltration facilities;
- Infiltration trenches designed without perforated pipe or a similar mechanism; or
- Storm drain components that contain perforated pipes, drain tiles, or other similar mechanism designed and intended to convey water directly or indirectly to a surface water body.

For discharge to UIC facilities, site BMPs must be chosen that will remove or reduce target pollutants to levels that comply with state groundwater quality standards when the discharge reaches the water table or first comes into contact with an aquifer (see WAC 173-200). Discharges to surface waters shall comply with WAC 173-201A, Water Quality Standards for Surface Waters of the State of Washington. Ecology's *Guidance for UIC Wells that Manage Stormwater* provides additional information.

6.3.1 LIMITATIONS ON THE USE OF UIC FACILITIES

Some water quality treatment BMPs presented in this chapter are not considered protective of groundwater for certain land uses. Because of the potential to contaminate groundwater, stormwater runoff shall not be discharged directly to UIC facilities from areas used for any of the following activities:

- Vehicle maintenance, repair and servicing;
- Commercial or fleet vehicle washing;
- Airport de-icing;
- Storage of treated lumber;
- Storage or handling of hazardous materials;
- Generation, storage, transfer, treatment or disposal of hazardous wastes;
- Handling of radioactive materials;
- Recycling (unless limited to glass products); and,

- Industrial or commercial areas without management plans for proper storage and spill prevention, control, and containment appropriate to the types of materials handled at the facility (refer to Ecology's *Stormwater Management Manual for Eastern Washington* for more information on stormwater pollution prevention plans and source control).

Stormwater runoff from these areas shall be handled on site with a closed-loop system or discharged to the sanitary sewer if allowed by the local jurisdiction. Stormwater from any portions of a site that do not contact the areas listed, such as roofs and parking areas, may be discharged to drywells, assuming that pre-treatment has been provided in accordance with the requirements presented in this chapter.

6.3.2 DRYWELL REGISTRATION

Drywells shall be registered with Ecology. The registration provides Ecology information to determine if a drywell is rule-authorized. Chapter 173-218 WAC lists the submittal requirements. Registration forms can be found on Ecology's UIC Program website.

A UIC facility may be rule-authorized when both of the following requirements are met:

- A registration form is submitted to Ecology; and,
- Discharge from the UIC facility does not contaminate groundwater.

Residential UIC facilities used for roof runoff or basement flood control automatically meet the non-endangerment standard and are considered rule-authorized; they are thus exempt from registering.

The project proponent should begin the registration process during the design phase and submit the completed paperwork prior to first use of the UIC facility.

6.4 POLLUTANT GENERATING IMPERVIOUS SURFACE AREAS

Pollutant generating impervious surface (PGIS) areas are significant sources of pollutants in stormwater runoff. These areas include surfaces subject to vehicular use, industrial activities, or storage of erodible or leachable materials that receive direct rainfall. A surface, whether paved or not, shall be considered a PGIS area if it is regularly used by motor vehicles. The following are considered PGIS areas: roads, unvegetated road shoulders, bike lanes within the traveled lane of a roadway, driveways, hydraulically connected sidewalks, parking lots, some roofs, fire lanes, vehicular equipment storage yards and airport runways.

Commercial roof runoff shall be pre-treated prior discharge to a UIC facility unless the project proponent, or his authorized agent, demonstrates that the runoff from the roof is not a waste fluid under WAC 173-218. Stormwater runoff is considered a waste fluid when discharged from the following:

- Metal roofs, unless coated with an inert, non-leachable material; or,
- Roofs subject to venting or manufacturing, commercial or other indoor pollutants (such as restaurants where oils or other solid particles are expelled due to cooking, processing, etc.); or,
- Asphalt-based roofs; or,
- Any roof area having electrical or mechanical equipment that is not hydraulically isolated from the remainder of the roof.

Some PGIS areas have additional requirements, as described in the following sections.

6.4.1 HIGH-USE SITES

High-use sites generate high concentrations of oil due to high traffic or the frequent transfer of petroleum products. High-use sites are land uses where sufficient quantities of free oil are likely to be present.

The following high-use sites require oil separator technology:

- A commercial or industrial site storing or transferring petroleum, not including locations where heating fuel is routinely delivered to end users;
- A commercial or industrial site subject to use, storage, or maintenance of a fleet of 25 or more vehicles that are over 10 tons gross weight;
- Fueling stations and facilities;
- Maintenance and repair facilities for vehicles, aircraft, construction equipment, railroad equipment or industrial machinery and equipment;
- Railroad yards, and,
- High-density road intersections with expected ADT count equal to or greater than 25,000 on the main roadway and equal to or greater than 15,000 on any intersecting roadway.

For the above sites, oil separator technology is defined as removing the oil from the stormwater inflow in a step separate from any other pollutant removal via BMPs such as a coalescing plate or baffle-type oil control mechanism. This typically involves a “treatment train” of two BMPs in series in order to meet the treatment goals of pollutants other than oil.

The following high-use sites are subject to oil control, but are only required to employ sorptive technologies (such as swales) that physically or chemically bind the pollutants to sediment organic particles:

- A commercial or industrial site with an expected trip end count equal to or greater than 100 vehicles per 1,000 square feet of gross building area;
- A parking lot with an expected trip end count equal to or greater than 300 vehicles;
- Commercial on-street parking areas located on streets with an expected total ADT count equal or greater than 7,500; and,
- Outdoor storage yards and other sites subject to frequent use or storage of forklifts or other hydraulic equipment.

6.4.2 HIGH-ADT SITES

The following are high-ADT sites and require oil separator technology:

- Non-employee parking areas of commercial or industrial sites with trip end counts greater than 100 vehicles per 1,000 square feet gross building area or greater than 300 total trip ends, and,
- Any road or parking area with an expected ADT count equal to or greater than 30,000 (assumes a straight stretch of road, where intersecting ADTs are low).

For the above sites, oil separator technology is defined as removing the oil from the stormwater inflow in a step separate from any other pollutant removal via BMPs such as a coalescing plate or baffle-type oil control mechanism. This typically involves a “treatment train” of two BMPs in series in order to meet the treatment goals of pollutants other than oil.

6.4.3 MODERATE-USE SITES

Moderate-use sites are defined as moderate-ADT roadways and parking areas; primary access points for high-density residential apartments; most intersections controlled by traffic signals; and transit center stops. The following land uses are moderate-use sites:

- Urban roads with expected ADT between 7,500 and 30,000;
- Rural roads or freeways with expected ADT between 15,000 and 30,000; and,
- Parking areas with 40 to 100 trip ends per 1,000 square feet of gross building area, or between 100 and 300 trip ends.

6.5 TREATMENT GOALS

The goal for water quality treatment facilities is to treat approximately 90% of the annual runoff volume generated at a project site. Facilities that are designed according to the criteria set forth in this chapter should also capture and treat nearly all of the runoff from first flush events (heavy rainfall after a dry period). In urban areas, bio-infiltration swales are the expected BMP for providing basic treatment. The following subsections describe the key pollutants of concern.

6.5.1 TOTAL SUSPENDED SOLIDS (TSS)

Basic treatment facilities presented in this chapter are intended to achieve 80% removal of suspended solids, including solid components of metals, for flows with TSS concentrations ranging from 100 mg/L to 200 mg/L. The following BMPs have been found to provide a significant removal process for TSS:

- Bio-infiltration swales;
- Biofiltration channels;
- Vegetated buffer strips;
- Evaporation ponds.

6.5.2 TOTAL PETROLEUM HYDROCARBONS (TPH)

The oil control facilities presented in this chapter are intended to achieve the goal of removing any visible sheen and reducing the TPH concentration to a maximum of 10 mg/L for a 24-hour average and a maximum of 15 mg/L for a discrete sample. The following BMPs provide removal of TPH:

- Significant removal for high-use and high-ADT sites:
  - Bio-infiltration swales;
  - Oil/water separators (coalescing plate and baffle type);
  - Vegetated buffer strips (for High-ADT sites only); and,
  - Evaporation ponds designed using the Alternative Method (refer to Section 5.7.2)
- Significant removal for all sites except high-ADT sites:
  - Oil/water separators (spill control type).
- Lesser removal (this BMP shall not be used for high-use or high-ADT sites unless preceded by an oil/water separator):
  - Biofiltration channels.

6.5.3 METALS TREATMENT

Metals treatment facilities presented in this chapter are intended to achieve approximately 50% removal of dissolved metals. The following BMPs have been found to provide removal for metals:

- Significant removal:
  - Bio-infiltration swales; and,
  - Evaporation ponds designed using the Alternative Method (refer to Section 5.7.2)
- Lesser removal (this BMP shall not be used for high-use or high-ADT sites without being preceded by another treatment BMP)
  - Biofiltration channels.

6.5.4 PHOSPHOROUS TREATMENT

The phosphorus treatment facilities are intended to achieve a goal of 50% total phosphorus removal for a range of influent concentrations from 0.1 to 0.5 mg/L of total phosphorus. Bio-infiltration swales are the only BMP presented here that have been found to meet this removal goal for phosphorus. The following BMPs have been found to provide a lesser removal of phosphorus and shall only be used for phosphorus removal in combination with some other basic treatment BMP:

- Biofiltration channels;
- Vegetated buffer strips; and,
- Evaporation ponds designed using the Alternative Method (refer to Section 5.7.2)

6.6 APPLICABILITY

The exemptions listed in the sections below are superseded by requirements set forth in any applicable Total Maximum Daily Load (TMDL) or other water cleanup plan. At the time of the writing of this Manual, no TMDLs exist for water bodies in Spokane County. Contact the local jurisdiction for current information on whether any TMDLs have been issued.

6.6.1 BASIC TREATMENT

Applicability

Basic treatment provides removal of total suspended solids (TSS) and is required for all projects proposing UIC facilities that are:

- Located within the moderate or high susceptibility areas of the CARA;
- Located within Township 26 North Range 43 East (excluding the delineated low susceptibility areas isolated in the northeast corner of this Township and Range);
- Located within a 1,000-foot radius of Group A and Group B wells without reported plans;
- Located within a DOH-approved wellhead protection area;
- Proposing a moderate-use, high-use or high ADT site and located in the low or moderate susceptible areas of the CARA;
- Located within the ASA boundaries; or
- Located within the City of Spokane.

Basic treatment is also required for all projects:

- Meeting the regulatory threshold and discharging to waters of the state, including perennial and seasonal streams, lakes and wetlands;
- Requiring a 401 Water Quality Certification; or,
- Regulated to provide water quality treatment under other rules outside of Phase II jurisdictions.

Exemptions

Basic treatment is not required for:

- Non-pollutant generating impervious surface (NPGIS) areas unless the runoff from these areas is hydraulically connected to PGIS areas;
- Projects that discharge to the subsurface and are located within the low susceptibility areas of the CARA and are not proposing moderate-use, high-use, or high-ADT sites; or,
- Projects discharging non-waste fluids from roofs (WAC 173-218) directly to drywells.

6.6.2 OIL CONTROL

Applicability

All projects that meet the regulatory threshold and are high-use or high-ADT areas are required to provide oil control. High-use sites generate high concentrations of petroleum hydrocarbons due to high traffic turnover or the frequent transfer of oil and/or other petroleum products.

High-use sites and high-ADT roadways and parking areas shall treat runoff from the high-use portion of the site prior to discharge or infiltration. For high-use sites located within a larger project area, only the impervious area associated with the high-use site is subject to oil control treatment, as long as the flow from that area is separated; otherwise the treatment controls shall be sized for the entire area.

Refer to Section 6.7.4 for information used to determine the appropriate oil control technology.

Exemptions

Non-high-use sites and non-high ADT sites are exempt from oil treatment requirements.

6.6.3 METALS TREATMENT

Applicability

Metals treatment is required for all projects that are moderate- or high-use sites, and for sites that discharge to a surface water or UIC facility and meet any of the following definitions:

- Industrial sites as defined by the EPA (40 CFR 122.26(b)(14)) with benchmark monitoring requirements for metals;
- Industrial sites that handle, store, produce, or dispose of metallic products or other materials, particularly those containing arsenic, cadmium, chromium, copper, lead, mercury, nickel or zinc;
- High-use or high-ADT roadways or parking areas;
- Urban roads with expected ADT greater than 7,500;
- Rural roads or freeways with expected ADT greater than 15,000;
- Commercial or industrial sites with an equivalent trip end (ETE) count equal to or greater than 40 vehicles per 1,000 square feet of gross building area;

- Parking lots with 100 ETE or more;
- Public on-street parking areas in commercial and industrial zones;
- Highway rest areas;
- Runoff from metal roofs not coated with an inert, non-leachable material; or,
- Discharge to a surface water of the state that has been identified through a TMDL or other water clean-up plan as requiring metals removal.

Exemptions

Stormwater runoff is exempt from metals treatment requirements in the following situations, unless a specific water quality problem has been identified:

- Discharges to non-fish bearing streams;
- Subsurface discharges, unless identified as hydraulically connected to surface waters of the State. The Spokane Valley – Rathdrum Prairie Aquifer is hydraulically connected to a surface water of the state;
- Restricted residential and employee-only parking areas, unless subject to through traffic;
- Preservation/maintenance projects and some improvement or safety enhancement projects that do not increase motorized vehicular capacities; and,
- Discharges to some Category 4 wetlands; contact the Washington Department of Ecology for additional information.

6.6.4 PHOSPHORUS TREATMENT

Applicability

Phosphorus treatment is required where it has been determined by the federal, state, or local government that a water body is sensitive to phosphorus and that a reduction in phosphorus from new development and redevelopment is necessary to achieve the water quality standard to protect its beneficial uses. Where it is deemed necessary, a strategy will be adopted to achieve the reduction in phosphorus. The strategy will be based on knowledge of the sources of phosphorus and the effectiveness of the proposed methods of removing phosphorus. At the time of the writing of this manual, no TMDLs exist for any water body in Spokane County. Contact the local jurisdiction to determine if any have been issued that may affect a project design with regard to phosphorus treatment.

Phosphorus treatment may be required for water bodies reported under Section 305(b) of the Clean Water Act, and for those listed in Washington State's Nonpoint Source Assessment required under Section 319(a) of the Clean Water Act.

The Spokane River has been designated as not supporting beneficial uses due to phosphorus, and phosphorus treatment may be required.

Exemptions

Projects that do not propose to discharge to a water body sensitive to phosphorus are exempt from phosphorus treatment requirements.

6.7 TREATMENT BMPS

Infiltration-based swales and ponds, filtration-based vegetated buffer strips and channels, and evaporative ponds can all be effective in treating stormwater runoff. In most cases, soil properties must be appropriate to achieve effective treatment without adversely impacting groundwater resources. The location and depth to bedrock, water table, or impermeable layers, and the proximity to wells, foundations, septic system drain-fields, and unstable slopes can preclude the use of infiltration. If a lined treatment facility is proposed, the soil properties are less important, as the treatment is meant to occur via containment, plant uptake, and evaporation of the pollutants within the area of the facility that does not drain.

Oil/water separators (OWS) can be used to physically separate petroleum products from stormwater. An OWS does not, however, meet the other treatment goals set forth in this Manual, so it may have to be used in combination with another water quality treatment BMP, depending upon the expected pollutants.

This section provides design information and minimum requirements for all treatment BMPs identified in this Manual except evaporation ponds; evaporation ponds are addressed in Chapter 7. Inspection and maintenance standards for treatment BMPs and information about tracts and easements are found in Chapter 11. Selection, establishment and maintenance criteria for treatment facility vegetated cover are discussed in Chapter 7.

6.7.1 BIO-INFILTRATION SWALES

Bio-infiltration swales (formerly referred to as grassed percolation areas (GPAs) or '208' swales) combine plant material and soil to remove stormwater pollutants by both physical and chemical (ionic bonding, decomposition, plant root uptake, etc.) means via filtration and percolation into the ground. Bio-infiltration swales are sized to treat the volume equivalent of the 6-month NRCS Type II 24-hour water quality design storm. If the bio-infiltration facility is designed to function as a flow control facility as well as a water quality treatment facility, it shall also accommodate the flow control design storm event (refer to Section 2.2.4). If a bio-infiltration facility will also be used as a detention facility, refer to Section 7.3.2 for additional information.

Bio-Infiltration Swale Design

Bio-infiltration swales shall be sized using either Equation 6-1a or 6-1b. These equations estimate the volume required to treat stormwater runoff and were developed using the Alternate Hydrograph Method found in the *Stormwater Management Manual for Eastern Washington*.

$$V = 1133AP^{1.53} \qquad (6\text{-}1a)$$

$$V = 1815AP^{1.53} \qquad (6\text{-}1b)$$

Where: V = volume of bio-infiltration swale (cubic feet);

A = hydraulically connected impervious area to be treated (acres); and,

P = precipitation amount for the 6-month NRCS Type II 24 hour water quality design storm.

P shall be 1 inch for the all of the Spokane region, therefore the above equations can be simplified as follows:

$$V = 1133A \qquad (6\text{-}1c)$$

$$V = 1815A \qquad (6\text{-}1d)$$

Equations 6-1a and 6-1c can only be used when the following requirements are met, otherwise, Equations 6-1b and 6-1d shall be used:

- The subgrade soils have less than 12% fines; and,
- The subgrade soils have an infiltration rate greater than 0.15 in/hr.

Appendix 6A provides an example calculation for bioinfiltration swales.

Bio-Infiltration Swale Minimum Requirements

Bio-infiltration facilities shall meet the minimum requirements for limiting layers, setbacks, slopes, embankments, planting, and general requirements specified in Sections 7.5.2 and 7.8. In addition, the design of bio-infiltration swales shall conform to the requirements described below.

<u>Treatment Design Depth and Soil Criteria:</u> Bio-infiltration swales shall fully contain the design treatment volume with a maximum treatment design depth (from the swale

bottom to the elevation of the drywell grate or the first overflow or outflow mechanism) of 6 inches.

Organic matter content or cation exchange capacity (CEC) testing must be completed in order to substantiate the treatment soil composition. The tests shall be performed on composite samples taken from the treatment soil layer from the constructed pond bottom. A composite sample consists of well-mixed soil obtained from at least four cores, to a depth of at least 6 inches, randomly distributed over the pond bottom test area. A minimum of one test shall be performed for each bio-infiltration swale of 1,500 square feet or less, with one additional test for each additional 2,000 square feet of swale bottom or fraction thereof. “One test” is equal to four core samples taken uniformly over the percolation area. The soils will be considered suitable if the minimum criteria for CEC or soil organic matter content are met. Testing results shall be submitted as part of the construction certification process prior to the release of surety posted on project (contact the local jurisdiction for specific requirements).

Unless recommended otherwise by a geotechnical engineer, bio-infiltration swales shall be constructed with a treatment zone of medium- to well-draining soil (tested for infiltrative and treatment criteria) at least 12 inches thick, underlain by a subgrade infiltrative layer at least 48 inches thick. All soils, including amended native soils, shall meet the infiltrative rate criteria indicated in Table 6-1.

TABLE 6-1
BIO-INFILTRATION SWALE DESIGN CRITERIA

Criteria	Design Requirement
Treatment Zone Infiltration Rate (vegetated cover and treatment layer)[1]	Between 0.25 and 0.50 inches/hour
Subgrade Infiltration Rate[2,3]	At least 0.15 inches/hour and facility must completely drain within 72 hours
Average Cation Exchange Capacity	At least 15 milliequivalents/100 grams
Organic Matter Content	At least 2% by weight

[1] Sand and coarser soils are not suitable to be used as top soils when treatment is required.

[2] An infiltration test (for example, a single-ring infiltrometer test) demonstrating the facility’s conformance to the infiltration rate criteria may be required prior to construction certification.

[3] The 48-inch layer of infiltrative subgrade soils must meet the geotechnical recommendations as per the requirements found in Chapter 4.

Unless otherwise approved by the local jurisdiction, the treatment zone shall be planted with sod or dryland grass. Trees and large shrubs may be planted in the treatment zone provided they do not inhibit the growth of the grass. Contact the local jurisdiction for additional information. In all cases the plant materials shall meet the requirements of Section 7.8.9.

Inlets and Overflow: Curb inlets discharging into bio-infiltration swales shall be per the criteria specified in Chapter 8. A minimum separation of 3 inches shall be maintained between the flow line in the gutter (at the curb drop) or swale inlet and the top of the drywell grate. In addition, a 2-inch drop to the finish grade (of the swale side slope or swale bottom) below the concrete apron shall be provided to inhibit vegetation overgrowth and ensure positive flow into the swale.

A bypass or overflow structure to a flow control facility must be provided unless the treatment facility is able to accommodate the flow control design storm event as well as the water quality design storm event. Swales shall not be designed to overflow to a street unless approved by the local jurisdiction.

Construction and Inspection: In order to reduce the potential for over-compaction of the swale bottom, construction equipment and vehicles shall be kept off the treatment facility. Unless waived by the local jurisdiction, an infiltration test (for example, a single-ring infiltrometer test) demonstrating the facility's conformance to the infiltrative rate criteria is required prior to construction certification. The treatment facility must have vegetation established prior to passing final inspection. In addition, if during final inspection, it is found that the constructed bio-infiltration swale does not conform to the accepted design, the system shall be reconstructed so that it does comply.

6.7.2 BIOFILTRATION CHANNELS

Biofiltration is the simultaneous process of filtration, particle settling, adsorption, and biological uptake of pollutants in stormwater that occurs when runoff flows over and through vegetated areas. A biofiltration channel is a sloped, vegetated channel or ditch that both conveys and treats stormwater runoff. It does not provide flow control but can convey runoff to facilities designed for that purpose.

Biofiltration Channel Design

The following procedure shall be followed when designing biofiltration channels:

1. Determine the peak flow rate using the 6-month NRCS Type II 24-hour storm which shall be 1 inch for the all of the Spokane region. The methods for calculating peak flow rates are found in Chapter 5

2. Determine the bottom width of the ditch using equation 6-2 or 6-3.

$$Q = \frac{1.486 A R^{2/3} S^{1/2}}{n} \tag{6-2}$$

Where: Q = flow (cfs);

A = cross-sectional area (square feet);

R = hydraulic radius (feet); and,

S = longitudinal slope of strip (feet/foot); slope criteria are given in the minimum geometry requirements in the following subsection; and,

n = Manning's roughness coefficient; Use n = 0.30 for sod (or channels that will be mowed regularly) and higher values such as n = 0.20 for natural (less dense) vegetation such as meadow or pasture.

For a trapezoidal channel with shallow flow, the hydraulic radius can be approximated to the depth of flow. Using this assumption, the following can be used to solve for the required width:

$$B = \frac{\left(\frac{n}{1.486}\right)Q}{y^{5/3} S^{1/2}} - Zy \tag{6-3}$$

Where: B = bottom width of the strip (feet);

n = Manning's roughness coefficient

y = depth of flow (feet); (3 inches maximum for dryland grass and 4 inches maximum for sod);

S = longitudinal slope of strip (feet/foot); slope criteria are given in the minimum geometry requirements in the following subsection;

Z = side slope of the strip in the form Z:1; and,

Q = flow (cfs).

3. Calculate the cross-sectional area of flow for the given channel;

4. Calculate the flow velocity. If the velocity is less than 1 foot/second, proceed to Step 5. Otherwise, change the channel dimensions and/or slope and return to Step 3; and,

5. Calculate the length of the channel and verify that the residence time is at least 9 minutes. The minimum channel length is 200 feet unless the width is increased per the minimum geometry requirements in the following subsection.

Commercially available software is most commonly used to compute many of the parameters associated with the sizing of a biofiltration channel. Appendix 6B provides an example calculation for biofiltration channels.

Biofiltration Channel Minimum Requirements

Biofiltration channels shall meet the minimum requirements found in Section 7.8, as well as the following geometry requirements:

- The biofiltration channel shall have a length of 200 feet. If a length of 200 feet is not possible, the width of the biofiltration channel must be increased so that the treatment area is the same as or more than it would be if a 200 foot length had been used. The length shall not be reduced such that the minimum residence time and/or maximum flow depth criteria are violated. The length shall in no case be less than 100 feet.
- The maximum bottom width is 10 feet and the minimum width is 1 foot. If the calculated bottom width exceeds 10 feet, parallel biofiltration channels shall be used in conjunction with a device that splits the flow and directs an equal amount to each channel.
- The ideal cross-section is a trapezoid with side slopes no steeper than 3:1. However, a rectangular shape can be proposed if there are topographical constraints or other construction concerns.
- Typically, the depth of flow shall not exceed 4 inches during the design storm. The depth of flow is 4 inches for sod and 3 inches for dryland grasses.
- The channel slope shall be at least 1% and no greater than 5%. Slopes of 2% to 4% provide the best performance. When slopes less than 2% are used, an under-drain is required. A 6-inch-diameter perforated pipe shall be installed in a trench lined with filter fabric and filled with 5/8-inch-minus round rocks. The pipe shall be placed at least 12 inches below the biofiltration channel bed and the bed shall incorporate topsoil that has a proportionately high sand content.
- The flow velocity shall not exceed 1 foot/second and the design shall provide for a 9 minute residence time.

6.7.3 VEGETATED BUFFER STRIPS

A vegetated buffer strip is a facility that is designed to provide stormwater quality treatment of conventional pollutants, but generally does not provide stormwater flow control.

Vegetated buffer strips are primarily used in rural areas adjacent to and parallel to paved areas such as parking lots or driveways, and along rural roadways where sheet flow from the paved area will pass through the buffer strip before entering a conveyance system or a flow control facility or being dispersed into areas where it can be infiltrated or evaporated.

Vegetated buffer strips are used to intercept overland sheet flow runoff from adjacent impervious areas. They slow runoff velocities, filter out sediment and other pollutants, and provide infiltration into underlying soils. One challenge associated with vegetated buffer strips is the difficulty in maintaining sheet flow. Concentrated flows can short circuit the buffer strips which can then contribute to eroded rills or flow channels across the strips. This results in little or no treatment of stormwater runoff.

This BMP is acceptable for use on any rural project that meets the following general criteria:

- The flow from the roadway must enter the buffer strip as sheet flow. Thus, the vegetated buffer strips must not receive concentrated flow discharges.
- A maximum flow path (paved width) of 30 feet can contribute to a buffer strip designed via this method (vegetated buffer strips should typically not be proposed for super-elevated roads, unless the 30 foot width is adhered to);
- Buffer strips may be used where the roadway ADT is less than 30,000;
- The longitudinal slope of the contributing impervious drainage area (parallel to the edge of the buffer area) shall be 5% or less;
- The lateral slope of the contributing drainage area perpendicular to the pavement edge (typically referred to as the cross-slope of the road)shall be 2% or less.

Vegetated buffer strips shall be constructed after other portions of the project are completed.

Vegetated Buffer Strip Design

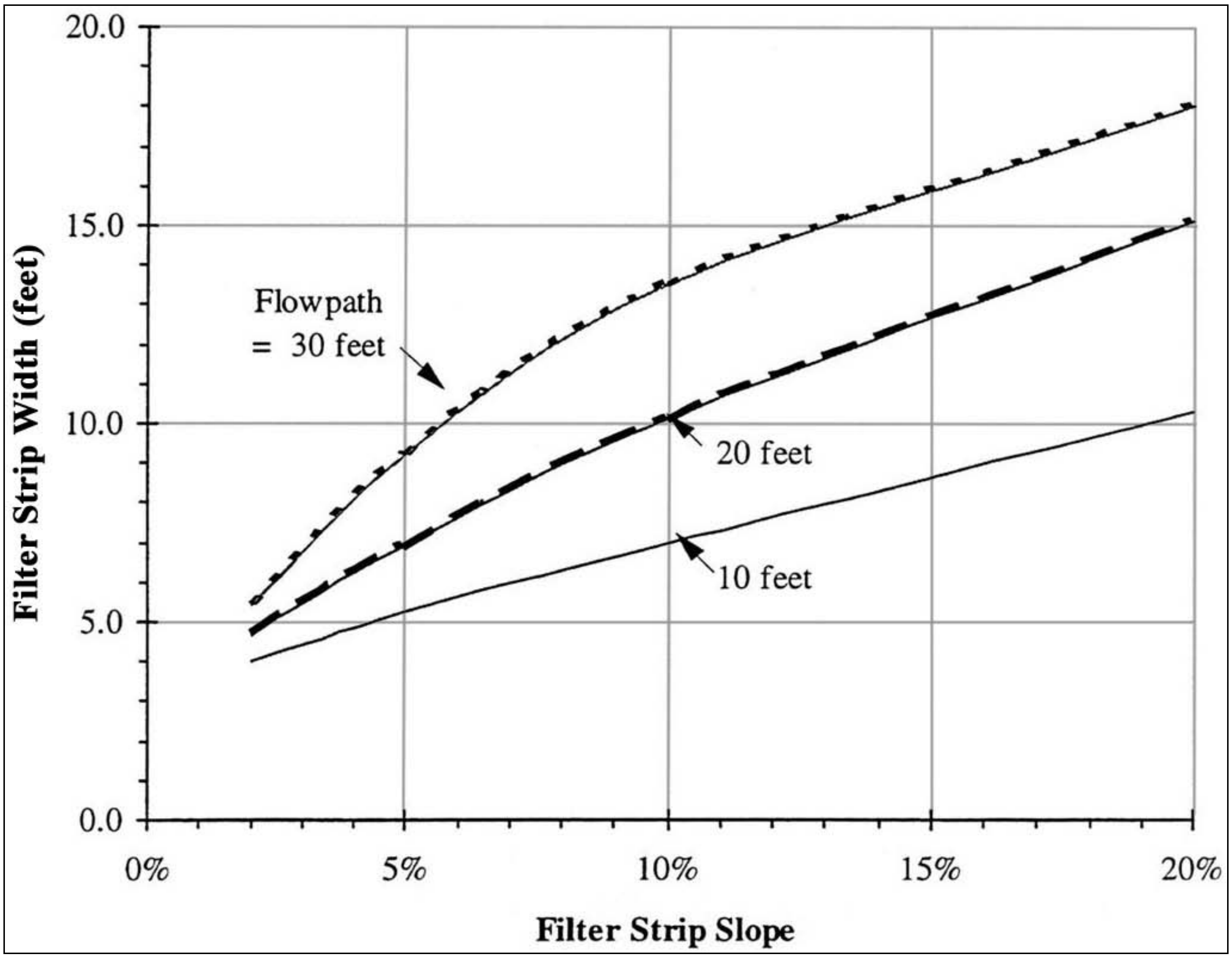
This procedure is based on the narrow area filter strips presented in the 1998 *King County Surface Water Design Manual*. The sizing of the buffer strip is based on the length of the flow path draining to the buffer strip and the longitudinal slope of the buffer strip itself (parallel to the flow path). The following design steps shall be followed:

1. Determine the flow path length draining to the buffer strip. Normally this is the width of the paved area draining to the strip, but if the site is sloped, the flow path may be longer. For crowned roads, the flow path is the distance from the crown to the edge of pavement;

2. Determine the average lateral or cross slope of the buffer strip: Calculate the cross slope of the buffer strip (parallel to the flow path), averaged over the total width of the buffer strip. If the slope is less than 2%, use 2% for sizing purposes. The maximum cross slope allowed is 6:1 horizontal to vertical or 17%; and,

3. Determine the required width of the buffer strip: Use Figure 6-3 to size the buffer strip. To use the figure, find the curve representing the appropriate width of the flow path (interpolate between curves as necessary). Find the point along the curve where the design longitudinal or cross slope of the buffer strip is directly below and read the buffer strip width to the left on the y-axis. The buffer strip must be designed to provide this minimum width (W) along the entire stretch of pavement draining to it.

Appendix 6C provides an example calculation for vegetated buffer strips.



Source: King County Surface Water Design Manual, 1998.

Figure 6-3 – Vegetated Buffer Strip

Vegetated Buffer Strip Minimum Requirements

Vegetated buffer strips shall meet the minimum requirements for planting, and general requirements specified in Sections 7.5.2 and 7.8. In addition, the design of buffer strips shall conform to the following requirements (see Figure 6-4):

- Geometry:
  - The minimum required buffer strip width is: 4 feet for a 10-foot flow path; 4.5 feet for a 25 foot flow path; and 5.5 feet for a 30-foot flow path. Flow path is the width of the paved surface discharging to the buffer strip.
  - The cross-slope of the buffer strip shall be no steeper than 6:1.
  - Along roadways, buffer strips shall be placed at least 1 foot, and preferably 3 to 4 feet, from the edge of pavement, to accommodate a vegetation free zone.
- Energy Dissipation:
  - A gravel-filled trench shall be installed between the pavement surface and the buffer strip to maintain sheet flow. This area serves as a flow spreader and shall consist of a trench filled with crushed aggregate (WSDOT Crushed Aggregate Base Course or WSDOT Crushed Aggregate Top Course).
  - The gravel filled trench shall be a minimum of 12 inches deep and 18 inches wide.

6.7.4 OIL/WATER SEPARATORS

Three types of OWS are included in this Manual:

- Coalescing plate types (gravity mechanism for separation),
- Baffle types,
- Spill control separators, such as T's or elbows located inside a catch basin.

OWSs are only effective in achieving oil and TPH removal at the required levels when regular maintenance is provided. Without proper sludge, oil and sediment removal, there is a high potential for clogging which can impair the long-term efficiency of the separator.

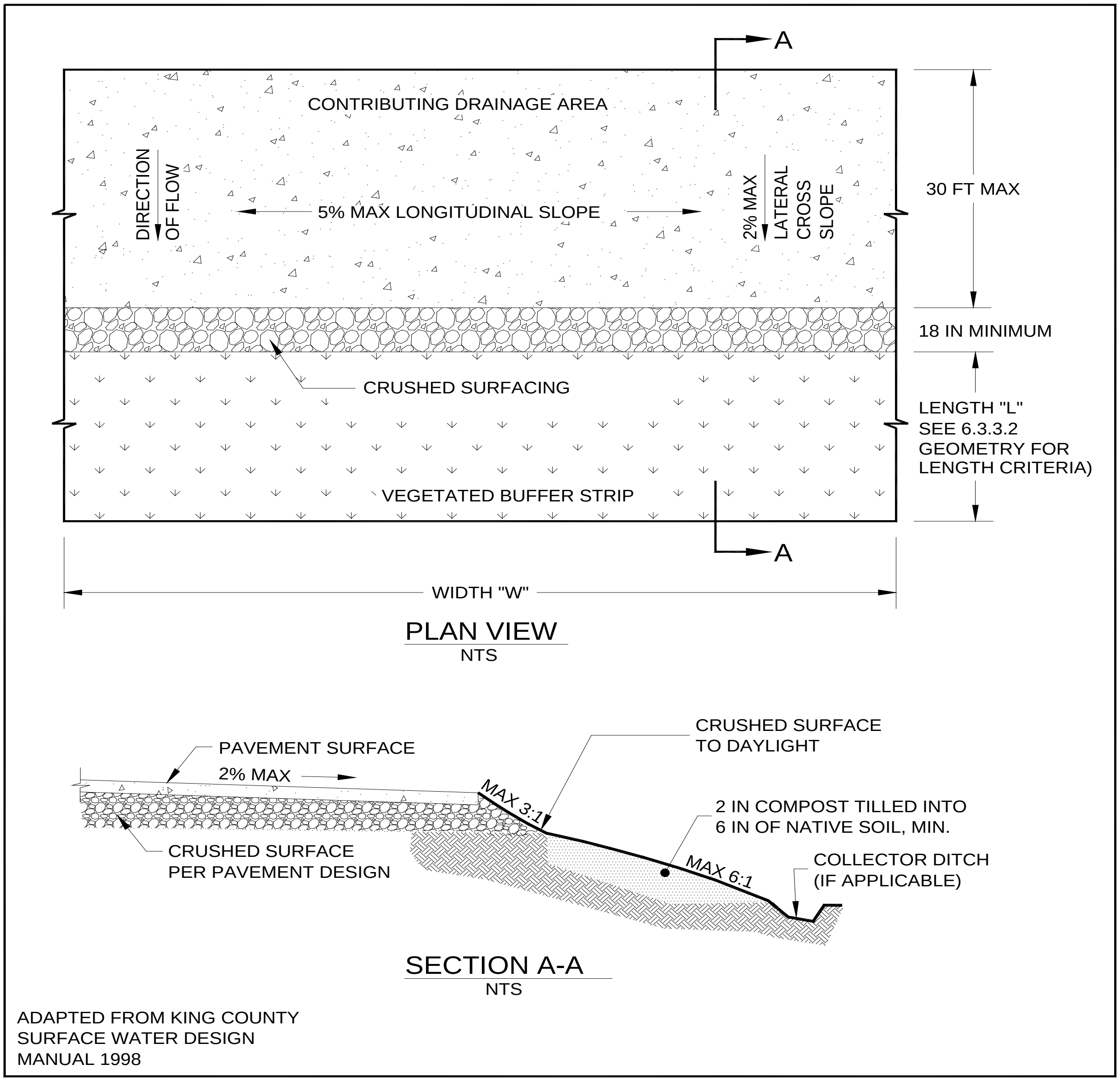


Figure 6-4 – Typical Vegetated Buffer Strip (details)

Oil/Water Separator Design

Detailed design information for coalescing plate and baffle type OWS can be found in Section 5.10.7 of the *Stormwater Management Manual for Eastern Washington*. Design information for spill control separators is presented in the minimum requirements subsection below.

Oil/Water Separator Minimum Requirements

The following design criteria are applicable to all types of oil control BMPS:

- Only impervious conveyances shall be used for oil-contaminated stormwater; and,
- Oil/water separators shall not be used for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols, and alcohols.

The following are design criteria applicable to spill control separators:

- “T” or elbow separators in a catch basin are not allowed as an oil control device for high-ADT sites unless used in series with another water quality treatment facility;
- Oil control shall occur prior to dispersal into or through a water quality treatment facility;
- If an oil/water separator is applicable, it shall comply with the local jurisdiction’s standard plan.

The following design criteria are applicable to both coalescing plate and baffle type oil/water separators:

- If practical, determine expected oil/grease (or TPH) and TSS concentrations, lowest temperature, pH, empirical oil rise rates in the runoff, oil viscosity and specific gravity of the oil;
- Locate the separator off-line and bypass flows in excess of the water quality design flow rate;
- Follow industry standards such that the separator has a forebay, separator section, and afterbay;
- Design the surface area of the forebay at 20 square feet per 10,000 square feet of area draining to the separator;
- The length of the forebay shall be one-third to one-half the length of the entire separator;
- Include roughing screens for the forebay to remove debris (screen openings should be about ¾ inch);
- Include a submerged inlet pipe with a turned-down elbow in the forebay at least two feet from the bottom; the outlet pipe shall be a “T” sized to pass the design peak flow and placed at least 12 inches below the water surface;
- Size the separator bay for the water quality design flow rate;
- Include a shutoff mechanism at the separator outlet pipe; and,
- Use absorbents and/or skimmers in the afterbay as needed.

The following are additional design criteria applicable to baffle type oil/water separators:

- Oil retaining baffles (top baffles) shall be located at least a quarter of the total separator length from the outlet and shall extend down at least 50% of the water height and at least 1 foot from the separator bottom; and,
- Baffle height to water depth ratios shall be 0.85 for top baffles and 0.15 for bottom baffles.

6.7.5 WETLANDS

Some wetlands can be considered for use in stormwater treatment, if approved by Ecology. The following criteria are applicable for wetlands that discharge to surface waters of the State, which are generally defined as wetlands with a defined outlet.

Typically, a wetland must meet one of the following criteria in order to be considered for use as a stormwater treatment facility:

- It is a Category 4 wetland according to the Eastern Washington Wetland Rating System; or,
- It is a Category 3 wetland according to the Eastern Washington Wetland Rating System and the wetland has been previously disturbed by human activity such as agriculture, fill areas, ditches or the wetland is dominated by introduced or invasive weedy plant species as identified in the rating analysis.

In addition, the wetland must meet the criteria for hydrologic modification of a wetland. Hydrologic modification of a wetland for the purpose of stormwater management means that the wetland will receive a greater total volume of surface runoff following development than it receives in the current condition. A Category 3 or 4 wetland can only be considered for hydrologic modification if both of the following are demonstrated:

- There is good evidence that the natural hydrologic regime of the wetland can be restored by augmenting its water supply with excess stormwater runoff; or the wetland is under imminent threat exclusive of stormwater management and could receive greater protection if acquired for a stormwater management project rather than left in existing ownership; and,
- The runoff is from the same natural drainage basin; the wetland lies in the natural routing of the runoff; and the site plan allows runoff discharge at the natural location. Exceptions may be made for regional facilities planned by a local jurisdiction, but the wetland should receive water from sites in the same watershed.

Hydrologic modification is not allowed for wetlands classified as Category 1 or 2 under the Eastern Washington Wetland Rating System unless the project proponent demonstrates to Ecology that the stormwater disposal methods outlined in this Manual are not possible at the site, and that other options would result in more damage to the wetland by limiting base flow.

Basic treatment (TSS removal) is not required prior to discharge to a Category 4 wetland, but it is required prior to discharge to a Category 3 wetland. A Category 3 wetland that meets the above requirements may be used to meet metals treatment requirements. Oil control is required for all high-use sites discharging to a wetland. Contact Ecology for specific treatment requirements with regard to any other wetland category or pollutant of concern.

Mitigation is usually required for the impact of hydrologic modification on a wetland. Appropriate measures include expansion, enhancement and/or preservation of a buffer around the wetland.

For wetlands that are isolated (i.e. are not hydraulically connected to a surface water of the State via an outlet from the wetland), the project proponent shall contact Ecology for further information with regard to using such a wetland for stormwater management.

6.8 EMERGING TECHNOLOGIES

Emerging technologies are new technologies that have not been evaluated using approved protocols, but for which preliminary data indicate that they may provide a desirable level of stormwater pollutant removal.

6.8.1 BACKGROUND

During recent years, new technologies have been under development to meet the needs of urban stormwater pollutant control. However, because no standardized statewide procedure for evaluating these technologies was available, local jurisdictions and commercial entities have had to decide individually as to the appropriateness of their use. This has resulted in a wide range of differences in the criteria for accepting new technologies.

Some emerging technologies have already been installed in Washington state as parts of treatment trains or as stand-alone systems for specific applications. In some instances, emerging technologies can be used for retrofits and/or where land is unavailable for larger treatment systems.

6.8.2 ECOLOGY'S ROLE IN EVALUATING EMERGING TECHNOLOGIES

Ecology has developed a new technology evaluation program, which is described briefly in this section. The program is based on reviewing engineering reports on the performance of new technologies and reporting the results at Ecology's website. The program includes:

- A Technical Review Committee (TRC) including representatives from local governments in eastern and western Washington that acts in an advisory capacity to provide recommendations to Ecology on the level of development of each technology.
- A website with brief descriptions of each new technology, TRC recommendations, and Ecology's determinations of the levels of development of each technology. Ecology's main website address can be accessed at http://www.ecy.wa.gov/.

6.8.3 LOCAL JURISDICTION'S ROLE IN EVALUATING EMERGING TECHNOLOGIES

Local jurisdictions reserve the right to deny the use of any emerging technology even if it has been approved by Ecology. Local jurisdictions shall consider the following as they make decisions regarding the use of new stormwater technologies in their jurisdictions:

- <u>Remember the goal:</u> The goal of any stormwater management program or BMP is to treat and release stormwater in a manner that does not harm beneficial uses. Compliance with other water quality standards is one measure of determining whether beneficial uses will be harmed. Emerging technologies proposed for use in the Spokane area shall be compatible with use over a sole-source aquifer.
- <u>Exercise reasonable caution:</u> An emerging technology shall not be considered for use for new development sites unless there are strong supporting data indicating that its performance is expected to be reasonably equivalent to the BMPs already approved by Ecology. Local jurisdictions can refer to Ecology's website to obtain the latest performance verification of an emerging technology.
- <u>Conduct a monitoring program:</u> Identify an acceptable monitoring protocol to apply to those emerging technologies that have not yet been verified for limited or full-scale use at Ecology's website.
- <u>Review Treatment Goals:</u> Refer to Section 6.5 for acceptable performance objectives.

- Maintenance: Some emerging technologies may not be approved for use in public roads due to maintenance concerns. Use of emerging technologies in private roads and tracts may require the formation of a Homeowners' Association to provide perpetual maintenance of the drainage facilities. Contact the local jurisdiction for additional information.

To achieve the goals of the Clean Water Act and the Endangered Species Act, local jurisdictions may find it necessary to retrofit existing stormwater systems. In these situations, the use of any BMPs that make substantial progress toward these goals is a step forward and is encouraged by Ecology.

6.8.4 TESTING PROTOCOL

To properly evaluate new technologies, performance data must be obtained using an industry accepted protocol. A test protocol has been developed which serves to standardize the test conditions. Sampling criteria, site and technology information, QA/QC, target pollutants, and evaluation report content are specified in the protocol.

6.8.5 ASSESSING LEVELS OF DEVELOPMENT OF EMERGING TECHNOLOGIES

Ecology has received several submittals from vendors to approve their technologies for statewide applications. Moreover, it is evident that some technologies have been under development for many years and have improved considerably during that time.

To assess and classify levels of developments, Ecology is proposing to use the criteria below. These criteria can also be found on Ecology's website. Emerging technologies shall be used only within the application criteria and performance limits listed at Ecology's website.

Pilot Use Level Designation: For emerging technologies with limited performance data, the pilot use level designation (PULD) allows limited use to enable field testing. PULDs may be given based solely on laboratory performance data. Ecology will limit the number of installations to five during the pilot use level period.

Local governments may allow PULD technologies to be installed provided the proponent agree(s) to conduct additional field testing based on the TAPE at all installations to obtain a general use level designation (GULD). Proponents must conduct field testing at a minimum of one site in the Pacific Northwest to obtain a GULD.

Local governments covered by a municipal stormwater NPDES permit must notify Ecology in writing when a PULD technology is proposed. Ecology encourages other jurisdictions to notify Ecology headquarters when a PULD technology is proposed. Ecology also encourages all local governments to require proponents to provide a performance guarantee stating that PULD facilities will be upgraded as necessary, to the maximum extent practical, to meet Ecology performance goals.

General Use Level Designation: The general use level designation (GULD) confers a general acceptance for treatment device. Technologies with a GULD may be used anywhere in Washington, subject to Ecology conditions. Ecology plans to include GULD technologies in future stormwater manual updates.

Conditional Use Level Designation: The TRC established the conditional use level designation (CULD) for emerging technologies that have a considerable amount of performance data but the data were not collected per the TAPE protocol. The TRC may recommend a CULD based on field data collected by a protocol that is reasonably consistent but does not necessarily fully meet the TAPE protocol. The field data must meet the statistical goals set out in the TAPE guidelines (Appendix D). Laboratory data may be used to supplement field data. Conditional use level designations apply for a specified time period only. During this time period, the vendor must complete all field testing and submit a TER to Ecology and the TRC. Proponents must complete field testing at a minimum of one site in the Pacific Northwest to obtain a general use level designation.

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APPENDIX 6A – EXAMPLE CALCULATION: BIO-INFILTRATION SWALE

GIVEN

- The existing site is approximately 5 acres, consisting of sandy soils. Existing surface vegetative conditions include short grass and weeds.
- The subgrade soil has 10% fines and an infiltration rate of 0.10 inches per hour.
- Post developed site conditions consist of:
    - 20 – 10,000-square foot lots
    - 1,500-square-foot homes with 500-square-foot driveways
    - 0.50 acres of road impervious areas

CALCULATIONS

1. Determine the total PGIS for the site.

   Road PGIS: (0.50 acres)(43,560 square feet/acre) = 21,780 square feet

   Driveway PGIS: (500 square feet)(20 driveways) = 10,000 square feet

   Total PGIS: 10,000 square feet + 21,780 square feet = **31,780 square feet**

   = 0.73 acres

2. Determine the required treatment volume, using Equation 6-1.

   $$V = 1815A \qquad \text{(Equation 6-1d)}$$

   $$V = (1815)(0.73) = 1{,}325 \text{ cubic feet}$$

3. Determine the geometry of the bio-infiltration facility

   Use a treatment depth of 6 inches

   Pond Bottom Area Required* = $\frac{1{,}325 \cdot cf}{6 \cdot in} * \frac{12 \cdot in}{1 ft} = 2{,}648 \cdot sq. ft.$

   * For this example, there are no space constraints and side slope volume has been ignored.

Provide an infiltrative facility with a 2,650 square foot pond bottom area

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APPENDIX 6B – EXAMPLE CALCULATION: BIOFILTRATION CHANNEL

GIVEN

- Weighted pervious CN = 67
- Pervious area = 4.25 acres
- Impervious CN = 98
- Impervious area = 0.75 acres
- PGIS = 31,720 square feet
- 6-month, 24 hour storm precipitation = 1.0 inch
- Time of concentration = 5 minutes
- n = 0.2

CALCULATIONS

1. Determine the peak flow rate using the 6-month NRCS Type II 24-hour storm and the methods described in Chapter 5.

   6-month precipitation = 1 inch

   Using a computer program, the peak flow rate is estimated to be 0.8 cfs.

2. Determine the bottom width of the ditch using Equation 6-3.

   Assume: A trapezoidal channel with 3:1 side slopes;
   3 inches for flow depth; and,
   3% longitudinal slope for biofiltration channel.

$$B = \frac{\left(\frac{n}{1.486}\right)Q}{y^{5/3} S^{1/2}} - Zy$$

$$B = \left[\frac{\left(\frac{0.2}{1.486}\right)(0.8cfs)}{\left(\frac{3in}{12 \, in/ft}\right)^{5/3}\left(0.03\frac{ft}{ft}\right)^{1/2}}\right] - \left[(3)\left(\frac{3in}{12 \, in/ft}\right)\right] = 5.6\,ft$$

3. Calculate the cross-sectional area of flow for the given channel and verify that the flow velocity is less than or equal to 1 foot/second;

$$\text{Area} = \text{y (B+ Zy)} = \left(\frac{3\cdot in}{12\, in/ft}\right)\left(5.6\cdot ft + 3\cdot ft\left(\frac{3\cdot in}{12\, in/ft}\right)\right) = 1.6\cdot sq.ft.$$

$$\text{Velocity} = \frac{Q}{A} = \frac{0.80\cdot cfs}{1.6\cdot sq.ft} = 0.5\cdot ft/\sec \leq 1 \qquad \textbf{OK}$$

4. Calculate the length of the channel to meet the 9 minute residence time. The minimum channel length is 200 feet unless the width is increased as described in the minimum requirements in Section 6.7.2.

$$L = (V)(t) = (0.5\ ft/\sec)(9\min)\left(\frac{60\cdot\sec}{1\min}\right) = 270\, ft$$

If the site cannot accommodate the required channel length, the width can be increased. Steps 3 and 4 should be repeated until the channel geometry best fits the existing site conditions.

The proposed channel geometry design is as follows:

- Trapezoidal shape with 3:1 side slopes
- 3% longitudinal slope
- Channel bottom width is 5.6 feet
- Minimum channel length is 270 feet

APPENDIX 6C – EXAMPLE CALCULATION: VEGETATED BUFFER STRIP

GIVEN

- A typical crowned road with a 30-foot-wide half road
- Average lateral road cross slope = 2%
- Average longitudinal slope = 4%
- The land adjacent to the road (where the buffer strip will be located) slopes away at an average slope = 5%

CALCULATIONS

1. Determine the flow path length draining to the buffer strip.

   Flow path is 30 feet

2. Determine the average lateral or cross slope of the buffer strip:

   Calculate the cross slope of the buffer strip (parallel to the flow path), averaged over the total width of the buffer strip.

   Use 5%

3. Determine required width of the buffer strip using Figure 6-3 to size the buffer strip.

   From Figure 6-3: buffer strip width = 9 feet

   9 feet > 5.5 feet (the minimum width for buffer strips with a 30-foot flow path) **OK**

   Provide an 18-inch-wide, 1-foot-deep gravel filled trench

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CHAPTER 7 – FLOW CONTROL

Chapter Organization

7.1 INTRODUCTION

This chapter outlines the minimum requirements for sizing flow control facilities. Standard flow control facilities are detention/retention ponds, drywells, and evaporation ponds. Any other facility is considered a non-standard system, and shall be evaluated individually by the local jurisdiction. Flow control facilities are necessary to mitigate potential adverse impacts on down-gradient properties due to the increase in stormwater runoff caused by land development.

Unless specifically approved by the local jurisdiction, the peak rate and volume of stormwater runoff from any proposed land development to any natural or constructed point of discharge downstream shall not exceed the pre-development peak rate or volume of runoff. A down-gradient analysis demonstrating that there will be no expected adverse impacts on downgradient properties will be required (refer to Section 3.4.5 for down-gradient analysis criteria). Exceptions with regard to rate and volume control can be made for regional facilities planned by the local jurisdiction.

All engineering work for flow control facilities shall be performed by, or under the direction of, a professional engineer currently licensed in the State of Washington.

Refer to Chapter 11 for maintenance requirements.

7.2 APPLICABILITY AND EXEMPTIONS

7.2.1 APPLICABILITY

All projects that meet the regulatory threshold shall comply with this Basic Requirement.

7.2.2 EXEMPTIONS

Projects are exempt from flow control if they discharge to any of the following:

- The Spokane River or other exempt water bodies, which are defined in the *Stormwater Management Manual for Eastern Washington* as fifth-order or greater stream channels, as determined from a 1:150,000 scale map;
- A river or stream that is fifth-order or greater as determined from a 1:24,000 scale map;
- A river or stream that is fourth-order or greater as determined from a 1:100,000 scale map;

- A stream that flows only during runoff-producing events. These streams are defined as those that do not discharge via surface flow to a non-exempt surface water following receipt of the 2-year, NRCS Type 1A, 24 hour rainfall event. In addition, for the stream to be exempt, it shall be able to carry the runoff from an average snowmelt event, but shall not have a period of base flow during a year of normal precipitation;
- A lake or reservoir with a contributing watershed areas greater than 100 square miles;
- A reservoir with outlet controls that are operated for varying discharges to the down-gradient reaches as for hydropower, flood control, irrigation or drinking water supplies (discharges to uncontrolled flow-through impoundments are not exempt).

In order to be exempted the discharge shall meet all of the following requirements:

- The project area must be drained by a conveyance system that consists entirely of manmade conveyance elements (i.e. pipes, ditches, outfall protection); and,
- The conveyance system must extend to the ordinary high water mark line of the receiving water, or (in order to avoid construction activities in sensitive areas) flows are properly dispersed before reaching the buffer zone of the sensitive or critical area; and,
- Any erodible elements of the conveyance system for the project area must be adequately stabilized to prevent erosion; and,
- Surface water from the project area must not be diverted from or increased to an existing wetland, stream, or near-shore habitat sufficient to cause a significant adverse impact. Adverse impacts are expected from uncontrolled flows causing a significant increase or decrease in the 1.5- to 2-year peak flow rate.

Maps shall be standard U.S. Geological Survey (USGS) maps or geographic information system (GIS) data sets derived from USGS base maps.

7.3 DETENTION FACILITIES

7.3.1 INTRODUCTION

A detention system is a storage facility that has a surface discharge. Detention ponds, vaults and underground storage tanks are all considered to be detention facilities. Refer to the *Stormwater Management Manual for Eastern Washington* for design criteria for vaults and underground storage tanks.

A detention facility is intended to control peak stormwater runoff rates, and if designed per the criteria in this chapter, does not control volume. If the subgrade soils meet the drawdown criteria specified in Section 7.8.3, the engineer may choose to propose a system that uses infiltration in conjunction with a detention pond as a means to control volume. Otherwise, the engineer can use evaporation to control volume, in conjunction with a detention pond (refer to Section 7.7.2).

7.3.2 MINIMUM REQUIREMENTS

The following minimum requirements shall be met. Additional requirements are specified in Section 7.8.

Design Criteria

Detention facilities shall be designed such that the release rate does not exceed the pre-developed conditions for multiple storm events. The analysis of multiple design storms is needed to control and attenuate both low and high flow storm events.

The total post-developed discharge rate leaving the site (including bypass flow) shall be limited to the pre-development rates outlined in Table 7-1. Bypass flow is the runoff that leaves the site without being conveyed through the drainage system.

TABLE 7-1
ALLOWABLE DISCHARGE RATES

Design Frequency (24 hr storm)	Post-Developed Discharge Rate[1]
2-year	≤ 2-year pre-developed
25-year	≤ 25-year pre-developed
100-year[2] (Emergency Overflow)	Overflow route only

[1] Post-developed flow is equal to the release from detention facility plus the bypass flow.

[2] The emergency overflow shall direct the 100-year post-developed flow safely towards the downstream conveyance system

Detention systems that store any stormwater below the first overflow shall adhere to the subgrade infiltrative criteria specified in Table 6-1. Unless waived by the local jurisdiction, the subgrade infiltration rate shall be verified through testing.

If the detention facility is also proposed to function as a water quality treatment facility, the following criteria must be met:

- The first orifice or outlet from the facility must be placed 6 inches above the pond bottom; and,

- The treatment zone shall meet the requirements specified in Table 6-1 and be verified through testing, unless waived by the local jurisdiction.

The NRCS Type 1A 24 hour storm event is the design storm to be used for all flow control facilities that use a surface discharge; for flow control facilities that involve infiltration into the subsurface, the NRCS Type II 24 hour storm event can be used for design.

A wetland may also be considered for use as a flow control facility, if approved by Ecology. Refer to Section 7.9.3 for additional information.

Setbacks

When a detention facility is proposed upslope of developed property or at the top of a slope inclined 10% or greater, down-gradient impacts shall be evaluated and the minimum setback from the slope must be greater than or equal to the height of the slope. The distance between the outlet structure and the inlet into the detention facility shall be maximized.

Release Point

Stormwater runoff from a developed site shall leave the site in the same manner and location as it did in the pre-developed condition. Therefore, a detention system may be used only when a well-defined natural drainage course is present prior to development.

7.4 OUTFLOW CONTROL STRUCTURES

7.4.1 INTRODUCTION

Control structures are weirs, orifices, culverts, or manholes with a restrictor device that is used for controlling outflow from a facility to meet a desired standard. This section presents a general overview of flow control structures. For additional information, the engineer should consult a hydraulics reference.

7.4.2 OUTFLOW CONTROL STRUCTURE TYPES

Weirs and Orifices

Weirs and orifices are partial obstructions in an open channel or in a detention facility at the point of discharge, typically used to limit and measure flow rates. Weirs have openings with no top, referred to as a notch, through which the water flows when its surface elevation is above the bottom of the opening (the weir invert). An orifice is typically a circular opening cut into the structure obstructing the stream. The following are common features of weirs:

- Weir Length: The weir length is the length of the notch in the direction perpendicular to the flow:
    - Contracted weirs (see Figure 7-1) have weir lengths less than the channel width or pond wall, and the falling liquid sheet (called the nappe) decreases in width as it falls.
    - Suppressed weirs (see Figure 7-2) extend the full channel width.

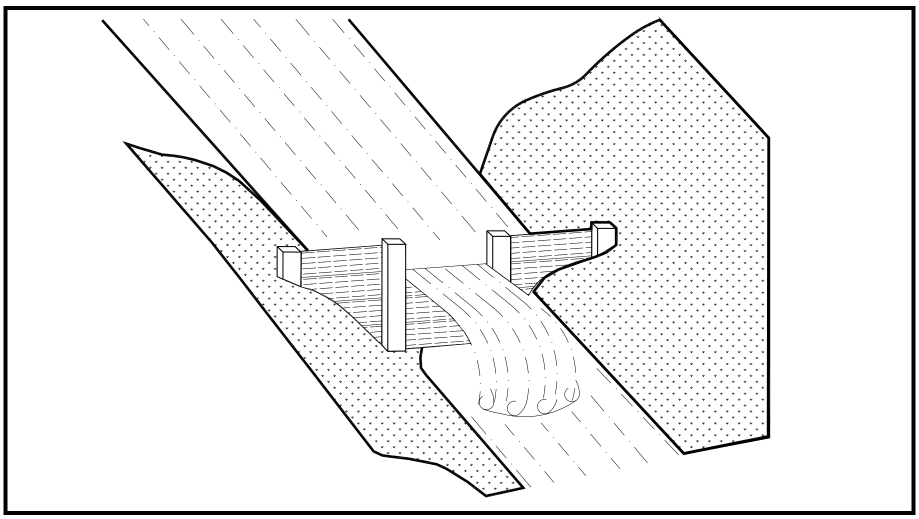


Figure 7-1 – Contracted Weir

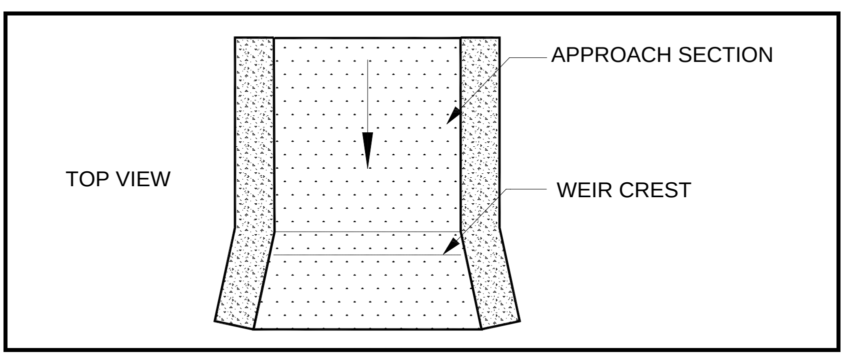


Figure 7-2 – Suppressed Weir

- <u>Weir Crest:</u> The weir crest is the surface of the weir invert in the direction of the flow:
    - <u>Broad-crested weirs</u> (see Figure 7-3) have a crest that extends horizontally in the direction of flow far enough that the flow leaves the weir in essentially a horizontal direction. A weir is broad-crested if the length of the crest in the direction of flow is greater than half of the head (H).
    - <u>Sharp-crested weirs</u> (see Figure 7-4) have a narrow crest with a sharp upstream edge so that water flows clear of the crest. The weir invert or top of the crest should be set above the pond bottom a height of at least twice the maximum head, preferably more.

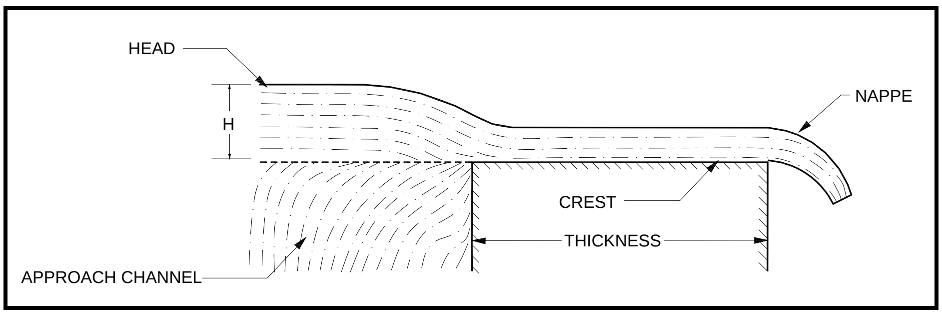


Figure 7-3 – Broad-Crested Weir

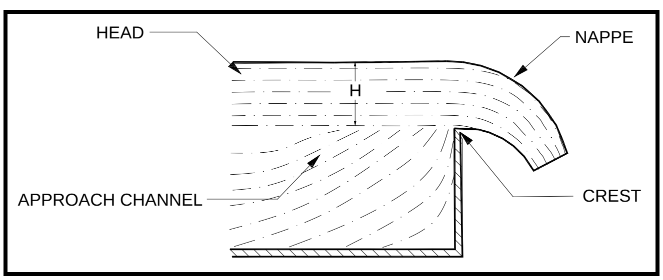


Figure 7-4 – Sharp-Crested Weir

- <u>Weir Notch Shape:</u> The following are the common shapes of weir openings, as viewed looking in the direction of the flow:
    - V-notch: The opening has two sloped sides coming together at a point at the bottom.
    - Rectangular: The opening has two vertical sides and a horizontal invert.

- Trapezoidal (Cipoletti): The opening has a horizontal invert and two sloped sides.

Table 7-2 provides equations and coefficients for calculating flow through the most common types of weirs and orifices used for flow control.

TABLE 7-2
FLOW EQUATIONS FOR VARIOUS WEIR AND ORIFICE TYPES

Weir/Orifice Type	Equation	*C*
Sharp Crested V-notch weir[1]	$Q = C\left(Tan\,\theta/2\right)H^{5/2}$	0.60
Broad Crested Suppressed Rectangular weir	$Q = CLH^{3/2}$	0.33
Rectangular Sharp Crested Weirs[1]: Contracted Suppressed	 $Q = C\left(L - 0.2H\right)H^{3/2}$ $Q = CLH^{3/2}$	$3.27 + 0.40\dfrac{H}{Y}$
Sharp Crested Cipoletti (Trapezoidal)[1] Side slopes are 1:4	$Q = CLH^{3/2}$	3.367
Broad Crested Trapezoidal Weir	$Q = C(2g)^{1/2}\left[\dfrac{2}{3}LH^{3/2} + \dfrac{8}{15}\left(Tan\,\vartheta\right)H^{5/2}\right]$	0.60
Orifice	$Q = CA\sqrt{2gH}$	0.62

[1] The weir inverts should be set above the pond bottom a height of at least twice the maximum head.

Q = flow (cfs); C = coefficient of discharge; A = area of orifice (square feet); H = hydraulic head (feet); g = gravity (32.2 feet/second^2); θ = angle of side slopes (degrees); Y = storage depth (feet); L = weir length or opening (feet)

Risers

A riser typically consists of a circular pipe or box inlet with its opening oriented parallel to the water surface. A riser operates under three hydraulic flow regimes in this order as the water surface elevation rises: weir, orifice, and full barrel. Full barrel flow occurs when the downstream conduit is undersized with respect to the riser capacity and when the water surface elevation rises high enough.

Figure 7-5 can 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). For additional information, consult a hydraulics reference.

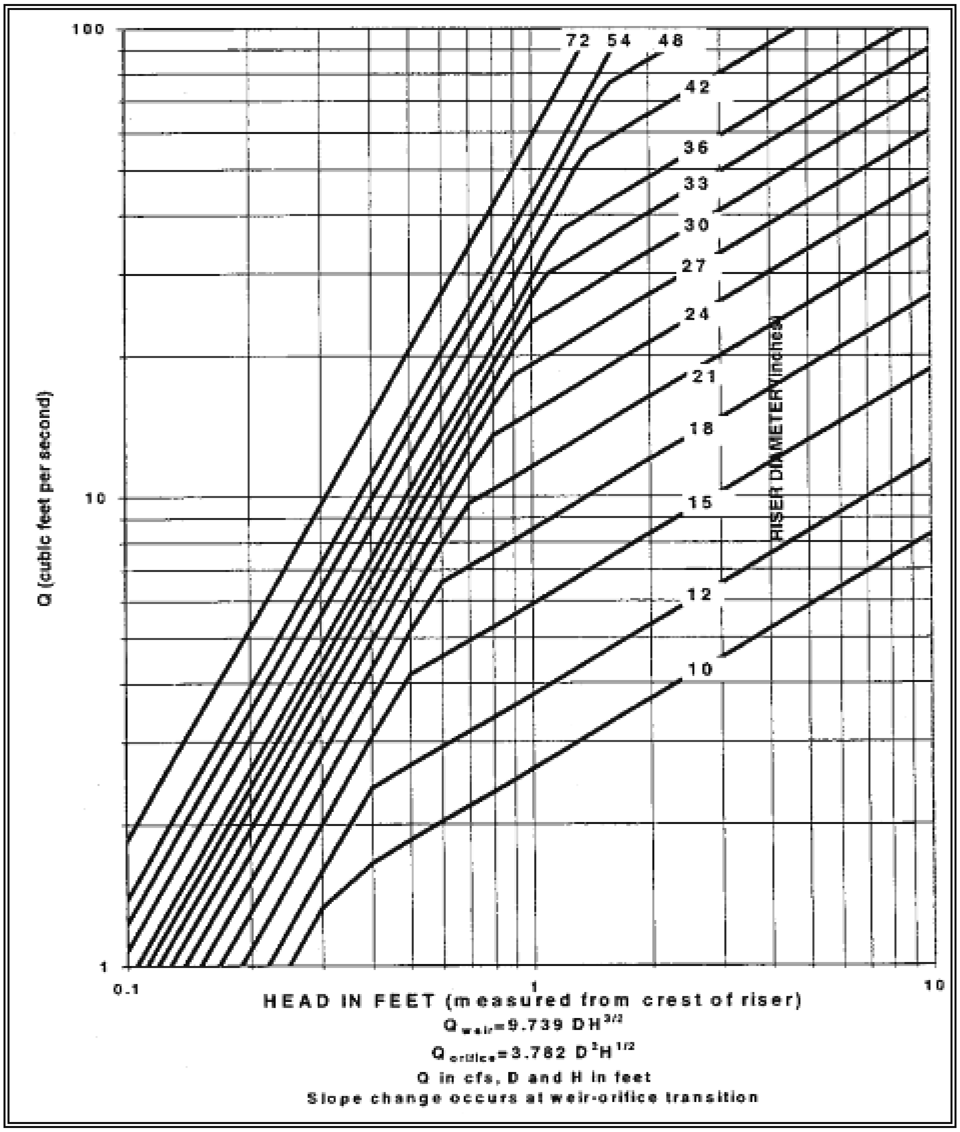


Figure 7-5 – Flow Rates vs. Head (riser)

7.4.3 MINIMUM REQUIREMENTS

Outflow control structures shall meet the following requirements:

- A weir used as a flow control structure shall be made of non-erosive material that is resistant to alteration or vandalism, such as reinforced concrete or metal with a non-corrosive surface. An emergency overflow weir can be made of soil with revetment;

- The inverts for sharp-crested weirs should be set above the pond bottom a height of at least twice the maximum head;
- The crest length for broad-crested weirs should be at least 3 times the maximum head and preferably 4 times the maximum head, or more;
- Runoff shall enter the detention facility through a conveyance system separate from the control and outflow conveyance system. The distance between the inlet and outlet shall be maximized to reduce sediment from accumulating in the outflow structure;
- Flow control structures discharging from a high use site to a drainage facility shall include an oil control BMP that meets the requirements outlined in Chapter 6;
- Control structures shall be selected taking into consideration the expected hydraulic heads. Table 7-3 presents typical control structures and their applicability.

TABLE 7-3
OPTIMAL APPLICATION OF CONTROL STRUCTURES

Control Structure	Pond Head
Outlet Pipe	Very Low
V-Notch Weir	Low
Slotted Weir	Moderate
Multi-Stage Orifice	High

- Circular orifices shall be 3 inches in diameter or greater. Slotted weirs can be used in lieu of smaller orifices to reduce the occurrence of plugging;
- The top of manhole/catch basin grates used for control structures shall be placed 2 inches above the finish grade when located in earth or gravel locations.

Figure 7-6 shows a typical flow control structure.

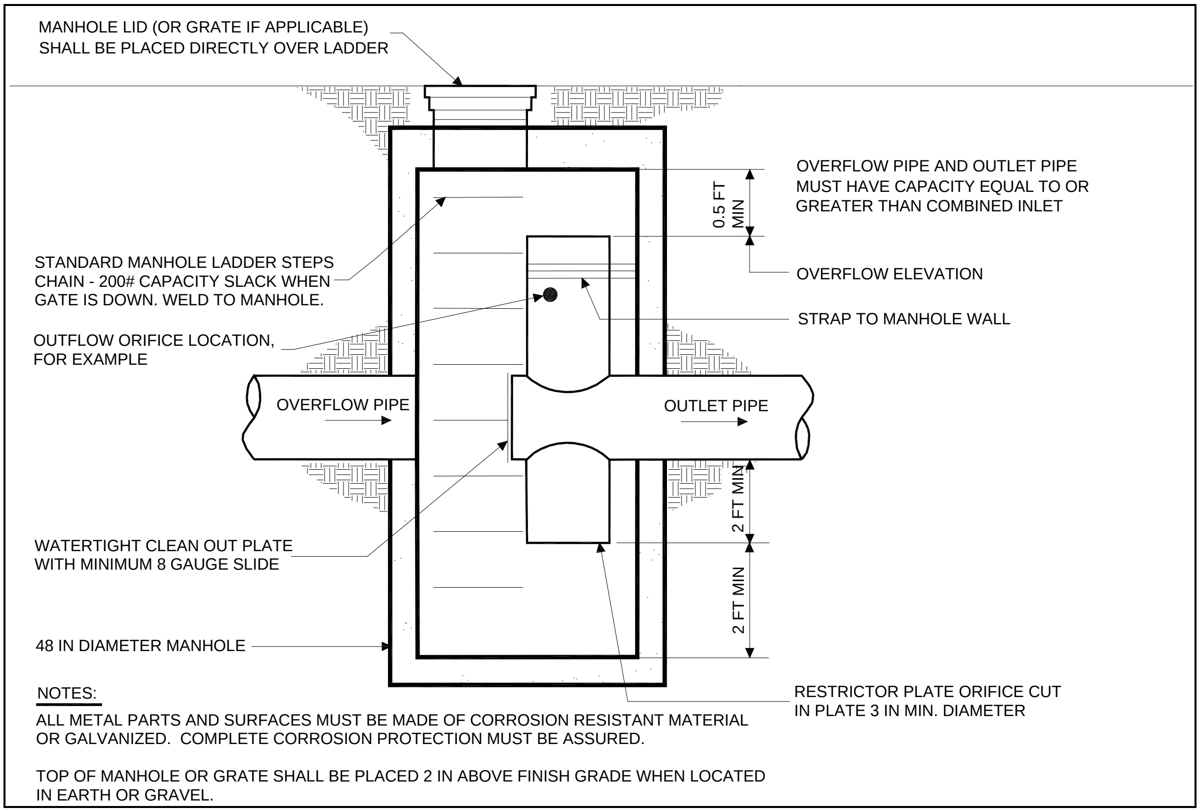


Figure 7-6 – Flow Control Structure Example

7.5 INFILTRATION FACILITIES

7.5.1 INTRODUCTION

An infiltration facility is used for disposing of stormwater runoff into the subsurface and can be used for flow control provided that:

- The discharge is uncontaminated or properly treated so that it does not violate water quality criteria per Chapter 6. For additional information regarding discharges to drywells, refer to Ecology's *Guidance for UIC Wells that Manage Stormwater*;
- The Geotechnical Site Characterization demonstrates the suitability of the soil for subsurface disposal;
- The down-gradient analysis indicates that adverse impacts are not anticipated; and,
- The discharge does not violate UIC regulations.

Drywells are considered standard infiltration facilities. The engineer shall consider the impact of infiltration on groundwater elevations both on site and on down-gradient properties.

For discharges to UIC facilities, the best management practices chosen for the site must remove or reduce the target pollutants to levels that will comply with state groundwater quality standards when the discharge reaches the water table or first comes into contact with an aquifer (see WAC 173-200). Pre-treatment is required prior to discharging to a UIC facility (refer to Chapter 6 for additional information). Discharges to surface waters shall comply with WAC 173-201A, Water Quality Standards for Surface Waters of the State of Washington. Refer to Chapter 6 for BMP selection.

7.5.2 MINIMUM REQUIREMENTS

In addition to the requirements specified in Section 7.8, infiltration facilities shall meet the minimum requirements described below.

Swale Sizing

The methodology for sizing swales is in Section 5.6.

Location

Drywells shall be spaced at least 30 feet center-to-center or twice the depth of the drywell, whichever is greater.

If the site has the potential for contaminated or unstable soil, then these conditions shall be investigated and appropriate mitigating measures taken before designing infiltration facilities in theses areas.

Infiltration facilities shall not be placed on or above a landslide hazard area or slopes greater than 15 percent without evaluation by a geotechnical engineer and jurisdictional approval.

Outflow Rates

Outflow rates shall be determined using the field methods presented in Section 4.3.1.

The active barrel of the drywell shall be installed within the target soil layer. Target soils with more than 12% fines (percent passing the No. 200 sieve) are not suitable for drywells.

The proponent may assume a maximum outflow rate of 0.3 cfs and 1.0 cfs for Type A and Type B drywells, respectively, if all of the following conditions are met:

- The drywells are located within the NRCS Garrison or Springdale soil groups. A full-scale drywell test may still be required;
- The soils are verified by a qualified professional. Field verification should include classifying the target layer soils, obtaining soil gradation data and confirming that the site soils are consistent with the design outflow rates.
- There is no history of drainage problems in the vicinity of the drywell location;
- The anticipated rise in the elevation of the local groundwater table resulting from the disposal facility will not significantly impact adjacent properties or structures; and,
- The local jurisdiction does not have concerns regarding the soil's ability to drain.

Limiting Layer

The optimal separation between the bottom of the drywell and the limiting layer (bedrock, groundwater, clay lens, etc.) shall equal the maximum drywell head, which is 6 feet for single-depth drywells and 10 feet for double-depth drywells. The limiting layer separation can be reduced to 4 feet when the factors of safety specified in Appendix 4A are applied.

For a pond or swale with no infiltrative structure, the separation shall be a minimum of 4.5 feet below the pond bottom, to account for the 6-inch treatment zone and 48 inches of subgrade infiltrative soil.

The local jurisdiction reserves the authority to increase the required depth to the limiting layer should there be evidence that the functionality of the facility will be negatively impacted.

Setback

Drywells shall be placed with the following setback distances:

- At least 100 feet from water wells;
- At least 200 feet from springs used for drinking water supplies,
- At least 100 feet from septic tanks or drainfields;
- At least 100 feet up-slope and 20 feet down-slope from building foundations, unless a reduction is geotechnically justified;
- At least 20 feet from a Native Growth Protection Easement; and,
- Per the geotechnical engineer's recommendations when located up-slope from a structure or behind the top of a slope inclined in excess of 15 percent.

7.6 NATURAL DISPERSION

7.6.1 INTRODUCTION

Natural dispersion attempts to minimize the hydrologic changes created by new impervious surfaces by restoring the natural drainage patterns of sheet flow and infiltration. There are three types of natural dispersion:

- Concentrated Flow Dispersion: Used for steep driveways or other small pavement areas, concentrated flow dispersion uses berms or drains to direct runoff from the paved area to a vegetated pervious area (the "dispersal area") that slows entry of the runoff into a conveyance system, allows for some infiltration and provides some water quality enhancement.
- Sheet Flow Dispersion: Used for flat or moderately sloped paved or cleared areas, sheet flow dispersion consists of a vegetated buffer zone through which sheet flow from the pavement passes, providing flow attenuation and treatment.
- Full Dispersion: Use for larger areas of new residential or commercial development, full dispersion is the preservation of native vegetation on some portion of the site to allow dispersion of runoff from roofs, driveways and roads within the site.

Natural dispersion can be used for impervious or pervious surfaces that are graded to avoid concentrating flows. This flow control method shall only be considered for use on rural projects, including linear roadway projects, large lot subdivision, short plat roads, driveways, sport courts, parking lots and roofs that are not guttered. This flow control method is not intended for use prior to discharge to a lake, stream or water body.

7.6.2 MINIMUM REQUIREMENTS

This section describes a sheet-flow dispersion technique; concentrated flow dispersion is not allowed in the Spokane Region at this time.

In addition to the requirements specified in Section 7.8, as applicable, the following minimum requirements shall be met:

- The dispersal area shall be well-vegetated;
- A vegetated dispersal width of 10 feet must be provided for every 20 feet of width of impervious surface that drains to the dispersal area, with 10 feet the minimum width in all cases. An additional 0.25 feet of vegetated dispersal width shall be provided for each additional foot of impervious surface;

- A vegetated dispersal width of 1 foot must be provided for every 6 feet of disturbed pervious area (i.e. bare soil and non-native landscaping);
- Natural dispersion areas (perpendicular to the impervious area) shall have a slope no steeper than 14% (7H:1V). If this criterion cannot be met due to site constraints, the dispersal width must be increased 1.5 feet for each percent increase in slope above 14%, and in no case shall the slope exceed 20%;
- The average longitudinal slope (roughly parallel to the road or diagonally away from the road) of the dispersal area shall be no more than 15%;
- The longitudinal slope of the contributing impervious or pervious drainage area (parallel to the edge of the dispersal area) shall be 5% or less;
- The lateral slope of the contributing impervious or pervious drainage area (perpendicular to the dispersal area, typically the road cross-slope) shall be 4.5% or less;
- The sheet flow path leading to the natural dispersal area shall not be longer than 75 feet for impervious areas or 150 feet for pervious areas;
- The longitudinal length of the dispersal area shall be equivalent to or greater than the longitudinal length of impervious area that is contributing the sheet flow;
- A 2-foot-wide transition zone (to discourage channeling) shall be provided between the edge of the impervious surface and the vegetated dispersal area, or under the eaves of a roof that has not been guttered. This may be an extension of the sub-grade material (crushed rock), modular pavement, or drain rock;
- The dispersal area shall have a minimum infiltration rate of 4 inches per hour;
- Clearing and grubbing of native dispersal area shall be minimized in order to help maintain the existing root systems that are vital to the success of natural dispersion;
- The area around the dispersal zones shall not be compacted;
- For sites with septic systems, the dispersal area must be downgradient of the drain field primary and reserve areas. This requirement may be waived by the local jurisdiction if the site topography clearly indicates that flow is prohibited from intersecting the drain field;
- The dispersal area shall be located down-gradient from building sites;
- The dispersal area shall be clearly identified on all construction plans, including grading plans, so that the area is not cleared, grubbed or compacted, and shall be clearly delineated on the site;

- Native vegetation and existing trees should not be removed from the natural growth retention areas except where required to meet sight distance, clear-zone or other traffic-related requirements, or if the vegetation is diseased;
- Dispersal is not allowed across, over or toward a landslide or geohazardous area; and,
- The dispersal area shall be preserved within the road right of way, a separate dedicated tract or an easement in order to ensure that treatment and flow control are not interrupted.

7.7 EVAPORATION FACILITIES

7.7.1 INTRODUCTION

Evaporation systems are used to collect and dispose of stormwater runoff when soils are not conducive to infiltration, shallow groundwater is present, or there is the potential for negative impacts due to post-developed stormwater runoff being injected into the subsurface.

The locally developed spreadsheet described in Section 5.7.3 is the most common tool used to perform evaporative pond capacity calculations.

7.7.2 MINIMUM REQUIREMENTS

Liner

Geosynthetic or natural liners may be required to limit infiltration in areas where there is the potential for down-gradient impacts or where the water table may adversely impact the pond via seepage or mounding. The liner shall be a product suitable for stormwater storage and installed per the geotechnical engineer’s or manufacturer’s recommendation.

When an evaporative pond is proposed, a geotechnical engineer shall provide evaluation of the following:

- Liner materials and installation;
- The potential for groundwater seepage into the pond from the surrounding area;
- The potential for any down-gradient adverse impacts due to the injection of developed stormwater volume into the subsurface; and,
- The potential for groundwater mounding or uplift for a lined pond.

Based upon the information in these evaluations, the geotechnical engineer shall make recommendations regarding the following, if applicable:

- Liner materials and installation; and,
- Any proposed mitigation measures.

Pond Geometry

Evaporative systems designed with the Preferred Method (refer to Section 5.7.2) shall have an evaporation volume separate from the detention volume that provides attenuation of peak flows. Depending on the site conditions and limitations, the proponent can provide separated cells or stacked cells to satisfy this requirement.

Separated system: This type of facility has one evaporation cell (upstream cell) followed by a detention or infiltration cell (downstream cell). The storage volume and design depth of the evaporation cell is determined by a water budget analysis as described in Section 5.7. A factor of safety of at least 1.2 is applied to the required evaporative volume or design depth. The invert of the overflow to the detention or infiltration facility is placed at or above the maximum surface water elevation of the evaporative system (including the factor of safety).

The downstream cell is designed per the criteria for detention facilities (refer to Section 7.3) or infiltration facilities (refer to Section 7.5). In order to allow a point discharge from a detention facility, it must be established that there is an existing, well-defined natural drainage course. A 1-foot freeboard above the maximum surface elevation of the detention or infiltration cell is required. Figure 7-7 shows a typical cross-section of a separated system.

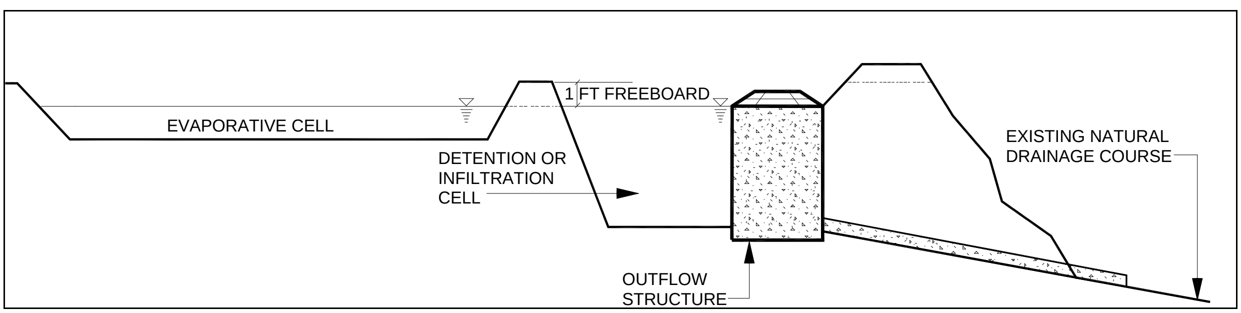


Figure 7-7 – Separated Evaporative/Detention Facility Cross-Section

A stacked system: This type of facility has the evaporative cell (lower cell) below the detention cell (upper cell). The storage volume and design depth of the evaporation cell are determined by a water budget analysis as described in Section 5.7. A factor of safety of at least 1.2 is applied to the required evaporative volume or design depth. Once the dimensions of the lower cell are determined, the upper cell is placed on top of the lower cell. Thus, the detention cell "bottom" and outflow structure must be placed at or above the maximum surface water elevation of the evaporative system (including the factor of safety).

The detention cell is designed per the criteria specified in Section 7.3. In order to allow a point discharge from a detention facility, it must be established that there is an existing, well-defined natural drainage course. A 1-foot freeboard above the maximum surface elevation of the detention or infiltration cell is required. Figure 7-8 shows a typical cross-section of a stacked system.

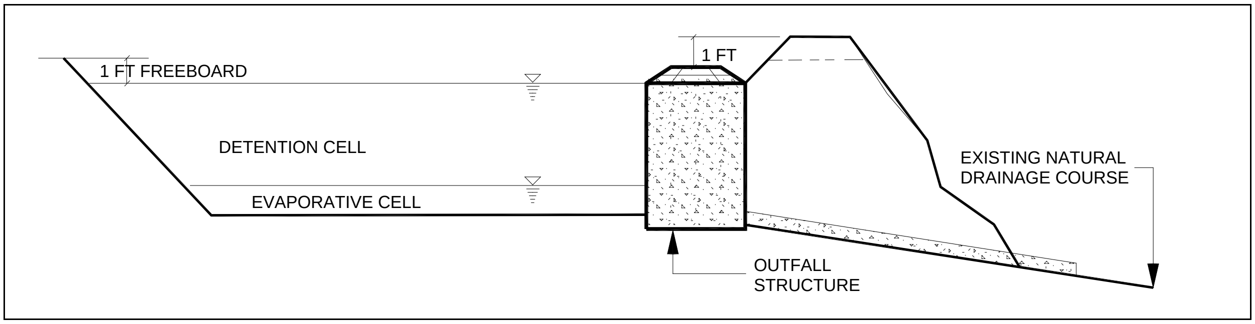


Figure 7-8 – Stacked Evaporative/Detention System Cross-Section

Treatment

Evaporative systems designed with the Alternative Method are not subject to water quality treatment requirements. Evaporative systems designed with the Preferred Method are required to provide water quality treatment per the goals, applicability and criteria specified in Chapter 6.

7.8 ADDITIONAL REQUIREMENTS FOR ALL FACILITIES

The following minimum requirements shall be met for all flow control facilities:

7.8.1 GENERAL

The design of flow control facilities shall adhere to the following:

- Pond bottoms shall be located a minimum of 0.5 feet below the outlet to provide sediment storage; and,
- In general, all pond bottoms shall be flat. Roadside swales are considered flat if the swale bottom slope is 1% or less. When calculating treatment volume, the designer can assume a flat bottom for swale/pond bottom slopes up to 1%. Note that if treatment volume versus area is the methodology used, the volume may be calculated assuming a flat bottom even if the roadside swale bottom has a slope (maximum of 1%).

However, for the calculation of stormwater disposal volume, the grade of the roadside swale bottom shall factor into the geometry used to size the facility. The drainage facility bottom shall slope away from the pond inlet and toward the control structure at 1% for a maximum distance of 20 feet.

- Drainage facilities shall be located within the right of way, within a border easement parallel to the road or within a drainage tract. In unincorporated Spokane County, drainage facilities may also be located in a drainage easement on private property (refer to Chapter 11 for specific information).

7.8.2 SETBACKS

Setbacks for any pond, swale or ditch (measured from the maximum design operating depth) shall be at least 30 feet when located up-gradient or 10 feet when located down-gradient from septic tanks or drainfields.

Pond overflow structures shall be located a minimum of 10 feet from any structure or property line. The toe of the berm or top of bank shall be a minimum of 5 feet from any structure or property line.

7.8.3 DRAWDOWN TIME

Detention and infiltration facilities shall have a minimum subgrade infiltration rate of 0.15 inches/hour and drain completely within 72 hours after a storm event.

7.8.4 SIDE SLOPES

Pond side slopes shall meet one of the following requirements:

- Interior side slopes shall not be steeper than 3:1 (horizontal to vertical);
- Interior side slopes may be increased to a maximum of 2:1 (horizontal to vertical) if the surrounding grade creates a cut or fill with no greater depth than 1.0 foot;
- Exterior side slopes shall not be steeper than 2:1 (horizontal to vertical) unless analyzed for stability by a geotechnical engineer.
- Pond walls may be vertical retaining walls, provided that:
  - A fence is provided along the top of the wall for walls 2.5 feet or taller;
  - A 4-foot-wide access ramp to the pond bottom is provided, with slopes less than 4:1 (horizontal to vertical); and,

- The design is stamped by an engineer with structural expertise if the wall is surcharged or if it is 4 feet or more in height. A separate building permit may be required by the local jurisdiction if the wall height exceeds 4 feet.

7.8.5 EMERGENCY OVERFLOW SPILLWAY

An emergency overflow spillway shall be provided, whenever reasonable, to bypass the 100-year developed peak flow toward the downstream conveyance system in the event of plugged orifices or high flows that exceed the design storm.

Emergency overflow spillways shall be provided for detention ponds with constructed berms 2 feet or more in height and for ponds located on grades in excess of 5%.

Emergency overflow spillways shall be analyzed as broad crested trapezoidal weirs and comply with the following requirements:

- The spillway shall have the capacity to pass the 100 year-developed peak flow with a 30% freeboard;
- The full width of the spillway shall be armored with riprap and extend downstream to where emergency overflows enter the conveyance system;
- If the detention facility is located on an embankment, the overflow spillway shall be armored to a minimum of 10 feet beyond the toe of the embankment; and;
- The overflow path shall be identified on the construction plans and easements shall be provided as necessary.

Engineers may choose to design the detention pond multi-stage outflow structure with an emergency bypass that can route the 100-year storm through the structure and out of the pond directly into the conveyance channel. However, due to the high potential for sedimentation and plugged orifices within these structures, an emergency overflow spillway shall still be provided in order to reduce the potential for a pond berm breach for detention ponds that require an emergency overflow spillway.

7.8.6 EMBANKMENTS

The height of an embankment is measured from the top of the berm to the catch point of the native soil at the lowest elevation. Embankments shall meet the following minimum requirements:

- Embankments 4 feet or more in height shall be constructed as recommended by a geotechnical engineer. Depending upon the site, geotechnical recommendations may be necessary for lesser embankment heights;

- Embankments shall be constructed on native consolidated soil, free of loose surface soil materials, fill, roots, and other organic debris or as recommended by the geotechnical engineer;
- Energy dissipation and erosion control shall be provided to stabilize the berm and its overflow;
- The embankment compaction shall produce a dense, low permeability engineered fill that can tolerate post-construction settlements with minimal cracking. The embankment fill shall be placed on a stable subgrade and compacted to a minimum of 95% of the Modified Proctor Density (ASTM Procedure D1557);
- Anti-seepage filter-drain diaphragms shall be considered on all outflow pipes and are required on outflow pipes when design water depths are 8 feet or greater;
- Embankments must be constructed by excavating a key. The key width shall equal 50 percent of the berm base width, and the key depth shall equal 50 percent of the berm height; and,
- The berm top width shall be a minimum of 4 feet.

7.8.7 FENCING

Fencing or other barriers may be required to protect the health, welfare and safety of the public. In general, fencing is required for the following:

- Drainage facilities with the first overflow at 2 or more feet above the pond bottom;
- Drainage facilities with retaining walls 2.5 feet high or taller;
- Drainage facilities located at, or adjacent to, schools, nursing homes, day-cares, or similar facilities; and,
- Evaporation Ponds.

Fencing is not required for a typical bio-infiltration swale. However, the local jurisdiction reserves the authority to require a fence along any swale or pond should there be a concern for safety.

At the discretion of the local jurisdiction, if a pond is proposed as an amenity (i.e. enhancements to the disposal facility are proposed, such as rocks, boulders, waterfalls, fountains, creative landscaping or plant materials), the design will be reviewed on a case-by-case basis, such that the fencing requirements may be reduced or waived.

At the discretion of the local jurisdiction, marking fences, terraces, shallower side-slopes, egress bars, etc. may be allowed instead of fencing.

The minimum fencing requirements are as follows:

- The fencing shall be at least 4 feet tall unless otherwise specified by the local jurisdiction, and provide visual access; and,
- Gates are to be provided where drainage facilities are fenced. The gates shall be a minimum of 12 feet wide and have locks.

The City of Spokane Valley reserves the authority to waive any and all fencing in commercial areas, as reviewed and accepted on a case-by-case basis by City staff.

7.8.8 PLANTING REQUIREMENTS

Exposed earth on the pond bottom and interior side slopes shall be sodded, seeded or vegetated in a timely manner, taking into account the current season. Unless a dryland grass or other drought tolerant plant material is proposed, irrigation shall be provided. All remaining areas of the tract or easement shall be sodded or planted with dryland grass or landscaped.

7.8.9 LANDSCAPING

Where space and circumstances allow, the landscaping scheme and common use areas should be integrated with the open drainage features and into the overall stormwater plan. Plants other than turf grass have characteristics that can provide additional stormwater management benefits such as enhanced evapotranspiration and improved soil-holding capabilities.

However, in all cases the landscaping and other uses must be subservient to the primary stormwater needs and functions. Landscaping that does not conflict with the collection, conveyance, treatment, storage, and disposal of stormwater is encouraged. The following general principles should guide the landscaping and selection of plants in conjunction with stormwater facilities:

- Supplemental landscaping areas should be grouped into irregular islands and borders outside of the immediate stormwater facilities and not uniformly dispersed throughout them. The constructed stormwater features should be irregular and curved in shape to look more natural. Avoid straight lines and regular shapes where and when possible;
- Trees and shrubs shall not be planted on pond liners due to potential leakage from root penetration;
- Trees and shrubs shall not be planted near drainage appurtenances such as outlet control structures, manholes, catch basins, inlets, storm drain lines, and underground disposal structures such as drywells or drain-fields. The minimum spacing between the tree or shrub and the drainage structure shall be equal to the crown diameter of the mature plant;

- Trees and shrubs shall not be planted within the treatment, storage, and conveyance zones of swales, ponds, and open channels, unless treatment and storage calculations take into account the mature tree size and allow runoff to reach the drainage facilities;
- Self-limiting plants shall be used, not spreading or self-seeding types.
- Full-size forest trees and trees with aggressive root systems should not be used except where space and circumstances allow. Deciduous trees with heavy shade and leaf-fall should also be avoided to allow the survival of the surrounding grass areas and not plug drainage facilities. Evergreens and smaller ornamental trees are normally better suited to urban conditions;
- Shrubs should be upright in form and groundcovers should have neat growth patterns to assist in their maintenance and that of the surrounding grass areas; and,
- The plant selection needs to consider the native soil conditions and altered moisture conditions created by the stormwater facilities. The plants need to be adaptable to the changes in site conditions. Plants that are self-sufficient and self-limiting, do not require year-round irrigation and require minimal care are encouraged.

7.8.10 MAINTENANCE

Maintenance is of primary importance for drainage facilities to operate as designed. The requirements of Chapter 11 shall be met as applicable.

7.8.11 DAM SAFETY

Detention facilities that can impound 10 acre-feet (435,600 cubic feet) or more with the water level at the embankment crest are subject to the state's dam safety requirements, even if water storage is intermittent and infrequent (WAC 173-175-020(1)). The principal safety concern is for the downstream population at risk if the dam should breach and allow an uncontrolled stormwater release. Peak flows from dam failures are typically much larger than the 100-year flows which these ponds are typically designed to accommodate.

Dam safety considerations generally apply only to the volume of water stored above natural ground level. Per the definition of dam height in WAC 173-175-030, natural ground elevation is measured from the downstream toe of the dam. If a trench is cut through natural ground to install an outlet pipe for a spillway or low-level drain, the natural ground elevation is measured from the base of the trench where the natural ground remains undisturbed.

Ecology's Dam Safety Office is available to provide written guidance documents and technical assistance for owners and engineers to address dam safety requirements. If the pond exceeds the volume criteria for dam safety, Ecology shall be contacted early in the facilities planning process.

7.9 SPECIAL REQUIREMENTS

7.9.1 SPECIAL DRAINAGE AREAS

Special Drainage Areas (SDAs) are designated areas with shallow soils, bedrock near the surface of the land, and soils or geological features that may make long-term infiltration of stormwater difficult or areas where infiltration may pose potential problems for on-site or adjacent properties. These areas may also contain steep slopes where infiltration of water and dispersion of water into the soils may be difficult or delayed, creating drainage problems such as erosion. Known areas of flooding or areas that historically have had drainage or high groundwater problems (mapped or unmapped) are also SDAs.

SDAs in the City of Spokane are described in SMC 17D.060 "Stormwater Facilities." Additional requirements for development in these areas are included in this ordinance.

Spokane County has mapped several SDAs. Among the mapped SDAs are portions of the Glenrose/Central Park Watershed, the North Spokane Stormwater Planning Area and the West Plains Stormwater Planning Areas. The Spokane County Stormwater Utility Section maintains and updates these maps. At the discretion of the local jurisdiction, an area can be designated as an SDA if it is determined that development may have adverse impacts on existing or future down-gradient or adjacent properties.

Unless specifically approved by the local jurisdiction, the peak rate and volume of stormwater runoff from any proposed land development to any natural or constructed point of discharge downstream shall not exceed the pre-development peak rate or volume of runoff. A down-gradient analysis demonstrating that there will be no expected adverse impacts on downgradient properties will be required. Exceptions with regard to rate and volume control can be made for regional facilities planned by the local jurisdiction.

7.9.2 FLOODPLAINS

In the City of Spokane and the City of Spokane Valley, floodplain requirements are administered by the planning department. Check with the local jurisdiction for more information and specific requirements.

When any property is developed in and around identified Areas of Special Flood Hazard (100-year floodplains) all work must conform to the requirements of the National Flood Insurance Program and the flood ordinance of the local jurisdiction. This section summarizes the general requirements for projects located within a floodplain. Specific requirements and additional information can be obtained from the local jurisdiction.

Land-actions located within a floodplain (A and B Flood Zones only) shall conform with the following requirements:

- A Floodplain Development permit shall be obtained from the local jurisdiction before any development (including structures, manufactured homes, bridges, culverts, grading, excavation or fill) is undertaken, constructed, located, extended, connected or altered on any property that is partly or entirely located in a floodplain;
- The 100-year Base Flood Elevation (BFE) shall not increase at any point by more than 1.0 foot within Unnumbered A Zones and B Zones; increase in other designated flood hazard areas (numbered A zones and floodways) may be further restricted.
- Projects proposing any increases in BFEs or in the way floodwaters enter and exit the property may require approval from the impacted property owners.
- Disposal of increases in stormwater runoff may not be allowed in an identified 100-year floodplain.
- The lowest floor (including basement floor) shall be elevated to a minimum of 1.0 foot above the BFE. Flood Insurance Rate Maps (FIRMs) provide the BFEs for some flood zones. Development in areas without established BFEs may be inspected by the local jurisdiction. When it is not evident that the proposed building will be outside the flood zone or if a subdivision is proposed, a flood study may be required to establish the 100-year BFE and delineate the 100-year floodplain;
- Commercial, industrial, or other nonresidential buildings may be floodproofed to 1 foot above the BFE in lieu of elevating the lowest floor elevation to a minimum of 1.0 foot above the BFE. Floodproofing techniques shall be certified by an engineer or architect licensed in the State of Washington;
- Residential emergency access and egress shall be provided for the 100-year event;
- The plat dedication of all subdivision proposals associated with floodplains shall contain language prescribed by the local jurisdiction.

A floodplain study is required when development impacts floodplains or may impact floodplains in an unnumbered A Flood Zone or when BFEs have not been established. Disturbance to the floodplain may include filling, excavating, etc. The floodplain study shall meet the following requirements:

- The 100-year peak flows and volumes shall be determined for each basin. The engineer shall review FEMA studies, previously accepted floodplain studies, USGS studies and gage data, or watershed plans for already established 100-year flows. If 100-year flows are not available from other sources acceptable to the local jurisdiction, the engineer shall calculate the required flow by comparison with similar watersheds where flows have been determined or the use of regression equations (see USGS Water Resources Investigations Report 97-4277, *Magnitude and Frequency of Floods in Washington* or the most current version), or by running a hydraulic model per the requirements of this Manual. Contact the local jurisdiction for guidance on the appropriate storm type and duration to use.
- The study shall include all relevant calculations for determining the 100-year flow. The study shall be presented in a rational format so as to allow a reviewer to reproduce the same results; a basin map showing the site boundary and the limits of the watershed contributing to the floodplain shall be included. Topographic contours shall extend beyond the floodplain's watershed boundary, as needed, to confirm the basin limits. The basin map shall meet the requirements of Section 3.4.3;
- In determining the BFE, the study shall use field-surveyed cross-sections of the floodplain in the project area. The cross-sections shall extend offsite, as necessary, to delineate the floodplain in the area of the proposal. FEMA-generated cross-sections may be available for use, but these shall be supplemented with field-surveyed cross-sections for the specific site;
- The BFE shall be determined and the floodplain shall be delineated for the pre-developed and post-developed conditions. The BFE shall be tabulated by station in order to estimate any change to the BFE and delineate modifications to the floodplain. The analysis shall calculate the pre-developed and post-developed BFEs as follows:
    - To the nearest 1/10 of a foot in unnumbered A and B zones;
    - To the nearest 1/100 of a foot in numbered A zones; and,
    - To the nearest 1/1,000 of a foot (as required by FEMA) in floodway areas.
- Floodplain analysis maps shall be prepared for the pre-developed and post-developed conditions and shall meet the following requirements:
    - The maps shall show the BFEs on-site to the nearest 1/10th of a foot and clearly delineate the 100-year floodplain;
    - Topographic contours shall be clearly marked, a bench mark shall be identified for the topographic work and the details of the bench mark shall be discussed;

- Maps shall clearly show no violations to the requirements of the local jurisdiction's Flood Ordinance;
- All lots and development, a north arrow, and a scale bar shall be shown on the map; and,
- The map must be stamped and signed by an engineer.

In unincorporated Spokane County, plats, short plats and commercial project floodplain requirements shall be coordinated during the pre-design meeting and submitted with the Drainage Submittal. For single-family residential projects, the engineer shall work directly with the Environmental Programs section of the Engineering Department as soon as possible in the planning process.

7.9.3 WETLANDS AND CLASSIFIED STREAMS

Wetlands and classified streams are regulated by the Department of Ecology, the Department of Fish and Wildlife and the local jurisdiction's critical areas ordinance. Classified streams are those identified and classified under the Washington Department of Natural Resources' water typing system. This section provides criteria for using a wetland for stormwater treatment or disposal. The engineer shall coordinate with the local building and planning department for further requirements.

The term wetland encompasses a variety of aquatic habitats including swamps, marshes, bogs or floodplains. Wetlands have a natural supply of water, from flooding rivers, streams, natural drainage channels, connections to groundwater, or a perched shallow groundwater table, and are typically inundated with water for a portion of the year. Wetlands are often vegetated with aspen, cattails, cottonwoods, willows, reed grasses and other aquatic plants.

Sites with a wetland or a classified stream often feature other Natural Location of Drainage Systems as well. In addition to the requirements in Section 8.3, the following are required for sites with a wetland or classified stream:

- A qualified wetland biologist shall categorize the wetland, according to the local jurisdiction's critical areas ordinance and Ecology's Wetland Rating System for Eastern Washington, and delineate the wetland boundaries and buffer areas. More information can be found at: http://www.ecy.wa.gov/programs/sea/wetlan.html;
- The proponent shall submit to the local jurisdiction a Mitigation Plan, accepted by the Department of Ecology, if the wetland is to be disturbed due to construction activity or if any natural source of recharge to the wetland will be eliminated or altered;
- A Hydraulic Permit shall be obtained when work is proposed within the normal high-water level of classified streams. Site alterations within the buffers of regulated streams are generally limited to essential access and

utility needs or restoration plans as reviewed and accepted by the State Department of Fish and Wildlife and under the local jurisdiction's critical areas ordinance; and,

- The local planning department and state and federal agencies shall be contacted for permitting and buffer requirements, etc.

Requirements for hydrologic modification of a wetland for stormwater treatment or disposal are presented in Section 6.7.5.

7.9.4 CLOSED DEPRESSIONS

Closed depressions are natural low areas that hold a fixed volume of surface water. Depending upon soil characteristics, a closed depression may or may not accumulate surface water during wet periods of the year. Some closed depressions may be classified as wetlands. If so, the engineer shall comply with the wetland criteria specified in this chapter and in Chapter 6. Analysis of closed depressions shall include the following at a minimum:

- Identification of the location of the closed depression on the pre-developed basin map;
- A routing analysis of the drainage basins contributing to the closed depression to estimate the peak flow rates and volumes leaving the site in the pre-developed condition;
- An estimation of the storage capacity of the closed depression for the 100-year storm event;

If the closed depression will be filled in, a facility shall be provided that has the capacity to store the 100-year volume that was historically intercepted by the closed depression. This is in addition to the drainage facilities required for flow control and treatment due to the increase in stormwater runoff. The construction plans shall include a grading plan of any closed depression areas to be filled in. The grading plan shall show both existing and finish grade contours. The plans shall also specify compaction and fill material requirements.

7.10 REGIONAL STORMWATER FACILITIES

Regional stormwater facilities are grass-lined ditches, natural drainageways, ponds, pipes and various other means of conveying, treating and disposing of stormwater runoff that serve as the "backbone" of a system to which smaller drainage elements can be connected. Most regional facilities serve more than a single development within a given contributing drainage basin. Regional facilities have the potential to lessen flooding in existing drainage problem areas and to provide new development with an alternative to on-site stormwater disposal.

If regional facilities consist of pipes or other non-infiltrative conveyance facilities, they have the potential to significantly increase stormwater runoff and contaminants going into selected discharge areas. The location of such discharges, and pretreatment levels, must be carefully considered to avoid adverse impacts on water resources.

Regional facilities may reduce a community's long term costs for stormwater management because they can free up buildable land for development and can be less expensive to build, operate, and maintain than multiple individual facilities. The local jurisdiction may assume responsibility, or form a partnership, for the design, construction, operation and maintenance of regional facilities.

Studies are currently being performed and completed for several planned regional facilities in the Spokane region. In addition, local jurisdictions have begun mapping natural stormwater features that will need to be incorporated into future regional stormwater systems. Due to this recent progress, developments in the near future may be allowed to discharge stormwater into regional systems. As regional facilities come "on-line," the requirements for on-site treatment and detention may vary from the basic requirements in this manual. Close coordination with the local jurisdiction will be required in order to determine the location and timing of any planned regional system, and to learn the specific design criteria for on-site stormwater facilities that may discharge into the system.

All projects shall be reviewed for the presence of natural drainageways, and a determination will be made as to their significance with regard to preservation of natural conveyance and potential use as part of a regional system.

When a local jurisdiction assumes the responsibility for any or all portions of the design, construction, operation, and maintenance of the drainage facilities, project proponents shall be required to contribute a pro-rated share of the cost (via system development charges or other related fees) based on the estimated cost of improvements the project proponent would otherwise have been required to install. The proponent shall supply the information to justify the estimated costs of the foregone individual improvements.

While opportunities may be available for private developments to use public regional stormwater facilities to accommodate runoff, local jurisdictions reserve the authority to limit or restrict discharge to public facilities.

Spokane County has completed Stormwater Management Plans for Chester Creek and the Glenrose, Central Park, North Spokane and West Plains Stormwater Planning Areas. The City of Spokane has completed a City Stormwater Management Plan and the City of Spokane Valley may also identify needed regional stormwater facilities in the near future. Project proponents shall coordinate with the appropriate local jurisdiction early in the project proposal process if the project is in an area for which natural drainage features with potential regional significance have been identified where regional facilities have been proposed, or where capital improvement plans have been adopted.

CHAPTER 8 – CONVEYANCE

Chapter Organization

8.1 INTRODUCTION

A conveyance system includes all natural or constructed components of a storm drain system that collect stormwater runoff and convey it away from structures, minimizing the potential for flooding and erosion.

Conveyance facilities consist of curbs and gutters, inlets, storm drains, catch basins, channels, ditches, pipes and culverts. The placement and hydraulic capacities of storm drain structures and conveyance systems shall consider the potential for damage to adjacent properties and minimize flooding within traveled roadways. The conveyance system shall also provide discharge capacity sufficient to convey the design flow at velocities that are self-cleaning without being destructive to the conveyance facilities. These objectives are achieved by designing all conveyance facilities using the design storm event specified for the given facility and by adhering to requirements such as minimum velocity, freeboard, cover, etc.

A properly designed conveyance system maximizes hydraulic efficiency by using the proper material, slope and size. Constructed conveyance systems should emulate natural, pre-developed conditions to the maximum extent feasible. Field-verified defined natural drainageways must be preserved and protected; filling them in and building on top of them is not an acceptable practice. In addition, some drainageways may be required for regional use (refer to Section 8.3.4 for criteria).

Inflow and discharge from the system shall occur at the natural drainage points in the same manner as the pre-developed condition as determined by topography and existing drainage patterns.

8.2 APPLICABILITY

All projects shall comply with this Basic Requirement regardless of whether the project they meet the regulatory threshold.

8.3 NATURAL AND CONSTRUCTED CHANNELS

8.3.1 CHANNEL ANALYSIS

A channel analysis shall be performed for all constructed channels proposed for a project and for all field-verified existing natural drainageways/channels present on-site (refer to Section 8.3.4 for details). The following requirements apply to the Drainage Report and the road and drainage plans, when applicable:

- Complete channel calculations shall be provided, indicating the design peak flow rates and assumptions, such as channel shape, slope and Manning's coefficient (see Table 5-4);
- Calculations, including the velocity, capacity, and Froude number shall be provided for each distinct channel segment whenever the geometry of the channel changes (i.e. if the slope, shape or roughness changes significantly);
- The centerline and direction of flow for all constructed drainage ditches or natural channels within the project limits are to be clearly shown on the construction plans and basin map. For all proposed channels, locating information shall be provided at all angle points;
- Calculations shall support the riprap area, thickness, riprap size and gradation, and filter blanket reinforcement for all channel protection, which shall be provided when permissible velocities are exceeded (see Table 8-1). This information shall be included in the plans;

TABLE 8-1
PERMISSIBLE VELOCITIES FOR CHANNELS WITH ERODIBLE LININGS, BASED ON UNIFORM FLOW IN CONTINUOUSLY WET, AGED CHANNELS

Soil Type Of Lining (Earth; No Vegetation)	Maximum Permissible Velocities (feet/second)		
	Clear Water	Water Carrying Fine Silts	Water Carrying Sand & Gravel
Fine sand (non-colloidal)	1.5	2.5	1.5
Sandy loam (non-colloidal)	1.7	2.5	2.0
Silt loam (non-colloidal)	2.0	3.0	2.0
Ordinary firm loam	2.5	3.5	2.2
Volcanic ash	2.5	3.5	2.0
Fine gravel	2.5	5.0	3.7
Stiff clay (very colloidal)	3.7	5.0	3.0
Graded, loam to cobbles (non-colloidal)	3.7	5.0	5.0
Graded, silt to cobbles (colloidal)	4.0	5.5	5.0
Alluvial silts (non-colloidal)	2.0	3.5	2.0
Alluvial silts (colloidal)	3.7	5.0	3.0
Coarse gravel (non-colloidal)	4.0	6.0	6.5
Cobbles and shingles	5.0	5.5	6.5
Shales and hard pans	6.0	6.0	5.0

Source: Special Committee on Irrigation Research, American Society of Civil Engineers, 1926.

- The Froude number shall be checked near the beginning and near the end of a channel that has significant grade changes to determine if a hydraulic jump occurs (as indicated by the Froude number changing from <1 to >1, or vice versa). Since it is difficult to correlate the location of a hydraulic jump to the actual location in the field, the engineer shall propose evenly spaced riprap berms, check dams, or other protective measures to ensure that the jump does not erode the conveyance facility;
- When geosynthetics are used for channel protection, the plans shall clearly specify fabric type, placement, and anchoring requirements. Installation shall be per the manufacturer's recommendation; and,
- Plans for grass-lined channels shall specify seed mixture and irrigation requirements, as applicable.

8.3.2 MINIMUM REQUIREMENTS

Slope

Minimum grades for constructed channels shall be as follows:

- 1.0% for asphalt concrete; and,
- 0.5% for cement concrete, graded earth or close-cropped grass.

Side Slopes

Ditch cross-sections may be V-shaped or trapezoidal. However, V-ditches are not recommended in easily erodible soils or where problems establishing vegetation are anticipated.

The side slope of roadside ditches shall conform to the requirements for clear zone of the local jurisdiction and WSDOT design standards.

No ditches or channels shall have side slopes that exceed the natural angle of repose for a given material or per Table 8-2.

Location

Constructed channels shall not be placed within or between residential lots. Ditches and channels shall be located within a drainage tract or within a border easement. Ditches or channels may be allowed to traverse through lots in large-lot subdivisions (lots of 1 acre or more) and consideration may be given to placement within an easement versus a tract. The local jurisdiction will review these proposals on a case-by-case basis.

TABLE 8-2
MAXIMUM DITCH OR CHANNEL SIDE SLOPES

Type of Channel	Side Slope (Horizontal: Vertical)
Firm rock	¼:1 to Vertical
Concrete-lined stiff clay	½:1
Fissured rock	½:1
Firm earth with stone lining	1½:1
Firm earth, large channels	1½:1
Firm earth, small channels	2:1
Loose, sandy earth	2:1
Sandy, porous loam	3:1

Source: Civil Engineering Reference Manual, 8th Edition

Depth

The minimum depth of open channels shall be 1.3 times the flow depth or 1 foot; whichever is greater.

Velocity

Table 8-1 lists the maximum permissible mean channel velocities for various types of soil and ground cover. If mean channel velocities exceed these values, channel protection is required (refer to Section 8.3.3). In addition, the following criteria shall apply:

- Where only sparse vegetative cover can be established or maintained, velocities should not exceed 3 feet/second;
- Where the vegetation is established by seeding, velocities in the range of 3 to 4 feet/second are permitted;
- Where dense sod can be developed quickly or where the normal flow in the channel can be diverted until a vegetative cover is established, velocities of 4 to 5 feet/second are permitted; and,
- On well established sod of good quality, velocities in the range of 5 to 6 feet/second are permitted.

8.3.3 CHANNEL DESIGN

Channel Capacity

Open channels shall be sized using the following variation of Manning's formula.

$$Q = VA = \frac{1.486\ A\ R^{2/3}\ \ S^{1/2}}{n} \tag{8-1}$$

Where:

Q	=	rate of flow (cfs);
V	=	mean velocity in channel (feet/second);
A	=	cross-sectional area of flow in the channel (square feet);
R	=	hydraulic radius (feet); where R = A/P, and
		P = wetted perimeter (feet)
S	=	channel slope (feet/foot);
n	=	Manning's roughness coefficient (Table 5-4); and,

Note: Manning's equation will give a reliable estimate of velocity only if the discharge, channel cross-section, roughness, and slope are constant over a sufficient distance to establish uniform flow conditions. Uniform flow conditions seldom, if ever, occur in nature because channel sections change from point to point. For practical purposes, however, Manning's equation can be applied to most open channel flow problems by making judicious assumptions.

Energy Dissipation Design

An energy dissipater is useful in reducing excess velocity, as a means of preventing erosion below an outfall or spillway. Common types of energy dissipaters for small hydraulic works are: hydraulic jumps, stilling wells, riprap outfall pads, and gabion weirs.

Channel Protection

Channel velocities shall be analyzed at the following locations, and if they are found to be erosive, channel protection shall be provided:

- At the top of a watershed, at the point where the stormwater runoff becomes concentrated into a natural or constructed channel;
- At all changes in channel configuration (grade, side slopes, depth, shape, etc.), if an erosive velocity is determined at a change in channel

configuration, the velocity shall be evaluated up the channel until the point at which the velocity is determined not to be erosive; and,

- At periodic locations along the entire channelized route.

A material shall be selected that has revetment and armoring capabilities, and the channel shall be analyzed using the Manning's "n" value for that material to determine if the material will reduce the velocity in the channel. In some cases, vegetative cover (natural grasses, etc.) may provide excellent protection without changing the flow characteristics and should be evaluated. If the calculations reveal that common materials such as riprap are not adequate, stronger protection such as gabions and/or stilling pools may be necessary.

Riprap Protection at Outlets

If the velocity at a channel or culvert outlet exceeds the maximum permissible velocity for the soil or channel lining, channel protection is required. The protection usually consists of a reach between the outlet and the stable downstream channel lined with an erosion-resistant material such as riprap.

The ability of riprap revetment to resist erosion is related to the size, shape and weight of the stones. Most riprap-lined channels require either a gravel filter blanket or filter fabric under the riprap.

Riprap material shall be blocky in shape rather than elongated. The riprap stone shall have sharp, angular, clean edges. Riprap stone shall be reasonably well-graded.

Apron Dimensions: The length of an apron (L_a) is determined using the following empirical relationships that were developed for the U.S. Environmental Protection Agency (ASCE, 1992):

$$L_a = \left(\frac{1.8Q}{D_O^{3/2}}\right) + \left(7D_O\right) \text{ for } \quad TW < \frac{D_O}{2} \tag{8-2}$$

Or

$$L_a = \left(\frac{3Q}{D_O^{3/2}}\right) + \left(7D_O\right) \text{ for } \quad TW \geq \frac{D_O}{2} \tag{8-3}$$

Where: D_o = maximum inside culvert width (feet);

Q = pipe discharge (cfs); and,

TW = tailwater depth (feet).

When there is no well-defined channel downstream of the apron, the width, W, of the apron outlet as shown in Figure 8-1, shall be calculated using Equation 8-4 or 8-5:

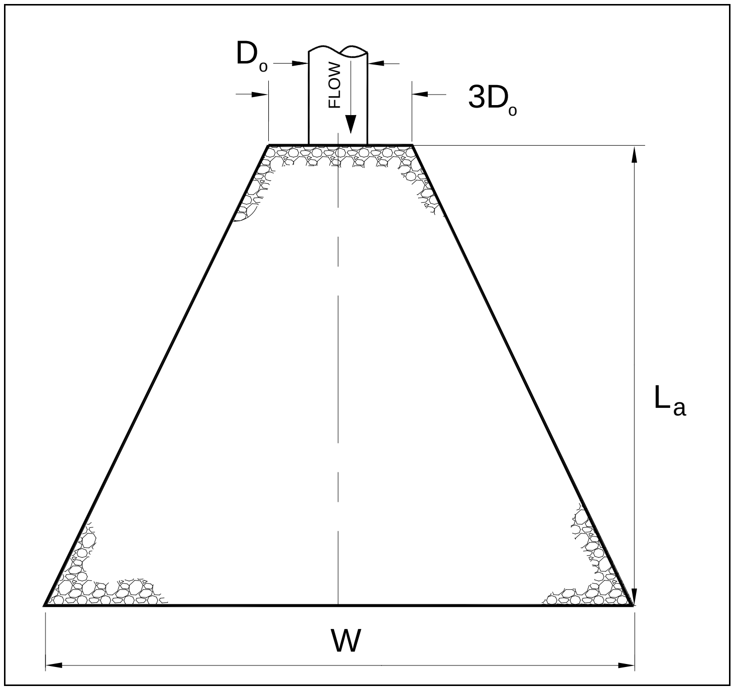


Figure 8-1 – Riprap Revetment at Outfall Schematic

$$W = 3D_O + 0.4L_a \text{ for } \qquad TW \geq \frac{D_O}{2} \qquad (8\text{-}4)$$

$$W = 3D_O + L_a \text{ for } \qquad TW < \frac{D_O}{2} \qquad (8\text{-}5)$$

When there is a well-defined channel downstream of the apron, the bottom width of the apron should be at least equal to the bottom width of the channel and the lining should extend at least 1 foot above the tailwater elevation.

The width of the apron at a culvert outlet should be at least 3 times the culvert width.

Apron Materials: The median stone diameter, D_{50} is determined from the following equation:

$$D_{50} = \frac{0.02Q^{4/3}}{TW(D_O)} \qquad (8\text{-}6)$$

Where: D_{50} = the diameter of rock, for which 50% of the particles are finer.

The riprap should be reasonably well graded, within the following gradation parameters:

$$1.25 \le \frac{D_{max}}{D_{50}} \le 1.50 \text{ and } \frac{D_{15}}{D_{50}} = 0.50 \text{ and } \frac{D_{min}}{D_{50}} = 0.25$$

Where: D_{max} = the maximum particle size;

D_{min} = the minimum particle size; and,

D_{15} = the diameter of rock, for which 15% of the particles are finer.

Minimum Thickness: The minimum thickness of the riprap layer shall be 12 inches, D_{max} or $1.5D_{50}$, whichever is greater.

Filter Blanket: A filter fabric blanket under the riprap is normally needed. If a gravel or sand filter blanket is used, then it shall conform to the gradation parameters listed in Table 8-3.

TABLE 8-3
CRITERIA FOR GRAVEL OR
SAND FILTER BLANKET GRADATION

Primary Criterion	$D_{15} < 5d_{85}$
Recommended Secondary Criteria	$5d_{15} < D_{15} < 40d_{15}$ $D_{50}/d_{50} < 50$

Guidelines for Stormwater Management, Spokane County, February 1998

The size of the filter blanket material is designated d_{xx}, the size of the riprap is designated D_{xx}, and the size of the subgrade is designated d'_{xx}. The thickness of each filter blanket should be one-half that of the riprap layer. If it is found that $D_{15}/d'_{85} < 2$ then no filter blanket is needed. Where very large riprap is used, it is sometimes necessary to use two filter blanket layers between the sub-grade and the riprap.

8.3.4 PRESERVATION OF NATURAL LOCATION OF DRAINAGE SYSTEMS (NLDS)

New development shall be designed to protect certain natural drainage features that convey or store water or allow it to infiltrate into the ground in its natural location, including drainageways, floodplains (Section 7.9.2), wetlands and streams (including classified streams) (Section 7.9.3), and natural closed depressions (Section 7.9.4). These features are collectively referred to as the Natural Location of Drainage Systems (NLDS). Preserving the NLDS will help ensure that stormwater runoff can continue to be conveyed and disposed of at its natural location. Preservation will also increase the ability to use the predominant systems as regional stormwater facilities. A regional stormwater facility is typically defined as a system designed and built by a local jurisdiction to receive an agreed-upon rate and volume of stormwater from a defined contributing drainage area, but it can also refer to a private system that serves multiple developments.

Projects located within the City of Spokane shall refer to the City of Spokane's Stormwater Ordinance for specific requirements with regard to the Natural Location of Drainage Systems that may differ from the information found in this section.

Definitions

Some of the drainageways that need to be evaluated for preservation purposes or for potential use as part of a regional facility have been mapped. These drainageways are generally defined as Type A and Type B:

- <u>Type A</u> drainageways are predominant systems that are considered a significant part of a larger existing natural conveyance system.
- <u>Type B</u> drainageways are systems that are generally less prominent, but are deemed to perform important functions in the existing management of stormwater runoff and may be necessary for managing stormwater as part of a larger regional or natural system.

Because every site is unique, the local jurisdiction shall make interpretations, as necessary, based on site visits and technical information as to the exact location and type of drainageways or any NLDS on a project site. The local jurisdiction may also require the project proponent to provide engineering information to assist in this determination.

The maps denoting these drainageways are not definitive; a computer program was used to generate the contours and identify the drainageways. The Type A/B designations are not concrete labels nor are they all inclusive. The maps are only one tool that may be used to identify existing natural drainageways; field verification will typically be required to fully identify the existence of a drainageway and its significance with regard to a natural conveyance system. The Spokane County Stormwater Utility Section maintains maps of drainageways identified within the Spokane County Stormwater Service Areas. The criteria for analysis and preservation of all other NLDS (floodplains, wetlands, closed depressions and wetlands/streams) are covered in Chapter 7.

Protection

No cuts or fills shall be allowed in predominant drainageways except for perpendicular driveway or road crossings with engineering plans showing appropriately sized culverts or bridges. Predominant drainageways shall be preserved for stormwater conveyance in their existing location and state, and shall also be considered for use as regional facilities.

Less prominent drainageways in a non-residential development and in a residential development containing lots 1 acre or smaller may be realigned within the development provided that the drainageway will enter and exit the site at the pre-developed location and that discharge will occur in the same manner as prior to development.

Realignment of a less prominent drainageway shall be defined as still following the “basic” flow path of the original drainageway. An acceptable example would be if the drainageway is proposed to be realigned such that it will follow a new road within the proposed development, and will be left in its existing state or utilized as part of the project’s on-site stormwater system.

Stormwater leaving the site in the same manner shall be defined as replicating the way the stormwater left the site in its existing condition. If the drainageway is preserved in its existing location and is left undisturbed, this goal should be met. If the local jurisdiction accepts the proposal to allow a less predominant drainageway to be routed through the site via a pipe, the following additional criteria shall be met:

- Where the less prominent drainageway enters the site, the design shall ensure that the entire drainageway is “captured” as it enters the site; i.e. the surrounding property shall not be regraded to “neck-down” the drainageway so that it fits into a drainage easement or tract or structure intended to capture and reroute the off-site stormwater runoff.
- Where the less prominent drainageway exits the site, the design shall ensure that the stormwater leaves the pipe, pond or structure a significant distance from the edge of the adjacent property so that by the time the stormwater reaches the property boundary, its dispersal shall mimic that of the pre-developed condition.

Since some of the less prominent drainageways may also be useful for managing regional stormwater, if identified as a significant drainageway (i.e. necessary conveyance for flood control, or being considered as a connection to a planned regional facility or conveyance route), then the drainageway may be subject to the same limitations and criteria as a predominant drainageway.

The size of the tract or easement containing the drainageway shall be determined based on an analysis of the existing and proposed stormwater flows directed to these drainage systems and any access and maintenance requirements found in this Manual. This analysis shall be performed as per the criteria found in Basic Requirement No. 5, Section 2.2.5.

All new development containing lots that are 1 acre or smaller shall be required to set aside the drainageway as open space in a separate tract. For new development containing lots that are greater than 1 acre, the drainageway may be set aside in either a tract or an easement.

All projects shall be reviewed for the presence of any NLDS and a determination will be made as to their significance with respect to preservation for continued natural conveyance and for potential use as part of a regional system.

8.4 CULVERTS

A culvert is a short pipe used to convey flow under a roadway or embankment. A culvert shall convey flow without causing damaging backwater flow constriction, or excessive outlet velocities. Factors to be taken into consideration in culvert design include design flows, the culvert's hydraulic performance, the economy of alternative pipe materials and sizes, horizontal and vertical alignment, and environmental concerns.

8.4.1 CULVERT ANALYSIS

When applicable, the following items shall be included in the Drainage Report, or on road and drainage plans:

- Complete culvert calculations that state the design peak flow rates, velocities at the inlet and outlet, flow control type, and design information for the culvert such as size, slope, length, material type, and Manning's coefficient (refer to Table 8-4);
- Headwater depths and water surface elevations for the design flow rate;
- Roadway cross-section and roadway profile;
- Location information for each of the culvert inverts and invert elevations;
- Type of end treatment (wingwall, flared end sections, etc); and,
- Wall thickness.

8.4.2 MINIMUM REQUIREMENTS FOR CULVERTS

Peak Flow Rate

Culverts shall be sized to handle the design peak flow rates calculated using the methods described in Chapter 5 and the design criteria specified in Chapter 2.

To avoid saturation of the road base, culverts shall be designed such that the water surface elevation for the design storm event does not exceed the elevation of the base course of the roadway.

Culverts shall be designed to withstand the 100-year storm event without damage.

TABLE 8-4
MANNING'S ROUGHNESS COEFFICIENT (n)
FOR CULVERTS

Material Type	n
Concrete pipe	0.013
Ductile iron	0.013
HDPE (only allowed in private roads)	0.013
CMP	0.024

HDPE = high-density polyethylene; CMP = corrugated metal pipe; PVC = polyvinyl chloride

Allowable Headwater Elevation

Headwater is the depth of water at the culvert entrance at a given design flow. Headwater depth is measured from the invert of the culvert to the water surface.

Culverts shall be designed to carry the design runoff with a headwater depth less than 2 times the culvert diameter for culverts 18 inches or less in diameter, and less than 1.5 times the culvert diameter for culverts more than 18 inches in diameter.

Velocity and Slope

To avoid silting, the minimum velocity of flow through culverts shall be 4 feet/second and the minimum slope shall be 0.5%.

Diameter

Table 8-5 lists required minimum culvert diameters.

TABLE 8-5
MINIMUM CULVERT SIZES

Culvert Location	Minimum Size (inches)
Under public roads	18
Under private roads	12
Under driveways/approaches	12

Material and Anchoring

Corrugated metal pipe, ductile iron, or concrete boxes can be used for all culverts. High-density polyethylene (HDPE) is only allowed in private roads. For grades greater than or equal to 20%, anchors are required unless calculations or the manufacturer's recommendations show that they are not necessary.

Placement/Alignment

Generally, culverts shall be placed on the same alignment and grade as the drainageway. Consideration should also be given to changes of conditions over time by using design measures such as:

- Cambering or crowning under high tapered fill zones;
- Raising intakes slightly above the flow line to allow for sedimentation;
- Using cantilevered outfalls away from road banks to allow for toe erosion; and,
- Using drop inlets or manholes to reduce exit velocities on steep terrain.

Angle Points

The slope of a culvert shall remain constant throughout the entire length of the culvert. However, in situations where existing roadways are to be widened, it may be necessary to extend an existing culvert at a different slope; the location where the slope changes is referred to as the angle point. The change in slope tends to create a location in the culvert that catches debris and sediment. If an extension of a culvert is to be placed at a different grade than the existing culvert, a manhole shall be provided at the angle point to facilitate culvert maintenance.

Outfalls

Outfalls shall conform to the requirements of all federal, state, and local regulations. Erosion control shall be provided at the culvert outfall. Refer to Section 8.3.3 for additional information regarding outfall protection.

Culvert Debris and Safety

The engineer shall evaluate the site to determine whether debris protection shall be provided for culverts. Debris protection shall be provided in areas where heavy debris flow is a concern, for example, in densely wooded areas. Methods for protecting culverts from debris problems include: upsizing the culvert and installing debris deflectors, trash racks or debris basins. Section 3.4.8 of the *WSDOT Hydraulic Manual* has additional information on debris protection.

Safety bars to prevent unauthorized individuals from entering the culvert shall be provided for culverts with a diameter greater than 36 inch (see WSDOT standard drawings).

When a trash rack is proposed, the effects of plugging shall be evaluated. Consideration should be given to the potential degree of damage to the roadway and adjacent property, potential hazard and inconvenience to the public, and the number of users of the roadway.

Structural Design

The *WSDOT Hydraulics Manual*, Tables 8-11.1 through 8-11.18, shows the maximum cover for different pipe materials and sizes.

For culverts under roadways, the amount of cover over the culvert is defined as the distance from the top of the pipe to the bottom of the pavement. It does not include asphalt or concrete paving above the base. The minimum amount of cover is 2 feet for culverts, unless proposing ductile iron pipe. The minimum cover for ductile iron pipe is 1 foot.

The minimum cover for culverts under private driveways is 1 foot from the top of the pipe to the finish grade of the drivable surface. Driveway culverts shall be a minimum of 12" CMP or ductile iron pipe.

If the depth of cover is shallow (less than 1 foot) and truck wheel loads are present, it will be necessary to propose a design to prevent structural damage to the pipe or to implement the manufacturer's recommendations. Also, extreme fill heights (20 feet or greater) may cause structural damage to pipes and will require a special design or adherence to the manufacturer's recommendations.

End Treatments

The type of end treatment used on a culvert depends on many interrelated and often conflicting considerations:

- <u>Projecting Ends</u> is a treatment in which the culvert is simply allowed to protrude out of the embankment. This is the simplest and most economical. There are several disadvantages such as susceptibility to flotation and erosion, safety when projecting into a roadway clear zone (an area beyond the traveled roadway provided for recovery of errant vehicles), and aesthetic concerns;
- <u>Beveled End Sections</u> consist of cutting the end of the culvert at an angle to match the embankment slope surrounding the culvert. Beveled ends should be considered for culverts 6 feet in diameter or less. Structural problems may be encountered for larger culverts not reinforced with a headwall or slope collar;

- Flared End Sections are manufactured culvert ends that provide a simple transition from culvert to a drainage way. Flared end sections are typically only used on circular pipe or pipe arches. This end treatment is typically the most feasible option in pipes up to 48 inches in diameter. Safety concerns generally prohibit their use in the clear zone for all but the smallest diameters;
- Headwalls are concrete frames poured around a beveled or projecting culvert. They provide structural support and eliminate the tendency for buoyancy. They are considered feasible for metal culverts that range from 6 to 10 feet in diameter. For larger diameters, a slope collar is recommended. A slope collar is a reinforced concrete ring that surrounds the exposed culvert end; or,
- Wingwalls and Aprons are intended for use on reinforced concrete box culverts. Their purpose is to retain and protect the embankment, and provide a smooth transition between the culvert and the channel.

8.4.3 CULVERT DESIGN

Culvert analysis is typically performed using commercially available computer software. If hand calculations are proposed, example calculations can be found in several technical publications and open channel hydraulics manuals.

8.5 STORM DRAIN SYSTEMS

A storm drain system is a network of pipes that convey surface drainage from catch basins or other surface inlets, through manholes, to an outfall.

The design of storm drain systems shall take into consideration runoff rates, pipe flow capacity, hydraulic grade line, soil characteristics, pipe strength, potential construction problems, and potential impacts on down-gradient properties.

8.5.1 PIPE ANALYSIS

The following items shall be included in the Drainage Report, or on road and drainage plans:

- A basin map showing on-site and off-site basins contributing runoff to each inlet, which includes a plan view of the location of the conveyance system;
- Complete pipe calculations that state the design peak flow rates and design information for each pipe run, such as size, slope, length, material type, and Manning’s coefficient (see Table 8-6);

- Velocities at design flow for each pipe run;
- The hydraulic grade line at each inlet, angle point, and outlet; and,

TABLE 8-6
MANNING'S ROUGHNESS COEFFICIENTS (n)
FOR CLOSED SYSTEMS

Material Type	n
Concrete pipe	0.013
Ductile iron	0.013
HDPE[1]	0.013
PVC (only allowed in closed system)	0.013

[1] Contact the local jurisdiction for additional requirements when using HDPE pipe.

For lateral pipe connections to storm drain lines in existing rights-of-way (i.e. from a catch basin to a drywell, a main line stormwater system, a pond or a swale), fixed invert elevations are preferred but not required. The minimum depth from finish grade to pipe invert and the minimum pipe slope necessary to satisfy the freeboard and self-cleaning velocity requirements shall be provided. If necessary, invert elevations may be adjusted during construction to avoid potential conflicts with existing utilities in the right of way.

8.5.2 MINIMUM REQUIREMENTS

Peak Flow Rate

Closed pipe systems shall be sized to handle the design peak flow rates. These peak rates can be calculated using the methods described in Chapter 5 and the design criteria specified in Chapter 2.

Hydraulic Grade Line

The hydraulic grade line (HGL) represents the free water surface elevation of the flow traveling through a storm drain system. Pipes in closed systems will be sized by calculating the HGL in each catch basin or manhole. A minimum of 0.5 feet of freeboard shall be provided between the HGL in a catch basin or manhole and the top of grate or cover.

Pipe Velocities and Slope

In Spokane County and the City of Spokane Valley pipe systems shall be designed to have a self-cleaning velocity of 2.5 feet/second at design flow. In the City of Spokane, pipe systems shall be designed to have a self-cleaning velocity of 3 feet/second or greater calculated under full flow conditions even if the pipe is only flowing partially full during the design storm.

Pipe velocities should not be excessively high since high flow velocities (approaching and above 10 feet/second) cause abrasion of the pipes. When the design velocities are 10 feet/second or greater, manufacturer's recommendations demonstrating that the pipe material can sustain the proposed velocities shall be provided.

When the grade of a storm pipe is greater than or equal to 20%, then pipe anchors are required at the joints, at a minimum, unless calculations and manufacturer's recommendations demonstrate that pipe anchors are not needed. Pipe anchor locations are to be defined on the plans, and a pipe anchor detail shall be referenced or provided.

Pipe material shall meet the WSDOT standards for storm sewer pipe. All pipe segments shall be pressure tested, according to WSDOT testing procedures and standards

Pipe Diameter and Length

The minimum pipe diameter shall be 12 inches, except that single pipe segments less than 50 feet long may be 8 inches in diameter. The maximum length of pipe between junctions shall be no greater than 300 feet. No pipe segment shall have a diameter smaller than the upstream segments.

Placement and Alignment

No storm drain pipe in a drainage easement shall have its centerline closer than 5 feet to a private rear or side property line. A storm drain located under a road shall be placed in accordance with the local jurisdiction's requirements or standard plans.

If it is anticipated that a storm drain system may be expanded in the future, provisions for the expansion shall be incorporated into the current design.

Outfalls

Pipe outfalls shall be placed on the same alignment and grade as the drainage way. Outfalls shall conform to the requirements of all federal, state, and local regulations. Erosion control is required at the storm system outfalls. Refer to Section 8.3.3 for additional information regarding outfall protection.

Storm Drain Debris and Safety

The engineer shall evaluate the site to determine whether debris protection shall be provided for storm drain systems. Debris protection shall be provided in areas where heavy debris flow is a concern, for example, in densely wooded areas. Methods for protecting storm drain systems from debris problems include debris deflectors, trash racks and debris basins. The WSDOT Hydraulic Manual has additional information on debris protection.

For enclosed storm drain systems in urban locations, safety bars shall be provided for outfalls with a diameter 18 inches or greater, in order to prevent unauthorized individuals from entering the storm drain system. Outfalls within a fenced area are not required to have safety bars. The clear space between bars shall be 4 inches maximum.

Structural Design

The *WSDOT Hydraulics Manual*, Tables 8-11.1 through 8-11.18, shows the maximum cover for different pipe materials and sizes.

In unincorporated Spokane County and the City of Spokane Valley, the amount of cover over the pipe is defined as the distance from the top of the pipe to the bottom of the pavement. It does not include asphalt or concrete paving above the base. The minimum amount of cover is 2 feet, unless proposing ductile iron. The minimum cover for ductile iron pipe is 1 foot.

In the City of Spokane, cover is measured from the top of pipe to the top of the pavement. The minimum amount of cover is 3 feet, unless proposing ductile iron. The minimum cover for ductile iron pipe is 1 foot.

If the depth of cover is shallow (less than 1 foot) and truck wheel loads are present, it will be necessary to propose a design to prevent structural damage to the pipe or to implement manufacturer’s recommendations. Extreme fill heights (20 feet or greater) may also cause structural damage to pipes and will thus require a special design or adherence to the manufacturer’s recommendations.

Inverts at Junctions

Whenever two pipes of the same size meet at a junction, the downstream pipe shall be placed with its invert 0.1 feet below the upstream pipe invert. When two different sizes of pipes are joined, pipe crowns shall be placed at the same elevation. The exception to this rule is at drop manholes. Exceptions may be allowed by the local jurisdiction when topographic conditions will significantly impact the depth of the disposal location.

Combined Systems

Combined sanitary and stormwater sewer systems are prohibited.

8.5.3 PIPE DESIGN

To analyze the conveyance capacity of a closed pipe system, the following general steps may be followed when steady flow conditions exist, or conditions can be accurately approximated assuming steady flow conditions:

1. Estimate the size of the pipes assuming a uniform flow condition, using Equation 8-1. Refer to Table 8-6 for Manning's coefficient values.
2. For the pipe sizes chosen, determine uniform and critical flow depth;
3. Determine if upstream (accelerated) flow conditions or downstream (retarded) flow conditions exist. Subcritical flow occurs when downstream conditions control, supercritical flow occurs when upstream conditions control. Determine what flow regime will occur by comparing uniform flow depth, critical flow depth, and initial flow depth. Identify hydraulic jump locations, and where any other discontinuity of flow depth will occur.
4. Conduct a more detailed analysis by computing the hydraulic grade line. The direct step method or standard step method is often used to calculate the hydraulic grade line. For supercritical flow, begin at the upstream end and compute flow sections in consecutive order heading downstream. For sub-critical flow, begin at the downstream end and compute flow sections in consecutive order heading upstream.

The analysis of closed pipe systems is typically done using commercially available computer software packages. If hand calculations are proposed, example calculations can be found in several technical publications on open channel hydraulics, such as: "Handbook of Hydraulics", by Brater and King; and "Open-Channel Hydraulics" by French.

8.6 GUTTERS

A gutter is a section of pavement adjacent to a roadway that conveys water during a storm runoff event. Gutter flow calculations are necessary to establish the spread of water onto the shoulder, parking lane, or travel lane. Roadways shall have an adequate non-flooded width to allow for the passing of vehicular traffic during the design storm event. The non-flooded width (L) is shown in Figure 8-2 and the minimum non-flooded widths for various road classifications are outlined in Table 8-7.

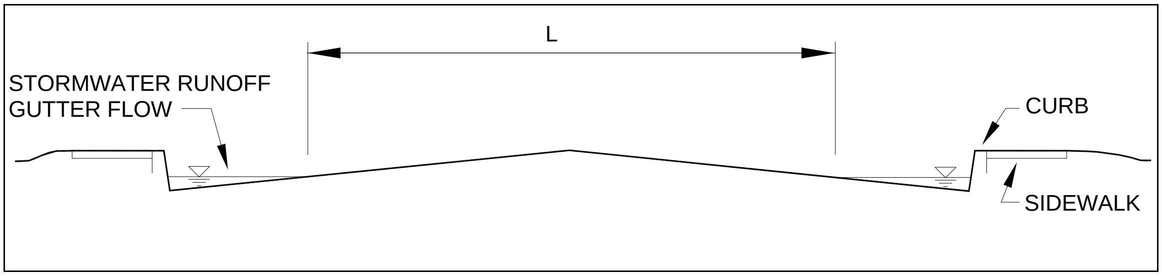


Figure 8-2 – Non-Flooded Road Width (L)

TABLE 8-7
NON-FLOODED ROAD WIDTH REQUIREMENTS

Road Classification	Non-Flooded Width (L)
Private Road	12 feet
Local Access	12 feet
Collector Arterial, 2 Lane	16 feet
Minor Arterial, 2 Lane	24 feet
Other road types	Per local jurisdiction

The non-flooded width shall be evaluated at low points and at proposed inlet locations. The non-flooded width shall also be evaluated at intersections. Bypass flow shall be limited to 0.1 cfs at intersections and at the project boundary.

Non-flooded width and flow depth at the curb are often used as criteria for spacing pavement drainage inlets (curb or grate inlets). Drainage inlets shall be spaced so that the non-flooded width requirements are met and stormwater does not flow over the back of the curb. Spacing shall not exceed 300 feet regardless of flooded width and flow depth compliance.

Generally, inlets shall be placed in the uphill side of the curb return. Additionally, the first inlet shall not be located more 500 feet from the point where the gutter flow path originates.

8.6.1 GUTTER ANALYSIS

When applicable, the drainage report shall include complete gutter calculations that state the design peak flow rates, design flow depth, road cross slope, road grade, and non-flooded width.

The equation for calculating gutter flow is a modified version of Manning’s equation.

$$Q = \frac{0.56\ S_x^{1.67} S_L^{0.5} T^{2.67}}{n} \tag{8-7}$$

Where:
- Q = flow rate (cfs);
- n = Manning's coefficient (from Table 8-8);
- S_L = longitudinal slope of the gutter (feet/foot);
- S_x = cross slope (feet/foot); and,
- T = spread (feet)

TABLE 8-8
MANNING'S ROUGHNESS COEFFICIENTS (*N*)
FOR STREET & PAVEMENT GUTTERS

Type of Gutter or pavement	n
Concrete gutter, troweled finish	0.012
Asphalt Pavement	
Smooth Texture	0.013
Rough Texture	0.016
Concrete pavement	
Float finish	0.014
Broom finish	0.016
Source: Federal Highway Administration (FHWA), Hydraulic Engineering Circular No. 22, Second Edition	

8.6.2 GUTTER DESIGN

Uniform Gutter Section

Uniform gutter sections have a cross slope that is equal to the cross slope of the shoulder or travel lane adjacent to the gutter (see Figure 8-3). The spread (T) in a uniform gutter section can be calculated using Equation 8-7 and solving for T (spread) as follows:

$$T = \left(\frac{Q\ n}{0.56\ S_x^{1.67} S_L^{0.5}} \right)^{0.375} \tag{8-8}$$

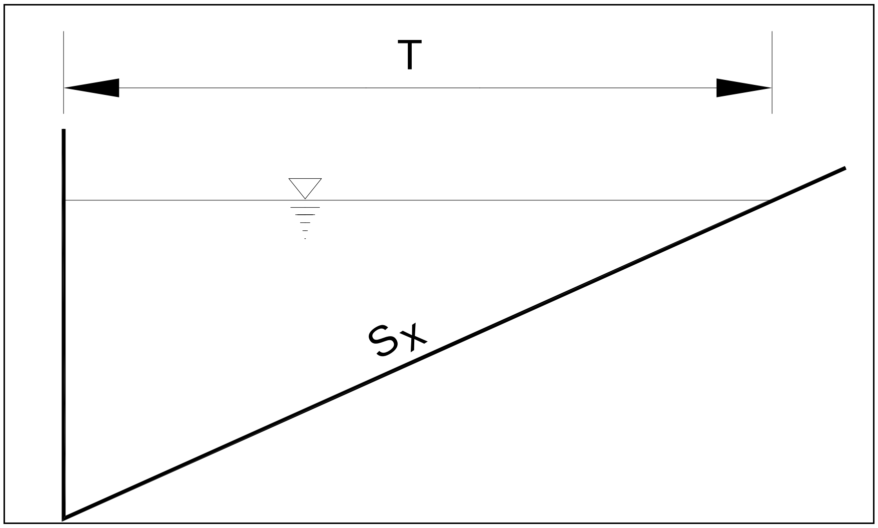


Figure 8-3 – Uniform Gutter Section

An example calculation for determining the non-flooded width and the depth of flow for a uniform gutter section is provided in Appendix 8A.

Composite Gutter Section

Gutters with composite sections have has a cross slope that is steeper than that of the adjacent pavement (see Figure 8-4). The design of composite gutters requires consideration of flow in the depressed segment of the gutter.

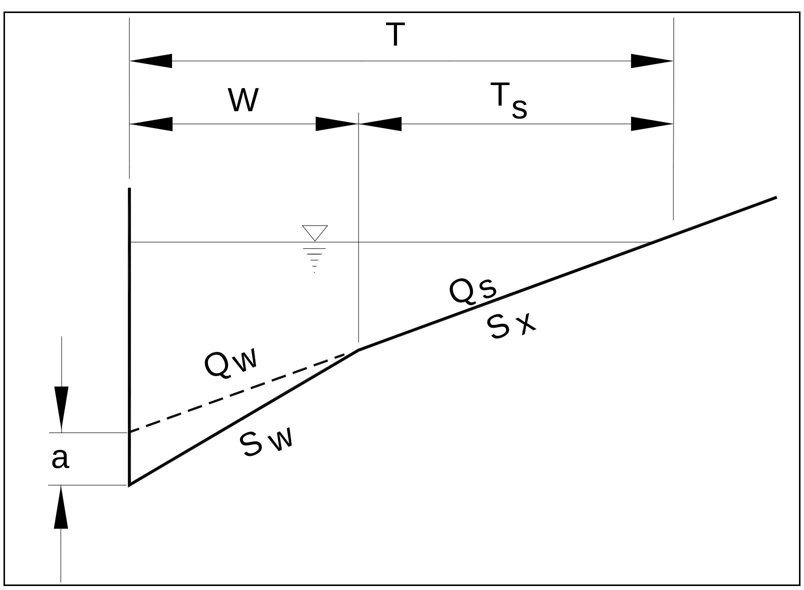


Figure 8-4 – Composite Gutter Section

The spread (T) in composite gutter sections cannot be determined by a direct solution; an iterative approach following the procedure outlined below must be used. An example calculation for determining the spread for a composite gutter section is included in Appendix 8B.

1. Assume a flow rate above the depressed gutter section, Q_s.
2. Compute Q_w using the following:

$$Q_w = Q - Q_s \tag{8-9}$$

Where: Q_w = flow rate in the depressed section of the gutter (cfs);
Q = design flow rate (cfs);
Q_s = flow rate in the gutter section beyond the depressed section (cfs);

3. Compute the gutter cross slope (if it is not given), S_w, using following equation:

$$S_w = S_x + a/W \tag{8-10}$$

Where: S_w = cross slope of the depressed gutter (feet/foot);
S_x = road cross slope (feet/foot);
W = gutter width (feet); and,
a = gutter depression (feet).

4. Compute E_o using the following equation:

$$E_o = \frac{Q - Q_s}{Q} = \frac{Q_w}{Q} \tag{8-11}$$

Where: E_o = ratio of flow in a chosen width (the width of a depressed gutter or grate) to the total gutter flow.

5. Solve for T using following equation:

$$T = W\left\{1 + \left(\frac{\frac{S_w}{S_x}}{\left[\frac{S_w}{S_x}\left(\frac{E_o}{1-E_o}\right)+1\right]^{3/8} - 1}\right)\right\} \tag{8-12}$$

6. Compute T_S using following equation:

$$T_S = T - W \qquad (8\text{-}13)$$

Where: T_S = the width of the spread from the junction of the gutter with the edge of pavement to the edge of the spread (feet).

7. Use Equation 8-7 to determine Q_s for T_S and compare to estimated Q_s from Step 1. Steps 1 through 6 shall be repeated until the estimated and computed Q_s are approximately the same.

8.7 DRAINAGE INLETS

Drainage inlets are used to collect runoff and discharge it to a storm drainage system. They are typically located in gutter sections, paved medians, and roadside and median ditches. Inlets most commonly used in the Spokane Region are as follows:

- Grate Inlets consist of an opening in the gutter or ditch covered by a grate. They perform satisfactorily over a wide range of longitudinal slopes. Grate inlets generally lose capacity as the grade of the road, gutter or ditch increases.
- Curb Inlets are vertical openings in the curb. They are most effective on flat grades, in sumps, and where flows are found to carry significant amounts of floating debris. Curb inlets lose interception capacity as the gutter grade increases; therefore, the use of curb inlets is recommended in sumps and on grades less than 3%.
- Combination Inlets consist of both a curb-opening and a grate inlet. They offer the advantages of both grate and curb inlets, resulting in a high capacity inlet.

There are many variables involved in designing the number and placement of inlets, and in determining the hydraulic capacity of an inlet. The hydraulic capacity of a storm drain inlet depends upon its geometry as well as the characteristics of the gutter flow. Inlet capacity governs both the rate of water removal from the gutter and the amount of water that can enter the storm drainage system. Inadequate inlet capacity or poor inlet location may cause flooding on the roadway resulting in a hazard to the traveling public.

8.7.1 MINIMUM REQUIREMENTS

Peak Flow Rate

The capacity of drainage inlets shall be determined using the design peak flow rates. These rates can be calculated using the methods described in Chapter 5 and the design storm criteria specified in Chapter 2.

Bypass flow shall be limited to 0.1 cfs at intersections and at the project boundary.

Structures

Catch basins, inlets and storm manholes shall conform to the standard plans of the local jurisdiction, or the standard plans jointly published by WSDOT and APWA (M21-01).

Catch basins shall be used in all public and private roads unless utility conflicts prohibit their use.

WSDOT/County Type 1 Catch Basins shall not be used where invert elevation depths are more than 5 feet below lid elevations. Manholes shall be used in these situations.

Catch basins, inlets, and storm manholes shall be placed at all breaks in grade and horizontal alignments. Pipe runs shall not exceed 300 feet for all pipe sizes.

Horizontal and vertical angle points shall not be allowed in a storm system unless a manhole is provided for cleaning.

Grates

Herringbone grates are no longer accepted in roadway applications.

All grate inlets constructed at low points shall be combination inlets. The most commonly used combination inlet is a vaned grate with a hooded curb cut area.

Grate inlets on grade shall have a minimum spacing of 20 feet to enable the bypass water to reestablish its flow against the face of curb. Drainage inlets shall not be located on the curved portion of a curb return.

Grates shall be depressed to ensure satisfactory operation; the maximum depression is 2 inches.

Inlets with larger openings may be used for additional capacity, such as WSDOT Grate Inlet Type 2 (WSDOT Standard Plan B-40.35-00) with frame and vaned grate (WSDOT Standard Plan B-40.40-00). WSDOT Grate Inlet Type 1 and Grates A and B shall not be used in areas of pedestrian or vehicular traffic. Refer to WSDOT Manual and Standard Plans if any of the WSDOT inlets are proposed.

Curb Inlets

Concrete curb inlets (i.e. aprons) shall be used at the entrances to all stormwater facilities to aid stormwater conveyance into the facility and to suppress grass growth at the inlet.

The curb inlet shall have a 2-inch depression at the curb line and a maximum length of 6 feet.

At a minimum (where space constraints allow), curb inlets shall be placed at the most upstream and downstream point along the road adjacent to the treatment or disposal facility, regardless of the flow directed to the curb inlet. In many cases, when a long drainage facility is proposed, and the engineering calculations support it, additional intermediate curb inlets may be required.

Overflow structures, such as drywells or catch basins, shall be located away from the point or points where runoff flows into the facility. When the overflow structure is located within the facility, slopes around the structure shall be no greater than 4:1 (horizontal to vertical).

8.7.2 DRAINAGE INLET DESIGN

Grate Inlets, Continuous Grade

The capacity of an inlet on a continuous grade can be found by determining the portion of the gutter discharge directly over the width of the inlet. On continuous grades (assuming that the grate has the capacity to intercept the entire flow rate directed toward it), the amount of stormwater intercepted by a grate is equal to the amount of stormwater runoff flowing directly over the grate plus the amount that flows in over the side of the grate through the slats/bars. The analysis shall include a 35% clogging factor. The use of formulas for side flow interception for grate inlets found in *FHWA Hydraulic Engineering Circular No. 22* (HEC-22) will be accepted.

The following procedure is most accurate when velocities are in the range of 3 to 5 feet/second at a 2% or 3% longitudinal slope. For instances where the velocity is found to exceed 5 feet/second, additional intermediate inlets can be added, contributing basins redefined, and the associated velocities recalculated. While adding inlets is one solution to reducing the velocity, more information may be found regarding the affect of side flow by consulting the HEC-22 Circular, Section 4.4 Drainage Inlet Design. Note that commercially available software may be used to determine grate inlet capacity.

The capacity of a grate inlet on a continuous grade may be calculated using the procedure outlined below. Figure 8-5 identifies key parameters. Example calculations for grate inlets on a continuous grade for a uniform gutter section and a composite gutter section are provided in Appendices 8C and 8D.

1. Determine the runoff from the contributing basin at the high point to the first inlet. This is the amount of runoff that could be intercepted by the first inlet.
2. Select an inlet and note the grate width (GW) in the calculations (refer to Table 8-9).

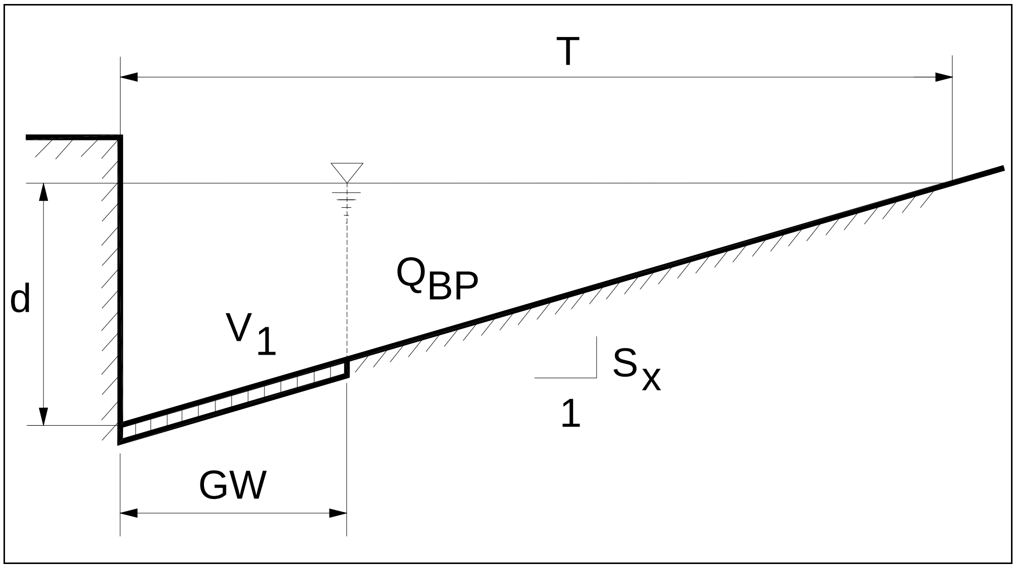


Figure 8-5 – Typical Grate Inlet Cross-Section

TABLE 8-9
ALLOWABLE WIDTH AND PERIMETER
FOR GRATE CAPACITY ANALYSIS

Structure Type	Allowable Width on a Continuous Grade (feet)	Allowable Perimeter in a Sump Condition (feet)
Vaned Grate for Catch Basin and Inlet	1.67	—
Metal Frame and Grate for Catch Basin and Inlet (Herringbone Pattern)[1]	1.67	—
Metal Frame with Hood and Bi-Directional Vaned Grate	1.67	3.13[4,5]
Frame and Vaned Grates for Grate Inlet Type 2 (WSDOT B-40.40-00)	1.75[2] 3.50[3]	2.96[4,5]

[1] Not recommended for new construction. Values are presented for evaluation of existing conditions.
[2] Normal Installation – see Figure 5-5.5 of WSDOT Hydraulics Manual
[3] Rotated Installation – see Figure 5-5.5 of WSDOT Hydraulics Manual
[4] This perimeter value has already been reduced by 50% for clogging.
[5] This perimeter value has also been reduced for bar area.

Note: Readers should review the most current versions of the local jurisdiction's standard plans for any revisions that may have been made to values provided in this table.

3. Analyze the most upstream inlet. The width of flow (T) is calculated using the procedure described in Section 8.6.2. Verify that T is within the allowable limit (see Table 8-7), then determine the amount of flow intercepted by the grate (basin flow – bypass flow).

4. The inlet bypass flow on a continuous grade is computed as follows:

$$Q_{BP} = Q\left[\frac{(T - GW)}{(T)}\right]^{\frac{8}{3}} \quad (8\text{-}14)$$

Where: Q_{BP} = portion of flow outside the grate width (cfs);
Q = total flow of gutter approaching the inlet (cfs);
T = spread, calculated from the gutter section upstream of the inlet (feet); and
GW = grate inlet width perpendicular to the direction of flow (feet), see Table 8-9.

5. The velocity shall not exceed 5 feet/second. The velocity of flow directly over the inlet is calculated as follows:

$$V_1 = \frac{Q - Q_{BP}}{(GW)\left[d - 0.5(GW)(S_x)\right]} \quad (8\text{-}15)$$

Where: V_1 = velocity over the inlet (feet/second);
S_x = cross slope (feet/foot); and,
d = depth of flow at the face of the curb (feet), given by:

$$d = (T)(S_x) \quad (8\text{-}16)$$

If the non-flooded road width does not meet the minimum criteria, an additional inlet should be placed at an intermediate location and the procedure repeated. If the velocity exceeds 5 feet/second then side flow shall be considered using the method outlined in HEC-22.

6. The analysis is then repeated with the next inlet. The bypass flow (Q_{BP}) from the previous inlet shall be added to the flow from the contributing basin to determine the total flow (to the inlet at the station being analyzed.

7. The last inlet may require an adjustment of spacing (usually smaller spacing) in order to prevent a bypass flow to the project boundaries.

Curb Inlets, Continuous Grade

The capacity of a curb inlet on a continuous grade depends upon the length of opening and the depth of flow at the opening. This depth in turn depends upon the amount of depression of the flow line at the inlet, the cross slope, the longitudinal slope, and the roughness of the gutter. The analysis shall include a 35% clogging factor.

The capacity of a curb inlet on a continuous grade may be calculated using the procedure outlined below. Example calculations for curb inlets on a continuous grade for a uniform gutter section and a composite gutter section are provided in Appendices 8E and 8F.

1. Determine the runoff from the contributing basin at the high point to the first curb inlet. This is the amount of runoff that could be intercepted by the first curb inlet.
2. Analyze the most upstream inlet. The width of flow (T) is calculated using the procedure described in Section 8.6.2. Verify that T is within the allowable limit (Table 8-7).
3. The length of the curb-opening inlet required for total interception of gutter flow is calculated as follows:

$$L_T = 0.6Q^{0.42}S_L^{0.3}\left(\frac{1}{nS_e}\right)^{0.6} \quad (8\text{-}17)$$

Where: L_T = curb opening length required to intercept 100% of the flow (feet);

S_e = equivalent cross slope (feet/foot);

for uniform gutter sections: $S_e = S_x$; and,

for composite gutter sections:

$$S_e = S_x + E_o(S_w - S_x) = S_x + \left(\frac{E_o a}{12W}\right) \quad (8\text{-}18)$$

where: a = gutter depression (inches);

E_o = ratio of flow in the depressed section to total gutter flow, calculated in the gutter configuration upstream of the inlet; and,

W = gutter width (feet).

4. When the actual curb inlet is shorter than the length required for total interception, calculate the efficiency of the curb inlet using Equation 8-19.

$$E = 1 - \left(1 - \frac{L}{L_T}\right)^{1.8} \quad (8\text{-}19)$$

Where: E = efficiency; and,

L = actual curb opening length (feet).

5. Compute the interception capacity of the curb inlet using the following relationship:

$$Q_i = (E)(Q) \qquad (8\text{-}20)$$

Where: Q_i = curb inlet capacity (cfs),

6. The analysis is then repeated with the next inlet. The bypass flow (Q_{BP}) from the previous inlet shall be added to the flow from the contributing basin to determine the total flow (Q) to the inlet at the station being analyzed.

$$Q_{BP} = Q - Q_i \qquad (8\text{-}21)$$

7. The last inlet may require an adjustment of spacing (usually smaller spacing) in order to prevent a bypass flow to the project boundaries.

Combination Inlets, Sump Condition

Inlets in sump locations perform differently than inlets on a continuous grade. Inlets in sump locations operate in one of two ways: 1) as a weir, at low ponding depths; or 2) as an orifice, at high ponding depths (1.4 times the grate opening length). It is very rare that ponding on a roadway will become deep enough to force the inlet to operate as an orifice; therefore, this section will focus on the inlet operating as a weir.

The interception capacity of a combination inlet in a sump is equal to that of a grate inlet alone in weir flow. Design procedures presented here are a conservative approach to estimating the capacity of inlets in sump locations. All inlets in a sump condition shall be evaluated using a 50% clogging factor.

The analysis shall include an evaluation of the inlet and the surrounding street, gutter, curb and adjacent properties for storm events exceeding the required level of service. An emergency overflow path shall be provided.

The capacity of a combination inlet operating in a sump as a weir may be estimated using the following procedure. There are also commercially available software programs that will analyze combination inlets in a sump location. An example calculation for a combination inlet in a sump location is provided in Appendix 8G.

1. Determine the runoff contributing to the combination inlet. This is the sum of the bypassed flows from all upstream inlets and the runoff generated from the basin contributing directly to the combination inlet.
2. Determine the allowable spread (T_{all}) based on the non-flooded width requirements in Table 8-7.
3. Calculate the depth of flow at the curb (d) using Equation 8-16.

4. Determine the average depth of flow over the grate using one of the following relationships:

   For uniform gutter sections:

$$d_{ave} = d - S_x\left(\frac{W}{2}\right) + y \tag{8-22}$$

   For composite gutter sections:

$$d_{ave} = d + \frac{W}{2}\left(S_w - 2S_x\right) + y \tag{8-23}$$

   Where: y = local depression (feet), Spokane County Standard Plans B-7 and B-18 show a 1-inch local depression at the grate.

5. Calculate the allowable flow (Q_{all}) using the following relationship:

$$Q_{all} = CPd^{3/2} \tag{8-24}$$

   Where: Q_{all} = allowable flow based upon the maximum allowable spread (cfs);

   P = perimeter of the grate inlet (refer to Table 8-9 for projects in Spokane County and the City of Spokane Valley);

   d = average depth of water across the grate (feet); and,

   C = may be taken as 3.0.

6. Compare the allowable flow to the actual flow. If the actual flow is less than the allowable flow then the combination inlet capacity is adequate. Otherwise, changes shall be made to the design and steps 1 through 5 repeated.

Curb Inlets, Sump Condition

The procedure below assumes that the curb inlet is operating as a weir and the depth of flow is less than the height of the curb opening.

The capacity of a concrete curb inlet (no grate) in a sump condition may be calculated by the method described below. An example calculation for a curb inlet in a sump location is provided in Appendix 8H.

1. Determine the runoff contributing to the curb inlet. This is the sum of the bypassed flows from all upstream inlets and the runoff generated from the basin contributing directly to the combination inlet.

2. Determine the allowable spread (T_{all}) based upon the non-flooded width requirements found in Table 8-7.
3. Calculate the depth of flow at the curb (d).
4. Calculate the allowable flow (Q_{all}) using one of the following relationships:

   For a depressed curb opening inlet:

$$Q_{all} = 2.3(L + 1.8W)d^{3/2} \quad (8\text{-}25)$$

Where: Q_{all} = allowable flow based upon the maximum allowable spread (cfs);

W = lateral width of depression (feet);

L = length of curb opening (feet); and,

d = depth of flow at the curb (feet).

For a curb opening inlet without a depression:

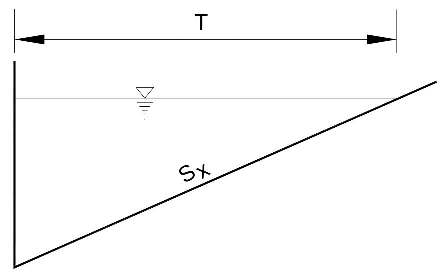
$$Q_{all} = 3.0Ld^{3/2} \quad (8\text{-}26)$$

5. Compare the allowable flow to the actual flow. If the actual flow is less than the allowable flow then the curb inlet capacity is adequate. Otherwise, changes shall be made to the design and steps 1 through 4 repeated.

APPENDIX 8A – EXAMPLE CALCULATION: NON-FLOODED WIDTH (UNIFORM GUTTER SECTION)

GIVEN

- A crowned private road with a uniform gutter section (as illustrated), assuming an equal flow rate on each side of the road.
  - Flow rate (Q) = 4.2 cfs
  - Gutter width (W) = 1.5 feet
  - Road/Gutter cross slope (S_X) = 0.02 feet/foot
  - Longitudinal slope (S_L) = 0.01 feet/ft
  - Manning's friction coefficient, n = 0.016
  - Road width (RW) = 30 feet



CALCULATIONS

1. Calculate the spread (T) for half of the roadway using Equation 8-8.

$$T = \left(\frac{Q\ n}{0.56\ S_x^{1.67} S_L^{0.5}} \right)^{0.375} = \left(\frac{(4.2)(0.016)}{0.56\ (0.02)^{1.67} (0.01)^{0.5}} \right)^{0.375} = 12.4 \text{ feet}$$

2. Calculate the non-flooded width using the following relationship for crowned roadways, and then verify that the non-flooded width is within the allowable limit (refer to Table 8-7):

Non-flooded width = 2[(½)(RW) + W – T)]
= 2[(½)(30) + 1.5 – 12.4)]
= 8.2 feet < 12 feet **FAIL***

* Table 8-7 indicates that the minimum non-flooded width is 12 feet for private roads. Therefore, the design fails to meet the required non-flooded road width criteria. The design will need to be altered (i.e. try an additional inlet placed at an intermediate location, contributing basins redefined, new flow rates calculated, and the above steps repeated).

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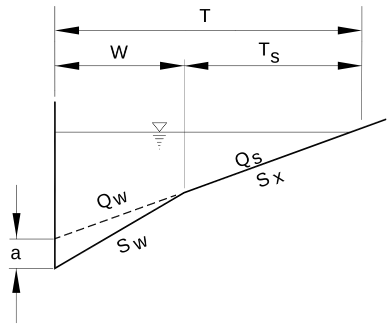
APPENDIX 8B – EXAMPLE CALCULATION: NON-FLOODED WIDTH (COMPOSITE GUTTER SECTION)

GIVEN

- A super-elevated local access road with a composite gutter section (as illustrated).
  - Flow rate (Q) = 4.2 cfs
  - Gutter width (W) = 1.5 feet
  - Road cross slope (S_X) = 0.02 feet/foot
  - Gutter cross slope (S_W) = .081 feet/foot
  - Longitudinal slope (S_L) = 0.01 feet/foot
  - Manning's friction coefficient, n = 0.016
  - Road width (RW) = 30 feet



CALCULATIONS

1. Assume a flow rate (Q_s) for that portion of the flow above the depressed gutter section.

   Assume Q_s = 1.4 cfs

2. Calculate Q_w using Equation 8-9.

$$Q_w = Q - Q_s = 4.2 - 1.4 = 2.8\text{cfs}$$

3. Calculate E_o using Equation 8-11.

$$E_o = \frac{Q - Q_s}{Q} = \frac{Q_w}{Q} = \frac{2.8}{4.2} = 0.67$$

4. Calculate the spread (T) using Equation 8-12.

$$T = W\left\{1 + \left(\frac{\frac{S_w}{S_x}}{\left[\frac{S_w}{S_x}\left(\frac{E_o}{1-E_o}\right)+1\right]^{3/8} - 1}\right)\right\} = 1.5\left\{1 + \left(\frac{\frac{0.081}{0.02}}{\left[\left(\frac{0.081}{0.02}\right)\left(\frac{0.67}{1-0.67}\right)+1\right]^{3/8} - 1}\right)\right\} = 6.17 \text{ ft}$$

5. Calculate T_S using Equation 8-13.

$$T_S = T - W = 6.17 - 1.5 = 4.67\text{ft}$$

6. Use Equation 8-7 to compute Q_s for the calculated Ts, then compare to the estimated Q_s from Step 1.

$$Q_S(\text{computed}) = \frac{0.56\ S_x^{1.67} S_L^{0.5} T_S^{2.67}}{n} = \frac{0.56\ (0.020)^{1.67}(0.01)^{0.5}(4.67)^{2.67}}{0.016} = 0.31\ \text{cfs} < 1.4\ \text{cfs}$$

Since Q_s (estimated) and Q_s (computed) are not approximately equal, repeat Steps 1 through 6 until the estimated and computed Q_s are numerically closer in value.

7. Assume a new Q_s and repeat steps 2 through 6. The following parameters are calculated using Q_S = 2.6 cfs.

Q_W = 1.6 cfs

E_o = 0.38

T = 11.68 feet

T_S = 10.18 feet

Q_s = 2.5 cfs (computed)

Q_s (estimated) ≈ Q_s (computed)

Note that a spreadsheet can be set up to perform the above calculations, and commercially available software can calculate spread in composite gutters.

8. Now that T has been found for the relationship: Qs (estimated) ≈ Qs (calculated), calculate the non-flooded width using the following relationship for super-elevated roadways, and then verify that the non-flooded width is within the allowable limit (refer to Table 8-7):

Non-flooded width = RW + 2W - T

= 30 + 2(1.5) - 11.68

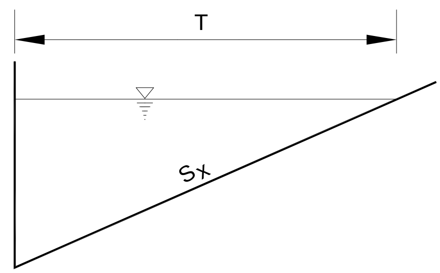
= 21.3 feet > 12 feet **OK***

* Table 8-7 indicates that the minimum non-flooded width is 12 feet for local access roads. Therefore, the design has met the required non-flooded road width criteria.

APPENDIX 8C – EXAMPLE CALCULATION: GRATE INLET CAPACITY (UNIFORM GUTTER SECTION)

GIVEN

- A crowned private road with a uniform gutter section (as illustrated), assuming an equal flow rate on each side of the road.
    - Flow rate (Q) = 2.5 cfs
    - Gutter width (W) = 1.5 ft
    - Spokane County Type 1 Grate (Standard Plan B-12) Grate width (GW) = 1.67 feet
    - Road/Gutter cross slope (S_X) = 0.02 feet/foot
    - Longitudinal slope (S_L) = 0.03 feet/foot
    - Manning's friction coefficient, n = 0.016
    - Road width (RW) = 30 feet



CALCULATIONS

1. Determine the runoff from the contributing basin at the high point to the first inlet;

   For this example, the design flow rate (Q) is given as 2.5 cfs

2. Select an inlet and note the grate width.

   For this example, the grate width (GW) is given as 1.67 ft

3. Calculate the spread (T) for half of the roadway using Equation 8-8.

$$T = \left(\frac{Q\ n}{0.56\ S_x^{1.67} S_L^{0.5}} \right)^{0.375} = \left(\frac{(2.5)(0.016)}{0.56\ (0.02)^{1.67} (0.03)^{0.5}} \right)^{0.375} = 8.31\text{feet}$$

4. Calculate the non-flooded width using the following relationship, and then verify that the non-flooded width is within the allowable limit (refer to Table 8-7):

Non-flooded width	=	2[(½)(RW) + W – T)]
	=	2[(½)(30) + 1.5 – 8.31)]
	=	16.38 feet > 12 feet **OK***

* Table 8-7 indicates that the minimum non-flooded width is 12 feet for private roads. Therefore, design has met the required non-flooded road width criteria.

5. Calculate the inlet bypass flow using Equation 8-14:

   With 35% clogging factor, grate width (GW) = 1.67(1 - 0.35) = 1.09’

$$Q_{BP} = Q\left[\frac{(T)-(GW)}{(T)}\right]^{\frac{8}{3}} = 2.5\left[\frac{8.31-1.09}{8.31}\right]^{\frac{8}{3}} = 1.72\text{cfs}$$

   Therefore the capacity of the inlet = 2.5 – 1.72 = 0.78 cfs

6. Verify that the velocity does not exceed 5 feet/second. The velocity of flow directly over the inlet is calculated using Equation 8-15 (where d = T S_x):

$$V_1 = \frac{Q-Q_{BP}}{(GW)\left[d-0.5(GW)(S_x)\right]} = \frac{2.5-1.72}{1.09\left[(8.31)(0.02)-0.5(1.09)(.02)\right]} = 4.61\text{ft/s} < 5 \text{ feet/second } \textbf{OK**}$$

   **Refer to Section 8.7.2 for guidance when the velocity exceeds 5 feet/second.

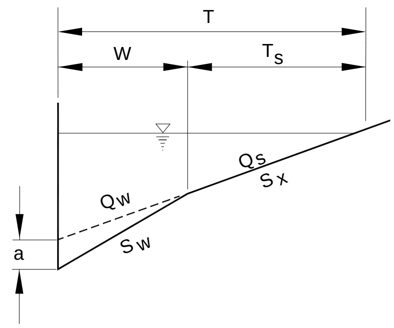
7. The analysis is then repeated with the next inlet. The bypass flow (Q_{BP}) from the previous inlet shall be added to the flow from the contributing basin to determine the total flow (Q) to the inlet at the station being analyzed.

Note that the City of Spokane requires the analysis to include a 50% clogging factor.

APPENDIX 8D – EXAMPLE CALCULATION: GRATE INLET CAPACITY, CONTINUOUS GRADE (COMPOSITE GUTTER SECTION)

GIVEN

- A super-elevated local access road with a composite gutter section (as illustrated)
  - Flow rate (Q) = 4.2 cfs
  - Gutter width (W) = 1.5 feet
  - Spokane County Type 1 Grate (Standard Plan B-12) Grate Width (GW) = 1.67 feet
  - Road cross slope (S_X) = 0.02 feet/foot
  - Gutter cross slope (S_W) = .081 feet/foot
  - Longitudinal slope (S_L) = 0.01 feet/foot
  - Manning's friction coefficient, n = 0.016
  - Road width (RW) = 30 feet



CALCULATIONS

1. Determine the runoff from the contributing basin at the high point to the first inlet;

   For this example, the design flow rate is given as 4.2 cfs

2. Select an inlet and note the grate width.

   For this example, the grate width (GW) is given as 1.67 feet

3. Calculate the spread (T) for half of the roadway using the method outlined in Appendix 8B and verify that the non-flooded width is within the allowable limit (Table 8-7).

   T = 11.68 feet (Solution from Appendix 8B)

   Non-flooded width = 21.3 feet > 12 feet **OK*** (Solution from Appendix 8B)

   * Table 8-7 indicates that the minimum non-flooded width is 12 feet for private roads. Therefore, design has met the required non-flooded road width criteria.

4. Calculate the inlet bypass flow using Equation 8-14:

   With 35% clogging factor, grate width (GW) = 1.67(1 - 0.35) = 1.09'

$$Q_{BP} = Q\left[\frac{(T)-(GW)}{(T)}\right]^{\frac{8}{3}} = 4.2\left[\frac{11.68-1.09}{11.68}\right]^{\frac{8}{3}} = 3.23\text{cfs}$$

Therefore the capacity of the inlet = 4.2 – 3.23 = 0.97 cfs

5. Verify that the velocity does not exceed 5 feet/second. The velocity of flow directly over the inlet is calculated using Equation 8-15:

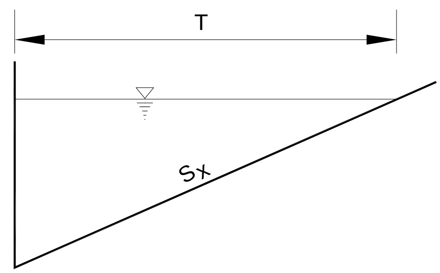
$$V_1 = \frac{Q - Q_{BP}}{(GW)\left[d - 0.5(GW)(S_x)\right]} = \frac{4.2 - 3.23}{1.09\left[(11.68)(0.02) - 0.5(1.09)(0.02)\right]} = 4.00\text{ft/s} < 5 \text{ feet/second } \textbf{OK}$$

6. The analysis is then repeated with the next inlet. The bypass flow (Q_{BP}) from the previous inlet shall be added to the flow from the contributing basin to determine the total flow (Q) to the inlet at the station being analyzed.

APPENDIX 8E – EXAMPLE CALCULATION: CURB INLET CAPACITY, CONTINUOUS GRADE (UNIFORM GUTTER SECTION)

GIVEN

- A crowned private road with a uniform gutter section (as illustrated), assuming an equal flow rate on each side of the road.
    - Flow rate (Q) = 1.5 cfs
    - Gutter width (W) = 1.5 feet
    - Curb Inlet Length (L) = 3 feet
    - Road/Gutter cross slope (S_x) = 0.02 feet/foot
    - Longitudinal slope (S_L) = 0.03 feet/foot
    - Manning's friction coefficient, n = 0.016
    - Road width (RW) = 30 feet



CALCULATIONS

1. Determine the runoff from the contributing basin at the high point to the first inlet;

   For this example, the design flow rate is given as 1.5 cfs

2. Calculate the spread (T) for half of the roadway using Equation 8-8 and verify that the non-flooded width is within the allowable limit (Table 8-7).

$$T = \left(\frac{Q\ \ n}{0.56\ \ S_x^{1.67} S_L^{0.5}} \right)^{0.375} = \left(\frac{(1.5)(0.016)}{0.56\ \ (0.02)^{1.67}\,(0.03)^{0.5}} \right)^{0.375} = 6.86\text{feet}$$

Non-flooded width = 2[(½)(RW) + W – T)]

= 2[(½)(30) + 1.5 – 6.86)]

= 19.3 feet > 12 feet **OK***

* Table 8-7 indicates that the minimum non-flooded width is 12 feet for private roads. Therefore, design has met the required non-flooded road width criteria.

3. Calculate the length of curb inlet required for total interception of gutter flow using Equation 8-17:

$$L_T = 0.6Q^{0.42}S_L^{0.3}\left(\frac{1}{nS_e}\right)^{0.6} = (0.6)(1.5^{0.42})(0.03^{0.3})\left(\frac{1}{0.016*0.02}\right)^{0.6} = 31.1\text{feet}$$

4. Calculate the efficiency of the curb inlet using Equation 8-19.

$$E = 1 - \left(1 - \frac{L}{L_T}\right)^{1.8} = 1 - \left(1 - \frac{3.0}{31.1}\right)^{1.8} = 0.167$$

5. Compute the interception capacity and the bypass flow of the curb inlet using Equations 8-20 and 8-21.

$$Q_i = (E)(Q) = (0.167)(1.5) = 0.25\text{cfs}$$

$$Q_{BP} = Q - Q_i = 1.5 - 0.25 = 1.25\text{cfs}$$

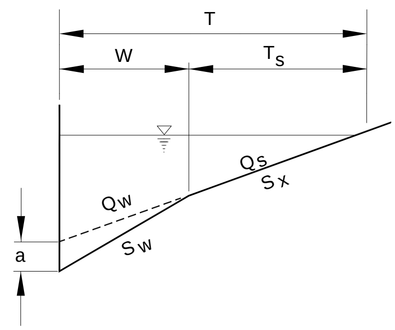
6. The analysis is then repeated with the next curb inlet. The bypass flow (Q_{BP}) from the previous inlet shall be added to the flow from the contributing basin to determine the total flow (Q) to the next inlet.

Note that the City of Spokane requires the analysis to include a 50% clogging factor.

APPENDIX 8F – EXAMPLE CALCULATION: CURB INLET CAPACITY, CONTINUOUS GRADE (COMPOSITE GUTTER SECTION)

GIVEN

- A super-elevated local access road with a composite gutter section (as illustrated)
    - Flow rate (Q) = 4.2 cfs
    - Gutter width (W) = 1.5 feet
    - Curb Inlet Width (GW) = 3 feet
    - Road cross slope (S_x) = 0.02 feet/foot
    - Gutter cross slope (S_w) = .081 feet/foot
    - Longitudinal slope (S_L) = 0.01 feet/foot
    - Manning's friction coefficient, n = 0.016
    - Road width (RW) = 30 feet



CALCULATIONS

1. Determine the runoff from the contributing basin at the high point to the first inlet;

   For this example, the design flow rate is given as 4.2 cfs

2. Calculate the spread (T) for half of the roadway using the method outlined in Appendix 8B and verify that the non-flooded width is within the allowable limit (Table 8-7).

   T = 11.68 feet (Solution from Appendix 8B)

   Non-flooded width = 21.3 feet > 12 feet **OK*** (Solution from Appendix 8B)

   * Table 8-7 indicates that the minimum non-flooded width is 12 feet for private roads. Therefore, design has met the required non-flooded road width criteria.

3. Calculate the equivalent cross slope (S_e) using Equation 8-18 and the length of curb inlet required for total interception of gutter flow (L_T) using Equation 8-17.

$$S_e = S_x + E_o(S_w - S_x) = 0.02 + 0.38(0.081 - 0.02) = 0.043$$

   Where, E_o = 0.38 (Solution from Appendix 8B)

$$L_T = 0.6Q^{0.42} S_L^{0.3} \left(\frac{1}{nS_e} \right)^{0.6} = (0.6)(4.2^{0.42})(0.01^{0.3}) \left(\frac{1}{(0.016)(0.043)} \right)^{0.6} = 21.8\text{feet}$$

4. Calculate the efficiency of the curb inlet using Equation 8-19.

$$E = 1 - \left(1 - \frac{L}{L_T} \right)^{1.8} = 1 - \left(1 - \frac{3.0}{21.8} \right)^{1.8} = 0.23$$

5. Compute the interception capacity and the bypass flow of the curb inlet using Equations 8-20 and 8-21.

$$Q_i = (E)(Q) = (0.23)(4.2) = 0.97\text{cfs}$$

$$Q_{BP} = Q - Q_i = 4.2 - 0.97 = 3.23\text{cfs}$$

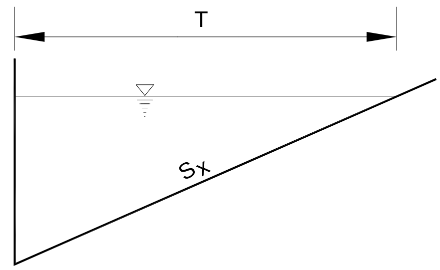
6. The analysis is then repeated with the next curb inlet. The bypass flow (Q_{BP}) from the previous inlet shall be added to the flow from the contributing basin to determine the total flow (Q) to the next inlet.

Note that the City of Spokane requires the analysis to include a 50% clogging factor.

APPENDIX 8G – EXAMPLE CALCULATION: COMBINATION INLET CAPACITY, SUMP

GIVEN

- A crowned private road with a uniform gutter section (as illustrated).
  - Inlet: Metal Frame with Hood, Type 2 and Bi-Directional Vaned Grate, Type 3 – Spokane County Standard Plans B-11 and B-14
  - Gutter Width (W) = 1.5 feet
  - Local depression = 1 inch
  - Cross slope (S_x) = 0.02 feet/foot
  - Road width (RW) = 30 feet
  - Q_{BP} = 0.68 cfs = Upstream inlets total bypass flow rate
  - Q_{BASIN} = 0.82 cfs = Contributing drainage basin direct flow rate



CALCULATIONS

1. Determine the total runoff contributing and bypassed to the combination inlet.

$$Q_{TOTAL} = Q_{BP} + Q_{BASIN} = 0.68\text{cfs} + 0.82\text{cfs} = 1.5\text{cfs}$$

2. From Table 8-7, the non-flooded width for a private road is 12 feet minimum. Determine the allowable spread (T) for the roadway using the following relationship for a crowned roadway:

$$T_{all} = \frac{\text{R}W + 2W - \text{Non - flooded Width}}{2} = \frac{30 + (2)(1.5) - 12}{2} = 10.5\,\text{feet}$$

3. Calculate the depth of flow at the curb (d) using Equation 8-16.

$$d = (T)(S_x) = (10.5)(0.02) = 0.21\,\text{feet}$$

4. Determine the average depth of flow over the grate using Equation 8-22.

$$d_{ave} = d - S_x\left(\frac{W}{2}\right) + y = 0.21 - 0.02\left(\frac{1.5}{2}\right) + \frac{1}{12} = 0.28\,\text{feet}$$

5. Calculate the allowable flow (Q_{all}) using Equation 8-24.

$$Q_{all} = CPd^{3/2} = (3.0)(3.13)(0.28)^{3/2} = 1.38\text{ cfs}$$

6. Compare the allowable flow to the actual flow.

$$1.38\text{ cfs}(Q_{all}) \prec 1.5\text{ cfs}(Q) \qquad \textbf{FAIL*}$$

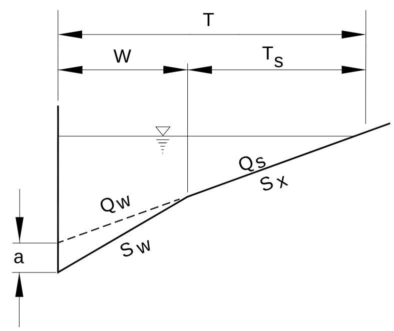
   * The actual flow rate directed at the given metal frame and grate inlet combination exceeds the calculated allowable flow capacity of the structure. The design will need to be altered (i.e. try an additional inlet placed at an intermediate location, contributing basins redefined, new flow rates calculated, and the above steps repeated).

Note that grate perimeter used in this example includes a 50% clogging factor (refer to Table 8-9).

APPENDIX 8H – EXAMPLE CALCULATION: CURB INLET CAPACITY, SUMP

GIVEN

- A crowned private road with a composite gutter section (as illustrated).
  - Curb opening length (L) = 3.0 feet (reduce by half – clogging safety factor)
  - Local depression = 1 inch
  - Cross slope (S_X) = 0.02 feet/foot
  - Gutter cross slope (S_W) = 0.081 feet/foot
  - Gutter Width = 1.5 feet
  - Road width (RW) = 30 feet
  - Q_{BP} = 0.68 cfs = Upstream inlets total bypass
  - Q_{BASIN} = 0.82 cfs = Contributing drainage basin direct flow rate



CALCULATIONS

1. Determine the total runoff contributing and bypassed to the curb inlet.

$$Q_{TOTAL} = Q_{BP} + Q_{BASIN} = 0.68\text{cfs} + 0.82\text{cfs} = 1.5\text{cfs}$$

2. From Table 8-7, the non-flooded width for a private road is 12 feet minimum. Determine the allowable spread (T) for the roadway using the following relationship for crowned roadways:

$$T_{all} = \frac{\text{R}W + 2W - \text{Non-flooded Width}}{2} = \frac{30 + (2)(1.5) - 12}{2} = 10.5\text{ feet}$$

3. Calculate the depth of flow at the curb (d).

$$d = (1.5)(0.081) + (10.5 - 1.5)(0.02) = 0.30\text{ feet}$$

4. Calculate the allowable flow (Q_{all}) using Equation 8-25.

$$Q_{all} = 2.3(L + 1.8W)d^{3/2} = 2.3[(1.5 + (1.8)(1.5)](0.30)^{3/2} = 1.59\text{ cfs}$$

5. Compare the allowable flow to the actual flow.

$$1.59\text{cfs}\left(Q_{all}\right) > 1.5\,\text{cfs}\,\left(Q\right) \qquad \textbf{OK*}$$

* The actual flow rate directed at the curb inlet is less than the calculated allowable flow capacity of the structure. The design is adequate.

CHAPTER 9 – EROSION AND SEDIMENT CONTROL DESIGN

Chapter Organization

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9.1 INTRODUCTION

This chapter lists the steps for developing a Erosion and Sediment Control (ESC) plan, which is a required component of a Drainage Submittal or permit. Controlling erosion and preventing sediment and other pollutants from leaving the project site during construction can be achieved by implementing the best management practices (BMPs) identified in this chapter. The ESC plan shall outline specific construction BMPs for a project site to avoid adverse stormwater impacts from construction activities on water resources, roads, drainage facilities, surrounding properties and other improvements. Potential impacts due to erosion and sedimentation include:

- Sediment accumulation in culverts, storm drains and open channels, resulting in decreased capacities and the potential for increased flooding and increased maintenance frequency;
- Sedimentation of storage ponds and swales, resulting in decreased infiltrative and storage capacity, and the potential for increased flooding and failure;
- Clogging and failure of Underground Injection Control (UIC) facilities;
- Destruction of vegetation, topsoil and seeds, making re-establishment of vegetation difficult;
- Increased turbidity, reducing water quality in water bodies; and,
- Air pollution due to fugitive dust.

Implementation of an effective ESC plan may help to reduce these potential impacts as well as other unforeseen environmental impacts and associated costs.

Although the construction phase of a project is usually considered a temporary condition, construction work may take place over several seasons. All BMPs used in the course of construction should be of sufficient size, strength, and durability to readily outlast the expected construction schedule and operate properly during the design storm rainfall conditions (see Basic Requirement No. 6 in Chapter 2 for design storm criteria).

9.2 APPLICABILITY

Land-disturbing activities are activities that result in a change in existing soil cover (vegetative or non-vegetative) or site topography. Land-disturbing activities include, but are not limited to, demolition, construction, clearing and grubbing, grading and logging. The following land-disturbing activities require an ESC plan:

- Major land-disturbing activities involving 1 acre or more of disturbed area; or,
- Minor land-disturbing activities, such as grading, involving less than 1 acre of disturbed area but requiring a permit by the local jurisdiction.

An ESC plan, when required, shall be submitted with either the road and drainage plans or the permit application, prior to any land-disturbing activity. Clearing and grading activities for developments will be permitted only if conducted pursuant to an accepted site development plan that establishes permitted areas of clearing, grading, cutting, and filling. When establishing these permitted clearing and grading areas, consideration shall be given to minimizing removal of existing trees and minimizing disturbance and compaction of native soils except as needed for building purposes. These permitted clearing and grading areas and any other areas with a preservation requirement, such as critical or sensitive areas, buffers, native growth protection easement areas or tree retention areas, shall be delineated on the site plans and development site plan. ESC plans are only required to address the area of land that is subject to the land-disturbing activity for which a permit is being requested and the area of land that will serve as the stockpile or staging area for materials.

9.3 EXEMPTIONS

An ESC plan is typically not required for the following activities:

- Commercial agriculture as regulated under RCW Chapter 84.34.020;
- Forest practices regulated under WAC Title 222, except for Class IV General Forest Practices that are conversions from timberland to other uses;
- Actions by a public utility or any other governmental agency to remove or alleviate an emergency condition, restore utility service, or reopen a public thoroughfare to traffic;
- Land divisions, interior improvements to an existing structure, and other activities requiring permits or approvals for which there is no physical disturbance to the surface of the land; and,
- Minor land-disturbing activities that do not require a permit.

Although an ESC plan may not be required for the situations noted above, that does not relieve the proponent from the responsibility of controlling erosion and sediment during construction nor the liability of damage claims associated with adverse impacts on off-site properties.

9.4 EROSION AND SEDIMENT CONTROL (ESC) PLAN

9.4.1 INTRODUCTION

The ESC plan must be prepared by a professional engineer currently licensed in the State of Washington with a good working knowledge of hydrology and ESC practices, or a Certified Erosion and Sedimentation Control Technician. A copy of the

ESC plan must be located on the construction site or within reasonable access to the site. As site construction progresses, the ESC plan may require modification to reflect changes in site conditions.

The ESC plan must accompany the road and drainage plans, grading plan, or permit request and should be integrated into the grading plan whenever possible. It must contain sufficient information to demonstrate to the local jurisdiction that potential problems associated with erosion, sediment, and pollution have been adequately addressed for the proposed project. The drawings and notes should be clear and concise and describe when and where each BMP is to be implemented.

9.4.2 MINIMUM REQUIREMENTS FOR ESC PLANS

At a minimum, all ESC plans must be legible, reproducible and on good quality 24” x 36” bond paper, and must contain the following information:

- Title block, north arrow, scale and plan preparation date;
- Name of property owner, permit applicant, anticipated contact person on-site, and the stamp and signature of the engineer who prepared the plan (note that for municipal projects, this information will be not be available until the pre-construction conference);
- Vicinity map, section, township and range, project address, project boundaries and dimensions;
- Description of project, list of on-site soils and existing vegetation, location of any existing water bodies and/or critical areas;
- Summary description of ESC BMPs utilized (see Section 9.4.3);
- ESC Standard Plan Notes (see Appendix 9A);
- Construction Sequence (see Section 9.4.3)

9.4.3 BEST MANAGEMENT PRACTICES FOR ESC PLANS

BMPs must be used to comply with the requirements of this chapter. It is not the intent of this chapter to limit innovative or creative efforts to effectively control erosion and sedimentation. Experimental ESC management practices to improve erosion control technology and meet the purpose and intent of this chapter are encouraged as a means of solving erosion and sedimentation problems. Minor modifications to standard BMPs are considered experimental ESC management practices and, as with any proposed BMP, must be reviewed and accepted by the local jurisdiction. It is important to note that not only do new facilities and off-site properties need to be protected from erosion and sedimentation, but existing facilities on-site or downstream also need to be evaluated and protected if there is potential for damage due to lack of erosion control.

As the season and subsequent site conditions dictate, alterations to existing ESC BMPs may be warranted or additional ESC measures may be required. Note that items below that are shown in *italics* are considered *General Erosion and Sedimentation Control Notes* (see Appendix 9A for complete list). These notes shall be shown on the ESC plan, when applicable to the given project site.

BMPs are referenced in this chapter by their identification code in the September 2004 *Stormwater Management Manual for Eastern Washington* (e.g., BMP C101, BMP C102). Detailed examples and descriptions of these BMPs are included in Chapter 7 of the Eastern Washington manual. At a minimum, the following items shall be addressed in the ESC plan:

1. Construction Sequence

- *The following construction sequence shall be followed in order to best minimize the potential for erosion and sedimentation control problems:*
    - *a) Clear and grub sufficiently for installation of temporary ESC BMPs;*
    - *b) Install temporary ESC BMPs; constructing sediment trapping BMPs as one of the first steps prior to grading;*
    - *c) Clear, grub and rough grade for roads, temporary access points and utility locations;*
    - *d) Stabilize roadway approaches and temporary access points with the appropriate construction entry BMP;*
    - *e) Clear, grub and grade individual lots or groups of lots;*
    - *f) Temporarily stabilize, through re-vegetation or other appropriate BMPS, lots or groups of lots in situations where substantial cut or fill slopes are a result of the site grading;*
    - *g) Construct roads, buildings, permanent stormwater facilities (i.e. inlets, ponds, UIC facilities, etc.);*
    - *h) Protect all permanent stormwater facilities utilizing the appropriate BMPs;*
    - *i) Install permanent ESC controls, when applicable; and,*
    - *j) Remove temporary ESC controls when:*
        - ♦ *Permanent ESC controls, when applicable, have been completely installed;*
        - ♦ *All land-disturbing activities that have the potential to cause erosion or sedimentation problems have ceased; and,*
        - ♦ *Vegetation had been established in the areas noted as requiring vegetation on the accepted ESC plan on file with the local jurisdiction.*

2. *Clearing Limits*

- Distinctly mark all clearing limits, both on the plans and in the field—taking precaution to visibly mark separately any sensitive or critical areas, and their buffers, and trees that are to be preserved—prior to beginning any land-disturbing activities, including clearing and grubbing; and,
- If clearing and grubbing has occurred, there is a window of 15 days in which construction activity must begin, otherwise the cleared area must be stabilized.
- Suggested BMPs:
    - BMP C101: Preserving Natural Vegetation
    - BMP C102: Buffer Zones
    - BMP C103: High Visibility Plastic or Metal Fence
    - BMP C104: Stake and Wire Fence

3. *Construction Access Route*

- Limit access for construction vehicles to one route whenever possible;
- Stabilize the construction access route with quarry spalls or crushed rock to minimize the tracking of sediment onto roadways;
- *Inspect all roadways, at the end of each day, adjacent to the construction access route. If it is evident that sediment has been tracked offsite and/or beyond the roadway approach, removal and cleaning is required.*
- *If sediment removal is necessary prior to street washing, it shall be removed by shoveling or pickup sweeping and transported to a controlled sediment disposal area.*
- *If street washing is required to clean sediment tracked offsite, once sediment has been removed, street wash wastewater shall be controlled by pumping back on-site or otherwise prevented from discharging into systems tributary to waters of the state;*
- Locate wheel washes or tire baths, if applicable to ESC plan, on site. Dispose of wastewater into a separate temporary on-site treatment facility in a location other than where a permanent stormwater facility is proposed; and,
- *Restore construction access route equal to or better than the pre-construction condition.*
- Suggested BMPs:
    - BMP C105: Stabilized Construction Entrance
    - BMP C106: Wheel Wash

- BMP C107: Construction Road/Parking Area Stabilization

4. Install Sediment Controls

- *Retain the duff layer, native topsoil, and natural vegetation in an undisturbed state to the maximum extent practical;*
- Pass stormwater runoff from disturbed areas through a sediment pond prior to leaving a construction site or discharging to an infiltration facility;
- Keep sediment on the project site, to the maximum extent practical, in order to protect adjacent properties, water bodies, and roadways;
- Stabilize earthen structures such as dams, dikes, and diversions with either quarry spalls, seed or mulch, or a combination thereof;
- Locate sediment facilities such that they will not interfere with natural drainage channels or streams; and,
- *Inspect sediment control BMPs weekly at a minimum, daily during a storm event, and after any discharge from the site (stormwater or non-stormwater). The inspection frequency may be reduced to once a month if the site is stabilized and inactive.*
- Suggested BMPs:
  - BMP C230: Straw Bale Barrier
  - BMP C231: Brush Barrier
  - BMP C232: Gravel Filter Berm
  - BMP C233: Silt Fence
  - BMP C234: Vegetated Strip
  - BMP C235: Straw Wattles
  - BMP C240: Sediment Trap
  - BMP C241: Temporary Sediment Pond

5. Soil Stabilization

- Select appropriate BMPs to protect the soil from the erosive forces of raindrop impact, flowing water and wind, taking into account the expected construction season, site conditions and estimated duration of use;
- *Control fugitive dust from construction activity in accordance with state and local air quality control authorities with jurisdiction over the project area;*
- *Stabilize exposed unworked soils (including stockpiles), whether at final grade or not, within 10 days during the regional dry season (July 1 through September 30) and within 5 days during the regional wet season*

(October 1 through June 30). Soils must be stabilized at the end of a shift before a holiday weekend if needed based on the weather forecast. This time limit may only be adjusted by a local jurisdiction with a "Qualified Local Program," if it can be demonstrated that the recent precipitation justifies a different standard and meets the requirements set fourth in the Construction Stormwater General Permit; and,

- Stabilization practices include, but are not limited to, temporary and permanent seeding, sodding, mulching, plastic covering, erosion control fabric and mats, soil application of polyacrylamide (PAM) and the early application of gravel base on areas to be paved, and dust control.
- Suggested BMPs:
    - BMP C120: Temporary and Permanent Seeding
    - BMP C121: Mulching
    - BMP C122: Nets and Blankets
    - BMP C123: Plastic Covering
    - BMP C124: Sodding
    - BMP C125: Topsoiling
    - BMP C126: Polyacrylamide (PAM) for Soil Erosion Protection
    - BMP C130: Surface Roughening
    - BMP C131: Gradient Terraces
    - BMP C140: Dust Control

6. Protection of Inlets

- *Protect inlets, drywells, catch basins and other stormwater management facilities from sediment, whether or not facilities are operable,* so that stormwater runoff does not enter the conveyance system (both on and off site) without being treated or filtered to remove sediment;
- *Keep roads adjacent to inlets clean;* sediment and street wash water shall not be allowed to enter the conveyance system (both on and offsite) without prior treatment;
- *Inspect inlets weekly at a minimum and daily during storm events.* Inlet protection devices shall be cleaned or removed and replaced before 6 inches of sediment can accumulate.
- Suggested BMP:
    - BMP C220: Storm Drain Inlet Protection

7. Runoff from Construction Sites

- Protect down-gradient properties, waterways, and stormwater facilities from possible impacts due to increased flow rates, volumes, and velocities of stormwater runoff from the project site that may temporarily occur during construction;
- *Construct stormwater control facilities (detention/retention storage pond or swales) before grading begins. These facilities shall be operational before the construction of impervious site improvements; and,*
- Protect permanent infiltration ponds that are used for flow control during construction.
- Suggested BMPs:
    - BMP C240: Sediment Trap
    - BMP C241: Temporary Sediment Pond

8. Washout Site for Concrete Trucks and Equipment

- Designate the location of a slurry pit where concrete trucks and equipment can be washed out. Slurry pits are not to be located in or upstream of a swale, drainage area, stormwater facility or water body, or in an area where a stormwater facility is existing or proposed.
- Suggested BMP:
    - BMP C151: Concrete Handling

9. Material Storage/Stockpile

- Identify locations for storage/stockpile areas, within the proposed ESC plan boundaries, for any soil, earthen and landscape material that is used or will be used on-site;
- *Stockpile materials (such as topsoil) on-site, keeping off roadway and sidewalks; and,*
- Maintain on-site, as feasible, items such as gravel and a roll of plastic, for emergency soil stabilization during a heavy rain event, or for emergency berm construction.
- Suggested BMP:
    - BMP C150: Materials On Hand

10. Cut and Fill Slopes

- Consider soil type and its erosive properties;

- Divert any off-site stormwater run-on or groundwater away from slopes and disturbed areas with interceptor dikes, pipes or temporary swales. Off-site stormwater shall be managed separately from stormwater generated on-site;
- Reduce slope runoff velocities by reducing the continuous length of slope with terracing and diversion, and roughening the slope surface;
- Place check dams at regular intervals within ditches and trenches that are cut into a slope; and,
- Stabilize soils on slopes, where appropriate.
- Suggested BMPs:
  - BMP C120: Temporary and Permanent Seeding
  - BMP C130: Surface Roughening
  - BMP C131: Gradient Terraces
  - BMP C200: Interceptor Dike and Swale
  - BMP C201: Grass-Lined Channels
  - BMP C204: Pipe Slope Drains
  - BMP C205: Subsurface Drains
  - BMP C206: Level Spreader
  - BMP C207: Check Dams
  - BMP C208: Triangular Silt Dike (Geotextile-Encased Check Dam)

11. Stabilization of Temporary Conveyance Channels and Outlets

- Design, construct and stabilize all temporary on-site conveyance channels to prevent erosion from the expected flow velocity of a 2-year, NRCS Type II, 24-hour frequency storm or 2-year Rational Method event, in the post-developed condition; and,
- Stabilize outlets of all conveyance systems adequately to prevent erosion of outlets, adjacent streambanks, slopes and downstream reaches.
- Suggested BMPs:
  - BMP C202: Channel Lining
  - BMP C209: Outlet Protection

12. Dewatering Construction Site

- Discharge any effluent of dewatering operations that has similar characteristics to stormwater runoff at the site, such as foundation, vault, and trench dewatering, into a controlled system prior to discharge into a sediment trap or sediment pond; and,

- Handle highly turbid or otherwise contaminated dewatering effluent, such as from a concrete pour, construction equipment operation, or work inside a coffer dam, separately from stormwater disposed of on-site.
- Consider other disposal options such as:
    - infiltration;
    - transportation off site for legal disposal in a way that does not pollute;
    - treatment and disposal on-site with chemicals or other technologies; and,

13. Control of Pollutants Other Than Sediment on Construction Sites

- Control on-site pollutants, such as waste materials and demolition debris, in a way that does not cause contamination of stormwater or groundwater. Woody debris may be chopped or mulched and spread on-site;
- *Cover, contain and protect all chemicals, liquid products, petroleum products, and non-inert wastes present on-site from vandalism (see Chapter 173-304 WAC for the definition of inert waste), use secondary containment for on-site fueling tanks;*
- *Conduct maintenance and repair of heavy equipment and vehicles involving oil changes, hydraulic system repairs, solvent and de-greasing operations, fuel tank drain down and removal, and other activities that may result in discharge or spillage of pollutants to the ground or into stormwater runoff using spill prevention measures, such as drip pans. Clean all contaminated surfaces immediately following any discharge or spill incident. If raining, perform on-site emergency repairs on vehicles or equipment using temporary plastic over and beneath the vehicle;*
- *Conduct application of agricultural chemicals, including fertilizers and pesticides, in such a manner, and at application rates, that inhibits the loss of chemicals into stormwater runoff facilities. Amend manufacturer's recommended application rates and procedures to meet this requirement, if necessary; and,*
- Locate pH-modifying sources, such as bulk cement, cement kiln dust, fly ash, new concrete washing and curing waters, waste streams generated from concrete grinding and cutting, exposed aggregate processes, and concrete pumping and mixer washout waters, downstream and away from any stormwater facilities or location of proposed stormwater facilities. Adjust pH if necessary to prevent violations of water quality standards. Obtain approval from Ecology for using chemicals other than liquid CO_2 or dry ice to adjust pH.

- Suggested BMPs:
  - See also Chapter 10 – Source Control
  - BMP C151: Concrete Handling
  - BMP C152: Sawcutting and Surfacing Pollution Prevention

14. Permanent BMPs

- Include permanent BMPs, if necessary, in the ESC plan to ensure the successful transition from temporary BMPs to permanent BMPs; and,
- Restore and rehabilitate temporary BMPs that are proposed to remain in place after construction as permanent BMPs.

15. Maintenance of BMPs

- *Inspect on a regular basis (at a minimum weekly, and daily during/after a runoff producing storm event) and maintain all ESC BMPs to ensure successful performance of the BMPs. Conduct maintenance and repair in accordance with individual ESC BMPs outlined in this section; and,*
- *Remove temporary ESC BMPs within 30 days after they are no longer needed. Permanently stabilize areas that are disturbed during the removal process.*

9.4.4 MODIFICATION TO ESC PLANS

ESC plans may be modified after submittal to the reviewing agency. An amended plan shall be submitted to illustrate any modifications to the methods used to prevent and control erosion and sedimentation.

9.5 ADDITIONAL INFORMATION REGARDING ESC PLANS

9.5.1 PERFORMANCE STANDARDS

The following performance standards represent a minimum threshold for controlling soil erosion and sedimentation caused by land-disturbing activities and will be used to determine if the requirements of this chapter have been met:

1. Minimize Tracking onto Roadways

This performance standard has not been met if soil, dirt, mud or debris is visibly tracked onto the road area and a reasonable attempt to control it through the use of ESC BMPs is not evident.

2. Protection of Roadways, Properties and Stormwater Facilities

This performance standard has not been met if there is visible downstream deposition of soil, dirt, mud or debris, originating from the project site, on adjacent or down-gradient roads, properties or stormwater systems.

3. Proper Washout of Concrete Trucks and Equipment

This performance standard has not been met if there is observation or evidence of concrete washout outside the area designated for concrete washout on the accepted ESC plan.

4. Protection of Water Bodies, Streams and Wetlands

This performance standard has not been met if there is obvious turbidity or deposition of soil, dirt, mud, or debris from the project site into adjacent water bodies or into sensitive or critical areas and their buffers. In addition, the performance standard requires that no construction activity, material or equipment encroach into sensitive or critical areas.

9.5.2 MAINTENANCE RESPONSIBILITY

The proponent is responsible to ensure that BMPs are used, maintained, and repaired so that the performance standards continue to be met. After all land-disturbing activity is complete and the site has been permanently stabilized, maintenance and the prevention of erosion and sedimentation is the responsibility of the property owner. Special criteria regarding the degradation of water resources are found in the Washington Administrative Code of various state agencies such as the Departments of Ecology, Natural Resources, and Fish and Wildlife.

9.5.3 ENFORCEMENT AND APPEALS PROCESS

Review the local jurisdiction’s code to determine the enforcement and appeal processes for violation of the above performance standards.

APPENDIX 9A – ESC STANDARD PLAN NOTES

The following ESC Standard Plan Notes originate from Section 9.4.3. These notes are an overall set; use only what applies to the given project.

1. The following construction sequence shall be followed in order to best minimize the potential for erosion and sedimentation control problems:
   (a) Clear and grub sufficiently for installation of temporary ESC BMPs;
   (b) Install temporary ESC BMPs, constructing sediment trapping BMPs as one of the first steps prior to grading;
   (c) Clear, grub and rough grade for roads, temporary access points and utility locations;
   (d) Stabilize roadway approaches and temporary access points with the appropriate construction entry BMP;
   (e) Clear, grub and grade individual lots or groups of lots;
   (f) Temporarily stabilize, through re-vegetation or other appropriate BMPS, lots or groups of lots in situations where substantial cut or fill slopes are a result of the site grading;
   (g) Construct roads, buildings, permanent stormwater facilities (i.e. inlets, ponds, UIC facilities, etc.);
   (h) Protect all permanent stormwater facilities utilizing the appropriate BMPs;
   (i) Install permanent ESC controls, when applicable; and,
   (j) Remove temporary ESC controls when:
2. Permanent ESC controls, when applicable, have been completely installed;
3. All land-disturbing activities that have the potential to cause erosion or sedimentation problems have ceased; and,
4. Vegetation had been established in the areas noted as requiring vegetation on the accepted ESC plan on file with the local jurisdiction.
5. Inspect all roadways, at the end of each day, adjacent to the construction access route. If it is evident that sediment has been tracked off site and/or beyond the roadway approach, cleaning is required.
6. If sediment removal is necessary prior to street washing, it shall be removed by shoveling or pickup sweeping and transported to a controlled sediment disposal area.
7. If street washing is required to clean sediment tracked off site, once sediment has been removed, street wash wastewater shall be controlled by pumping back on-site or otherwise prevented from discharging into systems tributary to waters of the state.
8. Restore construction access route equal to or better than the pre-construction condition.

9. Retain the duff layer, native topsoil, and natural vegetation in an undisturbed state to the maximum extent practical.
10. Inspect sediment control BMPs weekly at a minimum, daily during a storm event, and after any discharge from the site (stormwater or non-stormwater). The inspection frequency may be reduced to once a month if the site is stabilized and inactive.
11. Control fugitive dust from construction activity in accordance with the state and/or local air quality control authorities with jurisdiction over the project area.
12. Stabilize exposed unworked soils (including stockpiles), whether at final grade or not, within 10 days during the regional dry season (July 1 through September 30) and within 5 days during the regional wet season (October 1 through June 30). Soils must be stabilized at the end of a shift before a holiday weekend if needed based on the weather forecast. This time limit may only be adjusted by a local jurisdiction with a “Qualified Local Program,” if it can be demonstrated that the recent precipitation justifies a different standard and meets the requirements set fourth in the Construction Stormwater General Permit.
13. Protect inlets, drywells, catch basins and other stormwater management facilities from sediment, whether or not facilities are operable.
14. Keep roads adjacent to inlets clean.
15. Inspect inlets weekly at a minimum and daily during storm events.
16. Construct stormwater control facilities (detention/retention storage pond or swales) before grading begins. These facilities shall be operational before the construction of impervious site improvements.
17. Stockpile materials (such as topsoil) on site, keeping off of roadway and sidewalks.
18. Cover, contain and protect all chemicals, liquid products, petroleum product, and non-inert wastes present on site from vandalism (see Chapter 173-304 WAC for the definition of inert waste), use secondary containment for on-site fueling tanks.
19. Conduct maintenance and repair of heavy equipment and vehicles involving oil changes, hydraulic system repairs, solvent and de-greasing operations, fuel tank drain down and removal, and other activities that may result in discharge or spillage of pollutants to the ground or into stormwater runoff using spill prevention measures, such as drip pans. Clean all contaminated surfaces immediately following any discharge or spill incident. If raining over equipment or vehicle, perform emergency repairs on site using temporary plastic beneath the vehicle.
20. Conduct application of agricultural chemicals, including fertilizers and pesticides, in such a manner, and at application rates, that inhibits the loss of chemicals into stormwater runoff facilities. Amend manufacturer’s recommended application rates and procedures to meet this requirement, if necessary.
21. Inspect on a regular basis (at a minimum weekly, and daily during/after a runoff producing storm event) and maintain all erosion and sediment control BMPs to ensure successful performance of the BMPs. Note that inlet protection devices shall be cleaned or removed and replace before six inches of sediment can accumulate.

22. Remove temporary ESC BMPs within 30 days after the temporary BMPs are no longer needed. Permanently stabilize areas that are disturbed during the removal process.

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CHAPTER 10 – SOURCE CONTROL

Chapter Organization

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10.1 INTRODUCTION

Source control consists of measures taken to prevent pollutants from entering stormwater and thus affecting the water quality of surface water and groundwater. Source control measures are typically in the form of best management practices (BMPs) to keep the common pollutants generated in an urban environment from contacting stormwater, either through physical separation of areas or through careful management of activities that generate pollutants. Water pollutants are generally defined as hazardous or toxic solids that are water soluble or transportable, or substances that are liquids at ambient temperatures and pressures. Insoluble gases and vapors are not considered water pollutants.

The main purpose of source control BMPs is to prevent pollutants from coming into contact with stormwater through physical separation and/or management of activities that produce pollutants. Guidance for selecting BMPs to satisfy this basic requirement is presented in Chapter 8 of the *Stormwater Management Manual for Eastern Washington*. For more information regarding source control and the recommended BMPs, visit the Washington State Department of Ecology website at the following address:

- http://www.ecy.wa.gov/programs/wq/stormwater/index.html.

10.2 APPLICABILITY

All projects, unless exempted in Section 2.1.4, shall comply with this Basic Requirement. Project proponents are required to implement applicable source controls through the use of BMPs as specified in Chapter 8 of the *Stormwater Management Manual for Eastern Washington*.

A project proponent is not relieved from the responsibility of preventing pollutant release from coming in contact with stormwater, whether or not the project triggers the regulatory threshold.

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CHAPTER 11 – MAINTENANCE, TRACTS AND EASEMENTS

Chapter Organization

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11.1 MAINTENANCE

11.1.1 INTRODUCTION

Insufficient maintenance of stormwater control facilities can lead to poor performance, shortened life, increased maintenance and replacement costs, and property damage.

The local jurisdiction maintains the stormwater system structures located within the public road right of way and structures located within border easements that serve public road runoff, unless a separate agreement exists whereby the homeowner, property owner or other independent entity is responsible for the maintenance. Drainage tracts created by public projects will be maintained by the local jurisdiction. The project proponent is to provide for the perpetual maintenance of all elements of the stormwater system located outside the public right of way. The high-frequency maintenance of vegetated cover, turf grass and other landscaping within the public right of way and within border easements that accommodate public road runoff is the responsibility of the adjacent property owner. When applicable, the following maintenance-related items shall be submitted with the Drainage Submittal (refer to Chapter 3) for all projects:

- A copy of the conditions, covenants and restrictions (CC&Rs) for the homeowners' association (HOA) in charge of operating and maintaining all elements of the stormwater system;
- A Financial Plan outlining the funding mechanism for the operation, maintenance, repair, and replacement of the private stormwater system, including contingencies; and,
- An Operations and Maintenance (O&M) Manual.

Appendix 5A and 6A of the *Stormwater Management Manual for Eastern Washington* outline facility maintenance recommendations and frequencies.

11.1.2 APPLICABILITY

All projects that meet the regulatory threshold and that propose drainage facilities or structures shall comply with the Basic Requirement for operation and maintenance. All projects that propose UIC facilities also must comply with the operation and maintenance requirements, regardless of whether they meet the regulatory threshold.

11.1.3 HOMEOWNERS' AND PROPERTY OWNERS' ASSOCIATIONS

For privately maintained stormwater systems in residential neighborhoods, a homeowner's association, or alternate entity acceptable to the local jurisdiction, shall be formed to maintain the facilities located outside of the public right of way.

A draft copy of the CC&Rs for the HOA in charge of operating and maintaining the facilities associated with the stormwater system shall be submitted as part of the Drainage Submittal review package. The CC&Rs shall summarize the maintenance and fiscal responsibilities of the HOA, reference the O&M Manual (Section 11.1.4), and include a copy of the sinking fund calculations and Financial Plan (Section 11.1.5). Annual HOA dues shall provide funding for the annual operation and maintenance of all facilities associated with the stormwater system and for the eventual replacement of these facilities.

For commercial/industrial and multi-family residential developments with joint stormwater systems and multiple owners, a property owners' association (POA) or similar entity such as a business shall be formed, or a reciprocal-use agreement executed.

Homeowners' associations and property owners' associations are to be non-profit organizations accepted by the Washington Secretary of State. A standard business license is not acceptable for this purpose.

11.1.4 OPERATION AND MAINTENANCE MANUAL

For stormwater systems operated and maintained by a HOA or POA, an O&M Manual is required. The O&M Manual summarizes the tasks required to ensure the proper operation of all facilities associated with the stormwater system and must include, as a minimum:

- Description of the entity responsible for the perpetual maintenance of all facilities associated with the stormwater system, including legal means of successorship;
- Description of maintenance tasks to be performed and their frequency;
- A list of the expected design life and replacement schedule of each component of the stormwater system;
- A general site plan (drawn to scale) showing the overall layout of the site and all the facilities associated with the stormwater system; and,
- A description of the source control BMPs.

11.1.5 FINANCIAL PLAN

A Financial Plan is required in order to provide the entity responsible for maintenance with guidance with regard to financial planning for maintenance and replacement costs. The Financial Plan shall include the following items:

- A list of all stormwater-related facilities and their expected date of replacement and associated costs;
- Sinking fund calculations that take into consideration probable inflation over the life of the infrastructure and estimates the funds that need to be set aside annually (an example is provided in Appendix 11A); and,
- A mechanism for initiating and sustaining the sinking fund account demonstrating that perpetual maintenance of all facilities associated with the stormwater system will be sustained.

11.1.6 MAINTENANCE ACCESS REQUIREMENTS

An access road is required when the stormwater system facilities/structures are located 8 feet or more from an all weather drivable surface and are maintained by the local jurisdiction. Privately maintained facilities located 15 feet or more from an all weather drivable surface are also required to have an access road. When required, maintenance access roads shall meet the following minimum requirements:

- The horizontal alignment of all access roads shall be designed and constructed to accommodate the turning movements of a Single-Unit Truck (as defined by *AASHTO Geometric Design of Highways and Streets*, Exhibit 2-4, 2004 Edition). The minimum outside turning radius shall be 50 feet. The minimum width shall be 12 feet on straight sections and 15 feet on curves;
- Access roads shall consist of an all weather, drivable surface;
- Access roads shall be located within a 20-foot-minimum-width (or as required by the horizontal alignment requirements) tract or easement, extending from a public or private road;
- Access roads shall have a maximum grade of 10 percent;
- A paved apron must be provided where access roads connect to paved public roads; and,
- Gravel access roads shall have a minimum of 6 inches of crushed surfacing top course, in accordance with WSDOT Standard Specifications and shall be designed to support the heaviest anticipated maintenance vehicle year round.

The following access road requirements apply only when the local jurisdiction has assumed the responsibility of the maintenance and operation of the facilities, though it is recommended that access roads for privately maintained facilities also be designed to meet these criteria:

- If the maintenance access road is longer than 150 feet, a turn-around is required at or near the terminus of the access road. Turn-arounds are required for long, winding, or steep conditions, regardless of the length of the drive, where backing up would otherwise be difficult; and,
- Turn-arounds shall conform to the jurisdiction's standard plan.

11.2 TRACTS AND EASEMENTS

Flow control and treatment facilities must be located within the right of way, within a border easement parallel to the road or within an individual tract. For lots larger than 1 acre, the drainage facility may be located within a drainage easement if the facility does not occupy more than 10% of the lot and does not straddle private property lines. Stormwater facilities serving commercial projects do not generally require separate tracts or easements unless they serve more than one parcel.

A stormwater facility, as defined for this section, is a swale or pond. It is acceptable for other types of facilities, such as a pipe, to be in a drainage easement.

11.2.1 TRACTS

A drainage tract for access, maintenance, operation, inspection and repair shall be dedicated to the entity in charge of the maintenance and operation of the stormwater system. Unless otherwise approved by the local jurisdiction, a tract will be dedicated when any of the following situations are present:

- Facilities associated with a stormwater system serving a residential development are located outside of the public right of way;
- Drainage ditches are located in residential neighborhoods. The limits of the tract may have to be delineated with a permanent fence when the ditch is located near property lines; or,
- A drainageway is present on a lot of 1 acre or smaller (refer to Section 8.3.4).

Tracts shall be of sufficient width to provide access to, and maintain, repair or replace elements of, the stormwater system without risking damage to adjacent structures, utilities and normal property improvements, and without incurring additional costs for shoring or specialized equipment.

11.2.2 EASEMENTS

A drainage easement for access, maintenance, operation, inspection and repair shall be granted to the entity in charge of the maintenance and operation of the stormwater system. The easement shall grant to the local jurisdiction the right to ingress/egress over the easement for purposes of inspection or emergency repair. If not in a tract, the following infrastructure shall be placed within drainage easements:

- Elements of a stormwater system, such as a pipe, located outside the public right of way. Easements for stormwater conveyance pipes shall be of sufficient width to allow construction of all improvements, including any associated site disturbances, and access to maintain, repair or replace the pipe and appurtenances without risking damage to adjacent structures or incurring additional costs for shoring or special equipment. No storm pipe in a drainage easement shall have its centerline closer than 5 feet to a private rear or side property line. The storm drain shall be centered in the easement. The minimum drainage easement shall be 20 feet;
- For drainage ditches and natural drainageways, the easement width shall be wide enough to contain the runoff from a 50-year storm event for the contributing stormwater basin, plus a 30% freeboard or 1 foot, whichever is greater. Constructed drainage ditches will not typically be allowed to straddle lot lines. Natural drainageways (refer to Section 8.3.4) located on lots larger than 1 acre may be placed in an easement; and,
- Easements for access roads and turnarounds shall be at least 20 feet wide.

Easement documents shall be drafted by the project proponent for review by the local jurisdiction and recorded by the project proponent.

Off-Site Easements

When a land action proposes infrastructure outside the property boundaries, an off-site easement shall be recorded separately from plat documents, with the auditor's recording number placed on the face of the plat. The easement document shall include language prescribed by the local jurisdiction. The easement language shall grant the local jurisdiction the right to ingress and egress for purposes of routine or emergency inspection and maintenance. The following will be submitted to the local jurisdiction for review:

- A legal description of the site stamped and signed by a surveyor;
- An exhibit showing the entire easement limits and easement bearings, stamped and signed by a surveyor;
- Proof of ownership for the affected parcel and a list of signatories; and,
- Copy of the draft easement.

The legal exhibit and description shall have 1-inch margins for all four sides of the page. All text shall be legible and at least 8 point.

For plats and binding site plans, the off-site drainage facility must be clearly identified on the plans and operation and maintenance responsibilities must be clearly defined prior to acceptance of the project.

APPENDIX 11A – EXAMPLE CALCULATION: SINKING FUND

LIST OF QUANTITIES

Description	Units	Quantity	Unit Price		Total
24" Pipe	LF	175	$40.00	$	7,000.00
21" Pipe	LF	50	$40.00	$	2,000.00
18" Pipe	LF	700	$26.00	$	18,200.00
15" Pipe	LF	650	$24.00	$	15,600.00
12" Pipe	LF	1600	$22.00	$	35,200.00
10" Pipe	LF	50	$20.00	$	1,000.00
			Pipe Total	**$**	**79,000.00**
Inlets	EA	22	$500.00	$	11,000.00
Type B Drywells	EA	4	$2,500.00	$	10,000.00
			Structure Total	**$**	**21,000.00**

ANNUAL MAINTENANCE AND OPERATION COSTS

Description	Units	Quantity	Unit Price		Total
Inspect Structures	DAY	4	$50.00	$	200.00
Flush/Clean Inlets	EA	26	$100.00	$	2,600.00
Flush Pipes				$	-
Inspect Ponds and Clean Outlets	LS	1	$500.00	$	500.00
Mowing & Irrigation of Ponds	DAY	34	$250.00	$	8,500.00
			Annual Maintenance Cost	**$**	**11,800.00**

REPLACEMENT COST & ANNUAL COST PER LOT

Description		Total
Assume 50% of Pipe is Replaced in 20 years (=Pipe Total*0.5)	$	39,500.00
Assume 25% of Structures are Replaced in 20 years (=Structure Total*0.25)	$	5,250.00
Total Present Value (PV) of Replaced Pipe and Structures	**$**	**44,750.00**
Future Value of Pipe and Structures (FV), assume inflation=4%, n=20		
FV = PV(F/P, 4%, n=20)	$	98,052.76
Annual Set-Aside for Future Replacement (A), assume interest=6%, n=20		
A = FV(A/F, 6%, n=20)	$	2,665.52
Annual Maintenance and Operation Costs (from subtotal above)	$	11,800.00
Total Annual Costs	**$**	**14,465.52**
Total Charge per Lot, assume 100 Lots		
Charge per Lot = Total Annual Costs / # of Lots		
Charge per Lot	**$**	**144.66**

NOTE: F/P, A/F factors are from interest tables

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