Volume I – Stormwater Site Planning
Table of Contents

Volume
I

Volume I:
Stormwater Site Planning

Purpose of this Volume

This volume provides a discussion of the minimum requirements for stormwater management, and information and guidance for preparing a Stormwater Site Plan. This includes an overview of the impacts of development on water flow and quality, an overview of the affected watershed areas, procedures for preparing the plan, and information helpful for selecting BMPs and facilities for permanent stormwater management.

Content and Organization of this Volume

Volume I contains four chapters and five appendices.

- Chapter 1 describes the impacts of development and redevelopment on water flow and quality.
- Chapter 2 describes areas with special development requirements
- Chapter 3 defines the minimum requirements for stormwater management for development and redevelopment projects.
- Chapter 4 describes the Stormwater Site Plan, and provides step-by-step guidance for preparing the plan.
- Appendix A provides information about regulatory requirements.
- Appendix B provides a checklist of stormwater site plan submittal requirements.
- Appendix C provides a hydraulic analysis worksheet.
- Appendix D describes maintenance standards for drainage facilities.
- Appendix E describes guidelines for wetlands and stormwater management.

Chapter 1 Development and Redevelopment Impacts

1.1 Hydrologic Changes

As settlement occurs and the population grows, trees are logged and land is cleared for the addition of impervious surfaces such as rooftops, roads, parking lots, and sidewalks. Maintained landscapes that have much higher runoff characteristics typically replace the natural vegetation. The natural soil structure is also changed due to grading and compaction during construction. Roads are cut through slopes and low spots are filled. Drainage patterns are irrevocably altered. All of this can result in drastic changes in the natural hydrology, including:

- Increased volumetric flow rates of runoff
- Increased volume of runoff
- Decreased time for runoff to reach a natural receiving water
- Reduced groundwater recharge
- Increased frequency and duration of high stream flows and wetlands inundation during and after wet weather
- Reduced stream flows and wetlands water levels during the dry season
- Greater stream velocities
- Adverse impacts on existing City infrastructure and capacity

1.2 Water Quality Changes

Urbanization also can cause an increase in the types and quantities of pollutants in surface and groundwaters. Runoff from urban areas has been shown to contain many different types of pollutants, depending on the nature of the activities in those areas. The runoff from roads and highways can be contaminated with pollutants from vehicles. Oil and grease, polynuclear aromatic hydrocarbons (PAHs), lead, zinc, copper, cadmium, as well as sediments (soil particles) and road salts can be typical pollutants in road runoff. Runoff from industrial areas can contain many types of heavy metals, sediments, and a broad range of man-made organic pollutants, including phthalates, PAHs, and other petroleum hydrocarbons. Residential areas can contribute the same road-based pollutants to runoff, as well as herbicides, pesticides, nutrients (from fertilizers), bacteria, and viruses (from animal waste). All of these contaminants can seriously impair beneficial uses of receiving waters.

Regardless of the eventual land use conversion, the sediment load produced by a construction site can turn the receiving waters turbid and be deposited over the natural sediments of the receiving water. The addition of sediment loads also impacts existing City systems, causing localized flooding and increases in the cost and frequency of maintenance.

Urbanization can cause changes in water temperature. Heated stormwater from impervious surfaces and exposed treatment and detention ponds may discharge to streams with less riparian vegetation for shade. Urbanization also reduces groundwater recharge, which reduces sources of cool groundwater inputs to streams. In winter, stream temperatures may lower due to loss of riparian cover. There is also concern that the replacement of warmer groundwater inputs with colder surface runoff during colder periods may have biological impacts.

1.3 Biological Changes

Hydrologic and water quality changes can result in changes to the biological systems that were supported by the natural hydrologic system. In particular, aquatic life is greatly affected by urbanization. Habitats are altered when a stream changes its physical configuration and substrate due to increased flows. Natural riffles, pools, gravel bars and other areas can be altered or destroyed. These and other alterations produce a habitat structure that is very different from the one in which the resident aquatic life evolved.

The biological communities in wetlands also can be severely impacted and altered by the hydrological changes. Relatively small changes in the natural water elevation fluctuations can cause dramatic shifts in vegetative and animal species composition.

Chapter 2 Areas with Special Development Requirements

This chapter identifies geographic areas within the City of Auburn and the requirements specific to those areas. Theses requirements shall be in addition to the minimum requirements found in Chapter 3 of this volume unless the text in this chapter specifically indicates that the area-specific requirement supersedes or replaces a minimum requirement.

2.1 Groundwater Protection Area 2

In 2005, the City of Auburn adopted the Critical Areas Ordinance, ACC 16.10 which formally designates Groundwater Protection Areas within the City of Auburn. Groundwater Protection Zone 2 represents the land area in the central part of the city beneath which the principal aquifer used by the city for water supply is overlain by highly permeable sand and gravel deposits. These geologic conditions provide a direct pathway for contaminants that may be released to the soil to reach the aquifer.

Private infiltration systems used in Groundwater Protection Zone 2 that receive stormwater from any pollution-generating surfaces including streets, parking areas, or galvanized roofs are prohibited unless in the opinion of the Public Works Department no other reasonable alternative exists. In such case, the Public Works Department may approve a private disposal system. Design shall meet all requirements of the Public Works Department. Additional water quality measures may also be required.

To request infiltration of pollution-generating surfaces in Groundwater Protection Zone 2, a formal request for exception shall be submitted per Section 3.5 for review and approval.

2.2 Impaired Water Bodies

Section 305(b) of the Clean Water Act (CWA) requires the Department of Ecology to prepare a report every two years on the status of the overall condition of the state's waters. Section 303(d) of the CWA requires Ecology to prepare a list every two years containing water bodies not expected to meet state surface water quality standards after implementation of technology-based controls. The State is then required to complete a Total Maximum Daily Load (TMDL) for all water on that list. The existing list and other related information is available on Ecology's water quality website:

http://www.ecy.wa.gov/programs/wq/links/wq_assessments.html

If a project site discharges to one of these listed waterbodies, additional treatment or flow control requirements may apply.

2.3 Floodplains

Floodplains are not regulated through the Surface Water Management Manual. However, surface water facilities proposed within flood plains will be reviewed on a case-by-case basis to determine if the facilities are acceptable. Additional analysis and requirements may be needed for surface water facilities located within flood plains.

Chapter 3 Minimum Requirements for New Development and Redevelopment

This Chapter identifies the minimum requirements for stormwater management applicable to new development and redevelopment sites. These requirements are codified in Chapter 13.48 of the Auburn City Code (ACC). New development and redevelopment projects also may be subject to other City code requirements, depending on the nature and location of the project. These code requirement may include, but are not limited to, the subdivision and land use permit procedures in Titles 17 and 14 ACC; excavation and grading and off-site improvement Chapter 15.74 ACC; driveway control Chapter 12.20 ACC; groundwater protection, Chapter 8.08 ACC; shoreline regulation, Chapter 16.08 ACC; and critical areas preservation Chapter 16.10 ACC.

These requirements are intended to provide for and promote the health, safety and welfare of the general public, and are not intended to create or otherwise establish or designate any particular class or group of persons who will or should be especially protected or benefited by the provisions of this chapter.

3.1 Overview of the Minimum Requirements

The Minimum Requirements are:

1. Preparation of Stormwater Site Plans
2. Construction Stormwater Pollution Prevention
3. Source Control of Pollution
4. Preservation of Natural Drainage Systems and Outfalls
5. On-site Stormwater Management
6. Runoff Treatment
7. Flow Control
8. Wetlands Protection
9. Operation and Maintenance

The City also has one additional requirement beyond those required in Ecology's 2005 manual:

10. Off-Site Analysis and Mitigation

Depending on the type and size of the proposed project, different combinations of these minimum requirements apply. In general, small sites are required to control erosion and sedimentation from construction activities and to apply simpler approaches to treatment and flow control of stormwater runoff from the developed site. Large sites must provide erosion and sedimentation control during construction and permanent control of stormwater runoff from the developed site.

Section 3.4 provides additional information on applicability of the Minimum Requirements to different types of sites.

This manual is designed to be equivalent to Ecology's 2005 Stormwater Management Manual for Western Washington. Ecology considers its manual to include all known, available, and reasonable methods of prevention, control, and treatment (AKART). Ecology's manual has no independent regulatory authority. However, Ecology has required as a condition of the City's General Permit for Discharges from Municipal Separate Storm Sewers, the adoption of stormwater program components that are the substantial equivalent to the minimum requirements found in Ecology's 2005 manual.

The minimum requirements of this Chapter are conditions of the City's stormwater NPDES permit, and are required under Auburn City Code, Chapter 13.48 *Storm Drainage Utility.*

3.2 Exemptions

The following classes of projects have exemption from the minimum requirements. All other new development or redevelopment projects are subject to one or more of the Minimum Requirements (see Section 3.4).

3.2.1 Road Maintenance

The following road maintenance practices are exempt:

- pothole and square cut patching
- overlaying existing asphalt or concrete pavement with asphalt or concrete without expanding the area of coverage
- shoulder grading
- reshaping/regrading drainage systems
- crack sealing
- resurfacing with in-kind material without expanding the road prism
- vegetation maintenance

3.2.2 Parking Lots and Parking Lot Maintenance

Parking lots are considered pollution generating impervious surfaces and must comply with all relevant BMPs per the Minimum Requirements. Parking lot surfacing material requirements are regulated through the City's Land Use code. Parking lots must provide a design to control and manage surface water per the minimum requirements. No special consideration will be given to "temporary" parking areas as the impacts resulting from the proposed impervious surface must be mitigated as part of the construction.

The following parking lot maintenance practices are exempt:

- pothole and square cut patching
- overlaying existing asphalt or concrete pavement with asphalt or concrete without expanding the area of coverage
- crack sealing
- catch basin, pipe and vegetation maintenance

3.2.3 Underground Utility Projects

Underground utility projects that replace the ground surface with in-kind material or materials with similar runoff characteristics are only subject to Minimum Requirement #2, Construction Stormwater Pollution Prevention.

3.2.4 Minor Clearing and Grading

The following minor clearing and grading activities are exempt from all the Minimum Requirements except for Minimum Requirement #2; unless located within a critical or sensitive area governed by the City's Critical Areas Ordinance. Information on Critical Areas is available through the City of Auburn Planning Department.

- Excavation for wells, except that fill made with the material from such excavation shall not be exempt;
- Exploratory excavations under the direction of soil engineers or engineering geologists, except that fill made with the material from such excavation shall not be exempt;
- Removal of hazardous trees;
- Removal of trees or other vegetation which cause sight distance obstructions at intersections;
- Minor clearing and grading associated with cemetery graves;
- Land clearing associated with routine maintenance by public utility agencies, as long as appropriate vegetation management practices are followed as described in the Best Management Practices of the Regional Road Maintenance Endangered Species Act Program Guidelines located at http://www.wsdot.wa.gov/maintenance/roadside/esa.htm

3.2.5 Emergencies

Emergency projects which, if not performed immediately would substantially endanger life or property, are exempt only to the extent necessary to meet the emergency. Emergency activities may include but are not limited to: sandbagging, diking, ditching, filling, or similar work during or after periods of extreme weather. Permits authorizing the emergency work may be required after completion of the emergency project.

3.2.6 Key Terms

A few key words to be aware of pertaining to the requirements that follow are:

- Arterial
- Effective Impervious Surface
- Impervious Surface
- Land Disturbing Activity

- Maintenance
- Native Vegetation
- New Development
- Pollution-Generating Impervious Surface (PGIS)
- Pollution Generating Pervious Surfaces (PGPS)
- Pre-Developed Conditions
- Project Site
- Receiving Waters
- Redevelopment
- Replaced Impervious Surface
- Site
- Source Control BMP
- Threshold Discharge Area.

The definition of these and other stormwater-related words and phrases used in this manual are provided in the Glossary.

3.3 Applicability of the Minimum Requirements

NOTE: Throughout this section, **requirements are written in bold print.** Supplemental guidelines that serve as advice and other materials are not bolded.

Not all of the Minimum Requirements apply to every development or redevelopment project. The applicability varies depending on the type and size of the project. This section Identifies thresholds that determine the applicability of the Minimum Requirements to different projects. The thresholds shall be determined using the proposed improvements for the entire project site.

The flow charts in Figure I-3-1, Figure I-3-2, and Figure I-3-3, can be used to determine which requirements apply. The Minimum Requirements themselves are presented in Section 3.4.

Flow credits as outlined in Volume VI are used when determining project thresholds.

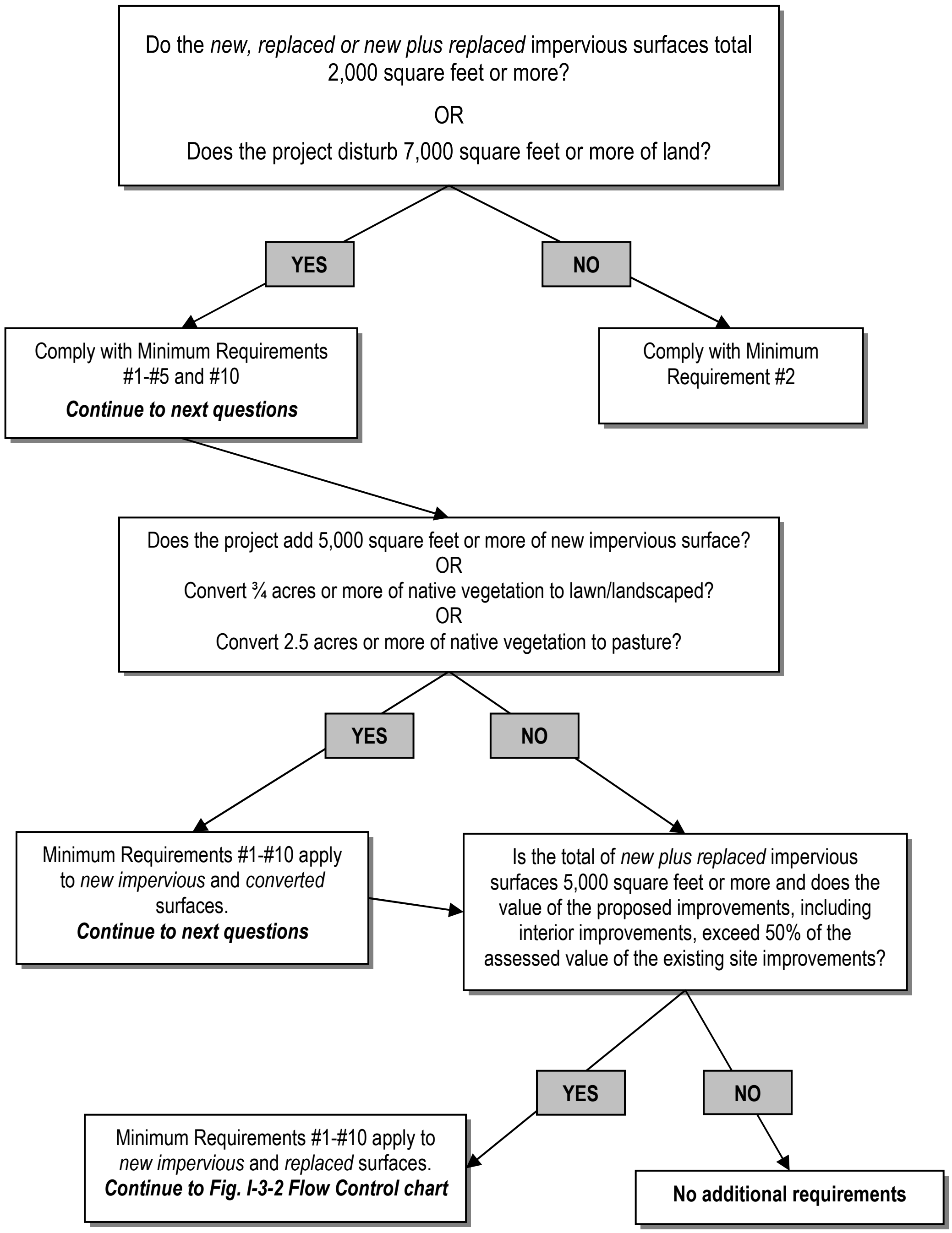


Figure I-3-1. Determining Minimum Requirements for New and Redevelopment Project Sites

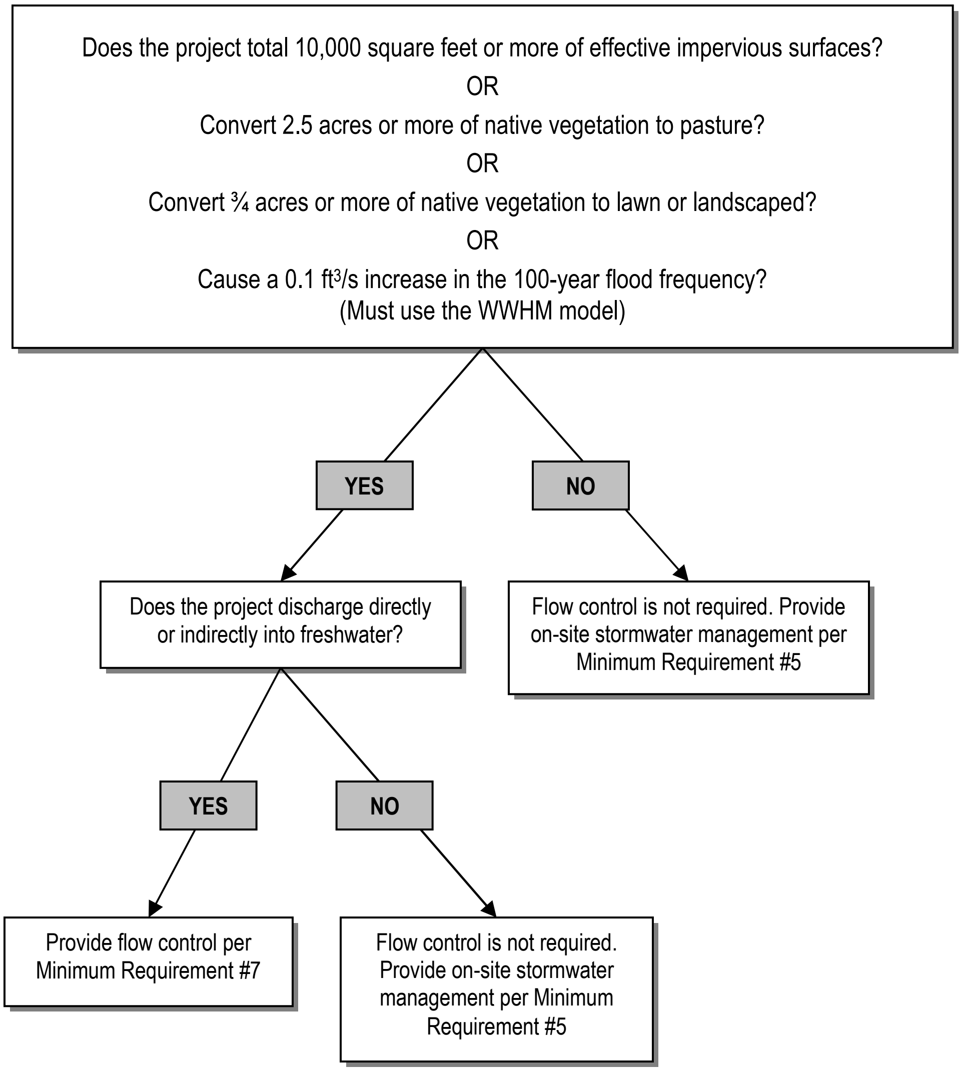


Figure I-3-2. Determining Minimum Requirements for Flow Control

3.3.1 New Development

All new development shall be required to comply with Minimum Requirement #2.

The following new development shall comply with Minimum Requirements #1 through #5 for the new and replaced impervious surfaces and the land disturbed:

- **Creates or adds 2,000 square feet, or greater, of new, replaced, or new plus replaced impervious surface area, or**
- **Has land disturbing activity of 7,000 square feet or greater.**

The following new development shall comply with Minimum Requirements #1 through #10 for the new impervious surfaces and the converted pervious surfaces.

- **Creates or adds 5,000 square feet , or more, of new impervious surface area, or**
- **Converts ¾ acres, or more, of native vegetation to lawn or landscaped areas, or**
- **Converts 2.5 acres, or more, of native vegetation to pasture.**

3.3.2 Redevelopment

Redevelopment is development on a site that is already substantially developed (i.e., has 35% or more existing impervious surface coverage). See the Glossary at the back of this manual for definitions.

Redevelopment projects have the same requirements as new development projects in order to minimize the impacts from new surfaces. To encourage redevelopment projects, replaced surfaces are not required to be brought up to new stormwater standards unless the thresholds noted in Section 3.3.3 are exceeded. As long as the replaced surfaces have similar pollution-generating potential, the amount of pollutants discharged should not be significantly different. However, if the redevelopment project scope is sufficiently large such that the thresholds noted in Section 3.3.3 are exceeded, it is reasonable to require the replaced surfaces to be brought up to current stormwater standards. This is consistent with other utility standards. When a structure or a property undergoes significant remodeling, local governments often require the site to be brought up to new building code requirements (e.g., onsite sewage disposal systems, fire systems).

All redevelopment shall be required to comply with Minimum Requirement #2. In addition, all redevelopment that exceeds certain thresholds shall be required to comply with additional Minimum Requirements as follows.

The following redevelopment shall comply with Minimum Requirements #1 through #5 for the new and replaced impervious surfaces and the land disturbed:

- **The new, replaced, or total of new plus replaced impervious surfaces is 2,000 square feet or more, or**
- **7,000 square feet or more of land disturbing activities.**

In addition to meeting Minimum Requirements #1 through #5, the following redevelopment shall comply with Minimum Requirements #6 through #10 for the new impervious surfaces and converted pervious areas:

- **Adds 5,000 square feet or more of *new* impervious surfaces or,**
- **Converts ¾ acres, or more, of native vegetation to lawn or landscaped areas, or**
- **Converts 2.5 acres, or more, of native vegetation to pasture.**

If the runoff from the new impervious surfaces and converted pervious surfaces is not separated from runoff from other surfaces on the project site, the stormwater treatment facilities must be sized for the entire flow that is directed to them. The City may allow the Minimum Requirements to be applied to an equivalent area (flow and pollution characteristics) within the same site. For public road projects, the equivalent area does not have to be within the project limits, but must drain to the same receiving water within the watershed.

3.3.3 Assessed Value

Other types of redevelopment projects shall comply with all the Minimum Requirements for the new and replaced impervious surfaces if the total of new plus replaced impervious surfaces is 5,000 square feet or more, and the valuation of proposed improvements (materials plus labor to construct) – including interior improvements – exceeds 50% of the assessed value of the existing site improvements as determined from the latest available building valuation data published by the International Code Council, available at http://www.iccsafe.org/cs/techservices/index.html .

3.3.4 Roads

For road-related projects, runoff from the replaced and new impervious surfaces (including pavement, shoulders, curbs, driveways, and sidewalks) shall meet all the Minimum Requirements if the new impervious surfaces total 5,000 square feet or more and total 50% or more of the existing impervious surfaces within the site (see Figure I-3-3). The site shall be defined by the length of the project and the width of the right-of-way. For the purposes of this manual, public roads (off-site improvements) required as part of a private project will be considered part of the threshold area determination for the minimum requirements.

The following road maintenance practices are considered redevelopment. The extent to which the manual applies is explained for each circumstance.

- Removing and replacing a paved surface to base course or lower, or repairing the roadway base: If impervious surfaces are not expanded, Minimum Requirements #1 - #5 apply. However, in most cases, only Minimum Requirement #2, Construction Stormwater Pollution Prevention, will be germane. Where appropriate, project proponents are encouraged to look for opportunities to use permeable and porous pavements.

- Extending the pavement edge without increasing the size of the road prism, or paving graveled shoulders: These are considered new impervious surfaces and are subject to the minimum requirements that are triggered when the thresholds identified for redevelopment projects are met.
- Resurfacing by upgrading from dirt to gravel, asphalt, or concrete; upgrading from gravel to asphalt or concrete; or upgrading from a bituminous surface treatment ("chip seal") to asphalt or concrete. These are considered new impervious surfaces and are subject to the minimum requirements that are triggered when the thresholds identified for redevelopment projects are met.

3.3.5 Cumulative Impact Mitigation Requirement

The determination of thresholds for a project site shall be based on the total increase or replacement of impervious surfaces that occurred after adoption of the 2009 SWMM. Under this provision, the City will consider the cumulative impacts of all permits issued on or after February 16, 2010. The combined total of new or replaced surfaces will be applied to the thresholds that determine applicability of the Minimum Requirements.

The intent of this Cumulative Impact Mitigation Requirement is to adequately mitigate the stormwater from improvements on a project site that are submitted under separate permits. The separate submittals could have project areas that do not meet the thresholds, but would meet the thresholds if the projects were combined as one project.

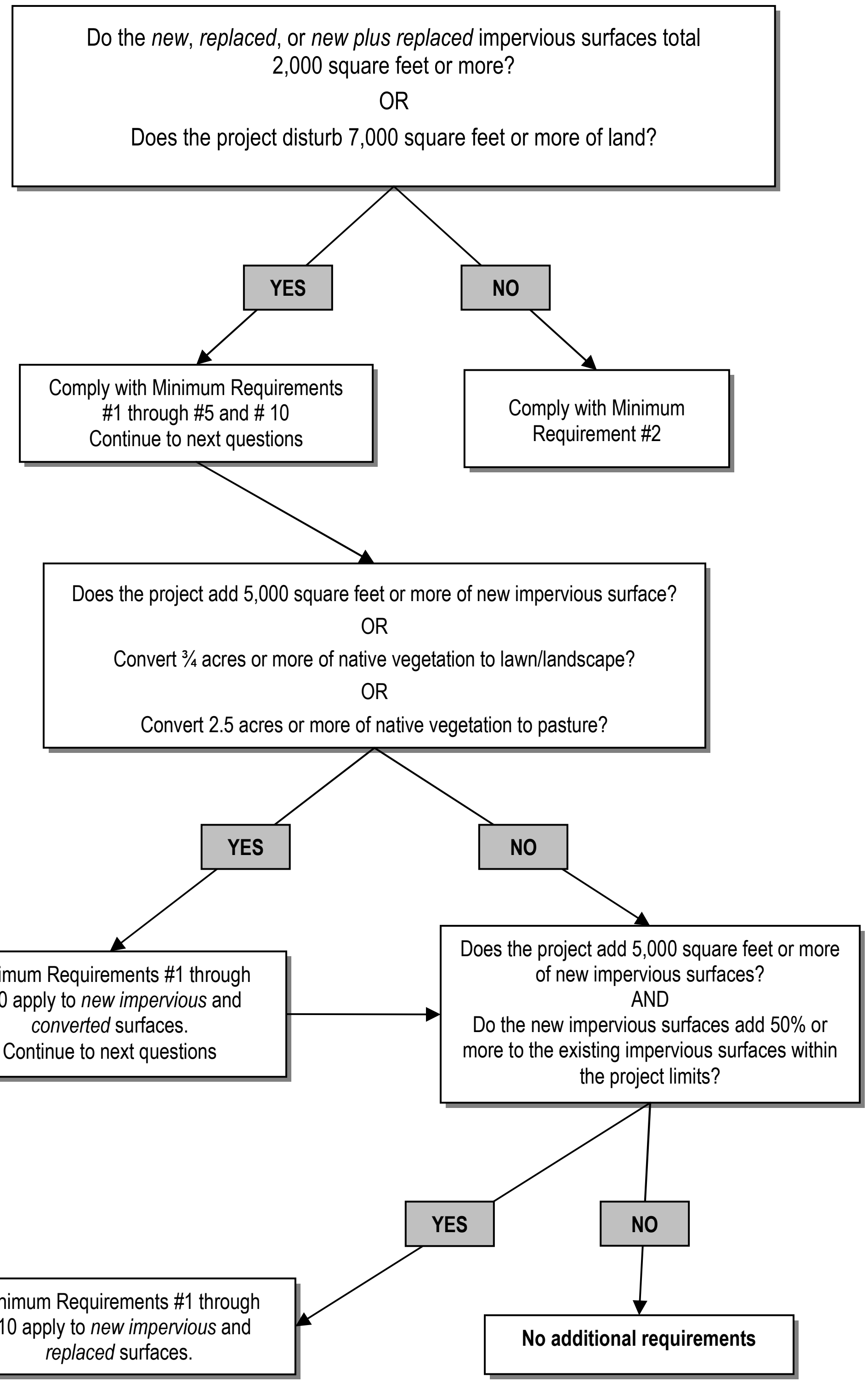


Figure I-3-3. Determining Minimum Requirements for Road-Related Projects

3.4 Description of Minimum Requirements

NOTE: Throughout this Section, **guidance to meet requirements is written in BOLD.** Supplemental guidelines that serve as advice and other materials are not written in bold.

This section describes the minimum requirements for stormwater management at new development and redevelopment sites. Consult Section 3.3 to determine which requirements apply to any given project.

Volumes II through VI of this manual present Best Management Practices (BMPs) for use in meeting the Minimum Requirements.

3.4.1 Minimum Requirement #1: Preparation of a Stormwater Site Plan

All projects meeting the thresholds in Section 3.3 shall prepare a Stormwater Site Plan for local government review. Stormwater Site Plans shall be prepared in accordance with Chapter 4 of this volume.

A Stormwater Site Plan consists of an assessment of both temporary and permanent stormwater and drainage impacts and may include a construction stormwater pollution prevention plan, when required by Minimum Requirement #2.

3.4.1.1 Objective

To outline the existing and post-developed conditions of the project site, describe the proposed stormwater facilities, and present the stormwater analysis.

3.4.2 Minimum Requirement #2: Construction Stormwater Pollution Prevention (SWPP)

All new development and redevelopment shall comply with Construction SWPP Elements #1 through #12. A full description of these elements can be found in Volume II, Chapter 2.

Projects which meet or exceed the thresholds of Volume I, Section 3.3 must prepare a Construction Stormwater Pollution Prevention Plan (SWPPP) as part of the Stormwater Site Plan (see Section 3.4.1). Each of the twelve elements must be considered and included in the Construction SWPPP unless site conditions render the element unnecessary and the exemption from that element is clearly justified in the narrative of the SWPPP.

The City has developed a Construction SWPPP Short Form for projects that:

- **Add or replace between 2,000 and 5,000 square feet of impervious surface, or**
- **Clear or disturb between 7,000 square feet and 1 acre of land.**

The SWPPP Short Form is intended to take the place of the Construction SWPPP. A Certified Erosion and Sediment Control Lead (CESCL) is not required for those projects using the City's Construction SWPPP Short Form.

For all other projects requiring a Construction SWPPP, a CESCL shall be identified in the Construction SWPPP and shall be on-site or on-call at all times. CESCLs must be trained through an Ecology approved training program found at: http://www.ecy.wa.gov/programs/wq/stormwater/cescl.htm

Unless located in a Critical Area, projects that add or replace less than 2,000 square feet of impervious surface or disturb less than 7,000 square feet of land are not required to prepare a Construction SWPPP, but must consider all of the twelve Elements of Construction Stormwater Pollution Prevention (SWPP) and develop controls for all elements that pertain to the project site.

SWPP Elements are:

Element 1: **Mark Clearing Limits**
Element 2: **Establish Construction Access**
Element 3: **Control Flow Rates**
Element 4: **Install Sediment Controls**
Element 5: **Stabilize Soils**
Element 6: **Protect Slopes**
Element 7: **Protect Drain Inlets**
Element 8: **Stabilize Channels and Outlets**
Element 9: **Control Pollutants**
Element 10: **Control De-Watering**
Element 11: **Maintain BMPs**
Element 12: **Manage the Project**

These Elements are described in detail in Volume II.

3.4.2.1 Objective

The purpose of construction SWPP is to control erosion and prevent sediment and other pollutants from leaving the site during the construction phase of a project.

3.4.3 Minimum Requirement #3: Source Control of Pollution

All known, available, and reasonable source control BMPs shall be applied to all projects. Source control BMPs shall be selected, designed, and maintained according to this manual. Structural source control BMPs shall be identified in the stormwater site plan and shall be shown on construction plans submitted for City review.

Source Control BMPs include Operational BMPs and Structural Source Control BMPs. See Volume IV for design details of these BMPs. For construction sites, see Volume II, Chapter 3.

3.4.3.1 Objective

The intent of source control BMPs is to prevent stormwater from coming in contact with pollutants. They are a cost-effective means of reducing pollutants in stormwater, and, therefore, should be a first consideration in all projects.

3.4.4 Minimum Requirement #4: Preservation of Natural Drainage Systems and Outfalls

Natural drainage patterns shall be maintained, and discharges from the project site shall occur at the natural location, to the maximum extent practicable. The manner by which runoff is discharged from the project site must not cause a significant adverse impact to downstream receiving waters and downgradient properties. All outfalls require energy dissipation.

As part of a submittal, the applicant shall identify the location of natural drainage, topography, historic drainage information and any potential impacts.

3.4.4.1 Objective

To preserve and utilize natural drainage systems to the fullest extent because of the multiple stormwater benefits these systems provide; and to prevent erosion at and downstream of the discharge location.

3.4.5 Minimum Requirement #5: On-Site Stormwater Management

Projects shall employ, where feasible and appropriate, On-site Stormwater Management BMPs to infiltrate, disperse, and retain stormwater runoff onsite to the maximum extent feasible without causing flooding, erosion, water quality or groundwater impacts. All projects required to comply with Minimum Requirement #5 shall employ all of the following BMPs as applicable:

- **Roof Downspout Control BMPs, functionally equivalent to those described in Volume III, Section 2.1, and**
- **Dispersion, functionally equivalent to those described in Volume VI, Section 2.2, and**
- **Soil Quality BMPs, functionally equivalent to those in Volume VI, Section 2.2.1.4.**

Where roof downspout controls are planned, the following three types shall be considered in descending order of preference:

- **Downspout infiltration systems including rain gardens (Volume III, Section 2.1.2 and Section 2.1.4, and Volume VI, Section 2.2.3).**
- **Downspout dispersion systems (Volume III, Section 2.1.3), only if infiltration is not feasible.**
- **Collect and convey to City system (Volume III, Section 2.1.5) if other alternatives are not feasible.**

3.4.5.1 Objective

To use inexpensive practices on individual properties to reduce the amount of disruption of the natural hydrologic characteristics of the site

3.4.6 Minimum Requirement #6: Runoff Treatment

3.4.6.1 Thresholds

The following require construction of stormwater treatment facilities:

- **Projects in which the total of effective pollution-generating impervious surface (PGIS) is 5,000 square feet or more in a threshold discharge area of the project, or**
- **Projects in which the total of pollution-generating pervious surfaces (PGPS) is three-quarters (3/4) of an acre or more in a threshold discharge area, and from which there is a surface discharge in a natural or man-made conveyance system from the site.**

Total effective pollution-generating impervious surface shall include all new plus replaced PGIS. That portion of any development project in which the above PGIS or PGPS thresholds are not exceeded in a threshold discharge area shall apply On-site Stormwater Management BMPs, where feasible, in accordance with Minimum Requirement #5.

3.4.6.2 Treatment Facility Selection, Design, and Maintenance

Stormwater treatment facilities shall be:

- **Selected in accordance with the process identified in Volume V, Chapter 1;**
- **Designed in accordance with the design criteria in Volume V; and**
- **Maintained in accordance with the maintenance standards in Volume I, Appendix D that shall be incorporated in the design as part of a facility operation and maintenance manual.**

3.4.6.3 Additional Requirements

- **Direct discharge of untreated stormwater from pollution-generating surfaces above the thresholds given in Section 3.4.6.1 to groundwater is prohibited.**
- **Infiltration of any amount of PGS is not allowed within the Groundwater Protection Zone 2 unless approved in writing per Volume I, Section 2.1.**

3.4.6.4 Objective

The purpose of runoff treatment is to reduce pollutant loads and concentrations in stormwater runoff using physical, biological, and chemical removal mechanisms so that beneficial uses of receiving waters are maintained and, where applicable, restored. When site conditions are appropriate, infiltration can potentially be the most effective BMP for runoff treatment.

3.4.6.5 Supplemental Guidelines

The above thresholds apply to both a project's on-site and off-site improvements. Once the project is required to meet this minimum requirement, all new and replaced pollution generating impervious surfaces are required to provide treatment. No net or average is permitted between non-pollution generating surfaces and pollution generating.

NOTE: With respect to Water Quality, a “net” total of pollution generating impervious surface will not be considered when dealing with replaced impervious surfaces. Construction of new surfaces that do not generate pollution does not balance the environmental impacts of newly created pollution generating surfaces. All new or redeveloped pollution generating surfaces that meet the thresholds for new and redevelopment and create, add and/or replace 5,000 square feet pollution generating impervious surface shall provide water quality.

See Volume V for more detailed guidance on selection, design, and maintenance of treatment facilities.

3.4.7 Minimum Requirement #7: Flow Control

3.4.7.1 Applicability

Projects must provide flow control to reduce the impacts of stormwater runoff from impervious surfaces and land cover conversions. Portions of projects discharging to a wetland shall also be subject to Minimum Requirement #8.

<u>The flow control requirement thresholds apply to projects that discharge directly or indirectly:</u>

- **Through a conveyance system, into fresh water; or**
- **Through a conveyance system into a gulch; or**
- **To a City identified capacity problem existing downstream of the development; or**
- **To a manmade conveyance system (ditch, swale, etc.) which has not been adequately stabilized to prevent erosion; or**
- **To a conveyance system without capacity to convey the fully developed design event as defined in Volume III, Chapter 3.**

3.4.7.2 Thresholds

Projects that meet or exceed the following thresholds require construction of flow control facilities and/or land use management BMPs.

- **Project sites in which the total of effective impervious surfaces is 10,000 square feet or more in a threshold discharge area, or**
- **Projects that convert ¾ acres or more of native vegetation to lawn or landscape, or convert 2.5 acres or more of native vegetation to pasture in a threshold discharge area, and from which there is a surface discharge in natural or man-made conveyance system from the site, or**
- **Projects that, through a combination of effective impervious surfaces and converted pervious surfaces, cause a 0.1 cfs increase in the 100-year flow frequency from a threshold discharge area as estimated using the Western Washington Hydrology Model or other approved model. Comparison will be between existing and proposed site conditions.**

That portion of any development project in which the thresholds listed above are not exceeded in a threshold discharge area, shall apply Onsite Stormwater Management BMPs in accordance with Minimum Requirement #5. Refer to Figure I-3-1, Figure I-3-2 and Figure I-3-3 to aid in determining project requirements.

3.4.7.3 Standard Requirement

Using WWHM for design, stormwater discharges shall match developed discharge durations to pre-developed durations for the range of pre-developed discharge rates from 50% of the 2-year peak flow up to the full 50-year peak flow. The pre-developed condition to be matched shall be a forested land cover. The pre-developed soil types shall be assumed as either outwash (Hydrologic Soil Group A/B) or till (Hydrologic Soil Group C/D) soils, depending on supporting geotechnical information. Saturated soil conditions shall only be considered when determining existing wetland hydrology.

This standard requirement is waived for sites that will reliably infiltrate all the runoff from impervious surfaces and converted pervious surfaces.

<u>Any areas for which the minimum thresholds are not exceeded must still meet the following criteria:</u>

- **The project must be drained by a conveyance system with capacity to convey the fully developed design event as defined in Volume III, Chapter 3. The conveyance system must consist entirely of manmade conveyance elements (e.g., pipes, ditches, outfall protection, etc.) and extend to the ordinary high water line of the receiving water; and**
- **Any erodible elements of the manmade conveyance system must be adequately stabilized to prevent erosion under future build-out conditions from areas that contribute flow to the system; and**
- **No City identified capacity problems may exist downstream of the development; and**
- **Surface water flows from the area must not be diverted from or increased to an existing wetland, stream, or near-shore habitat sufficient to cause a significant adverse impact.**

3.4.7.4 Infrastructure Protection Requirement

The infrastructure protection requirement is intended to mitigate stormwater impacts from projects that are not required to provide flow control, but discharge to a system with capacity limitations such as projects with the following characteristics:

- **Inadequate capacity in downstream conveyance.**

Applicant may resolve the downstream capacity problem or may provide on-site detention. Where detention is provided, stormwater discharges for the developed condition shall match the discharges under existing conditions.

3.4.7.5 Objective

To prevent increases in the stream channel erosion rates that are characteristic of natural conditions (i.e., prior to the European settlement). The standard intends to maintain the total amount of time that a receiving stream exceeds an erosion-causing threshold based upon historic rainfall and natural land cover conditions. That threshold is assumed to be 50% of the 2-year peak flow. Maintaining the naturally occurring erosion rates within streams is vital, though by itself insufficient, to protect fish habitat and production.

3.4.7.6 Modeling Requirements

To meet the Standard Requirement, the applicant shall use the most current software version of the Department of Ecology's Western Washington Hydrology Model (WWHM) model (see Volume III). Alternative models for sizing flow control and water quality facilities may be considered, provided they are Washington State Department of Ecology equivalent, and approved by the City of Auburn. Approval from the City shall be obtained prior to submittal of design documents.

To meet the Downstream Analysis requirements, piped conveyance systems shall be modeled using either continuous simulation or single event methods. Stream systems shall be modeled using only continuous simulation methods.

The designer shall provide a copy of the completed hydrology analysis worksheet (Appendix C) and a copy of the electronic project files.

NOTE: Hand-calculated hydrographs and flow routing will no longer be accepted because of the wide availability of various software programs.

3.4.8 Minimum Requirement #8: Wetlands Protection

Wetlands are regulated by the City of Auburn through this requirement and the Critical Areas Code, Auburn City Code 16.10. For more information about wetlands, wetland permits and development close to wetlands, please contact the Planning, Building & Community Department at (253) 931-3090.

3.4.8.1 Applicability

Stormwater discharges to wetlands are regulated under the City's Critical Areas Ordinance (ACC 16.10).

The requirements below are in addition to requirements given in ACC 16.10 and apply only to projects whose stormwater discharges into a wetland, either directly or indirectly through a conveyance system. These requirements must be met <u>in addition</u> to meeting Minimum Requirement #6, Runoff Treatment. All pollution generating surfaces discharging to wetlands shall require water quality treatment prior to discharge to the wetlands. Streams may also be regulated under this requirement as part of the wetland permit.

3.4.8.2 Thresholds

When either of the thresholds identified in Minimum Requirement #6 – Runoff Treatment, or Minimum Requirement #7 – Flow Control are met or exceeded, this requirement shall also be applied.

3.4.8.3 Standard Requirement

Discharges to wetlands shall maintain the hydrologic conditions, hydrophytic vegetation, and substrate characteristics necessary to support existing and designated uses. The hydrologic analysis shall use the existing land cover condition to determine the existing hydrologic conditions unless directed otherwise by a regulatory agency with jurisdiction. A wetland can be considered for hydrologic modification and/or stormwater treatment in accordance with Guidesheet 1B in Appendix E. Modeling shall be completed with a continuous simulation model. Model calibration and pre- and post-development monitoring of wetland levels, groundwater levels, and water quality may be required by the City.

3.4.8.4 Additional Requirements

The standard requirement does not excuse any discharge from the obligation to apply whatever technology is necessary to comply with state water quality standards, Chapter 173-201A WAC, or state groundwater standards, Chapter 173-200 WAC. Additional treatment requirements to meet those standards may be required by federal, state, or local governments.

Stormwater treatment and flow control facilities shall not be constructed within a natural vegetated buffer, except for:

- **Necessary conveyance systems as approved by the City; or**
- **As allowed in wetlands approved for hydrologic modification and/or treatment in accordance with Guidesheet 1B in Appendix E of this Volume.**

Flow splitting devices or drainage BMPs must be applied to route natural runoff volumes from the project site to any downstream stream or wetland.

Design of flow splitting devices or drainage BMPs will be based on continuous hydrologic modeling analysis. The design will assure that flows delivered to stream reaches will approximate, but in no case exceed, durations ranging from 50% of the 2-year to the 50-year peak flow.

Flow splitting devices or drainage BMPs that deliver flow to wetlands shall be designed using continuous hydrologic modeling to preserve pre-project wetland hydrologic conditions unless specifically waived or exempted by regulatory agencies with permitting jurisdiction;

An adopted and implemented basin plan, or a Total Maximum Daily Load (TMDL, also known as a Water Clean-up Plan) may be used to develop requirements for wetlands that are tailored to a specific basin.

3.4.8.5 Objective

To ensure that wetlands receive the same level of protection as any other waters of the state. Wetlands are extremely important natural resources which provide multiple stormwater benefits, including groundwater recharge, flood control, and stream channel erosion protection. They are easily impacted by development unless careful planning and management are conducted. Wetlands can be severely degraded by stormwater discharges from urban development due to pollutants in the runoff and also due to disruption of natural hydrologic functioning of the wetland system. Changes in water levels and the frequency and duration of inundations are of particular concern.

3.4.8.6 Supplemental Guidelines

Appendix E contains guidance for wetlands when interacting with stormwater. **The City of Auburn may require applicants to utilize portions or all of the guidance in analyzing and mitigating wetland impacts.**

3.4.9 Minimum Requirement #9: Operation and Maintenance

An operation and maintenance manual that is consistent with the provisions in Section 4.1 of this Volume shall be provided for all proposed stormwater facilities and BMPs at the time construction plans are submitted for review, and the party (or parties) responsible for maintenance and operation shall be identified.

For private facilities, a copy of the manual shall be retained onsite or within reasonable access to the site, and shall be transferred with the property to the new owner. For private systems serving multiple lots within residential developments or other developments, a separate covenant or other guarantee of proper maintenance that can be recorded on title shall be provided and recorded. For public facilities, a copy of the manual shall be retained in the appropriate department.

For all facilities (public and private), a log of maintenance activity that indicates what actions were taken shall be kept and be available for inspection by the City.

3.4.9.1 Objective

To ensure that stormwater control facilities are adequately maintained and operated properly.

3.4.9.2 Supplemental Guidelines

Inadequate maintenance is a common cause of failure for stormwater control facilities. The description of each BMP in Volumes II, III, V, and VI includes a section on maintenance. Appendix D of Volume I includes a schedule of maintenance standards for drainage facilities.

3.4.10 Minimum Requirement #10: Off-Site Analysis and Mitigation

As required by the Minimum Requirements of this Chapter, development projects that discharge stormwater offsite shall submit as part of their Stormwater Site Plan and Report an off-site analysis that assesses the potential off-site impacts of stormwater discharge.

All projects shall perform a *qualitative* analysis downstream from the site.

The City may require a quantitative analysis for any project deemed to need additional downstream information.

3.4.10.1 Qualitative Analysis:

Project applicants shall submit a *qualitative* analysis of each upstream system entering a site (run-on) and each downstream system leaving a site (run-off). The qualitative analysis shall extend downstream for the entire flow path, from the project site to the receiving water, or up to one-quarter mile, whichever is less. The upstream analysis shall identify and describe points where water enters the site and the tributary area. A basin map defining the onsite and offsite basins tributary to the site shall be provided. The basin map shall be to a defined scale.

Upon review of this analysis, the City may require a qualitative analysis further downstream, mitigation measures deemed adequate to address the problems, or a quantitative analysis, depending upon the presence of existing or predicted flooding, erosion, or water quality problems, and on the proposed design of the onsite drainage facilities. Details on how to perform this analysis are located in Volume I, Chapter 4 and Volume I, Appendix B.

3.4.10.2 Quantitative Analysis

The City may require a *quantitative* analysis for any project deemed to need additional downstream information. Details on how to perform this analysis are located in Volume III, Section 3.1.2.

3.4.10.3 Objective

To identify and evaluate offsite water quality, erosion, slope stability, and drainage impacts that may be caused or aggravated by a proposed project, and to determine measures for preventing impacts and for not aggravating existing impacts. Aggravated shall mean increasing the frequency of occurrence and/or severity of a problem. Some of the most common and potentially destructive impacts of land development are erosion of downgradient properties, localized flooding, and slope failures. These are caused by increased surface water volumes and changed runoff patterns. The City believes taking the precautions of offsite analysis could prevent substantial property damage and public safety risks. In addition the applicant will evaluate types and locations of surface run-on to the project site. These must be safely conveyed across the project site.

3.5 Exceptions

NOTE: Throughout this Section, **guidance to meet the requirements is written in BOLD.** Supplemental guidelines that serve as advice and other materials are not written in bold.

Deviations from the Minimum Requirements may be requested, in writing, in accordance with ACC 13.48.226 to allow a waiver of a requirement, a reduction or modification of a requirement, or to permit an alternative requirement. Public notice of application for a deviation, draft decision, and written findings will be published in accordance with ACC 13.48.226, with an opportunity for public comment. Deviations must meet the following criteria:

- **The minimum requirements would impose a severe and unexpected economic hardship; and**
- **The deviation will not increase risk to the public health and welfare, nor injurious to other properties in the vicinity and/or downstream, and to the quality of waters of the state; and**
- **The deviation is the least possible exception that could be granted to comply with the intent of the Minimum Requirements.**

In accordance with ACC 13.48.226, the City Engineer may grant a deviation following a documented finding that:

The deviation is likely to be equally protective of public health, safety and welfare, the environment, and public and private property, as the requirement from which an exception is sought.

OR

Substantial reasons exist under ACC 13.48.226 C., for approving the requested deviation and the deviation will not cause significant harm. The substantial reasons may include, but are not limited to:

- **The requirement to be imposed is not technically feasible; or**
- **An emergency situation necessitates approval of the deviation; or**
- **No reasonable use of the property is possible unless the deviation is approved; or**
- **The requirement would cause significant harm or a significant threat of harm to public health, safety and welfare, the environment, or to public and private property, or would cause extreme financial hardship which substantially outweighs its benefits.**

The decision to grant a deviation is within the sole discretion of the City, and the City Engineer shall only approve a deviation to the extent it is necessary. The City Engineer may impose new or additional requirements to offset or mitigate harm that may be caused by approving the deviation. The City Engineer may require the applicant to submit a licensed engineer's report or analysis along with a request, in writing, for a deviation. Deviations are intended to maintain necessary flexible working relationship between the City and applicants.

The approval of a deviation shall not be construed to be an approval of any violation of any of the other provisions of the City's Municipal Code, or of any other valid law of any governmental entity having jurisdiction.

Applications for a deviation from the Minimum Requirements of ACC13.48.225 must be in writing and include the following information:

- **The current (pre-project) use of the site, and**

- **How the application of the minimum requirement(s) restricts the proposed use of the site compared to the restrictions that existed prior to the adoption of the minimum requirements; and**

- **The possible remaining uses of the site if the deviation were not granted; and**

- **The uses of the site that would have been allowed prior to the adoption of the minimum requirements; and**

- **A comparison of the estimated amount and percentage of value loss as a result of the minimum requirements versus the estimated amount and percentage of value loss as a result of requirements that existed prior to adoption of the minimum requirements; and**

- **The feasibility for the owner to alter the project to apply the minimum requirements.**

Chapter 4 Preparation of Stormwater Site Plans

The Stormwater Site Plan is the comprehensive report containing all of the technical information and analysis necessary for the City to evaluate a proposed new development or redevelopment project for compliance with stormwater requirements. Contents of the Stormwater Site Plan will vary with the type and size of the project, and individual site characteristics. The scope of the Stormwater Site Plan also varies depending on the applicability of Minimum Requirements (see Section 3.4). However, typical Stormwater Site Plans will contain both a report and detailed plans.

This chapter describes the contents of a Stormwater Site Plan and provides a general procedure for how to prepare the plan. The goal of this chapter is to provide a framework for uniformity in plan preparation. Such uniformity will promote predictability and help secure prompt review. Properly drafted engineering plans and supporting documents will also facilitate the operation and maintenance of the proposed system long after construction is complete.

To aid the design engineer, a checklist containing submittal requirements is located in Appendix B and a hydraulic analysis worksheet is provided in Appendix C. These appendices should be completed and provided by the design engineer. These documents will be utilized by the City during the project review.

Stormwater Site Plans shall be prepared by a licensed Professional Engineer. All Stormwater Site Plans and drawings shall be signed, stamped, and dated prior to review by the City.

4.1 Stormwater Site Plan Outline

The Stormwater Site Plan (SSP) encompasses the entire submittal to the City for drainage review. This section provides an outline for a SSP and details drawing requirements.

Chapter 1 - Project Overview

The project overview must provide a general description of the project, pre-developed and developed conditions of the site, site area, and size of the improvements, and the pre- and post-developed stormwater runoff conditions. The overview shall summarize difficult site parameters, the natural drainage system, and drainage to and from adjacent properties, including bypass flows.

The vicinity map shall clearly locate the property, identify all roads bordering the site, show the route of stormwater off-site to the local natural receiving water, and show significant geographic features and sensitive/critical areas (streams, wetlands, lakes, steep slopes, etc.).

Include a list of other necessary permits and approvals as required by other regulatory agencies, if those permits or approvals include conditions that affect the drainage plan, or contain more restrictive drainage-related requirements.

Chapter 2 – Existing Conditions Summary

Collect and review information on the existing site conditions, including topography, drainage patterns, soils, ground cover, presence of any critical areas, adjacent areas, existing development, existing stormwater facilities, and adjacent on- and off-site utilities. Analyze data to determine site limitations including:

- Areas with high potential for erosion and sediment deposition (based on soil properties, slope, etc.); and
- Locations of sensitive and critical areas (e.g. vegetative buffers, wetlands, steep slopes, floodplains, geologic hazard areas, streams, etc.).
- Points where existing surface water enters and exits the project site.

Delineate these areas on the vicinity map and/or a site map. Prepare an Existing Conditions Summary that will be submitted as part of the Site Plan. Part of the information collected in this step should be used to help prepare the Construction Stormwater Pollution Prevention Plan.

Chapter 3 – Off-Site Analysis – Minimum Requirement # 10

The existing or potential impacts to be evaluated and mitigated as part of any off-site/downstream analysis shall include:

- Conveyance system capacity problems;
- Localized flooding;
- Aquatic habitat (wetlands) impacts;
- FEMA flood plain;
- Upland erosion impacts, including landslide hazards;
- Stream channel erosion at the outfall location;
- Impacts to surface water, groundwater, or sediment quality as identified in a Basin Plan or TMDL (Water Clean-up Plan);
- Locations where surface water enters and exits the site.

Qualitative Analysis:

Project applicants shall submit a *qualitative* analysis of each upstream system entering a site (run-on) and each downstream system leaving a site (run-off). The qualitative analysis shall extend downstream for the entire flow path, from the project site to the receiving water, or up to one-quarter mile, whichever is less. The upstream analysis shall identify and describe points where water enters the site and the tributary area. A basin map defining the onsite and offsite basins tributary to the site shall be provided. The basin map shall be to a defined scale.

Upon review of this analysis, the City may require a qualitative analysis further downstream, mitigation measures deemed adequate to address the problems, or a quantitative analysis, depending upon the presence of existing or predicted flooding, erosion, or water quality problems, and on the proposed design of the onsite drainage facilities. Details on how to perform this analysis are located in Volume I, Appendix B.

Quantitative Analysis:

The City may require a *quantitative* analysis for any project deemed to need additional downstream information. Details on how to perform this analysis are located in Volume III, Section 3.1.2.

The off-site analysis shall extend downstream of the site for a minimum of ¼ mile from the point of connection to the existing public drainage system, or until a trunk main is reached.

Chapter 4 – Permanent Stormwater Control Plan

The Permanent Stormwater Control Plan consists of those stormwater control BMPs and facilities that will serve the project site in its developed condition.

A preliminary design of the BMPs and facilities is necessary to determine how they will fit within and serve the entire preliminary development layout. After a preliminary design is developed, the designer may want to reconsider the site layout to reduce the need for construction of facilities, or the size of the facilities by reducing the amount of impervious surfaces created and increasing the areas to be left undisturbed. After the designer is satisfied with the BMP and facilities selections, the information must be presented within a Permanent Stormwater Control Plan.

Where modeling is completed, the City may require the model files be provided electronically.

The Permanent Stormwater Control Plan should contain the following sections:

1. Threshold Discharge Areas and Applicable Requirements for Treatment, Flow Control and Wetlands Protection

Complete the following tasks:

A. Read the definitions in the Glossary located at the back of this manual for the following terms: effective impervious surface, impervious surface, pollution-generating impervious surface (PGIS), pollution-generating pervious surface (PGPS), threshold discharge area, project site, and replaced impervious surfaces.

B. Outline the threshold discharge areas for your project site.

C. Determine the amount of effective pollution-generating impervious surfaces and pollution –generating pervious surfaces in each threshold discharge area. Compare those totals to the categories in Section 3.4.6 to determine where treatment facilities are necessary. Note that On-site Stormwater Management BMPs are always applicable.

D. Determine the amount of effective impervious surfaces and converted pervious surfaces in each threshold discharge area. Using an approved continuous runoff simulation model, estimate the increase in the 100-year flow frequency within each threshold discharge area.

E. Compare those totals to the categories in Section 3.4.7 to determine where flow control facilities are necessary. Note that On-site Stormwater Management BMPs may alter the calculation of effective impervious surface. See Volume VI for WWHM flow credit information.

2. Pre-developed Site Hydrology

The acreage, soil types, and land covers used to determine the pre-developed flow characteristics, along with basin maps, graphics, and exhibits for each sub-basin affected by the project should be included.

Provide a topographic map, of sufficient scale and contour intervals to determine basin boundaries accurately, and show:

- Delineation and acreage of areas contributing runoff to the site;
- Flow control facility location;
- Outfall;
- Overflow route; and
- All natural streams and drainage features.

The direction of flow, acreage of areas contributing drainage, and the limits of development should be indicated. Each basin within or flowing through the site should be named and model input parameters referenced, as appropriate.

If stormwater facilities that require sizing are proposed, provide a listing of assumptions and site parameters used in analyzing the pre-developed site hydrology.

For projects requiring flow control, the pre-developed condition to be matched shall be a forested land cover unless reasonable, historic information is provided that indicates the site was prairie prior to settlement.

3. Developed Site Hydrology

All Projects:

Total of impervious surfaces, total pollution-generating impervious surfaces, total pollution-generating pervious surfaces, and total disturbed area must be tabulated for each threshold discharge area. These are needed to verify which minimum requirements apply to a project.

Projects and Threshold Discharge Areas within Projects That Require Treatment and Flow Control Facilities:

Provide narrative, mathematical, and graphic presentations of model input parameters selected for the developed site condition, including acreage, soil types, and land covers, road layout, and all drainage facilities. The applicant shall reference sources for all variables and equations. All submissions shall be in typed format with a table of contents and labels for all figures and calculations. If calculations are used from other sections of the submittal, they shall be referenced with the appropriate, section and page number to the point of their original derivation.

Previous stormwater reports may be referenced. The City may request submission of all reference reports in their entirety.

Developed basin areas and flows shall be shown on a map and cross-referenced to computer printouts or calculation sheets. Developed basin flows should be listed and tabulated.

Any documents used to determine the developed site hydrology should be included. Maintain the same basin name as used for the pre-developed site hydrology. If the boundaries of a basin have been modified by the project, that should be clearly shown on a map and the name modified to indicate the change.

Final grade topographic maps shall be provided including finished floor elevations, where appropriate.

4. Performance Standards and Goals

If treatment facilities are proposed, provide a listing of the water quality menus used (Chapter 2 of Volume V). If flow control facilities are proposed, provide a confirmation of the flow control standard being achieved (e.g., the Ecology flow duration standard).

5. Flow Control System

Provide a drawing of the flow control facility and its appurtenances. This drawing must show basic measurements necessary to calculate the storage volumes available from zero to the maximum head, all orifice/restrictor sizes and head relationships, control structure/restrictor placement, and placement on the site.

Include computer printouts, calculations, equations, references, storage/volume tables, graphs as necessary to show results and methodology used to determine the storage facility volumes. Where the Western Washington Hydrology Model is used, its documentation files shall be submitted electronically.

6. Water Quality System

Provide a drawing of the proposed treatment facilities, and any structural source control BMPs. The drawing must show overall measurements and dimensions, placement on the site, location of inflow, bypass, and discharge systems.

Include computer printouts, calculations, equations, references, and graphs as necessary to show the facilities are designed in accordance with the requirements and design criteria in Volume V.

If using a manufactured system provide a specification from the manufacturer as well as all design specific parameters.

7. Conveyance System Analysis and Design

Present an analysis of any existing conveyance systems, and the analysis and design of the proposed stormwater conveyance system for the project. Portions of this analysis may include the criteria established in Item 3 above. This information should be presented in a clear, concise manner that can be easily followed, checked, and verified. All pipes, culverts, catch basins, channels, swales, and other stormwater conveyance appurtenances must be clearly labeled and correspond directly to the engineering plans. The analysis should be based on the design elements within the City of Auburn Engineering Design and Construction Standards and Volume III, Chapter 3 of this manual.

Chapter 5 – Discussion of Minimum Requirements

Provide a list of the minimum requirements that apply to the project site. Indicate where in the Stormwater Site Plan the documentation showing how the minimum requirements are satisfied can be found.

Appendix A – Operation and Maintenance (O & M) Manual

The O&M manual shall be designed as a stand-alone document, including all necessary figures and maps. The document may be submitted as either an Appendix to the SSP or bound separately.

Submit an operations and maintenance manual for each permanent stormwater facility. The manual shall contain a description of the facility, what it does, and how it works. The manual must identify and describe the maintenance tasks, and the required frequency of each task. The maintenance tasks and frequencies must meet the standards established in this manual.

Include a recommended format for a maintenance activity log. The log will have space to list maintenance activities.

The manual must prominently indicate where it shall be kept, and that it must be made available for inspection by the City. Specifically the manual will include:

Statements:

- Where the O&M manual shall be kept.
- That the O&M manual must be made available for inspection by the City.
- Name of the person or organization responsible for maintenance of the on-site storm system, including the phone number of the current responsible party.

Descriptions of:

- Each flow control and treatment facility, what it does, how it works, and maintenance tasks and frequency
- Operation and Maintenance Guidelines from the manufacturer of any proprietary flow control and treatment facility.

Sample forms:

- A summary sheet of the required inspection and maintenance frequencies for each specific facility (catch basins, ponds, vaults)
- A recommended format for a maintenance activity log that will indicate what maintenance actions have been taken for each flow control and treatment facility
- Relevant maintenance checklists from Appendix D of Volume 1 of the SWMM.

Figures and/or maps:

- An 11” x 17” map of the site, with the locations of the flow control and treatment facilities prominently noted.

Appendix B – Construction Stormwater Pollution Prevention Plan

This is the plan described in Section 3.4.2 and Volume II.

Appendix C – Submittal Requirements Checklist

A copy of the checklist can be found in Volume I, Appendix B and shall be completed by the engineer.

Appendix D – Hydraulic Analysis Worksheet

A copy of the worksheet can be found in Volume I, Appendix C and shall be completed by the engineer.

Appendix E – Other Special Reports

In this Appendix, include any special reports and studies conducted to prepare the Stormwater Site Plan (e.g. soil testing, wetlands delineation).

4.2 Plans Required After Stormwater Site Plan Approval

Follow the plan approval process given in the Chapters 2 and 3 of the City of Auburn Engineering Design Standards Manual.

4.3 Land Use Submittal Requirements

A reference to the subdivision checklists will be inserted here.

Appendix A Regulatory Requirements

This appendix contains the regulatory requirements that apply to applicable sites and their stormwater discharges.

Relationship of this Manual to Federal, State, and Local Regulatory Requirements

This manual is modeled after Ecology's 2005 Stormwater Management Manual for Western Washington. Ecology considers its manual to include all known, available, and reasonable methods of prevention, control, and treatment (AKART; RCW 90.48.010). Within Auburn, Ecology's manual has no independent regulatory authority except where Ecology directly requires or issues permits. The City of Auburn currently is regulated under a General Permit for Discharges from Municipal Separate Storm Sewers, effective February 16, 2007. Under federal regulations, Auburn is required to obtain coverage under this permit, and the permit is expected to require the adoption of stormwater program components that are the substantial equivalent to the minimum requirements found in Ecology's 2005 stormwater manual for western Washington. Upon adoption, Auburn will use this manual in issuing permits and other authorizations for development.

The Puget Sound Water Quality Management Plan

The current Puget Sound Water Quality Management Plan (the Plan), adopted in 2000 by the Puget Sound Action Team (PSAT), is a voluntary plan that calls for every city and county in the Puget Sound Basin to develop and implement a comprehensive stormwater management program. The Plan recognizes that stormwater programs will vary among jurisdictions, depending on the jurisdiction's population, density, threats posed by stormwater, and results of watershed planning efforts. Under the Plan, cities and counties are encouraged to form intergovernmental cooperative agreements in order to pool resources and carry out program activities more efficiently. More information about what the Plan contains can be found in Chapter 1 of Ecology's Manual, and a complete copy of the Plan can be downloaded from the PSAT website.

Phase II - Ecology's NPDES and State Waste Discharge Stormwater Permits for Municipalities

Auburn is subject to permitting under the U.S. Environmental Protection Agency (EPA) Phase II Stormwater Regulations (40 CFR Part 122) under the Clean Water Act National Pollutant Discharge Elimination System (NPDES) provisions. In Washington State, administration of the NPDES program is delegated to the Department of Ecology. In Western Washington, Ecology has issued joint NPDES and State Waste Discharge permits to regulate the discharges of stormwater from the municipal separate storm sewer systems operated by small municipal permittees.

Requirements arising out of Auburn's municipal stormwater permit are incorporated into this manual.

Ecology's State Waste Discharge Permits for Direct Discharges

The requirements imposed under the Phase II EPA Stormwater Regulations apply to discharges to Auburn's municipal stormwater system. However, the regulations do not apply to "direct discharges," that is, discharges that do not enter the City's system but go directly into receiving waters such as creeks or rivers.

Direct discharges are subject to permitting under Ecology's State Waste Discharge Permit program in Chapter 90.48 RCW.

Ecology's Industrial Stormwater Permit (i.e. NPDES and State Waste Discharge Baseline General Permit for Stormwater Discharges Associated With Industrial Activities)

This is a statewide permit for facilities conducting industrial activities. Most industrial facilities that discharge stormwater to a surface water body or to a municipal storm sewer system require permit coverage. Existing and new facilities for private entities, state, and local governments are required to have coverage. For a complete list of industrial categories identified for coverage, see Ecology's website or the permit itself. Ecology can also require permit coverage of any facility on a case-by-case basis in order to protect waters of the state. As above, direct discharges from industrial activities are subject to permitting under Ecology's State Waste Discharge Permit program in Chapter 90.48 RCW.

Ecology's Construction Stormwater Permit (i.e. NPDES and State Waste Discharge General Permit for Stormwater Discharges Associated With Construction Activity)

Coverage under Ecology's Construction General Permit is required for any clearing, grading, or excavating that will disturb one or more acres of land area and that will discharge stormwater from the site into surface water(s), or into storm drainage systems that discharge to a surface water. The permit requires:

- Application of stabilization and structural practices to reduce the potential for erosion and the discharge of sediments from the site. The stabilization and structural practices cited in the permit are similar to the minimum requirements for sedimentation and erosion control in Volume II of this manual.
- Construction sites within the Puget Sound basin to select from BMPs described in Volume 2 of the most recent edition of Ecology's Stormwater Management Manual (SWMM) that has been available at least 120 days prior to the BMP selection.

If local government requirements for construction sites are at least as stringent as Ecology's, Ecology will accept compliance with the local requirements. Accordingly, projects subject to Auburn's permitting authority that are also required to obtain coverage under Ecology's NPDES Construction Permit should be designed in accordance with Auburn's manual.

The permit is also required for projects or construction activities that disturb less than one acre of land area, if the project or activity is part of a larger common plan of development or sale that will ultimately disturb one or more acres of land area. The "common plan" in a common plan of development or sale is broadly defined as any announcement or piece of documentation (including a sign, public notice or hearing, sales pitch, advertisement, drawing, permit application, zoning request, computer design, etc.) or physical demarcation (including boundary signs, lot stakes, surveyor markings, etc.) indicating construction activities may occur on a specific plot.

The permit is not required for routine maintenance that is performed to maintain the original line and grade, hydraulic capacity, or original purpose of the site. For example, re-grading a dirt road or cleaning out a roadside drainage ditch to maintain its "as built" state does not require permit coverage.

Any construction activity discharging stormwater that Ecology and/or the City determine to be a "significant contributor of pollutants" to waters of the state may also be required to apply for and obtain permit coverage regardless of project size.

Applicants for coverage under the Construction General Permit must do the following:

- File a Notice of Intent (application for coverage). The permit application, called a Notice of Intent (NOI), shall be submitted to Ecology before the date of the first public notice and at least 38 days prior to the start of construction.
- Publish a Public Notice. At the time of application, the applicant must publish a notice that they are seeking coverage under Ecology's general stormwater permit for construction activities. This notice must be published at least once each week for two consecutive weeks in a single newspaper that has general circulation in the county in which the construction is to take place. Refer to the NOI instructions for public notice language requirements. State law requires a 30-day public comment period prior to permit coverage; therefore, permit coverage will not be granted sooner than 31 days after the date of the last public notice. Applicants who discharge surface water associated with construction activity to a storm drain operated by the City of Auburn are also required to submit a copy of the NOI to the municipality.
- Prepare a Construction Stormwater Pollution Prevention Plan. Permit coverage will not be granted until the permittee has indicated completion of the SWPPP or certified that development of a SWPPP in accordance with Special Condition S9 of the permit will occur prior to the commencement of construction. The construction SWPPP prepared using the City's manual will satisfy both the Ecology permit and City of Auburn permits.

Endangered Species Act

With the listing of multiple species of salmon as threatened or endangered across much of Washington state, and the probability of more listings in the future, implementation of the requirements of the Endangered Species Act will have a dramatic effect on urban stormwater management. The manner in which that will occur is still evolving. Provisions of the Endangered Species Act that may apply directly to stormwater management include the Section 4(d) rules, Section 7 consultations, and Section 10 Habitat Conservation Plans (50 CFR).

Section 401 Water Quality Certifications

For projects that require a fill or dredge permit under Section 404 of the Clean Water Act, Ecology must certify to the permitting agency, the U.S. Army Corps of Engineers, that the proposed project will not violate state water quality standards. In order to make such a determination, Ecology may do a more specific review of the potential impacts of a stormwater discharge from the construction phase of the project and from the completed project. As a result of that review, Ecology may condition its certification to require:

- Application of the minimum requirements and BMPs in Ecology's manual; or
- Application of more stringent requirements.

Hydraulic Project Approvals (HPAs)

Under Chapter 77.55 RCW, the Hydraulics Act, the Washington State Department of Fish and Wildlife has the authority to require actions when stormwater discharges related to a project would change the natural flow or bed of state waters. The implementing mechanism is the issuance of a Hydraulic Project Approval (HPA) permit.

Aquatic Lands Use Authorizations

The Washington State Department of Natural Resources (DNR), as the steward of public aquatic lands, may require a stormwater outfall to have a valid use authorization, and to avoid or mitigate resource impacts under authority of Chapter 79.90 through 96 RCW, and in accordance with Chapter 332-30 WAC.

Requirements Identified through Watershed/Basin Planning or Total Maximum Daily Loads

A number of the requirements of this manual can be superseded or modified by the adoption of ordinances and rules to implement the recommendations of watershed plans or basin plans.

Requirements in this manual can also be superseded or added to through the adoption of specific actions and requirements identified in a Waste Load Allocation or cleanup plan that implements a Total Maximum Daily Load (TMDL) approved by the EPA.

Underground Injection Control Authorizations

Congress passed the Safe Drinking Water Act in 1974 and required the Environmental Protection Agency (EPA) to create the Underground Injection Control (UIC) Program as on of the key programs for protecting drinking water sources. The UIC program is administered under 40 CFR Part 144. In 1984, Ecology received the authority from EPA to regulate UIC wells and adopted the UIC rule, Chapter 173-218 WAC. Ecology adopted revisions to Chapter 173-218 WAC rules on January 3, 2006 and the new rule went into affect on February 3, 2006.

The program requires:

- A non-endangerment performance standard be met, prohibiting injection that allows the movement of fluids containing any contaminant into groundwater.
- All well owners must provide inventory information by registering their wells with Ecology.

More information on the UIC program and how to register your well is available at: http://www.ecy.wa.gov/programs/wq/grndwtr/uic/index.html.

It is the responsibility of applicants/owners to contact Ecology and determine if their facilities are regulated under this program. If regulated, the applicant/owner is responsible to fulfill the program requirements properly.

Other City Requirements

The Planning, Building and Community Development Department is responsible for all land use permitting activities, including permits for buildings, grading, paving, shoreline activities, critical areas, short plats, formal subdivisions, etc.

Title 13 of the Auburn City Code (ACC) governs wastewater and surface water and gives the City its authority to regulate water quality control of surface waters, the stormwater system, and the sanitary sewer system. This Title also provides inspection authority, and enforcement authority for illegal discharges to the stormwater system.

New development and redevelopment projects also may be subject to other city code requirements, depending upon the nature and location of the project. These code requirements may include, but are not limited to the subdivision and land use permit procedures in Titles 17 and 14 ACC; excavation and grading in ACC Chapter 15.74; off-site improvements that include storm drainage in ACC 13.48.330; driveway control in Chapter 12.20 ACC; groundwater protection in Chapter 8.08 ACC; shoreline regulation in Chapter 16.08 ACC; and critical areas protection in Chapter 16.10 ACC.

The City of Auburn's Permit Center assists customers through every aspect of the permitting process, from initial questions and pre-application meetings through inspections and final certificate of occupancy. Applicants are encouraged to meet with City staff prior to plan submittal. Contact the City's Permit Counter at 253-591-5030 for more information.

Under the Growth Management Act, Chapter 36.70A RCW, the City has developed utilities and capital facilities plans to help ensure the provision of adequate utilities, including storm drainage. Depending upon the type of projects, new development and redevelopment may be required to contribute to the construction of facilities necessary to accommodate impacts created by that development.

Appendix B Stormwater Site Plan Submittal Requirements Checklist

The Submittal Requirements Checklist is intended to aid the design engineer in preparing a Stormwater Site Plan. All items included in the following checklist must be addressed as part of any stormwater site plan. The City recommends the design engineer follow the order and structure of the checklist to facilitate review, which in turn will expedite permit issuance.

Chapter 1 – Project Overview

The project overview is intended to be a summary of detailed information contained in the body of the Stormwater Site Plan.

- ☐ Identify type of permit requested and permit number
- ☐ Identify other permits required (e.g. hydraulic permits, Army Corps 404 permits, wetlands, etc.).
- ☐ Identify the project location (including address, legal description, and parcel number).
- ☐ Brief description of project to include the following:
  - ☐ Current and proposed condition/land-use
  - ☐ Size of parcel
  - ☐ Acreage developed, redeveloped, replaced or converted by the project
  - ☐ Current assessed value and cost of proposed improvements (for redevelopment projects)
  - ☐ Watershed
  - ☐ Proposed flow control improvements
  - ☐ Proposed runoff treatment improvements
  - ☐ Proposed conveyance improvements
  - ☐ Proposed discharge location and improvements
  - ☐ Downstream condition, impacts and problem
  - ☐ Locations of surface water run-on to the property
  - ☐ Reference appropriate Sections/Chapters/Appendices of the document for detailed descriptions.

Chapter 2 – Existing Condition Summary

The Existing Condition Summary is intended to provide a complete understanding of the project site and must be based on thorough site research and investigation.

- ☐ Describe, discuss and identify the following for the project site:
  - ☐ Topography
  - ☐ Land use and ground cover
  - ☐ Natural and man-made drainage patterns
  - ☐ Points of entry and exit for existing drainage to and from the site
  - ☐ Any known historical drainage problems such as flooding, erosion, etc.
  - ☐ Existing utilities (storm, water, sewer)
  - ☐ Areas with high potential for erosion and sediment deposition
  - ☐ Locations of sensitive and critical areas (i.e. vegetative buffers, wetlands, steep slopes, floodplains, geologic hazard areas, streams, creeks, ponds, ravines, springs, etc).
  - ☐ Existing fuel tanks

- ☐ Groundwater wells on-site and within 100 feet of site
- ☐ Septic systems on-site and/or within 100 feet of the site

☐ Identify difficult site conditions.

☐ State whether the project is located in an aquifer recharge area or wellhead protection area as defined by the Washington State Health Department, the Environmental Protection Agency or by the City.

☐ Identify any Superfund areas in the vicinity, and state whether they are tributary to, or receive drainage from, the project site.

☐ Identify any specific requirements included in a basin plan for the area.

☐ Include references to relevant reports such as basin plans, flood studies, groundwater studies, wetland designations, sensitive area designations, environmental impact statements, environmental checklists, lake restoration plans, water quality reports, etc. Where such reports impose additional conditions on the Proponent, state these conditions, and describe any proposed mitigation measures.

☐ Grading Plan per requirements.

☐ A soil report to identify the following:

- ☐ Soil types
- ☐ Hydrologic soil group classification
- ☐ Groundwater elevation
- ☐ Presence of perched aquifers, acquitters and confined aquifers
- ☐ Location of test pits
- ☐ Infiltration rates determined per the requirements of Volume III (where applicable)
- ☐ Discussion of critical areas or geologic hazards where present

☐ Soil reports should be contained in an Appendix of the report or as a separate document.

☐ Describe the 100-year flood hazard zone.

Chapter 3 – Off-Site Analysis (Minimum Requirement #10)

The City requires a qualitative discussion of the off-site upstream and downstream system for all projects. The City may require a quantitative analysis for any project deemed to need additional downstream information. Detailed calculations shall be contained in an Appendix of the report. Volume I, Chapter 4 describes the Off-site Analysis. In addition, a list of elements to be included is provided as follows.

Qualitative Analysis

☐ Review all available plans, studies, maps pertaining to the off-site study area.

☐ Investigate the drainage system ¼ mile downstream from the project by site visit, including the following items:

- ☐ Problems reported or observed during the resource review
- ☐ Existing/potential constrictions or capacity deficiencies in the drainage system
- ☐ Existing/potential flooding problems
- ☐ Existing/potential overtopping, scouring, bank sloughing, or sedimentation
- ☐ Significant destruction of aquatic habitat (e.g., siltation, stream incision)
- ☐ Existing public and private easements through the project site and their corresponding widths
- ☐ Qualitative data on features such as land use, impervious surface, topography, soils, presence of streams, and wetlands

  - ☐ Information on pipe sizes, channel characteristics and drainage structures
  - ☐ Verification of tributary drainage areas
  - ☐ Date and weather at the time of the inspection
- ☐ Describe the drainage system and its existing and predicted problems through observations, reports, and hydraulic modeling (as necessary) of the City-specified design storm event described in Chapter 3 of Volume III. Describe all existing or potential problems as listed above (e.g. pooling water or erosion). The following information shall be provided for each existing or potential problem:
  - ☐ Magnitude of or damage caused by the problem
  - ☐ General frequency and duration
  - ☐ Return frequency of storm or flow when the problem occurs (may require quantitative analysis)
  - ☐ Water elevation when the problem occurs
  - ☐ Names and concerns of the parties involved
  - ☐ Current mitigation of the problem
  - ☐ Possible cause of the problem
  - ☐ Whether the project is likely to aggravate the problem or create a new one
- ☐ Properly include off-site areas in drainage calculations.

Quantitative Analysis (see Volume III, Section 3.1.2)

- ☐ Clearly describe tail water assumptions.
- ☐ Summarize results in text.
- ☐ Include calculations in Appendix B of the report.
- ☐ Discuss potential fixes for capacity problems.
- ☐ Provide profiles where appropriate.

Chapter 4 – Permanent Stormwater Control Plan

Chapter 4 will contain the information used to select, size and locate permanent stormwater control BMPs for the project site.

Pre-Developed Site Hydrology

- ☐ Provide a list of assumptions and site parameters for the pre-developed condition.
- ☐ Identify all sub-basins within, or flowing through, the site. Use consistent labeling for all sub-basins throughout figures, calculations, and text.
- ☐ For each sub-basin, identify current land use, acreage, hydrologic soil group and land use to be modeled under pre-developed conditions. The format used in Example Table I-B-1 show below is recommended.
- ☐ Provide justification for land uses other than forest.
- ☐ The pre-developed soil types shall be assumed as either outwash (Hydrologic Soil Group A/B) or till (Hydrologic Soil Group C/D) soils, depending on supporting geotechnical information. Saturated soil conditions shall only be considered when determining existing wetland hydrology.
- ☐ Summarize output data from the pre-developed condition. Example Tables I-B-2a or I-B-2b are recommended formats.
- ☐ Include completed Hydraulic Analysis worksheet (see Appendix C in this volume) and hydrologic calculations in Appendix D of the report.
- ☐ For WWHM models, provide model files electronically.

Example Table I-B-1

Sub-Basin ID	Land Use and Cover Condition	Acreage	Soil Group	Modeled as: (List CN)	Comments

Example Table I-B-2a

Pre-Developed Condition Event Output: SBUH			
Basin ID:			
	Peak Flow (cfs)	**Volume (ac-ft)**	**Area (ac)**
2-year existing			
10-year existing			
25-year existing			
100-year existing			

Example Table I-B-2b

Pre-Developed Condition Event Output: WWHM		
Basin ID:		
	Peak Flow (cfs)	**Area (ac)**
2-year existing		
10-year existing		
25-year existing		
100-year existing		

Developed Site Hydrology

- ☐ Provide a list of assumptions and site parameters for the developed condition.
- ☐ Identify all sub-basins within, or flowing through, the site. Use consistent labeling for all sub-basins throughout figures, calculations, and text.
- ☐ For each sub-basin, identify current land use, acreage, hydrologic soil group and land use to be modeled under developed conditions. The format used in Example Table I-B-1 is recommended.
- ☐ Summarize output data from the developed condition. The formats used in Example Tables I-B-2a or I-B-2b are recommended.
- ☐ Include completed Hydraulic Analysis worksheet (see Appendix C in this volume) and hydrologic calculations in Appendix D of the report.

Performance Goals and Standards

- ☐ Indicate total acreage of impervious surfaces, pollution-generating impervious surfaces and pollution-generating pervious surfaces for each Threshold Discharge Area (TDA). The format used in Example Table I-B-3 is recommended.
- ☐ Include applicable decision chart (Figure I-3-1, Figure I-3-2, or Figure I-3-3) with treatment requirements clearly marked and supported.
- ☐ Include applicable decision chart (Figure I-3-2) with flow control requirements clearly marked and supported. If flow control facilities are required, indicate that they are required.
- ☐ State conclusions from decision and flow charts.

Example Table I-B-3

Threshold Discharge Area ID:	
Total pollution generating pervious surface (PGPS)	acres
Total pollution generating impervious surface ((PGIS)	acres
Native vegetation converted to lawn/landscape	acres
Total effective impervious surface	acres
Increase in 100-yer storm peak	cfs

Flow Control System (where required)

- ☐ Identify sizing system used.
- ☐ Summarize model results.
- ☐ Describe proposed flow control system and appurtenances, including size, type, and characteristics of storage facility and control structure.
- ☐ Provide a drawing of the flow control facility and its appurtenances, including:
- ☐ Include Hydraulic Analysis Worksheet, calculations, and computer printouts (including stage storage tables) for the flow control system to be included in Appendix D of the report.

Water Quality System (where required)

- ☐ Identify the sizing method used.
- ☐ Summarize model results.
- ☐ Identify treatment methods used, including size, type, and characteristics of treatment facility and appurtenances.
- ☐ Provide a drawing of the treatment facility and its appurtenances, including:
  - ☐ Dimensions
  - ☐ Inlet/outlet sizes and elevations
  - ☐ Location of the facility on the project site
  - ☐ Appurtenances/fittings
- ☐ Calculations for the water quality design storm and facility sizing calculations must be included in an Appendix of the report.
- ☐ Where appropriate, include manufacturer’s specifications in an Appendix of the report.

Conveyance System Analysis and Design

- ☐ Illustrate the proposed conveyance system on a project site plan.
- ☐ Identify pipe sizes, types, and slopes.
- ☐ Describe capacities, design flows, and velocities for each reach.
- ☐ Include conveyance calculations in an Appendix of the report.

Chapter 5 – Discussion of Minimum Requirements

Chapter 5 is intended as a checklist for the applicant and reviewer to verify that the applicable Minimum Requirements have been met within the project submittal.

- ☐ Include applicable flowcharts for determining minimum requirements (Figure I-3-1, Figure I-3-2, or Figure I-3-3) with decision path clearly marked.
- ☐ List the minimum requirements that apply to the project.
- ☐ Discuss how the project satisfies each minimum requirement.
- ☐ Indicate where in the project documentation each minimum requirement is satisfied.

Chapter 6 – Operation and Maintenance Manual

The Operation and Maintenance Manual may be included in the Stormwater Site Plan, however it shall be written with the intention of becoming a stand-alone document for the project owner once the project is complete. The Operation and Maintenance Manual must include:

- ☐ A narrative description of the on-site storm system.
- ☐ An 11 x 17 inch map of the site, with the locations of the **treatment/detention/infiltration/etc**. facilities prominently noted. This is needed to enable the Operation and Maintenance manual to be a stand-alone document.
- ☐ The person or organization responsible for maintenance of the on-site storm system, including the phone number and current responsible party.
- ☐ Where the Operation and Maintenance manual is to be kept. Note that it must be made available to the City for inspection.
- ☐ A description of each flow control and treatment facility, including what it does and how it works. Include any manufacturer's documentation.
- ☐ A description of all maintenance tasks and the frequency of each task for each flow control and treatment facility. Include any manufacturer's recommendations.
- ☐ A sample maintenance activity log indicating emergency and routine actions to be taken.

Chapter 7 – Construction Stormwater Pollution Prevention Plan

- ☐ Short-Form – Please refer to Volume II, Appendix C for a complete checklist, or
- ☐ Formal/Long-Form – Please refer to Volume II, Chapter 2 for a complete checklist.

Appendices

- ☐ Appendix A – Operations and Maintenance Manual
- ☐ Appendix B – Construction Stormwater Pollution Prevention Plan
- ☐ Appendix C – Submittal Requirements Checklist
- ☐ Appendix D – Hydraulic Analysis Worksheet
- ☐ Appendix E – Other reports, as required

Required Drawings

Project drawings shall be provided as required in Chapter 4, and shall include the following:

- ☐ Vicinity Map
- ☐ Site Map and Grading Plan
- ☐ Basin Map
- ☐ Storm Plan and Profile
- ☐ Erosion Control Plan
- ☐ Detail Sheets

Appendix C Hydraulic Analysis Worksheet

Provide the following information for all projects, as applicable.

Name/Project: ______________________________

Address ______________________________

Parcel Number ______________ Permit Number: ______________

Watershed: ______________________________

WWHM or Continuous Models Input

Model files must be provided electronically. Include both on-site and off-site quantities.

Amount of new impervious (square feet): ______________

Amount of replaced impervious (square feet): ______________

Amount of new plus replaced (square feet): ______________

Amount of land disturbed (square feet): ______________

Native vegetation to lawn/landscaped (acres): ______________

Native vegetation to pasture (acres): ______________

Value of proposed improvements ($): ______________

Assessed value of existing site improvements ($): ______________

Amount to be graded/filled (cubic feet): ______________

Existing impervious: ______________

Amount of new pgis (square feet): ______________

Amount of existing pgis (square feet): ______________

Amount of new pgs (square feet): ______________

Amount of existing pgs (square feet): ______________

SBUH Input

Rainfall Type: ______________

Hydraulic Method: ______________

Hydraulic Interval: ______________

Peak Factor: ______________

Tp Factor: ______________

Complete the following tables for sub-basins tributary to the project site (on-site and off-site).

Pre-Developed Conditions

Sub-basin Name	Acreage	Land Use/ Ground Cover*	Hydrologic Soil Group*	Curve Number

* Where more than one land use or soil group are present within a sub-basin, a line item must be shown for each to support calculation of the composite pervious and impervious Curve Numbers.

Developed Conditions

Sub-basin Name	Acreage	Land Use/ Ground Cover*	Hydrologic Soil Group*	Curve Number

* Where more than one land use or soil group are present within a sub-basin, a line item must be shown for each to support calculation of the composite pervious and impervious Curve Numbers.

Provide pervious and impervious Tc data for each sub-basin including the flow path shown on an attached figure.

Flow Control Facilities

For the flow control facility, provide the following:

- Bottom length: ____________________
- Bottom width: ____________________
- Side slopes: ____________________
- Stage/ Storage Table with units: ____________________

For the control structure, provide the following:

- Outlet pipe size: ____________________
- Orifice elevation: ____________ Diameter: ____________
- Orifice elevation: ____________ Diameter: ____________
- Orifice elevation: ____________ Diameter: ____________
- Riser elevation: ____________ Diameter: ____________
- V-notch weir data (alternate): ____________________

Appendix D Maintenance Standards for Drainage Facilities

The facility-specific maintenance standards contained in this section are intended to be conditions for determining if maintenance actions are required as identified through inspection. They are not intended to be measures of the facility's required condition at all times between inspections. In other words, exceeding these conditions at any time between inspections and/or maintenance does not automatically constitute a violation of these standards. However, based upon inspection observations, the inspection and maintenance schedules shall be adjusted to minimize the length of time that a facility is in a condition that requires a maintenance action.

Table I-D-1. Maintenance Standards

No. 1 – Detention Ponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash & Debris	Any trash and debris which exceed 5 cubic feet per 1,000 square feet (this is about equal to the amount of trash it would take to fill up one standard size garbage can). In general, there should be no visual evidence of dumping. If less than threshold all trash and debris will be removed as part of next scheduled maintenance.	Trash and debris cleared from site.
	Poisonous Vegetation and noxious weeds	Any poisonous or nuisance vegetation which may constitute a hazard to maintenance personnel or the public. Any evidence of noxious weeds as defined by State or local regulations. (Apply requirements of adopted IPM policies for the use of herbicides).	No danger of poisonous vegetation where maintenance personnel or the public might normally be. (Coordinate with local health department) Complete eradication of noxious weeds may not be possible. Compliance with State or local eradication policies required
	Contaminants and Pollution	Any evidence of oil, gasoline, contaminants or other pollutants (Coordinate removal/cleanup with local water quality response agency).	No contaminants or pollutants present
	Rodent Holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents destroyed and dam or berm repaired. (Coordinate with local health department; coordinate with Ecology Dam Safety Office if pond exceeds 10 acre-feet.)

No. 1 – Detention Ponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Beaver Dams	Dam results in change or function of the facility.	Facility is returned to design function. (Coordinate trapping of beavers and removal of dams with appropriate permitting agencies)
	Insects	When insects such as wasps and hornets interfere with maintenance activities.	Insects destroyed or removed from site. Apply insecticides in compliance with adopted IPM policies
	Tree Growth and Hazard Trees	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements). If trees are not interfering with access or maintenance, do not remove If trees are dead, diseased, or dying. (Use a certified Arborist to determine health of tree or removal requirements)	Trees do not hinder maintenance activities. Harvested trees should be recycled into mulch or other beneficial uses (e.g., alders for firewood). Remove hazard trees
Side Slopes of Pond	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted berm embankment.	Slopes should be stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction. If erosion is occurring on compacted berms a licensed civil engineer should be consulted to resolve source of erosion.
Storage Area	Sediment	Accumulated sediment that exceeds 10% of the designed pond depth unless otherwise specified or affects inletting or outletting condition of the facility.	Sediment cleaned out to designed pond shape and depth; pond reseeded if necessary to control erosion.
	Liner (If Applicable)	Liner is visible and has more than three 1/4-inch holes in it.	Liner repaired or replaced. Liner is fully covered.

No. 1 – Detention Ponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Pond Berms (Dikes)	Settlements	Any part of berm which has settled 4 inches lower than the design elevation. If settlement is apparent, measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works. A licensed civil engineer should be consulted to determine the source of the settlement.	Dike is built back to the design elevation.
	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Geotechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved.
Emergency Overflow/ Spillway and Berms over 4 feet in height.	Tree Growth	Tree growth on emergency spillways creates blockage problems and may cause failure of the berm due to uncontrolled overtopping. Tree growth on berms over 4 feet in height may lead to piping through the berm which could lead to failure of the berm.	Trees should be removed. If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored. A licensed civil engineer should be consulted for proper berm/spillway restoration.
	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Geotechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved.
Emergency Overflow/ Spillway	Emergency Overflow/ Spillway	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil at the top of out flow path of spillway. (Rip-rap on inside slopes need not be replaced.)	Rocks and pad depth are restored to design standards.
	Erosion	See “Side Slopes of Pond”	

No. 2 – Infiltration

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash & Debris	See "Detention Ponds" (No. 1).	See "Detention Ponds" (No. 1).
	Poisonous/Noxious Vegetation	See "Detention Ponds" (No. 1).	See "Detention Ponds" (No. 1).
	Contaminants and Pollution	See "Detention Ponds" (No. 1).	See "Detention Ponds" (No. 1).
	Rodent Holes	See "Detention Ponds" (No. 1).	See "Detention Ponds" (No. 1)
Storage Area	Sediment	Water ponding in infiltration pond after rainfall ceases and appropriate time allowed for infiltration. (A percolation test pit or test of facility indicates facility is only working at 90% of its designed capabilities. If two inches or more sediment is present, remove).	Sediment is removed and/or facility is cleaned so that infiltration system works according to design.
Filter Bags (if applicable)	Filled with Sediment and Debris	Sediment and debris fill bag more than 1/2 full.	Filter bag is replaced or system is redesigned.
Rock Filters	Sediment and Debris	By visual inspection, little or no water flows through filter during heavy rain storms.	Gravel in rock filter is replaced.
Side Slopes of Pond	Erosion	See "Detention Ponds" (No. 1).	See "Detention Ponds" (No. 1).
Emergency Overflow Spillway and Berms over 4 feet in height.	Tree Growth	See "Detention Ponds" (No. 1).	See "Detention Ponds" (No. 1).
	Piping	See "Detention Ponds" (No. 1).	See "Detention Ponds" (No. 1).
Emergency Overflow Spillway	Rock Missing	See "Detention Ponds" (No. 1).	See "Detention Ponds" (No. 1).
	Erosion	See "Detention Ponds" (No. 1).	See "Detention Ponds" (No. 1).
Pre-settling Ponds and Vaults	Facility or sump filled with sediment and/or debris	6" or designed sediment trap depth of sediment.	Sediment is removed.

No. 3 – Closed Detention Systems (Tanks/Vaults)

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Storage Area	Plugged Air Vents	One-half of the cross section of a vent is blocked at any point or the vent is damaged.	Vents open and functioning.
	Debris and Sediment	Accumulated sediment depth exceeds 10% of the diameter of the storage area for 1/2 length of storage vault or any point depth exceeds 15% of diameter. (Example: 72-inch storage tank would require cleaning when sediment reaches depth of 7 inches for more than 1/2 length of tank.)	All sediment and debris removed from storage area.
	Joints Between Tank/Pipe Section	Any openings or voids allowing material to be transported into facility. (Will require engineering analysis to determine structural stability).	All joint between tank/pipe sections are sealed.
	Tank Pipe Bent Out of Shape	Any part of tank/pipe is bent out of shape more than 10% of its design shape. (Review required by engineer to determine structural stability).	Tank/pipe repaired or replaced to design.
	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch and any evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determines that the vault is not structurally sound.	Vault replaced or repaired to design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or any evidence of soil particles entering the vault through the walls.	No cracks more than 1/4-inch wide at the joint of the inlet/outlet pipe.
Manhole	Cover Not in Place	Cover is missing or only partially in place. Any open manhole requires maintenance.	Manhole is closed.
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread (may not apply to self-locking lids).	Mechanism opens with proper tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. Intent is to keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person.
	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, misalignment, not securely attached to structure wall, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.
Catch Basins	See “Catch Basins” (No. 5)	See “Catch Basins” (No. 5).	See “Catch Basins” (No. 5).

No. 4 – Control Structure/Flow Restrictor

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and Debris (Includes Sediment)	Material exceeds 25% of sump depth or 1 foot below orifice plate.	Control structure orifice is not blocked. All trash and debris removed.
	Structural Damage	Structure is not securely attached to manhole wall.	Structure securely attached to wall and outlet pipe.
		Structure is not in upright position (allow up to 10% from plumb).	Structure in correct position.
		Connections to outlet pipe are not watertight and show signs of rust.	Connections to outlet pipe are water tight; structure repaired or replaced and works as designed.
		Any holes--other than designed holes--in the structure.	Structure has no holes other than designed holes.
Cleanout Gate	Damaged or Missing	Cleanout gate is not watertight, is missing, or is left open.	Gate is watertight, works as designed, and is left closed.
		Gate cannot be moved up and down by one maintenance person.	Gate moves up and down easily and is watertight.
		Chain/rod leading to gate is missing or damaged.	Chain is in place and works as designed.
		Gate is rusted over 50% of its surface area.	Gate is repaired or replaced to meet design standards.
Orifice Plate	Damaged or Missing	Control device is not working properly due to missing, out of place, or bent orifice plate.	Plate is in place and works as designed.
	Obstructions	Any trash, debris, sediment, or vegetation blocking the plate.	Plate is free of all obstructions and works as designed.
Overflow Pipe	Obstructions	Any trash or debris blocking (or having the potential of blocking) the overflow pipe.	Pipe is free of all obstructions and works as designed.
Manhole	See “Closed Detention Systems” (No. 3).	See “Closed Detention Systems” (No. 3).	See “Closed Detention Systems” (No. 3).
Catch Basin	See “Catch Basins” (No. 5).	See “Catch Basins” (No. 5).	See “Catch Basins” (No. 5).

No. 5 – Catch Basins

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is performed
General	Trash & Debris	Trash or debris which is located immediately in front of the catch basin opening or is blocking inletting capacity of the basin by more than 10%.	No Trash or debris located immediately in front of catch basin or on grate opening.
		Trash or debris (in the basin) that exceeds 60 percent of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of six inches clearance from the debris surface to the invert of the lowest pipe.	No trash or debris in the catch basin.
		Trash or debris in any inlet or outlet pipe blocking more than 1/3 of its height.	Inlet and outlet pipes free of trash or debris.
		Dead animals or vegetation that could generate odors that could cause complaints or dangerous gases (e.g., methane).	No dead animals or vegetation present within the catch basin.
	Sediment	Sediment (in the basin) that exceeds 60 percent of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the sediment surface to the invert of the lowest pipe.	No sediment in the catch basin
	Structure Damage to Frame and/or Top Slab	Top slab has holes larger than 2 square inches or cracks wider than 1/4 inch (Intent is to make sure no material is running into basin).	Top slab is free of holes and cracks.
		Frame not sitting flush on top slab, i.e., separation of more than 3/4 inch of the frame from the top slab. Frame not securely attached	Frame is sitting flush on the riser rings or top slab and firmly attached.
	Fractures or Cracks in Basin Walls/ Bottom	Maintenance person judges that structure is unsound.	Basin replaced or repaired to design standards.
		Grout fillet has separated or cracked wider than 1/2 inch and longer than 1 foot at the joint of any inlet/outlet pipe or any evidence of soil particles entering catch basin through cracks.	Pipe is regrouted and secure at basin wall.
	Settlement/ Misalignment	If failure of basin has created a safety, function, or design problem.	Basin replaced or repaired to design standards.
	Vegetation	Vegetation growing across and blocking more than 10% of the basin opening.	No vegetation blocking opening to basin.
		Vegetation growing in inlet/outlet pipe joints that is more than six inches tall and less than six inches apart.	No vegetation or root growth present.

No. 5 – Catch Basins (continued)

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is performed
General	Contamination and Pollution	See "Detention Ponds" (No. 1).	No pollution present.
Catch Basin Cover	Cover Not in Place	Cover is missing or only partially in place. Any open catch basin requires maintenance.	Catch basin cover is closed
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread.	Mechanism opens with proper tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. (Intent is keep cover from sealing off access to maintenance.)	Cover can be removed by one maintenance person.
Ladder	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, not securely attached to basin wall, misalignment, rust, cracks, or sharp edges.	Ladder meets design standards and allows maintenance person safe access.
Metal Grates (If Applicable)	Grate opening Unsafe	Grate with opening wider than 7/8 inch.	Grate opening meets design standards.
	Trash and Debris	Trash and debris that is blocking more than 20% of grate surface inletting capacity.	Grate free of trash and debris.
	Damaged or Missing.	Grate missing or broken member(s) of the grate.	Grate is in place and meets design standards.

No. 6 – Debris Barriers (e.g., Trash Racks)

Maintenance Components	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and Debris	Trash or debris that is plugging more than 20% of the openings in the barrier.	Barrier cleared to design flow capacity.
Metal	Damaged/ Missing Bars.	Bars are bent out of shape more than 3 inches.	Bars in place with no bends more than 3/4 inch.
		Bars are missing or entire barrier missing.	Bars in place according to design.
		Bars are loose and rust is causing 50% deterioration to any part of barrier.	Barrier replaced or repaired to design standards.
	Inlet/Outlet Pipe	Debris barrier missing or not attached to pipe	Barrier firmly attached to pipe

No. 7 – Energy Dissipaters

Maintenance Components	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
External:			
Rock Pad	Missing or Moved Rock	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil.	Rock pad replaced to design standards.
	Erosion	Soil erosion in or adjacent to rock pad.	Rock pad replaced to design standards.
Dispersion Trench	Pipe Plugged with Sediment	Accumulated sediment that exceeds 20% of the design depth.	Pipe cleaned/flushed so that it matches design.
	Not Discharging Water Properly	Visual evidence of water discharging at concentrated points along trench (normal condition is a “sheet flow” of water along trench). Intent is to prevent erosion damage.	Trench redesigned or rebuilt to standards.
	Perforations Plugged.	Over 1/2 of perforations in pipe are plugged with debris and sediment.	Perforated pipe cleaned or replaced.
	Water Flows Out Top of “Distributor” Catch Basin.	Maintenance person observes or receives credible report of water flowing out during any storm less than the design storm or its causing or appears likely to cause damage.	Facility rebuilt or redesigned to standards.
	Receiving Area Over-Saturated	Water in receiving area is causing or has potential of causing landslide problems.	No danger of landslides.
Internal:			
Manhole/Chamber	Worn or Damaged Post, Baffles, Side of Chamber	Structure dissipating flow deteriorates to 1/2 of original size or any concentrated worn spot exceeding one square foot which would make structure unsound.	Structure replaced to design standards.
	Other Defects	See “Catch Basins” (No. 5).	See “Catch Basins” (No. 5).

No. 8 – Typical Biofiltration Swale

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits on grass treatment area of the bio-swale. When finished, swale should be level from side to side and drain freely toward outlet. There should be no areas of standing water once inflow has ceased.
	Standing Water	When water stands in the swale between storms and does not drain freely.	Any of the following may apply: remove sediment or trash blockages, improve grade from head to foot of swale, remove clogged check dams, add underdrains or convert to a wet biofiltration swale.
	Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire swale width.	Level the spreader and clean so that flows are spread evenly over entire swale width.
	Constant Baseflow	When small quantities of water continually flow through the swale, even when it has been dry for weeks, and an eroded, muddy channel has formed in the swale bottom.	Add a low-flow pea-gravel drain the length of the swale or by-pass the baseflow around the swale.
	Poor Vegetation Coverage	When grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom.	Determine why grass growth is poor and correct that condition. Re-plant with plugs of grass from the upper slope: plant in the swale bottom at 8-inch intervals. Or re-seed into loosened, fertile soil.
	Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.	Mow vegetation or remove nuisance vegetation so that flow not impeded. Grass should be mowed to a height of 3 to 4 inches. Remove grass clippings.
	Excessive Shading	Grass growth is poor because sunlight does not reach swale.	If possible, trim back over-hanging limbs and remove brushy vegetation on adjacent slopes.
	Inlet/Outlet	Inlet/outlet areas clogged with sediment and/or debris.	Remove material so that there is no clogging or blockage in the inlet and outlet area.
	Trash and Debris Accumulation	Trash and debris accumulated in the bio-swale.	Remove trash and debris from bioswale.
	Erosion/Scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. If bare areas are large, generally greater than 12 inches wide, the swale should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident, or take plugs of grass from the upper slope and plant in the swale bottom at 8-inch intervals.

No. 9 – Wet Biofiltration Swale

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation	Sediment depth exceeds 2-inches in 10% of the swale treatment area.	Remove sediment deposits in treatment area.
	Water Depth	Water not retained to a depth of about 4 inches during the wet season.	Build up or repair outlet berm so that water is retained in the wet swale.
	Wetland Vegetation	Vegetation becomes sparse and does not provide adequate filtration, OR vegetation is crowded out by very dense clumps of cattail, which do not allow water to flow through the clumps.	Determine cause of lack of vigor of vegetation and correct. Replant as needed. For excessive cattail growth, cut cattail shoots back and compost off-site. Note: normally wetland vegetation does not need to be harvested unless die-back is causing oxygen depletion in downstream waters.
	Inlet/Outlet	Inlet/outlet area clogged with sediment and/or debris.	Remove clogging or blockage in the inlet and outlet areas.
	Trash and Debris Accumulation	See "Detention Ponds" (No. 1).	Remove trash and debris from wet swale.
	Erosion/Scouring	Swale has eroded or scoured due to flow channelization, or higher flows.	Check design flows to assure swale is large enough to handle flows. By-pass excess flows or enlarge swale. Replant eroded areas with fibrous-rooted plants such as Juncus effusus (soft rush) in wet areas or snowberry (Symphoricarpos albus) in dryer areas.

No. 10 – Filter Strips

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits, re-level so slope is even and flows pass evenly through strip.
	Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.	Mow grass, control nuisance vegetation, such that flow not impeded. Grass should be mowed to a height between 3-4 inches.
	Trash and Debris Accumulation	Trash and debris accumulated on the filter strip.	Remove trash and Debris from filter.
	Erosion/Scouring	Eroded or scoured areas due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. The grass will creep in over the rock in time. If bare areas are large, generally greater than 12 inches wide, the filter strip should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident.
	Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire filter width.	Level the spreader and clean so that flows are spread evenly over entire filter width.

No. 11 – Wetponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Water level	First cell is empty, does not hold water.	Line the first cell to maintain at least 4 feet of water. Although the second cell may drain, the first cell must remain full to control turbulence of the incoming flow and reduce sediment resuspension.
	Trash and Debris	Accumulation that exceeds 1 CF per 1000-SF of pond area.	Trash and debris removed from pond.
	Inlet/Outlet Pipe	Inlet/Outlet pipe clogged with sediment and/or debris material.	No clogging or blockage in the inlet and outlet piping.
	Sediment Accumulation in Pond Bottom	Sediment accumulations in pond bottom that exceeds the depth of sediment zone plus 6-inches, usually in the first cell.	Sediment removed from pond bottom.
	Oil Sheen on Water	Prevalent and visible oil sheen.	Oil removed from water using oil-absorbent pads or vactor truck. Source of oil located and corrected. If chronic low levels of oil persist, plant wetland plants such as Juncus effusus (soft rush) which can uptake small concentrations of oil.
	Erosion	Erosion of the pond's side slopes and/or scouring of the pond bottom, that exceeds 6-inches, or where continued erosion is prevalent.	Slopes stabilized using proper erosion control measures and repair methods.
	Settlement of Pond Dike/Berm	Any part of these components that has settled 4-inches or lower than the design elevation, or inspector determines dike/berm is unsound.	Dike/berm is repaired to specifications.
	Internal Berm	Berm dividing cells should be level.	Berm surface is leveled so that water flows evenly over entire length of berm.
	Overflow Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.	Rocks replaced to specifications.

No. 12 – Wetvaults

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash/Debris Accumulation	Trash and debris accumulated in vault, pipe or inlet/outlet (includes floatables and non-floatables).	Remove trash and debris from vault.
	Sediment Accumulation in Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6-inches.	Remove sediment from vault.
	Damaged Pipes	Inlet/outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened or removed, especially by one person.	Pipe repaired or replaced to proper working specifications.
	Ventilation	Ventilation area blocked or plugged.	Blocking material removed or cleared from ventilation area. A specified % of the vault surface area must provide ventilation to the vault interior (see design specifications).
	Vault Structure Damage - Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	Maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection staff.	Baffles repaired or replaced to specifications.
	Access Ladder Damage	Ladder is corroded or deteriorated, not functioning properly, not attached to structure wall, missing rungs, has cracks and/or misaligned. Confined space warning sign missing.	Ladder replaced or repaired to specifications, and is safe to use as determined by inspection personnel. Replace sign warning of confined space entry requirements. Ladder and entry notification complies with OSHA standards.

No. 13 – Sand Filters (above ground/open)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Above Ground (open sand filter)	Sediment Accumulation on top layer	Sediment depth exceeds 1/2-inch.	No sediment deposit on grass layer of sand filter that would impede permeability of the filter section.
	Trash and Debris Accumulations	Trash and debris accumulated on sand filter bed.	Trash and debris removed from sand filter bed.
	Sediment/ Debris in Clean-Outs	When the clean-outs become full or partially plugged with sediment and/or debris.	Sediment removed from clean-outs.
	Sand Filter Media	Drawdown of water through the sand filter media takes longer than 24-hours, and/or flow through the overflow pipes occurs frequently.	Top several inches of sand are scraped. May require replacement of entire sand filter depth depending on extent of plugging (a sieve analysis is helpful to determine if the lower sand has too high a proportion of fine material).
	Prolonged Flows	Sand is saturated for prolonged periods of time (several weeks) and does not dry out between storms due to continuous base flow or prolonged flows from detention facilities.	Low, continuous flows are limited to a small portion of the facility by using a low wooden divider or slightly depressed sand surface.
	Short Circuiting	When flows become concentrated over one section of the sand filter rather than dispersed.	Flow and percolation of water through sand filter is uniform and dispersed across the entire filter area.
	Erosion Damage to Slopes	Erosion over 2-inches deep where cause of damage is prevalent or potential for continued erosion is evident.	Slopes stabilized using proper erosion control measures.
	Rock Pad Missing or Out of Place	Soil beneath the rock is visible.	Rock pad replaced or rebuilt to design specifications.
	Flow Spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed across sand filter.	Spreader leveled and cleaned so that flows are spread evenly over sand filter.
	Damaged Pipes	Any part of the piping that is crushed or deformed more than 20% or any other failure to the piping.	Pipe repaired or replaced.

No. 14 –Sand Filters (below ground/enclosed)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Below Ground Vault.	Sediment Accumulation on Sand Media Section	Sediment depth exceeds 1/2-inch.	No sediment deposits on sand filter section that which would impede permeability of the filter section.
	Sediment Accumulation in Pre-Settling Portion of Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6-inches.	No sediment deposits in first chamber of vault.
	Trash/Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault and inlet/outlet piping.
	Sediment in Drain Pipes/Cleanouts	When drain pipes, cleanouts become full with sediment and/or debris.	Sediment and debris removed.
	Short Circuiting	When seepage/flow occurs along the vault walls and corners. Sand eroding near inflow area.	Sand filter media section re-laid and compacted along perimeter of vault to form a semi-seal. Erosion protection added to dissipate force of incoming flow and curtail erosion.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/deformation of cover. Maintenance person cannot remove cover using normal lifting pressure.	Cover repaired to proper working specifications or replaced.
	Ventilation	Ventilation area blocked or plugged	Blocking material removed or cleared from ventilation area. A specified % of the vault surface area must provide ventilation to the vault interior (see design specifications).
	Vault Structure Damaged; Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab.	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles/Internal walls	Baffles or walls corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned	Ladder replaced or repaired to specifications, and is safe to use as determined by inspection personnel.

No. 15 – STORMFILTER™

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Below Ground Vault	Sediment Accumulation on Media.	Sediment depth exceeds 0.25-inches.	No sediment deposits which would impede permeability of the compost media.
	Sediment Accumulation in Vault	Sediment depth exceeds 6-inches in first chamber.	No sediment deposits in vault bottom of first chamber.
	Trash/Debris Accumulation	Trash and debris accumulated on compost filter bed.	Trash and debris removed from the compost filter bed.
	Sediment in Drain Pipes/Clean-Outs	When drain pipes, clean-outs, become full with sediment and/or debris.	Sediment and debris removed.
	Damaged Pipes	Any part of the pipes that are crushed or damaged due to corrosion and/or settlement.	Pipe repaired and/or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened; one person cannot open the cover using normal lifting pressure, corrosion/deformation of cover.	Cover repaired to proper working specifications or replaced.
	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking warping, and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.
Below Ground Cartridge Type	Media	Drawdown of water through the media takes longer than 1 hour, and/or overflow occurs frequently.	Media cartridges replaced.
	Short Circuiting	Flows do not properly enter filter cartridges.	Filter cartridges replaced.

No. 16 – Baffle Oil/Water Separators (API Type)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Monitoring	Inspection of discharge water for obvious signs of poor water quality.	Effluent discharge from vault should be clear with out thick visible sheen.
	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6-inches in depth.	No sediment deposits on vault bottom that would impede flow through the vault and reduce separation efficiency.
	Trash and Debris Accumulation	Trash and debris accumulation in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault, and inlet/outlet piping.
	Oil Accumulation	Oil accumulations that exceed 1-inch, at the surface of the water.	Extract oil from vault by vactoring. Disposal in accordance with state and local rules and regulations.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/deformation of cover.	Cover repaired to proper working specifications or replaced.
	Vault Structure Damage - Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	See "Catch Basins" (No. 5)	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.

No. 17 – Coalescing Plate Oil/Water Separators

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Monitoring	Inspection of discharge water for obvious signs of poor water quality.	Effluent discharge from vault should be clear with no thick visible sheen.
	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6-inches in depth and/or visible signs of sediment on plates.	No sediment deposits on vault bottom and plate media, which would impede flow through the vault and reduce separation efficiency.
	Trash and Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault, and inlet/outlet piping.
	Oil Accumulation	Oil accumulation that exceeds 1-inch at the water surface.	Oil is extracted from vault using vactoring methods. Coalescing plates are cleaned by thoroughly rinsing and flushing. Should be no visible oil depth on water.
	Damaged Coalescing Plates	Plate media broken, deformed, cracked, and/or showing signs of failure.	A portion of the media pack or the entire plate pack is replaced depending on severity of failure.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and or replaced.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Vault Structure Damage - Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.

No. 18 – Catchbasin Inserts

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Sediment Accumulation	When sediment forms a cap over the insert media of the insert and/or unit.	No sediment cap on the insert media and its unit.
	Trash and Debris Accumulation	Trash and debris accumulates on insert unit creating a blockage/restriction.	Trash and debris removed from insert unit. Runoff freely flows into catch basin.
	Media Insert Not Removing Oil	Effluent water from media insert has a visible sheen.	Effluent water from media insert is free of oils and has no visible sheen.
	Media Insert Water Saturated	Catch basin insert is saturated with water and no longer has the capacity to absorb.	Remove and replace media insert
	Media Insert-Oil Saturated	Media oil saturated due to petroleum spill that drains into catch basin.	Remove and replace media insert.
	Media Insert Use Beyond Normal Product Life	Media has been used beyond the typical average life of media insert product.	Remove and replace media at regular intervals, depending on insert product.

No. 19 – Ecology Embankment

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
No Vegetation Zone adjacent to pavement	Erosion, scour, or vehicular damage	No vegetation zone uneven or clogged so that flows are not uniformly distributed	Level the area and clean so that flows are spread evenly
	Sediment accumulation on edge of pavement	Flows no longer sheeting off of roadway. Sediment accumulation on pavement edge exceeds top of pavement elevation.	Remove sediment deposits such that flows can sheet off of roadway.
Vegetated Filter	Sediment accumulation on grass	Sediment depth exceeds two inches	Remove sediment deposits, re-level so slope is even and flows pass evenly through Ecology Embankment.
	Excessive vegetation or undesirable species	When grass becomes excessively tall; when nuisance weeds and other vegetation starts to take over or shades out desirable vegetation growth characteristics. See also Pierce County Noxious Weeds list at: piercecountyweedboard.wsu.edu/ weedlist.html	Mow grass, control nuisance vegetation such that flow is not impeded. Grass should be mowed to a height that encourages dense, even herbaceous growth.
	Erosion, scour, or vehicular damage	Eroded or scoured areas due to flow channelization, high flows, or vehicular damage.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with suitable topsoil. The grass will creep in over the rock in time. If bare areas are large, generally greater than 12 inches wide, the filter strip should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident.
Media Bed	Erosion, scour, or vehicular damage	Eroded or scoured areas due to flow channelization, high flows, or vehicular damage.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with suitable media. If bare areas are large, generally greater than 12 inches wide, the media bed should be re-graded.
	Sediment accumulation on media bed	Sediment depth inhibits free infiltration of water	Remove sediment deposits, re-level so slope is even and flows pass freely through the media bed.
Underdrains	Sediment	Depth of sediment within perforated pipe exceeds one-half inch	Flush underdrains through access ports and collect flushed sediment.
General	Trash and debris accumulation	Trash and debris which exceed 5 cubic feet per 1,000 square feet (this is about equal to the amount of trash it would take to fill up one 32-gallow garbage can). In general, there should be no visual evidence of dumping. If less than threshold, all trash and debris will be removed as part of the next scheduled maintenance	Remove trash and debris.

No. 19 – Ecology Embankment

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Flows are bypassing Ecology Embankment	Evidence of significant flows downslope (rills, sediment, vegetation damage, etc.) of Ecology Embankment	Remove sediment deposits, relevel so slope is even and flows pass evenly through Ecology Embankment. If Ecology Embankment is completely clogged, it may require more extensive repair or replacement.

No. 20 – Bioretention Rain Gardens

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Ponding Area	Cracks or failure in concrete planter reservoir	Cracks wider than ½ inch or maintenance/inspection personnel determine that the vault is not structurally sound	Vault repaired or replaced so that it meets design specification and is structurally sound
	Failure in earthen reservoir (embankments, dikes, berms, and side slopes)	Erosion (gullies/rills) greater than 2 inches around inlets, outlet, and along side slopes	Eliminate source of erosion and stabilize damaged area (regrade, rock, vegetation, erosion control blanket)
		Settlement greater than 4 inches (relative to undisturbed sections of the berm)	Restore to design height
		Downstream face of the berm or embankment wet, seeps or leaks evident	Plug holes. Contact geotechnical engineer ASAP.
		Any evidence of rodent holes or water piping around holes if facility acts as a dam or berm	Eradicate rodents and repair holes (fill and compact)
	Sediment or debris accumulation	Accumulation of sediment or debris	Remove excess sediment or debris. Identify and control the sediment source, if feasible. Facility should be free of material. May contain standing water.
	Rockery reservoir or walls	Rock walls are insecure	Stabilize walls
	Basin inlet via surface flow	Soil is exposed or signs of erosion are visible.	Repair and control erosion sources.
	Basin inlet via concentrated flow (e.g. curb cuts)	Sediment, vegetation, or debris partially or fully blocking inlet structure	Clear the blockage. Identify the source of the blockage and take actions to prevent future blockages.
	Basin inlet splash block failure	Water splashes adjacent buildings	Reconfigure/repair blocks.
		Water disrupts soil media.	
	Inlet/outlet pipe failure	Pipe is damaged.	Repair/replace pipe.
		Pipe is clogged.	Remove roots or debris.
	Outlet pipe/ structure failure	Sediment, vegetation, or debris is partially or fully blocking the outlet structure.	Clear the blockage. Identify the source of the blockage and take actions to prevent future blockages.
	Trash rack failure	Trash or debris present on trash rack.	Clean and dispose of trash.
		Bar screen damaged or missing.	Replace bar screen.
	Check dams and weirs failures	Sediment, vegetation, or debris is partially or fully blocking the check dam or weir.	Clear the blockage. Identify the source of the blockage and take actions to prevent future blockages.
Ponding Area	Check dams and weirs failures	Erosion and/or undercutting is present.	Repair and take preventative measures to prevent future erosion and/or undercutting.

No. 20 – Bioretention Rain Gardens

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
	Flow spreader problems	Sediment blocks 35% or more of ports/notches or, sediment fills 35% or more of sediment trap.	Remove and dispose of sediment.
		Grade board/baffle damaged or not level.	Remove and reinstall to level position.
	Overflow/ emergency spillway	Overflow spillway is partially or fully plugged with sediment or debris.	Remove and dispose of sediment.
		Native soil is exposed, or other signs of erosion are present.	Repair erosion and stabilize surface of spillway.
		Spillway armament is missing.	Replace armament.
	Bioretention soil	Water remains in the basin 48 hours or longer after the end of a storm.	Ensure that underdrain (if present) is not clogged. If necessary, clear underdrain. If this is not the problem, the bioretention soil is likely clogged. Remove the upper 2 to 3 inches of soil and replace with imported bioretention soil. Identify sources of clogging and correct.
Vegetation	Bottom swale vegetation	Less than 80% of swale bottom is covered with healthy wetland vegetation.	Plant additional vegetation. Ideally, planting should be performed in the fall or winter.
	Upland slope vegetation	Less than 70% of upland slopes are covered with healthy vegetation.	
	Trees and shrubs	Large trees and shrubs interfere with operation of the basin or access for maintenance	Prune or remove large trees and shrubs.
		Standing dead vegetation is present	Remove standing dead vegetation when covering greater than 10% of the basin area. Replace dead vegetation annually or immediately if necessary to control erosion (e.g. on a steep slope).
	Mulch	Bare spots (without much cover) are present or mulch covers less than 3 inches deep for compost or 4 inches deep for coarse, woody mulch.	Replenish with the appropriate type of mulch to cover bare spots and augment to minimum depth.
	Clippings	Grass or other vegetation clippings accumulate to 2 inches or greater in depth.	Remove clippings.
Vegetation	Noxious weeds	Listed noxious vegetation is present. See Pierce County noxious weed list.	By law, noxious weeds must be removed and disposed immediately. Herbicides and pesticides shall not be used in order to protect water quality.
	Weeds	Weeds are present (unless on edge and providing erosion control).	Remove and dispose of weed material. Herbicides and pesticides shall not be used in order to protect water quality.

No. 20 – Bioretention Rain Gardens

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Irrigation	Irrigation system (if any)	Irrigation system present	Follow manufacturer's instructions for O&M
	Plant watering	Plant establishment period (1-3 years)	Water weekly during periods of no rain to ensure plant establishment
		Longer term period (3+ years)	Water during drought conditions or more often if necessary to maintain plant cover.
Spill Prevention and Response	Spill prevention	Storage or use of potential contaminants in the vicinity of the facility.	Exercise spill prevention measures whenever handling or storing potential contaminants.
	Spill response	Release of pollutants. Call to report any spill to the Washington Dept. of Emergency Management 1-800-258-5990	Cleanup spills as soon as possible to prevent contamination of stormwater.
Training and Documentation	Training/written guidance	Training/written guidance is required for proper O&M	Provide property owners and tenants with proper training and a copy of the O&M manual and Landscape and Maintenance Manual.
Safety	Safety (slopes)	Erosion of sides causes slope to exceed 1:4 or otherwise become a hazard.	Take actions to eliminate the hazard.
	Safety (hydraulic structures)	Hydraulic structures (pipes, culverts, vaults, etc.) become a hazard to children playing in and around the facility.	Take actions to eliminate the hazard (such as covering and securing any openings).
	Line of sight	Vegetation causes some visibility (line of sight) or driver safety issues.	Prune.
Aesthetics	Aesthetics	Damage/vandalism/debris accumulation	Restore facility to original aesthetic conditions.
	Grass/vegetation	Less than 75% of planted vegetation is healthy with a generally good appearance.	Take appropriate maintenance actions (e.g. remove/replace plants, amend soil, etc.)
	Edging	Grass is starting to encroach on swale.	Repair edging.
Pest Control	Mosquitoes	Standing water remains in the basin for more than three days following storms.	Identify the cause of the standing water and take appropriate actions to address the problem (see Bioretention Soil above)
	Rodents	Rodent holes are present near the facility.	Fill and compact the soil around the holes (refer to Integrated Pest Management).

No. 21 - Cistern

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Collection Facilities	Roof	Debris has accumulated	Remove debris
	Gutter	Debris has accumulated.	Clean gutters (the most critical cleaning is mid- to late-spring to flush the pollen deposits from surrounding trees).
	Screens at the top of the downspout and cistern inlet	Screen has deteriorated.	Replace
		Preventative maintenance	Clear screen of any accumulated debris.
	Low flow orifice	Preventative maintenance.	Clean low flow orifice.
	Overflow pipe	Pipe is damaged.	Repair/replace
		Pipe is clogged.	Remove debris.
	Cistern	Debris has accumulated in the bottom of the tank.	Remove debris.
Training and Documentation	Training/written guidance	Training/written guidance is required for proper O&M.	Provide property owners and tenants with proper training and a copy of the O&M manual.
Safety	Access and safety	Access to cistern required for maintenance or cleaning.	Any cistern detention systems opening that could allow the entry of people must be marked: “DANGER – CONFINED SPACE”.
Pest Control	Mosquitoes	Standing water remains for more than three days following storms.	Ensure cause of standing water is corrected. Also ensure all inlets, overflows, and other openings are protected with mosquito screens.

No. 22 – Compost Amended Soil

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General Facility Requirements	Soil media (maintain high organic soil content)	Vegetation not fully covering ground surface	Re-mulch landscape beds with 2-3 inches of mulch until the vegetation fully closes over the ground surface
		Preventative maintenance	Return leaf fall and shredded woody materials from the landscape to the site as mulch.
			On turf areas, “grasscycle” ((mulch-mow or leave the clippings) to build turf health.
			Avoid broadcast use of pesticides (bug and weed killers) like “weed & feed”, which damage the soil life.
			Where fertilization is needed (mainly turf and annual flower beds), use a moderate fertilization program that relies on natural organic fertilizers (like compost) or slow-release synthetic balanced fertilizers.
	Compaction	Soils become waterlogged, do not appear to be infiltrating.	To remediate, aerate soil, till or further amend soil. If drainage is still slow, consider investigating alternative causes (e.g. high wet-season groundwater levels, low-permeability soils). Also consider land use and protection from compacting activities. If areas are turf, aerate compacted areas and top dress them with ¼ to ½ inch of compost to renovate them.
	Erosion/scouring	Areas of potential erosion are visible.	Take steps to repair or prevent erosion. Identify and address the causes of erosion.
General Facility Requirements	Grass/vegetation	Less than 75% of planted vegetation is healthy with a generally good appearance.	Take appropriate maintenance actions (e.g. remove/replace plants).
	Noxious weeds	Listed noxious vegetation is present. See Pierce County noxious weed list.	By law, noxious weeds must be removed and disposed immediately. Herbicides and pesticides shall not be used in order to protect water quality.
	Weeds	Weeds are present.	Remove and dispose of weed material. Herbicides and pesticides shall not be used in order to protect water quality.

No. 23 – Vegetated Roof

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Soil/Growth Medium	Growth medium	Water does not permeate growth media (runs off soil surface)	Aerate or replace media
	Fallen leaves/debris	Fallen leaves or debris are present.	Remove/dispose
	Erosion/scouring	Areas of potential erosion are visible.	Take steps to repair or prevent erosion. Stabilize with additional soil substrate/growth medium and additional plants.
System Structural Components	General	Structural components are present.	Inspect structural components for deterioration or failure. Repair/replace as necessary.
	Inlet pipe	Sediment, vegetation, or debris blocks 35% or more of inlet structure	Clear blockage. Identify and correct any problems that led to blockage.
		Inlet pipe is in poor condition.	Repair/replace.
		Inlet pipe is clogged.	Remove roots or debris.
Vegetation	Coverage	Vegetative coverage falls below 75% (unless design specifications stipulate less than 75% coverage).	Install more vegetation.
	Noxious weeds	Listed noxious vegetation is present. See Pierce County noxious weed list.	By law, noxious weeds must be removed and disposed immediately. Herbicides and pesticides shall not be used in order to protect water quality.
	Weeds	Weeds are present.	Remove and dispose of weed material. Herbicides and pesticides shall not be used in order to protect water quality.
	Plants	Dead vegetation is present.	Remove dead vegetation when covering greater than 10% of basin area. Replace dead vegetation annually or immediately if necessary to control erosion.

No. 23 – Vegetated Roof

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Irrigation	Irrigation system (if any)	Irrigation system present	Follow manufacturer's instructions for O&M.
	Plant watering	Plant establishment period (1-3 years)	Water weekly during periods of no rain to ensure plant establishment
		Longer term period (3+ years)	Water during drought conditions or more often if necessary to maintain plant cover.
Spill Prevention and Response	Spill prevention	Storage or use of potential contaminants in the vicinity of the facility.	Exercise spill prevention measures whenever handling or storing potential contaminants.
	Spill response	Release of pollutants. Call to report any spill to the Washington Dept. of Emergency Management 1-800-258-5990	Cleanup spills as soon as possible to prevent contamination of stormwater.
Training and Documentation	Training/written guidance	Training/written guidance is required for proper O&M.	Provide property owners and tenants with proper training and a copy of the O&M manual and Landscape and Maintenance manual.
Safety	Access and Safety	Egress and ingress routes	Maintain egress and ingress routes to design standards and fire codes.
Aesthetics	Aesthetics	Damage/vandalism/debris accumulation	Restore facility to original aesthetic conditions.
	Grass/vegetation	Less than 75% of planted vegetation is healthy with a generally good appearance.	Take appropriate maintenance actions (e.g. remove/replace plants, amend soils, etc.)
Pest Control	Mosquitoes	Standing water remains for more than three days following a storm.	Remove standing water. Identify the cause of the standing water and take appropriate action to address the problem (improve drainage).

No. 24 – Pervious Pavement

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Surface	Pervious asphalt or cement concrete	Maintenance to prevent clogging with fine sediment.	Use conventional street sweepers equipped with vacuums.
			Prohibit use of sand and sealant application and protect from construction runoff.
		Major cracks or trip hazards	Fill with patching mixes. Large cracks and settlement may require cutting and replacing the pavement section.
		Utility cuts	Any damage or change due to utility cuts must be replaced in kind.
	Fallen leaves/debris	Fallen leaves or debris	Remove/dispose
	Interlocking concrete paver blocks	Interlocking paving block missing or damaged.	Replace paver block
		Settlement of surface	May require resettling
		Sediment or debris accumulation between paver blocks	Remove/dispose
		Loss of void material between paver blocks	Refill per manufacturer's recommendations.
		Varied conditions	Perform O&M per manufacturer's recommendations.

Appendix E Wetlands and Stormwater Management Guidelines

As Amended from Chapter 14 of "Wetlands and Urbanization, Implications for the Future," by Richard R. Horner, Amanda A. Azous, Klaus O. Richter, Sarah S. Cooke, Lorin E. Reinelt and Kern Ewing

If you are unfamiliar with these guidelines, read the description of the approach and organization that follows. If you are familiar, proceed directly to the appropriate guide sheet(s) for guidelines covering your issue(s) or objective(s):

Guide Sheet 1: Comprehensive Landscape Planning for Wetlands and Stormwater Management

Guide Sheet 2: Wetlands Protection Guidelines

Approach and Organization of the Management Guidelines

Introduction

The Puget Sound Wetlands and Stormwater Management Research Program performed comprehensive research with the goal of deriving strategies that protect wetland resources in urban and urbanizing areas, while also benefiting the management of urban stormwater runoff that can affect those resources. The research primarily involved long-term comparisons of wetland ecosystem characteristics before and after their watersheds urbanized, and between a set of wetlands that became affected by urbanization (treatment sites) and a set whose watersheds did not change (control sites). This work was supplemented by shorter term and more intensive studies of pollutant transport and fate in wetlands, several laboratory experiments, and ongoing review of relevant work being performed elsewhere. These research efforts were aimed at defining the types of impacts that urbanization can cause and the degree to which they develop under different conditions, in order to identify means of avoiding or minimizing impacts that impair wetland structure and functioning. The program's scope embraced both situations where urban drainage incidentally affects wetlands in its path, as well as those in which direct stormwater management actions change wetlands' hydrology, water quality or both.

This document presents preliminary management guidelines for urban wetlands and their stormwater discharges based on the research results. The set of guidelines is the principal vehicle to implement the research findings in environmental planning and management practice.

Guidelines Scope and Underlying Principles.

NOTE: For terms in **boldface** type see item 1 under Support Materials.

1. These provisions currently have the status of guidelines rather than requirements. Application of these guidelines does not fulfill assessment and permitting requirements that may be associated with a project. It is, in general, necessary to follow the stipulations of the State Environmental Policy Act and to contact such agencies as the local planning agency;

the Washington Departments of Ecology, Fisheries, and Wildlife; the U. S. Environmental Protection Agency; and the U. S. Army Corps of Engineers.

2. Using the guidelines should be approached from a problem-solving viewpoint. The “problem” is regarded to be accomplishing one or more particular planning or management objectives involving a **wetland** potentially or presently affected by stormwater drainage from an urban or urbanizing area. The objectives can be broad, specific, or both. Broad objectives involve comprehensive planning and subsequent management of a drainage catchment or other **landscape unit** containing one or more wetlands. Specific objectives pertain to managing a wetland having particular attributes to be sustained. Of course, the prospect for success is greater with ability to manage the whole landscape influencing the wetland, rather than just the wetland itself.

3. The guidelines are framed from the standpoint that some change in the landscape has the potential to modify the physical and chemical **structure** of the wetland environment, which in turn could alter biological communities and the wetland’s ecological **functions**. The general objective in this framework would be to avoid or minimize negative ecological change. This view is in contrast to one in which a wetland has at some time in the past experienced negative change, and consequent ecological degradation, and where the general objective would be to recover some or all of the lost structure and functioning through **enhancement** or **restoration** actions. Direct attention to this problem was outside the scope of the Puget Sound Wetlands and Stormwater Management Research Program. However, the guidelines do give information that applies to enhancement and restoration. For example, attempted restoration of a diverse amphibian community would not be successful if the water level fluctuation limits consistent with high amphibian species richness are not observed.

4. The guidelines can be applied with whatever information concerning the problem is available. Of course, the comprehensiveness and certainty of the outcome will vary with the amount and quality of information employed. The guidelines can be applied in an iterative fashion to improve management understanding as the information improves. Wetlands Guidance Appendix 1 lists the information needed to perform basic analyses, followed by other information that can improve the understanding and analysis.

5. These guidelines emphasize avoiding structural, hydrologic, and water quality **modifications** of existing wetlands to the extent possible in the process of urbanization and the management of urban stormwater runoff.

6. In pursuit of this goal, the guidelines take a systematic approach to management problems that potentially involve both urban stormwater (quantity, quality, or both) and wetlands. The consideration of wetlands involves their area extent, **values**, and functions. This approach emphasizes a comprehensive analysis of alternatives to solve the identified problem. The guidelines encourage conducting the analysis on a landscape scale and considering all of the possible stormwater management alternatives, which may or may not involve a wetland. They favor **source control best management practices** (BMPs) and **pre-treatment** of stormwater runoff prior to release to wetlands.

7. Furthermore, the guidelines take a holistic view of managing wetland resources in an urban setting. Thus, they recognize that urban wetlands have the potential to be affected structurally and functionally whether or not they are formally designated for stormwater management purposes. Even if an urban wetland is not structurally or hydrologically engineered for such purposes, it may experience altered hydrology (more or less water), reduced water quality, and a host of other impacts related to urban conditions. It is the objective of the guidelines to avoid or reduce the negative effects on wetland resources from both specific stormwater management actions and incidental urban impacts.

Support Materials

1. The guidelines use certain terms that require definition to ensure that the intended meaning is conveyed to all users. Such terms are printed in **boldface** the first time that they appear in each guide sheet, and are defined in Wetlands Guidance Appendix B.

2. The guideline provisions were drawn principally from the available results of the Puget Sound Wetlands and Stormwater Management Research Program, as set forth in Sections 2 and 3 of the program's summary publication, Wetlands and Urbanization, Implications for the Future (Horner et al. 1996). Where the results in this publication are the basis for a numerical provision, a separate reference is not given. Numerical provisions based on other sources are referenced. See Wetlands Guidance References at the end of this appendix.

3. Appendix 3 presents a list of plant species native to wetlands in the Puget Sound Region. This appendix is intended for reference by guideline users who are not specialists in wetland botany. However, non-specialists should obtain expert advice when making decisions involving vegetation.

4. Appendix 4 compares the water chemistry characteristics of *Sphagnum* bog and fen wetlands (termed **priority peat wetlands** in these guidelines) with more common wetland communities. These bogs and fens appear to be the most sensitive among the Puget Sound lowland wetlands to alteration of water chemistry, and require special water quality management to avoid losses of their relatively rare communities.

Guide Sheet 1: Comprehensive Landscape Planning for Wetlands and Stormwater Management

Wetlands in newly developing areas will receive urban effects even if not specifically "used" in stormwater management. Therefore, the task is proper overall management of the resources and protection of their general **functioning**, including their role in storm drainage systems. Stormwater management in newly developing areas is distinguished from management in already developed locations by the existence of many more feasible stormwater control options prior to development. The guidelines emphasize appropriate selection among the options to achieve optimum overall resource protection benefits, extending to downstream receiving waters and ground water aquifers, as well as to wetlands.

The comprehensive planning guidelines are based on two principles that are recognized to create the most effective environmental management: (1) the best management policies for the protection of wetlands and other natural resources are those that prevent or minimize the development of impacts at potential sources; and (2) the best management strategies are self-perpetuating, that is they do not require periodic infusions of capital and labor. To apply these principles in managing wetlands in a newly developing area, carry out the following steps.

Guide Sheet 1A: Comprehensive Planning Steps

1. Define the **landscape unit** subject to comprehensive planning. Refer to the definition of landscape unit in Appendix 2 for assistance in defining it.

2. Begin the development of a plan for the landscape unit with attention to the following general principles:

   - Formulate the plan on the basis of clearly articulated community goals. Carefully identify conflicts and choices between retaining and protecting desired resources and community growth.
   - Map and assess land suitability for urban uses. Include the following landscape features in the assessment: forested land, open unforested land, steep slopes, erosion-prone soils, foundation suitability, soil suitability for waste disposal, aquifers, aquifer recharge areas, wetlands, floodplains, surface waters, agricultural lands, and various categories of urban land use. When appropriate, the assessment can highlight outstanding local or regional resources that the community determines should be protected (e. g., a fish run, scenic area, recreational area, threatened species habitat, farmland). Mapping and assessment should recognize not only these resources but also additional areas needed for their sustenance.

3. Maximize natural water storage and infiltration opportunities within the landscape unit and outside of existing wetlands, especially:

   - Promote the conservation of forest cover. Building on land that is already deforested affects basin hydrology to a lesser extent than converting forested land. Loss of forest cover reduces interception storage, detention in the organic forest floor layer, and water losses by evapotranspiration, resulting in large peak runoff increases and either their negative effects or the expense of countering them with structural solutions.

   - Maintain natural storage reservoirs and drainage corridors, including depressions, areas of permeable soils, swales, and intermittent streams. Develop and implement policies and regulations to discourage the clearing, filling, and channelization of these features. Utilize them in drainage networks in preference to pipes, culverts, and engineered ditches.

   - In evaluating infiltration opportunities refer to the stormwater management manual for the jurisdiction and pay particular attention to the selection criteria for avoiding groundwater contamination and poor soils and hydrogeological conditions that cause these facilities to fail. If necessary, locate developments with large amounts of impervious surfaces or a potential to produce relatively contaminated runoff away from groundwater recharge areas. Relatively dense developments on glacial outwash soils may require additional runoff treatment to protect groundwater quality.

4. Establish and maintain **buffers** surrounding wetlands and in riparian zones as required by local regulations or recommended by the Puget Sound Water Quality Authority's wetland guidelines. Also, maintain interconnections among wetlands and other natural habitats to allow for wildlife movements.

5. Determine whether the wetland has a breeding, native amphibian population. A survey should be conducted in the spring.

6. Take specific management measures to avoid general urban impacts on wetlands and other water bodies (e. g., littering, vegetation destruction, human and pet intrusion harmful to wildlife).

7. To support management of runoff water quantity, perform a hydrologic analysis of the contributing drainage catchment to define the type and extent of flooding and stream channel erosion problems associated with existing development, redevelopment, or new development that require control to protect the beneficial uses of receiving waters, including wetlands. This analysis should include assembly of existing flow data and hydrologic modeling as necessary to establish conditions limiting to attainment of beneficial uses. Modeling should be performed as directed by the stormwater management manual in effect in the jurisdiction.

8. In wetlands previously relatively unaffected by human activities, manage stormwater quantity to attempt to match the **pre-development hydroperiod** and **hydrodynamics**. In wetlands whose hydrology has been disturbed, consider ways of reducing hydrologic impacts. This provision involves not only management of high runoff volumes and rates of flow during the wet season, but also prevention of water supply depletion during the dry season. The latter guideline may require flow augmentation if urbanization reduces existing surface or groundwater inflows. Refer to Guide Sheet 2, Wetland Protection Guidelines, for detail on implementing these guidelines.

9. Assess alternatives for the control of runoff water quantities as follows:

   a. Define the runoff quantity problem subject to management by analyzing the proposed land development action.

   b. For existing development or **redevelopment**, assess possible alternative solutions that are applicable at the site of the problem occurrence, including:

      – Protect health, safety, and property from flooding by removing habitation from the flood plain.
      – Prevent stream channel erosion by stabilizing the eroding bed and/or bank area with **bioengineering** techniques, preferably, or by structurally reinforcing it, if this solution would be consistent with the protection of aquatic habitats and beneficial uses of the stream (refer to Chapter 173-201A of the Washington Administrative Code (WAC) for the definition of beneficial uses).

c. For new development or redevelopment, assess possible regulatory and incentive land use control alternatives, such as density controls, clearing limits, impervious surface limits, transfer of development rights, purchase of conservation areas, etc.

d. If the alternatives considered in Steps 9a or 9b cannot solve an existing or potential problem, perform an analysis of the contributing drainage catchment to assess possible alternative solutions that can be applied **on-site** or on a **regional** scale. The most appropriate solution or combination of alternatives should be selected with regard to the specific opportunities and constraints existing in the drainage catchment. For new development or redevelopment, on-site facilities that should be assessed include, in approximate order of preference:

   – Infiltration basins or trenches;
   – Retention/detention ponds;
   – Below-ground vault or tank storage;
   – Parking lot detention.

   Regional facilities that should be assessed for solving problems associated with new development, redevelopment, or existing development include:

   – Infiltration basins or trenches;
   – Detention ponds;
   – **Constructed wetlands;**
   – Bypassing a portion of the flow to an acceptable receiving water body, with treatment as required to protect water quality and other special precautions as necessary to prevent downstream impacts.

e. Consider structurally or hydrologically engineering an existing wetland for water quantity control only if upland alternatives are inadequate to solve the existing or potential problem. To evaluate the possibility, refer to the Storm-water Wetland Assessment Criteria in Guide Sheet 1B.

10. Place strong emphasis on water resource protection during construction of new development. Establish effective erosion control programs to reduce the sediment loadings to receiving waters to the maximum extent possible. No preexisting wetland or other water body should ever be used for the sedimentation of solids in construction-phase runoff.

11. In wetlands previously relatively unaffected by human activities, manage stormwater quality to attempt to match pre-development water quality conditions. To support management of runoff water quality, perform an analysis of the contributing drainage catchment to define the type and extent of runoff water quality problems associated with existing development, redevelopment, or new development that require control to protect the beneficial uses of receiving waters, including wetlands. This analysis should incorporate the hydrologic assessment performed under step 7 and include identification of key water pollutants, which may include solids, oxygen-demanding substances, nutrients, metals, oils, trace organics,

and bacteria, and evaluation of the potential effects of water pollutants throughout the drainage system.

12. Assess alternatives for the control of runoff water quality as follows:

    a. Perform an analysis of the contributing drainage catchment to assess possible alternative solutions that can be applied on-site or on a regional scale. The most appropriate solution or combination of alternatives should be selected with regard to the specific opportunities and constraints existing in the drainage catchment. Consider both **source control BMPs** and **treatment BMPs** as alternative solutions before considering use of existing wetlands for quality improvement according to the following considerations:

        – Implementation of source control BMPs prevent the generation or release of water pollutants at potential sources. These alternatives are generally both more effective and less expensive than treatment controls. They should be applied to the maximum extent possible to new development, redevelopment, and existing development.

        – Treatment BMPs capture water pollutants after their release. This alternative often has limited application in existing developments because of space limitations, although it can be employed in new development and when redevelopment occurs in already developed areas. Refer to Minimum Requirement #6 in Volume 1 of the Stormwater Management Manual for Western Washington to determine whether a treatment facility is necessary for your site. If a facility is required, refer to Chapter 4 of Volume I, or Chapter 2 of Volume V to determine which treatment requirement – basic, enhanced, phosphorus, or oil control - applies to your site. Then refer to the corresponding BMP menu for that requirement in Chapter 3 of Volume V. From the menu select a BMP that fits with your project site.

    b. Consider structurally or hydrologically engineering an existing wetland for water quality control only if upland alternatives are inadequate to solve the existing or potential problem. Use of Waters of the State and Waters of the United States, including wetlands, for the treatment or conveyance of wastewater, including stormwater, is prohibited under state and federal law. Discussions with federal and state regulators during the research program led to development of a statement concerning the use of existing wetlands for improving stormwater quality (**polishing**), as follows. Such use is subject to analysis on a case-by-case basis and may be allowed only if the following conditions are met:

        – If **restoration** or **enhancement** of a previously **degraded** wetland is required, and if the upgrading of other wetland functions can be accomplished along with benefiting runoff quality control, and

        – If appropriate source control and treatment BMPs are applied in the contributing catchment on the basis of the analysis in Step 12a, and any legally adopted water quality standards for wetlands are observed.

If these circumstances apply, refer to the Stormwater Wetland Assessment Criteria in Guide Sheet 1B to evaluate further.

13. Stimulate public awareness of and interest in wetlands and other water resources in order to establish protective attitudes in the community. This program should include:

    - Education regarding the use of fertilizers and pesticides, automobile maintenance, the care of animals to prevent water pollution, and the importance of retaining buffers;
    - Descriptive signboards adjacent to wetlands informing residents of the wetland type, its functions, the protective measures being taken, etc.
    - If beavers are present in a wetland, educate residents about their ecological role and value and take steps to avoid human interference with beavers.

Guide Sheet 1B: Stormwater Wetland Assessment Criteria

This guide sheet gives criteria that disqualify a natural wetland from being structurally or hydrologically engineered for control of stormwater quantity, quality, or both. These criteria should be applied only after performing the alternatives analysis outlined in Guide Sheet 1A.

1. A wetland should not be structurally or hydrologically engineered for runoff quantity or quality control and should be given maximum protection from overall urban impacts (see Guide Sheet 2, Wetland Protection Guidelines) under any of the following circumstances:

    - In its present state it is primarily an **estuarine** or **forested wetland** or a **priority peat system**.
    - It is a rare or irreplaceable wetland type, as identified by the Washington Natural Heritage Program, the Puget Sound Water Quality Preservation Program, or local government.
    - It provides **rare, threatened, or endangered species** habitat that could be impaired by the proposed action. Determining whether or not the conserved species will be affected by the proposed project requires a careful analysis of its requirements in relation to the anticipated habitat changes.

    In general, the wetlands in these groups are classified in Categories I and II in the Puget Sound Water Quality Authority's draft wetland guidelines.

2. A wetland can be considered for structural or hydrological modification for runoff quantity or quality control if most of the following circumstances exist:

    - It is classified in Category IV in the Puget Sound Water Quality Authority's draft wetland guidelines. In general, Category IV wetlands have monotypic vegetation of similar age and class, lack special habitat features, and are isolated from other aquatic systems.
    - The wetland has been previously **disturbed** by human activity, as evidenced by agriculture, fill, ditching, and/or introduced or **invasive weedy plant species**.

- The wetland has been deprived of a significant amount of its water supply by draining or previous urbanization (e. g., by loss of groundwater supply), and stormwater runoff is sufficient to augment the water supply. A particular candidate is a wetland that has experienced an increased summer dry period, especially if the drought has been extended by more than two weeks.
- Construction for structural or hydrologic modification in order to provide runoff quantity or quality control will disturb relatively little of the wetland.
- The wetland can provide the required storage capacity for quantity or quality control through an outlet orifice modification to increase storage of water, rather than through raising the existing overflow. Orifice modification is likely to require less construction activity and consequent negative impacts.
- Under existing conditions the wetland's experiences a relatively high degree of water level fluctuation and a range of velocities (i.e., a wetland associated with substantially flowing water, rather than one in the headwaters or entirely isolated from flowing water).
- The wetland does not exhibit any of the following features:
  - Significant priority peat system or forested zones that will experience substantially altered hydroperiod as a result of the proposed action;
  - Regionally **unusual biological community types**;
  - Animal habitat features of relatively high value in the region (e. g., a protected, undisturbed area connected through undisturbed corridors to other valuable habitats, an important breeding site for protected species);
  - The presence of protected commercial or sport fish;
  - Configuration and topography that will require significant modification that may threaten fish stranding;
  - A relatively high degree of public interest as a result of, for example, offering valued local open space or educational, scientific, or recreational opportunities, unless the proposed action would enhance these opportunities;
- The wetland is threatened by potential impacts exclusive of stormwater management, and could receive greater protection if acquired for a stormwater management project rather than left in existing ownership.
- There is good evidence that the wetland actually can be restored or enhanced to perform other functions in addition to runoff quantity or quality control.
- There is good evidence that the wetland lends itself to the effective application of the Wetland Protection Guidelines in Guide Sheet 2.
- The wetland lies in the natural routing of the runoff. Local regulations often prohibit drainage diversion from one basin to another.
- The wetland allows runoff discharge at the natural location.

Guide Sheet 2: Wetland Protection Guidelines

This guide sheet provides information about likely changes to the ecological **structure** and **functioning** of **wetlands** that are incidentally subject to the effects of an urban or urbanizing watershed or are **modified** to supply runoff water quantity or quality control benefits. The guide sheet also recommends management actions that can avoid or minimize deleterious changes in these wetlands.

Guide Sheet 2A: General Wetland Protection Guidelines

1. Consult regulations issued under federal and state laws that govern the discharge of pollutants. Wetlands are classified as "Waters of the United States" and "Waters of the State" in Washington.

2. Maintain the wetland **buffer** required by local regulations or recommended by the Puget Sound Water Quality Authority's draft wetland guidelines.

3. Retain areas of native vegetation connecting the wetland and its buffer with nearby wetlands and other contiguous areas of native vegetation.

4. Avoid compaction of soil and introduction of exotic plant species during any work in a wetland.

5. Take specific site design and maintenance measures to avoid general urban impacts (e. g., littering and vegetation destruction). Examples are protecting existing buffer zones; discouraging access, especially by vehicles, by plantings outside the wetland; and encouragement of stewardship by a homeowners' association. Fences can be useful to restrict dogs and pedestrian access, but they also interfere with wildlife movements. Their use should be very carefully evaluated on the basis of the relative importance of intrusive impacts versus wildlife presence. Fences should generally not be installed when wildlife would be restricted and intrusion is relatively minor. They generally should be used when wildlife passage is not a major issue and the potential for intrusive impacts is high. When wildlife movements and intrusion are both issues, the circumstances will have to be weighed to make a decision about fencing.

6. If the wetland inlet will be modified for the stormwater management project, use a diffuse flow method, such as a spreader swale, to discharge water into the wetland in order to prevent flow channelization.

Guide Sheet 2B: Guidelines for Protection from Adverse Impacts of Modified Runoff Quantity Discharged to Wetlands

1. Protection of wetland plant and animal communities depends on controlling the wetland’s **hydroperiod**, meaning the pattern of fluctuation of water depth and the frequency and duration of exceeding certain levels, including the length and onset of drying in the summer. A <u>hydrologic assessment</u> is useful to measure or estimate elements of the hydroperiod under existing **pre-development** and anticipated **post-development** conditions. This assessment should be performed with the aid of a qualified hydrologist. Post-development estimates of watershed hydrology and wetland hydroperiod must include the cumulative

effect of all anticipated watershed and wetland modifications. Provisions in these guidelines pertain to the full anticipated build-out of the wetland's watershed.

This analysis hypothesizes a fluctuating water stage over time before development that could fluctuate more, both higher and lower after development; these greater fluctuations are termed **stage excursions**. The guidelines set limits on the frequency and duration of excursions, as well as on overall water level fluctuation, after development.

To determine existing hydroperiod use one of the following methods, listed in order of preference:

- Estimation by a continuous simulation computer model--The model should be calibrated with at least one year of data taken using a continuously recording level gage under existing conditions and should be run for the historical rainfall period. The resulting data can be used to express the magnitudes of depth fluctuation, as well as the frequencies and durations of surpassing given depths. [Note: Modeling that yields high quality information of the type needed for wetland hydroperiod analysis is a complex subject. Providing guidance on selecting and applying modeling options is beyond the scope of these guidelines but is being developed by King County Surface Water Management Division and other local jurisdictions. An alternative possibility to modeling depths, frequencies, and durations within the wetland is to model durations above given discharge levels entering the wetland over various time periods (e. g., seasonal, monthly, weekly). This option requires further development.]
- Measurement during a series of time intervals (no longer than one month in length) over a period of at least one year of the maximum water stage, using a crest stage gage, and instantaneous water stage, using a staff gage--The resulting data can be used to express water level fluctuation (WLF) during the interval as follows:

  Average base stage = (Instantaneous stage at beginning of interval + Instantaneous stage at end of interval)/2

  WLF = Crest stage - Average base stage

  Compute mean annual and mean monthly WLF as the arithmetic averages for each year and month for which data are available.

To forecast future hydroperiod use one of the following methods, listed in order of preference:

- Estimation by the continuous simulation computer model calibrated during pre-development analysis and run for the historical rainfall period--The resulting data can be used to express the magnitudes of depth fluctuation, as well as the frequencies and durations of surpassing given depths. [Note: Post-development modeling results should generally be compared with pre-development modeling results, rather than directly with field measurements, because different sets of assumptions underlie modeling and monitoring. Making pre- and post-development comparisons on the basis of common assumptions allows cancellation of errors inherent in the assumptions.]

- Estimation according to general relationships developed from the Puget Sound Wetlands and Stormwater Management Program Research Program, as follows (in part adapted from Chin 1996):
  - Mean annual WLF is very likely (100% of cases measured) to be < 20 cm (8 inches or 0.7 ft) if total impervious area (TIA) cover in the watershed is < 6% (roughly corresponding to no more than 15% of the watershed converted to urban land use).
  - Mean annual WLF is very likely (89% of cases measured) to be > 20 cm if TIA in the watershed is > 21% (roughly corresponding to more than 30% of the watershed converted to urban land use).
  - Mean annual WLF is somewhat likely (50% of cases measured) to be > 30 cm (1.0 ft) if TIA in the watershed is > 21% (roughly corresponding to more than 30% of the watershed converted to urban land use).
  - Mean annual WLF is likely (75% of cases measured) to be > 30 cm, and somewhat likely (50% of cases measured) to be 50 cm (20 inches or 1.6 ft) or higher, if TIA in the watershed is > 40% (roughly corresponding to more than 70% of the watershed converted to urban land use).
  - The frequency of stage excursions greater than 15 cm (6 inches or 0.5 ft) above or below pre-development levels is somewhat likely (54% of cases measured) to be more than six per year if the mean annual WLF increases to > 24 cm (9.5 inches or 0.8 ft).
  - The average duration of stage excursions greater than 15 cm above or below pre-development levels is likely (69% of cases measured) to be more than 72 hours if the mean annual WLF increases to > 20 cm.

2. The following hydroperiod limits characterize wetlands with relatively high vegetation species richness and apply to all zones within all wetlands over the entire year. If these limits are exceeded, then species richness is likely to decline. If the analysis described above forecasts exceedences, one or more of the management strategies listed in step 5 should be employed to attempt to stay within the limits.

   - Mean annual WLF (and mean monthly WLF for every month of the year) does not exceed 20 cm. Vegetation species richness decrease is likely with: (1) a mean annual (and mean monthly) WLF increase of more than 5 cm (2 inches or 0.16 ft) if pre-development mean annual (and mean monthly) WLF is greater than 15 cm, or (2) a mean annual (and mean monthly) WLF increase to 20 cm or more if pre-development mean annual (and mean monthly) WLF is 15 cm or less.
   - The frequency of stage excursions of 15 cm above or below pre-development stage does not exceed an annual average of six. Note: A short-term lagging or advancement of the continuous record of water levels is acceptable. The 15 cm limit applies to the temporary increase in maximum water surface elevations (hydrograph

peaks) after storm events and the maximum decrease in water surface elevations (hydrograph valley bottoms) between events and during the dry season.

- The duration of stage excursions of 15 cm above or below pre-development stage does not exceed 72 hours per excursion. Note: A short-term lagging or advancement of the continuous record of water levels is acceptable. However, the 15 cm limit applies throughout the entire hydrograph, not just the peaks and valleys.
- The total dry period (when pools dry down to the soil surface everywhere in the wetland) does not increase or decrease by more than two weeks in any year.
- Alterations to watershed and wetland hydrology that may cause perennial wetlands to become **vernal** are avoided.

3. The following hydroperiod limit characterizes **priority peat wetlands** (bogs and fens as more specifically defined by the Washington Department of Ecology) and applies to all zones over the entire year. If this limit is exceeded, then characteristic bog or fen wetland vegetation is likely to decline. If the analysis described above forecasts exceedance, one or more of the management strategies listed in step 5 should be employed to attempt to stay within the limit.

   - The duration of stage excursions above the pre-development stage does not exceed 24 hours in any year.

     NOTE: This guideline is in addition to the guidelines in #2 directly above. To apply this guideline a continuous simulation computer model needs to be employed. The model should be calibrated with data taken under existing conditions at the wetland being analyzed and then used to forecast post-development duration of excursions.

4. The following hydroperiod limits characterize wetlands inhabited by breeding native amphibians and apply to breeding zones during the period 1 February through 31 May. If these limits are exceeded, then amphibian breeding success is likely to decline. If the analysis described above forecasts exceedences, one or more of the management strategies listed in step 5 should be employed to attempt to stay within the limits.

   - The magnitude of stage excursions above or below the pre-development stage should not exceed 8 cm for more than 24 hours in any 30-day period.

     NOTE: To apply this guideline a continuous simulation computer model needs to be employed. The model should be calibrated with data taken under existing conditions at the wetland being analyzed and then used to forecast post-development magnitude and duration of excursions.

5. If it is expected that the hydroperiod limits stated above could be exceeded, consider strategies such as:

   - Reduction of the level of development;
   - Increasing runoff infiltration

NOTE: Infiltration is prone to failure in many Puget Sound Basin locations with glacial till soils and generally requires **pretreatment** to avoid clogging. In other situations infiltrating urban runoff may contaminate groundwater. Consult the stormwater management manual adopted by the jurisdiction and carefully analyze infiltration according to its prescriptions.

- Increasing runoff storage capacity; and
- Selective runoff bypass.

6. After development, monitor hydroperiod with a continuously recording level gauge or staff and crest stage gauges. If the applicable limits are exceeded, consider additional applications of the strategies in step 5 that may still be available. It is also recommended that goals be established to maintain key vegetation species, amphibians, or both, and that these species be monitored to determine if the goals are being met.

Guide Sheet 2C: Guidelines for Protection from Adverse Impacts of Modified Runoff Quality Discharged to Wetlands

1. Require effective erosion control at any construction sites in the wetland's drainage catchment.

2. Institute a program of **source control BMPs** to minimize the generation of pollutants that will enter storm runoff that drains to the wetland.

3. Provide a water quality control facility consisting of one or more **treatment BMPs** to treat all urban runoff entering the wetland. Refer to Chapter 4 of Volume 1 or Chapter 2 of Volume 5 of the Stormwater Management Manual for Western Washington to determine treatment requirements. Then refer to the corresponding BMP menu for that requirement in Chapter 3 of Volume V. From the menu select a BMP that fits with the project site.

   - If the wetland is a **priority peat wetland** (bogs and fens as more specifically defined by the Washington Department of Ecology), the facility should include a BMP with the most advanced ability to control nutrients (e. g., an infiltration device, a wet pond or constructed wetland with residence time in the pooled storage of at least two weeks). [Note: Infiltration is prone to failure in many Puget Sound Basin locations with glacial till soils and generally requires **pretreatment** to avoid clogging. In other situations infiltrating urban runoff may contaminate groundwater. Consult the stormwater management manual adopted by the jurisdiction and carefully analyze infiltration according to its prescriptions.] Refer to Appendix 4 for a comparison of water chemistry conditions in priority peat versus more typical wetlands.

     Refer to the stormwater management manual to select and design the facility. Generally, the facility should be located outside and upstream of the wetland and its buffer.

4. Design and perform a water quality monitoring program for priority peat wetlands and for other wetlands subject to relatively high water pollutant loadings. The research results (Horner 1989) identified such wetlands as having contributing catchments exhibiting either of the following characteristics:

   - More than 20 percent of the catchment area is committed to commercial, industrial, and/or multiple family residential land uses; or
   - The combination of all urban land uses (including single family residential) exceeds 30 percent of the catchment area.

   A recommended monitoring program, consistent with monitoring during the research program, is:

   - Perform pre-development **baseline sampling** by collecting water quality grab samples in an open water pool of the wetland for at least one year, allocated through the year as follows: November 1-March 31--4 samples, April 1-May 31--1 sample, June 1-August 31--2 samples, and September 1-October 31--1 sample (if the wetland is dry during any period, reallocate the sample(s) scheduled then to another time). Analyze samples for pH; dissolved oxygen (DO); conductivity (Cond); total suspended solids (TSS); total phosphorus (TP); nitrate + nitrite-nitrogen (N); fecal coliforms (FC); and total copper (Cu), lead (Pb), and zinc (Zn). Find the median and range of each water quality variable.
   - Considering the baseline results, set water quality goals to be maintained in the post-development period. Example goals are: (1) pH--no more than “x” percent (e. g., 10%) increase (relative to baseline) in annual median and maximum or decrease in annual minimum; (2) DO--no more than “x” percent decrease in annual median and minimum concentrations; (3) other variables --no more than “x” percent increase in annual median and maximum concentrations; (4) no increase in violations of the Washington Administrative Code (WAC) water quality criteria.
   - Repeat the sampling on the same schedule for at least one year after all development is complete. Compare the results to the set goals.

     If the water quality goals are not met, consider additional applications of the source and treatment controls described in steps 2 and 3. Continue monitoring until the goals are met at least two years in succession.

     NOTE: Wetland water quality was found to be highly variable during the research, a fact that should be reflected in goals. Using the maximum (or minimum), as well as a measure of central tendency like the median, and allowing some change from pre-development levels are ways of incorporating an allowance for variability. Table I-E-2 presents data from the wetlands studied during the research program to give an approximate idea of magnitudes and degree of variability to be expected. Non-urbanized watersheds (N) are those that have both < 15% urbanization and < 6% impervious cover. Highly urbanized watersheds (H) are those that have both lost all forest cover and have > 20% impervious cover. Moderately urbanized watersheds (M) are those that fit neither the N nor H category.

Table I-E-2. Water Quality Ranges Found in Study Wetlands

	N			M			H		
Metric	**Median**	**Mean**	**Std.Dev./n[a]**	**Median**	**Mean**	**Std.Dev./n[a]**	**Median**	**Mean**	**Dev./n[a]**
pH[b]	6.4	6.4	0.5/162	6.7	6.5	0.8/132	6.9	6.7	0.6/52
DO (mg/L)	5.9	5.7	2.6/205	5.1	5.53.6/173	6.3	5.4	2.9/67	
Cond. (µS/cm)	46	73	64/190	160	142	73/161	132	151	86/61
TSS (µg/L)	2.0	4.6	8.5/204	2.8	9.2	22/175	4.0	9.2	15/66
TP (µg/L)	29	52	87/206	70	93	92/177	69	110	234/67
N (µg/L)	112	368	485/206	304	598	847/177	376	395	239/67
FC (no./100mL)	9.0	271	1000/206	46	2665	27342/173	61	969	4753/66
Cu (µg/L)	<5.0	<3.3	>2.7/93	<5.0	<3.7	>1.9/78	<5.0	<4.1	<2.5/29
Pb (µg/L)	1.0	<2.7	>2.8/136	3.0	<3.4	>2.7/122	5.0	<4.5	>4.0/44
Zn (µg/L)	5.0	8.4	8.3/136	8.0	9.8	7.2/122	20	20	17/44

[a] Std. Dev.--standard deviation; n--number of observations.
[b] Values do not apply to priority peat wetlands. The program did not specifically study these wetlands but measured pH in three wetlands with “bog-like” characteristics. The minimum value measured in these wetlands was 4.5, and the lowest median was 4.8; but pH can be approximately 1 unit lower in wetlands of this type.

Guide Sheet 2D: Guidelines for the Protection of Specific Biological Communities

1. For wetlands inhabited by breeding native amphibians:
   - Refer to step 4 of Guide Sheet 2B for hydroperiod limit.
   - Avoid decreasing the sizes of the open water and aquatic bed zones.
   - Avoid increasing the channelization of flow. Do not form channels where none exist, and take care that inflows to the wetland do not become more concentrated and do not enter at higher velocities than accustomed. If necessary, concentrated flows can be uniformly distributed with a flow-spreading device such as a shallow weir, stilling basin, or perforated pipe. Velocity dissipation can be accomplished with a stilling basin or rip-rap pad.
   - Limit the post-development flow velocity to < 5 cm/s (0.16 ft/second) in any location that had a velocity in the range 0-5 cm/s in the pre-development condition.
   - Avoid increasing the gradient of wetland side slopes.
2. For wetlands inhabited by forest bird species:
   - Retain areas of coniferous forest in and around the wetland as habitat for forest species.
   - Retain shrub or woody debris as nesting sites for ground-nesting birds and downed logs and stumps for winter wren habitat.
   - Retain snags as habitat for cavity-nesting species, such as woodpeckers.

- Retain shrubs in and around the wetland for protective cover. If cover is insufficient to protect against domestic pet predation, consider planting native bushes such as rose species in the buffer.

3. For wetlands inhabited by **wetland obligate** bird species:

   - Retain **forested zones**, sedge and rush meadows, and deep open water zones, both without vegetation and with submerged and floating plants.
   - Retain shrubs in and around the wetland for protective cover. If cover is insufficient to protect against domestic pet predation, consider planting native bushes such as rose species in the buffer.
   - Avoid introducing **invasive weedy plant species**, such as purple loosestrife and reed canary grass.
   - Retain the buffer zone. If it has lost width or forest cover, consider re-establishing forested buffer area at least 30 meters (100 ft) wide.
   - If human entry is desired, establish paths that permit people to observe the wetland with minimum disturbance to the birds.

4. For wetlands inhabited by fish:

   - Protect fish habitats by avoiding water velocities above tolerated levels (selected with the aid of a qualified fishery biologist to protect fish in each life stage when they are present), siltation of spawning beds, etc. Habitat requirements vary substantially among fish species. If the wetland is associated with a larger water body, contact the Department of Fisheries and Wildlife to determine the species of concern and the acceptable ranges of habitat variables.
   - If stranding of protected commercial or sport fish could result from a structural or hydrologic modification for runoff quantity or quality control, develop a strategy to avoid stranding that minimizes disturbance in the wetland (e. g., by making provisions for fish return to the stream as the wetland drains, or avoiding use of the facility for quantity or quality control during fish presence).

Wetlands Guidance Appendix 1: Information Needed to Apply Guidelines

The following information listed for each guide sheet is most essential for applying the Wetlands and Stormwater Management Guidelines. As a start, obtain the relevant soil survey; the National Wetland Inventory, topographic and land use maps, and the results of any local wetland inventory.

Guide Sheet 1

1. Boundary and area of the contributing watershed of the wetland or other landscape unit
2. A complete definition of goals for the wetland and landscape unit subject to planning and management
3. Existing management and monitoring plans
4. Existing and projected land use in the landscape unit in the categories commercial, industrial, multi-family residential, single-family residential, agricultural, various categories of undeveloped, and areas subject to active logging or construction (expressed as percentages of the total watershed area)
5. Drainage network throughout the landscape unit
6. Soil conditions, including soil types, infiltration rates, and positions of seasonal water table (seasonally) and restrictive layers
7. Groundwater recharge and discharge points
8. Wetland category (I - IV in draft Puget Sound Water Quality Authority wetland protection guidelines); designation as rare or irreplaceable. Refer to the Washington Natural Heritage Program database. If the needed information is not available, a biological assessment will be necessary.
9. Watershed hydrologic assessment
10. Watershed water quality assessment
11. Wetland type and zones present, with special note of estuarine, priority peat system, forested, sensitive scrub-shrub zone, sensitive emergent zone and other sensitive or critical areas designated by state or local government (with dominant plant species)
12. Rare, threatened, or endangered species inhabiting the wetland
13. History of wetland changes
14. Relationship of wetland to other water bodies in the landscape unit and the drainage network
15. Flow pattern through the wetland
16. Fish and wildlife inhabiting the wetland
17. Relationship of wetland to other wildlife habitats in the landscape unit and the corridors between them

Guide Sheet 2

1. Existing and potential stormwater pollution sources
2. Existing and projected landscape unit land use (see number 4 under Guide Sheet 1)
3. Existing and projected wetland hydroperiod characteristics
4. Wetland bathymetry
5. Inlet and outlet locations and hydraulics
6. Landscape unit soils, geologic and hydrogeologic conditions
7. Wetland type and zones present (see number 11 under Guide Sheet 1)
8. Presence of breeding populations of native amphibian species
9. Presence of forest and wetland obligate bird species
10. Presence of fish species

Wetlands Guidance Appendix 2: Definitions

Baseline sampling	Sampling performed to define an existing state before any modification occurs that could change the state.
Bioengineering	Restoration or reinforcement of slopes and stream banks with living plant materials.
Buffer	The area that surrounds a wetland and that reduces adverse impacts to it from adjacent development.
Constructed wetland	A wetland intentionally created from a non-wetland site for the sole purpose of wastewater or stormwater treatment. These wetlands are not normally considered Waters of the United States or Waters of the State.
Degraded (disturbed) wetland (community)	A wetland (community) in which the vegetation, soils, and/or hydrology have been adversely altered, resulting in lost or reduced functions and values; generally, implies topographic isolation; hydrologic alterations such as hydroperiod alteration (increased or decreased quantity of water), diking, channelization, and/or outlet modification; soils alterations such as presence of fill, soil removal, and/or compaction; accumulation of toxicants in the biotic or abiotic components of the wetland; and/or low plant species richness with dominance by invasive weedy species
Enhancement	Actions performed to improve the condition of an existing degraded wetland, so that functions it provides are of a higher quality.
Estuarine wetland	Generally, an eelgrass bed; salt marsh; or rocky, sandflat, or mudflat intertidal area where fresh and salt water mix. (Specifically, a tidal wetland with salinity greater than 0.5 parts per thousand, usually semi-enclosed by land but with partly obstructed or sporadic access to the open ocean).
Forested communities (wetlands)	In general terms, communities (wetlands) characterized by woody vegetation that is greater than or equal to 6 meters in height; in these guidelines the term applies to such communities (wetlands) that represent a significant amount of tree cover consisting of species that offer wildlife habitat and other values and advance the performance of wetland functions overall.

Functions	The ecological (physical, chemical, and biological) processes or attributes of a wetland without regard for their importance to society (see also Values). Wetland functions include food chain support, provision of ecosystem diversity and fish and wildlife habitat, flood flow alteration, groundwater recharge and discharge, water quality improvement, and soil stabilization.
Hydrodynamics	The science involving the energy and forces acting on water and its resulting motion.
Hydroperiod	The seasonal occurrence of flooding and/or soil saturation; encompasses the depth, frequency, duration, and seasonal pattern of inundation.
Invasive weedy plant species	Opportunistic species of inferior biological value that tend to out-compete more desirable forms and become dominant; applied to non-native species in these guidelines.
Landscape unit	An area of land that has a specified boundary and is the locus of interrelated physical, chemical, and biological processes.
Modification, Modified (wetland)	A wetland whose physical, hydrological, or water quality characteristics have been purposefully altered for a management purpose, such as by dredging, filling, forebay construction, and inlet or outlet control.
On-site	An action (here, for stormwater management purposes) taken within the property boundaries of the site to which the action applies.
Polishing	Advanced treatment of a waste stream that has already received one or more stages of treatment by other means.
Pre-development, post-development	Respectively, the situation before and after a specific stormwater management project (e. g., raising the outlet, building an outlet control structure) will be placed in the wetland or a land use change occurs in the landscape unit that will potentially affect the wetland.
Pre-treatment	An action taken to remove pollutants from runoff before it is discharged into another system for additional treatment.
Priority peat systems	Unique, irreplaceable fens that can exhibit water pH in a wide range from highly acidic to alkaline, including fens typified by *Sphagnum* species, *Rhododendron groenlandicum* (Labrador tea), *Drosera rotundifolia* (sundew), and *Vaccinium oxycoccos* (bog cranberry); marl fens; estuarine peat deposits; and other moss peat systems with relatively diverse, undisturbed flora and fauna.

Bog is the common name for peat systems having the *Sphagnum* association described, but this term applies strictly only to systems that receive water income from precipitation exclusively.

Rare, threatened, or endangered species — Plant or animal species that are regional relatively uncommon, are nearing endangered status, or whose existence is in immediate jeopardy and is usually restricted to highly specific habitats. Threatened and endangered species are officially listed by federal and state authorities, whereas rare species are unofficial species of concern that fit the above definitions.

Redevelopment — Conversion of an existing development to another land use, or addition of a material improvement to an existing development.

Regional — An action (here, for stormwater management purposes) that involves more than one discrete property.

Restoration — Actions performed to reestablish wetland functional characteristics and processes that have been lost by alterations, activities, or catastrophic events in an area that no longer meets the definition of a wetland.

Source control best management practices (BMPs) — Actions that are taken to prevent the development of a problem (e. g., increase in runoff quantity, release of pollutants) at the point of origin.

Stage excursion — A post-development departure, either higher or lower, from the water depth existing under a given set of conditions in the pre-development state.

Structure — The components of an ecosystem, both the abiotic (physical and chemical) and biotic (living).

Treatment best management practices (BMPs) — Actions that remove pollutants from runoff through one or more physical, chemical, biological mechanisms.

Unusual biological community types — Assemblages of interacting organisms that are relatively uncommon regionally.

Values — Wetland processes or attributes that are valuable or beneficial to society (also see Functions). Wetland values include support of commercial and sport fish and wildlife species, protection of life and property from flooding, recreation, education, and aesthetic enhancement of human communities.

Vernal wetland A wetland that has water above the soil surface for a period of time during and/or after the wettest season but always dries to or below the soil surface in warmer, drier weather.

Wetland obligate A biological organism that absolutely requires a wetland habitat for at least some stage of its life cycle.

Wetlands Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. Wetlands do not include those artificial wetlands intentionally created from non-wetland sites, including, but not limited to, irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction of a road, street, or highway. Wetlands may include those artificial wetlands intentionally created from non-wetland areas to mitigate the conversion of wetlands. (Waterbodies not included in the definition of wetlands as well as those mentioned in the definition are still waters of the state.)

Wetlands Guidance Appendix 3: Native and Recommended Noninvasive Plant Species for Wetlands in the Puget Sound Basin

CAUTION: Extracting plants from an existing wetland donor site can cause a significant negative effect on that site. It is recommended that plants be obtained from native plant nursery stocks whenever possible. Collections from existing wetlands should be limited in scale and undertaken with care to avoid disturbing the wetland outside of the actual point of collection. Plant selection is a complex task, involving matching plant requirements with environmental conditions. It should be performed by a qualified wetlands botanist. Refer to Restoring Wetlands in Washington by the Washington Department of Ecology for more information.

The following plants are preferred in Puget Sound Basin freshwater wetlands:

Open water zone

Potamogeton species (pondweeds)
Nymphaea odorata (pond lily)
Brasenia schreberi (watershield)
Nuphar luteum (yellow pond lily)
Polygonum hydropiper (smartweed)
Alisma plantago-*aquatica* (broadleaf water plantain)
Ludwigia palustris (water purslane)
Menyanthes trifoliata (bogbean)
Utricularia minor, U. vulgaris (bladderwort)

Emergent zone

Carex obnupta, C. utriculata, C. arcta, C. stipata, C. vesicaria C. aquatilis, C. comosa, C. lenticularis (sedge)
Scirpus atricinctus (woolly bulrush)
Scirpus microcarpus (small-fruited bulrush)
Eleocharis palustris, E. ovata (spike rush)
Epilobium watsonii (Watson's willow herb)
Typha latifolia (common cattail) (Note: This native plant can be aggressive but has been found to offer certain wildlife habitat and water quality improvement benefits; use with care.)
Veronica americana, V. scutellata (American brookline, marsh speedwell)
Mentha arvensis (field mint)
Lycopus americanus, L. uniflora (bugleweed or horehound)
Angelica species (angelica)
Oenanthe sarmentosa (water parsley)
Heracleum lanatum (cow parsnip)
Glyceria grandis, G. elata (manna grass)
Juncus acuminatus (tapertip rush)
Juncus ensifolius (daggerleaf rush)
Juncus bufonius (toad rush)
Mimulus guttatus (common monkey flower)

Scrub-shrub zone	Salix lucida, S. rigida, S. sitchensis, S. scouleriana, S. pedicellaris (willow) Lysichiton americanus (skunk cabbage) Athyrium filix-femina (lady fern) *Cornus sericea* (redstem dogwood) Rubus spectabilis (salmonberry) Physocarpus capitatus (ninebark) *Ribes species* (gooseberry) Rhamnus purshiana (cascara) *Sambucus racemosa* (red elderberry) (occurs in wetland-upland transition) Loniceria involucrata (black twinberry) Oemleria cerasiformis (Indian plum) *Stachys cooleyae* (Stachy's horsemint) Prunus emarginata (bitter cherry)
Forested zone	Populus balsamifera, ssp. trichocarpa (black cottonwood) Fraxinus latifolia (Oregon ash) *Thuja plicata* (western red cedar) *Picea sitchensis* (Sitka spruce) *Alnus rubra* (red alder) *Tsuga heterophylla* (hemlock) *Acer circinatum* (vine maple) *Maianthemum dilatatum* (wild lily-of-the-valley) *Ivzula parviflora* (small-flower wood rush) *Torreyochloa pauciflora* (weak alkaligrass) *Ribes* species (currants)
Bog	*Sphagnum* species (sphagnum mosses) *Rhododendron groenlandicum* (Labrador tea) *Vaccinium oxycoccos* (bog cranberry) Kalmia microphylla, ssp. occidentalis (bog laurel)

The following exotic plants should not be introduced to existing, created, or constructed Puget Sound Basin freshwater wetlands:

Hedera helix (English ivy)
Phalaris arundinacea (reed canarygrass)
Lythrum salicaria (purple loosestrife)
Iris pseudacorus (yellow iris)
Ilex aquifolia (holly)
Impatiens glandulifera (policeman's helmet)
Lotus corniculatus (birdsfoot trefoil)
Lysimachia thyrsiflora (tufted loosestrife)
Myriophyllum species (water milfoil, parrot's feather)
Polygonum cuspidatum (Japanese knotweed)
Polygonum sachalinense (giant knotweed)
Rubus discolor (Himalayan blackberry)
Tanacetum vulgare (common tansy)

The following native plants should not be introduced to existing, created, or constructed Puget Sound Basin freshwater wetlands

Potentilla palustris (Pacific silverweed)
Solarum dulcimara (bittersweet nightshade)
Juncus effusus (soft rush)
Conium maculatum (poison hemlock)
Ranunculus repens (creeping buttercup)

Wetlands Guidance Appendix 4: Comparison of Water Chemistry Characteristics in *Sphagnum* Bog and Fen versus More Typical Wetlands

Water Quality Variable	Typical Wetlands	*Sphagnum* Bogs and Fens
PH	6 - 7	3.5 - 4.5
Dissolved oxygen (mg/L)	4 - 8	Shallow surface layer oxygenated, anoxic below
Cations	Divalent Ca, Mg common	Divalent Ca, Mg uncommon; Univalent Na, K predominant
Anions	HCO_3^-, CO_3^{2-} predominant	Cl^-, SO_4^{2-} predominant; almost no HCO_3^-, CO_3^{2-} (organic acids form buffering system)
Hardness	Moderate	Very low
Total phosphorus (µg/L)	50 - 500	5 - 50
Total Kjeldahl nitrogen (µg/L)	500 - 1000	~ 50

Wetland Protection Guidelines References

Chin, N. T. 1996. Watershed Urbanization Effects on Palustrine Wetlands: A Study of the Hydrologic, Vegetative, and Amphibian Community Response over Eight Years. M. S. C. E. Thesis, University of Washington, Seattle, WA.

Clymo, R. S. 1963. Ion exchange in *Sphagnum* and its relation to bog ecology. Annals of Botany 27 (106):310-324.

Cooke, S. S., Puget Sound Wetlands and Stormwater Management Research Program, unpublished Queen's Bog data.

Horner, R. R. 1989. Long-term effects of urban runoff on wetlands. Pp. in L. A. Roesner, B. Urbonas, and M. B. Sonnen (eds.), Design of Urban Runoff Controls, American Society of Civil Engineers, New York, NY.

Horner, R. R., J. J. Skupien, E. H. Livingston, and H. E. Shaver. 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. Terrene Institute, Washington, D. C.

Horner, R. R., S. S. Cooke, K. O. Richter, A. L. Azous, L. E. Reinelt, B. L. Taylor, K. A. Ludwa, and M. Valentine. 1996. Wetlands and Urbanization, Implications for the Future. Puget Sound Wetlands and Stormwater Management Research Program, Engineering Professional Programs, University of Washington, Seattle, WA.

Meyer, J., L. Vogel, and T. Duebendorfer, East Lake Sammamish wetland no. 21 unpublished data, submitted to L. Kulzer, King County Surface Water Management Division.

Moore, P. D. and D. J. Bellamy. 1974. Chapter 3, The Geochemical template. Peatlands. Elek Science, London, U. K.

Thurman, E. M. 1985. Organic Geochemistry of Natural Waters. Martinus Nijhoff/Dr W. Junk Publishers, Dordrecht, The Netherlands.

Vitt, D. H., D. G. Horton, N. G. Slack, and N. Malmer. 1990. *Sphagnum*-dominated peatlands of the hyperoceanic British Columbia coast: Patterns in surface water chemistry and vegetation. Canadian Journal of Forest Research 20:696-711.

Volume II – Stormwater Management for Construction Sites Table of Contents

THIS PAGE INTENTIONALLY LEFT BLANK.

Volume
II

Volume II: Stormwater Management for Construction Sites

Purpose of this Volume

This volume of the Surface Water Management Manual discusses stormwater impacts and controls associated with construction activities. It addresses the planning, design, and implementation of stormwater management activities prior to and during the construction phase of projects.

The purpose of this volume is to provide guidance to prevent construction activities from adversely impacting downstream resources and on-site stormwater flows. Prevention of soil erosion, capture of water-borne sediment that has been unavoidably released from exposed soils, and protection of water quality from on-site pollutant sources are all readily achievable when the proper Best Management Practices (BMPs) are planned, installed, and properly maintained.

Content and Organization of this Volume

Volume II consists of three chapters that address the preparation and implementation of Construction Stormwater Pollution Prevention Plans (SWPPPs).

- Chapter 1 describes the 12 elements of stormwater pollution prevention.
- Chapter 2 presents a step-by-step method for developing a Construction SWPPP. It encourages examination of all possible conditions that could reasonably affect a particular project's stormwater control systems during the construction phase of the project.
- Chapter 3 contains BMPs for construction stormwater control and site management. The first section of Chapter 3 contains BMPs for Source Control. The second section addresses runoff, conveyance, and treatment BMPs. Various combinations of these BMPs should be used in the Construction SWPPP to satisfy each of the 12 elements applying to the project.

Chapter 1 The 12 Elements of Construction Stormwater Pollution Prevention

The 12 elements of construction stormwater pollution prevention cover the general water quality protection strategies of limiting site impacts, preventing erosion and sedimentation, and managing activities and sources. The applicant is required to address the following 12 elements in the construction stormwater pollution prevention plan (SWPPP). If an element is considered unnecessary, the Construction SWPPP must describe why that element is not needed.

The 12 elements are:

- Element 1 – Mark Clearing Limits
- Element 2 – Establish Construction Access
- Element 3 – Control Flow Rates
- Element 4 – Install Sediment Controls
- Element 5 – Stabilize Soils
- Element 6 – Protect Slopes
- Element 7 – Protect Drain Inlets
- Element 8 – Stabilize Channels and Outlets
- Element 9 – Control Pollutants
- Element 10 – Control Dewatering
- Element 11 – Maintain BMPs
- Element 12 – Manage the Project

Element #1: Mark Clearing Limits

- Before beginning any land disturbing activities, including clearing and grading, clearly mark all clearing limits, sensitive areas and their buffers, and trees that are to be preserved within the construction area to prevent damage and offsite impacts. Mark clearing limits both in the field and on the plans.
- Plastic, metal, or stake wire fence may be used to mark the clearing limits.
- 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

Element #2: Establish Construction Access

- Construction vehicle ingress and egress shall be limited to one route. Additional routes may be allowed for very large projects or linear projects.
- Access points shall be stabilized per BMP C105 – Stabilized Construction Entrance.
- Wheel wash or tire baths shall be located on site, if applicable. Wheel washes shall be required if other measures fail to control sediment from leaving the site.
- No tracking of sediment onto the roadway is allowed. If sediment is tracked onto the road, the road shall be thoroughly and immediately cleaned by shoveling or pickup sweeping. Transport sediment to a controlled sediment disposal area.
- Keep streets clean at ALL times. Clean tracked sediment immediately.
- Street washing of sediment to the storm drain system is not allowed.
- Suggested BMPs:
    - BMP C105: Stabilized Construction Entrance
    - BMP C106: Wheel Wash
    - BMP C107: Construction Road/Parking Area Stabilization

Element #3: Control Flow Rates

- Protect properties and waterways downstream of development sites from erosion due to increases in the volume, velocity, and peak flow rate of stormwater runoff from the project site.
- Conduct a downstream analysis if changes to offsite flows could impair or alter conveyance systems, stream banks, bed sediment, or aquatic habitat. See Volume I, Chapter 3 – Minimum Requirement #11 for offsite analysis guidelines.
- Construct stormwater detention facilities as one of the first steps in grading. Detention facilities shall be functional prior to construction of site improvements (e.g. impervious surfaces).
- During construction, the City may require non-standard temporary sediment control pond designs in order to provide additional flow control necessary to address local conditions or to protect properties and waterways downstream from erosion due to construction activities.
- Permanent infiltration ponds shall not be used for flow control during construction unless specifically allowed in writing by the City. If allowed, these facilities shall be protected from siltation during the construction phase as required by the City. A liner may be required. The ponds shall be excavated to final grade after the site is stabilized.
- Suggested BMPs:
    - BMP C240: Sediment Trap
    - BMP C241: Temporary Sediment Pond

Element #4: Install Sediment Controls

- Retain the duff layer, native topsoil, and natural vegetation in an undisturbed state to the maximum extent practicable. If it is not practicable to retain the duff layer in place, it should be stockpiled on-site, covered to prevent erosion, and replaced immediately upon completion of the ground disturbing activities.
- Prior to leaving a construction site or prior to discharge to an infiltration facility, surface water runoff from disturbed areas shall pass through a sediment pond or other appropriate sediment removal BMP.
- Construct sediment ponds, vegetated buffer strips, sediment barriers or filters, dikes, and other BMPs intended to trap sediment on site as one of the first steps in grading. These BMPs shall be functional before other land disturbing activities take place.
- Locate BMPs in a manner to avoid interference with the movement of juvenile salmonids attempting to enter off-channel areas or drainages.
- Seed and mulch earthen structures such as dams, dikes, and diversions according to the timing indicated in Element #5.
- Suggested BMPs:
  - 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
  - BMP C250: Construction Stormwater Chemical Treatment
  - BMP C251: Construction Stormwater Filtration
- Proprietary technologies exist that can be used for sediment control. Ecology to determine if the temporary sediment control device is equivalent to an existing BMP or requires Ecology approval via the Technology Assessment Protocol Ecology program.

Element #5: Stabilize Soils

- Stabilize exposed and unworked soils by application of effective BMPs that protect the soil from the erosive forces of raindrop impact, flowing water, and wind.
- From October 1 through April 30, no soils shall remain exposed and unworked for more than 2 days. From May 1 to September 30, no soils shall remain exposed and unworked for more than 7 days. This stabilization requirement applies to all soils on site, whether at final grade or not. (See City's Clearing and Grading Code ACC 15.74).

- Stabilize soils at the end of the shift, before a holiday or weekend, if needed, based on the weather forecast.
- Select appropriate soil stabilization measures for the time of year, site conditions, estimated duration of use, and the potential water quality impacts that stabilization agents may have on downstream waters or groundwater.
- Stabilize soil stockpiles from erosion, protect stockpiles with sediment trapping measures, and where possible, locate piles away from storm drain inlets, waterways, and drainage channels.
- 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: Compost
  - BMP C126: Topsoiling
  - BMP C127: Polyacrylamide for Soil Erosion Protection
  - BMP C130: Surface Roughening
  - BMP C131: Gradient Terraces
  - BMP C140: Dust Control
  - BMP C180: Small Project Construction Stormwater Pollution Prevention

Element #6: Protect Slopes

- Reduce slope runoff velocities by reducing continuous length of slope with terracing and diversions, reducing slope steepness, and/or roughing slope surface.
- Divert off-site stormwater (sometimes called run-on) away from slopes and disturbed areas with interceptor dikes and/or swales. Manage off-site stormwater separately from stormwater generated on the site.
- At the top of slopes, collect drainage in pipe slope drains or protected channels to prevent erosion. Size temporary pipe slope drains for the peak flow from a 10-year, 24-hour event. Alternatively, the 10-year and 25-year, 1-hour flow rates indicated by WWHM, increased by a factor of 1.6, may be used. Size permanent pipe slope drains for the 25-year, 24-hour event. Use the existing land cover condition for predicting flow rates from tributary areas outside the project limits for the hydrologic analysis. For tributary areas on the project site, use the temporary or permanent project land cover condition, whichever will produce the higher flows for the analysis. If using WWHM to predict flows, model bare soils and landscaped areas.

- Provide drainage to remove groundwater seepage from the slope surface of exposed soil areas.
- Place excavated material on the uphill side of trenches, consistent with safety and space considerations.
- Place check dams at regular intervals within channels that are cut down a slope.
- Stabilize soils on slopes, as specified in Element #5.
- 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)

Element #7: Protect Drain Inlets

- Protect all storm drain inlets that are operable during construction so that stormwater runoff does not enter the conveyance system without first being filtered or treated to remove sediment.
- Keep all approach roads clean. Do not allow sediment to enter storm drains.
- Inspect inlets weekly at a minimum and after each storm events. Clean or remove and replace inlet protection devices when sediment has filled one-third of the available storage (unless a different standard is specified by the product manufacturer).
- Suggested BMPs:
    - BMP C220: Storm Drain Inlet Protection

Element #8: Stabilize Channels and Outlets

- Design, construct, and stabilize all temporary on-site conveyance channels to prevent erosion from the expected peak 10-minute velocity of a 10-year, 24-hour frequency storm for the developed condition. Alternatively, the 10-year, 1-hour flow rate indicated by an approved continuous runoff model, increased by a factor of 1.6, may be used. For tributary areas outside the project limits, use the existing land cover conditions for predicting flow rates from tributary areas outside the project limits for the hydrologic analysis. For tributary areas on the project site, use the temporary or permanent project land cover condition, whichever will produce the highest flow rates, for the hydrologic analysis. If using WWHM, model bare soils as landscaped.

- Provide stabilization, including armoring material, adequate to prevent erosion of outlets, adjacent stream banks, slopes, and downstream reaches at the outlets of all conveyance systems.
- Suggested BMPs:
  - BMP C202: Channel Lining
  - BMP C209: Outlet Protection

Element #9: Control Pollutants

- All discharges to the City sewer system (storm or sanitary sewers) require City approval.
- Handle and dispose of all pollutants, including waste materials and demolition debris that occur on site during construction in a manner that does not cause contamination of stormwater. Woody debris may be chopped and spread on site.
- Provide cover, containment, and protection for all chemicals, liquid products, petroleum products, and other materials that have the potential to pose a threat to human health and the environment. Include secondary containment for on-site fueling tanks.
- Use spill prevention and control measures, such as drip pans, when conducting maintenance and repair of heavy equipment and vehicles involving oil changes, hydraulic system drain down, solvent and de-greasing cleaning operations, fuel tank drain down and removal, and other activities which may result in discharge or spillage of pollutants to the ground or into stormwater runoff. Clean contaminated surfaces immediately following any discharge or spill incident. Emergency repairs may be performed on-site using temporary plastic placed beneath and, if raining, over the vehicle.
- Discharge wheel wash or tire bath wastewater to a separate on-site treatment system or to the sanitary sewer.
- Only apply agricultural chemicals, including fertilizers and pesticides, when absolutely necessary and only in a manner and at application rates that will not result in loss of chemical to stormwater runoff. Follow manufacturers' recommendations for application rates and procedures.
- Use BMPs to prevent or treat contamination of stormwater runoff by pH modifying sources. These sources include, but are not limited to, bulk cement, cement kiln dust, fly ash, new concrete washing and curing waters, waste streams generated from concrete grinding and sawing, exposed aggregate processes, and concrete pumping and mixer washout waters. Construction site operators must adjust the pH of stormwater to prevent violations of water quality standards.

- Written approval from the Department of Ecology is required prior to using chemical treatment other than CO_2 or dry ice to adjust pH.
- Suggested BMPs:
  - BMP C151: Concrete Handling
  - BMP C152: Sawcutting and Surfacing Pollution Prevention
  - BMP C154: Concrete Washout Area
  - Source Control BMPs from Volume IV, as appropriate

Element #10: Control Dewatering

- All discharges to the City sewer system (storm or sanitary sewers) require City approval.
- Discharge foundation, vault, and trench dewatering water that has similar characteristics to site stormwater runoff into a controlled conveyance system prior to discharge to a sediment pond or sediment tank/vault. Stabilize channels as specified in Element #8.
- Clean, non-turbid dewatering water, such as well-point groundwater, can be discharged to systems tributary to state surface waters, as specified in Element #8, provided the dewatering flow does not cause erosion or flooding of receiving waters. These clean waters should not be routed through stormwater sediment ponds/tanks.
- Handle highly turbid or contaminated dewatering water from construction equipment operation, clamshell digging, concrete tremie pour, or work inside a cofferdam separately from stormwater at the site.
- Other disposal options, depending on site constraints, may include:
  - Infiltration
  - Transport off-site in vehicle, such as a vacuum flush truck, for legal disposal in a manner that does not pollute state waters
  - Ecology approved on-site chemical treatment or other suitable treatment technologies
  - Use of a sedimentation bag with outfall to a ditch or swale for small volumes of localized dewatering

Element #11: Maintain BMPs

- Maintain and repair as needed all temporary and permanent erosion and sediment control BMPs to assure continued performance of their intended function. Conduct maintenance and repair in accordance with BMP specifications.
- Remove temporary erosion and sediment control BMPs within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Permanently stabilize disturbed soil resulting from removal of BMPs or vegetation.

Element #12: Manage the Project

- ***Phasing of Construction*** – Phase development projects in order to prevent soil erosion and the transport of sediment from the project site during construction, unless the project engineer can demonstrate that construction phasing is infeasible. Revegetation of exposed areas and maintenance of that vegetation shall be an integral part of the clearing activities for any phase.
- ***Seasonal Work Limitations*** – From October 1 through April 30, clearing, grading, and other soil disturbing activities shall only be permitted if shown to the satisfaction of the City that silt-laden runoff will be prevented from leaving the site through a combination of the following:
  - Site conditions including existing vegetative coverage, slope, soil type, and proximity to receiving waters;
  - Limitations on activities and the extent of disturbed areas; and
  - Proposed erosion and sediment control measures.

  Based on the information provided and local weather conditions, the City may expand or restrict the seasonal limitation on site disturbance. The following activities are exempt from the seasonal clearing and grading limitations:

  - Routine maintenance and necessary repair of erosion and sediment control BMPs
  - Routine maintenance of public facilities or existing utility structures that do not expose the soil or result in the removal of the vegetative cover to soil
  - Activities where there is one hundred percent infiltration of surface water runoff within the site in approved and installed erosion and sediment control facilities
- ***Coordination with Utilities and Other Contractors*** – Include surface water management requirements for the entire project, including the utilities and other contractors, in the Construction SWPPP.
- ***Inspection and Monitoring*** – Inspect, maintain, and repair all BMPs as needed to assure continued performance of their intended function. At a minimum, inspect all BMPs after each storm event. Site inspections shall be conducted by a person who is knowledgeable in the principles and practices of erosion and sediment control. The person must have the skills to 1) assess the site conditions and construction activities that could impact the quality of stormwater, and 2) assess the effectiveness of erosion and sediment control measures used to control the quality of stormwater discharges.

  For construction sites one acre or larger that discharge to surface waters of the state, a Certified Erosion and Sediment Control Lead (CESCL) shall be identified in the Construction SWPPP and shall be on-site or on-call at all times. Certification must be obtained through an Ecology-approved training program.

Sampling and analysis of the surface water discharges from a construction site may be necessary on a case-by-case basis to ensure compliance with standards. Ecology or the City will establish these monitoring and associated reporting requirements.

Whenever inspection and/or monitoring reveals that the BMPs identified in the Construction SWPPP are inadequate, due to the actual discharge of or potential to discharge a significant amount of any pollutant, the appropriate BMPs or design changes shall be implemented as soon as possible.

- ***Reporting*** – Report spillage or discharge of pollutants within 24-hours to the City of Auburn Spill Hotline 24-hour phone number at (253) 931-3048.
- ***Maintenance of the Construction SWPPP*** – Keep the Construction SWPPP on-site or within reasonable access to the site. Modify the SWPPP whenever there is a change in the design, construction, operation, or maintenance at the construction site that has, or could have, a significant effect on the discharge of pollutants to waters of the state.

  Modify the SWPPP if, during inspections or investigations conducted by the owner/operator, City staff, or by local or state officials, it is determined that the SWPPP is ineffective in eliminating or significantly minimizing pollutants in stormwater discharges from the site. Modify the SWPPP as necessary to include additional or modified BMPs designed to correct problems identified. Complete revisions to the SWPPP within seven (7) days following the inspection.

  The inspector may require that a modification to the SWPPP go through additional City review.

Chapter 2 Developing a Construction Stormwater Pollution Prevention Plan (SWPPP)

This chapter provides an overview of the important components of, and the process for, developing and implementing a Construction Stormwater Pollution Prevention Plan (SWPPP).

2.1 General Requirements and Guidelines

The Construction SWPPP is a document that describes the potential for pollution problems on a construction project. The Construction SWPPP explains and illustrates the measures to be taken on the construction site to control those problems.

All sites are required to comply with elements #1-#12.

Unless located in a critical area, a SWPPP is not required for projects that:

- Add or replace less than 2000 square feet of impervious surface, or,
- Disturb less than 7000 square feet of land

The Construction Stormwater Pollution Prevention Plan Short Form (Appendix C) may be used for projects that:

- Add or replace between 2000 square feet and 5000 square feet of impervious surface, or,
- Disturb between 7000 square feet and 1 acre

A complete SWPPP is required for projects that:

- Add or replace 5000 square feet or greater of impervious surface, or,
- Disturb greater than1 acre, or,
- Grade/Fill greater than 500 cubic yards of material.

The Construction SWPPP shall be prepared as a separate stand-alone document. Keep the Construction SWPPP on the construction site or within reasonable access to the site for construction and inspection personnel. As site work progresses, the plan must be modified to reflect changing site conditions, subject to the rules for plan modification by the City.

Include all 12 elements described in Volume II, Chapter 1 in the Construction SWPPP unless an element is determined not to be applicable to the project and the exemption is justified in the narrative.

2.1.1 BMP Standards and Specifications

Chapter 3 of this volume contains standards and specifications for the BMPs referred to in this chapter. Wherever any of these BMPs are to be employed on a site, clearly reference the specific title and number of the BMP in the narrative and mark it on the drawings.

Where appropriate BMPs do not exist, experimental practices may be considered or minor modifications to standard practices may be employed. Such practices must be approved by the City before implementation.

2.1.2 General Principles

The following general principles should be applied to the development of any Construction SWPPP.

- Retain the duff layer, native topsoil, and natural vegetation in an undisturbed state to the maximum extent practicable.
- Prevent pollutant release. Select source control BMPs as a first line of defense. Prevent erosion rather than treat turbid runoff.
- Select BMPs depending on site characteristics (topography, drainage, soil type, ground cover, and critical areas) and the construction plan.
- Divert runoff away from exposed areas wherever possible. Keep clean water clean.
- Limit the extent of clearing operations and phase construction operations.
- Before reseeding a disturbed soil area, amend all soils with compost wherever topsoil has been removed.
- Incorporate natural drainage features whenever possible, using adequate buffers and protecting areas where flow enters the drainage system.
- Minimize slope length and steepness.
- Reduce runoff velocities to prevent channel erosion.
- Prevent the tracking of sediment off-site.
- Select appropriate BMPs for the control of pollutants in addition to sediment.
- Be realistic about the limitations of BMPs specified and the operation and maintenance of those BMPs. Anticipate what may go wrong, how you can prevent it from happening, and what will need to be done to fix it.

2.2 Step-by-Step Procedure

There are three basic steps in producing a Construction SWPPP:

- Step 1 - Data Collection
- Step 2 - Data Analysis
- Step 3 - Construction SWPPP Development and Implementation

Steps 1 and 2, described in more detail below, are intended for projects that must complete a full SWPPP. Smaller projects below the thresholds indicated in Section 2.1 may prepare a short form Construction SWPPP, consisting of a checklist and a plan view (see Appendix C).

2.2.1 Step 1 – Data Collection

Evaluate existing site conditions and gather information that will help develop the most effective Construction SWPPP. The information gathered should be explained in the narrative and shown on the drawings. Appendix A provides standard notes required on the drawing.

- ***Topography* -** Prepare a topographic drawing of the site to show the existing contour elevations at intervals of 1 to 5 feet depending upon the slope of the terrain.
- ***Drainage* -** Locate and clearly mark existing drainage ditches, swales, and patterns on the drawing, including existing storm drain pipe systems. Mark location of site runon and runoff on drawing.
- ***Soils* -** Identify and label soil type(s) and erodibility (low, medium, high). A geotechnical investigation may be required since published soils information in the City is very limited. Regardless of the availability of published soils information, the project proponent is responsible for characterizing site soils for erosive potential.
- ***Ground Cover* -** Label existing vegetation on the drawing. Show such features as tree clusters, grassy areas, and unique or sensitive vegetation. Unique vegetation may include existing trees above a given diameter. The City of Auburn encourages tree preservation where possible. In addition, indicate existing denuded or exposed soil areas.
- ***Critical Areas* -** Delineate critical areas adjacent to or within the site on the drawing. Such features as steep slopes, streams, floodplains, lakes, wetlands, sole source aquifers, and geologic hazard areas, etc., should be shown. Delineate setbacks and buffer limits for these features on the drawings. Other related jurisdictional boundaries such as Shorelines Management and the Federal Emergency Management Agency (FEMA) base floodplain should also be shown on the drawings.
- ***Adjacent Areas* -** Identify existing buildings, roads, and facilities adjacent to or within the project site on the drawings. Identify existing and proposed utility locations, construction clearing limits, and erosion and sediment control BMPs on the drawings.
- ***Existing Encumbrances* -** Identify wells, existing and abandoned septic drain fields, utilities, easements, and site constraints.
- ***Precipitation Records* -** Determine the average monthly rainfall and rainfall intensity for the required design storm events.

2.2.2 Step 2 – Data Analysis

Consider the data collected in Step 1 to visualize potential problems and limitations of the site. Determine those areas that have critical erosion hazards. The following are some important factors to consider in data analysis:

- ***Topography* -** The primary topographic considerations are slope steepness and slope length. The longer and steeper the slope, the greater the erosion potential. Erosion potential should be determined by a qualified engineer, soil professional, or certified erosion control specialist. Measures to decrease erosion potential shall be considered.
- ***Drainage* -** Natural drainage patterns that consist of overland flow, swales, and depressions should be used to convey runoff through the site to avoid construction of an artificial drainage system. Man-made ditches and waterways will become part of the erosion problem if they are not properly stabilized. Care should be taken to

ensure that increased runoff from the site will not erode or flood the existing natural drainage system. Possible sites for temporary surface water retention and detention should be considered at this point.

- Direct construction site runoff away from saturated soil areas where groundwater may be encountered and critical areas where drainage will concentrate. Preserve natural drainage patterns on the site.
- ***Soils* -** Evaluate soil properties such as surface and subsurface runoff characteristics, depth to impermeable layer, depth to seasonal groundwater table, permeability, shrink-swell potential, texture, settleability, and erodibility. Develop the Construction SWPPP based on known soil characteristics. Infiltration sites should be properly protected from clay and silt which will reduce infiltration capacities.
- ***Ground Cover* -** Ground cover is the most important factor in terms of preventing erosion. Existing vegetation that can be saved will prevent erosion better than constructed BMPs. Trees and other vegetation protect the soil structure. Disturb as little of the site as required to construct proposed improvements. If the existing vegetation cannot be saved, consider such practices as phasing of construction, temporary seeding, and mulching. Phasing of construction involves stabilizing one part of the site before disturbing another. In this way, the entire site is not disturbed at once.
- ***Critical Areas* -** Critical areas may include flood hazard areas, mine hazard areas, slide hazard areas, sole source aquifers, wetlands, stream banks, fish-bearing streams, and other water bodies. Any critical areas within or adjacent to the development shall be a key consideration on land development decisions. Critical areas and their buffers shall be delineated on the drawings and clearly flagged in the field. Critical areas identified by the City of Auburn are available from the Planning, Building & Community Department. Orange plastic fencing may be more useful than flagging to assure that equipment operators stay out of critical areas. Only unavoidable work should take place within critical areas and their buffers. Such unavoidable work will require special BMPs, permit restrictions, and mitigation plans.
- ***Adjacent Areas* -** An analysis of adjacent properties should focus on areas upslope and down slope from the construction project. Water bodies that will receive direct runoff from the site are a major concern. Investigate and identify runon to the site. The types, values, and sensitivities of and risks to downstream resources, such as private property, stormwater facilities, public infrastructure, or aquatic systems, should be evaluated. Develop a plan to route runon around areas disturbed by construction. Erosion and sediment controls should be selected accordingly.
- ***Precipitation Records* -** Refer to Volume III to determine the required rainfall records and the method of analysis for design of BMPs.
- ***Timing of the Project* -** An important consideration in selecting BMPs is the timing and duration of the project. Projects that will proceed during the wet season and projects that will last through several seasons must take all necessary precautions to remain in compliance with the water quality standards.

2.2.3 Step 3 – Construction SWPPP Development and Analysis

The Construction SWPPP consists of two parts: a narrative and the drawings. This section describes the contents of the narrative and the drawings. The Department of Ecology has prepared a SWPPP template that offers a quick and convenient means for developing a SWPPP for development and redevelopment projects in the City of Auburn. This template can be found on Ecology's website at:

http://www.ecy.wa.gov/programs/wq/stormwater/construction/

NOTE: Ensure that BMP numbers and references match the City SWMM when using the Ecology template.

2.2.3.1 Construction SWPPP Narrative

The following topic headings shall be used, at a minimum, when preparing the Construction SWPPP narrative.

- **Project Description** – Describe the nature and purpose of the construction project. Include the total size of the area, any increase in existing impervious area; the total area expected to be disturbed by clearing, grading, excavation or other construction activities, including off-site borrow and fill areas; and the volumes of grading, cut and fill that are proposed.
- **Existing Site Conditions** – Describe the existing topography, vegetation, and drainage (including runon and runoff). Include a description of any structures or development on the parcel including the area of existing impervious surfaces.
- **Adjacent Areas** – Describe adjacent areas, including streams, lakes, wetlands, residential areas, and roads that might be affected by the construction project. Provide a description of the downstream drainage leading from the site to the receiving body of water.
- **Critical Areas** – Describe areas on or adjacent to the site that are classified as critical areas. Critical areas that receive runoff from the site shall be described up to ¼ mile away. The distance may be increased by the City if special downstream critical areas exist. Describe special requirements for working near or within these areas. Critical areas identified by the City of Auburn from the Planning, Building & Community Department. Critical areas not identified on the website still require consideration.
- **Soils** – Describe the soils on the site, giving such information as soil names, mapping unit, erodibility, settleability, permeability, depth, texture, and soil structure.
- **Potential Erosion Problem Areas** – Describe areas on the site that have potential erosion problems.
- **Construction Stormwater Pollution Prevention Elements** – Describe how the Construction SWPPP addresses each of the 12 required elements. Include the type and location of BMPs used to satisfy the required element. If an element is not applicable to a project, provide a written justification for why it is not necessary.

- **Construction Phasing** – Describe the intended sequence and timing of construction activities.
- **Construction Schedule** – Describe the construction schedule. If the schedule extends into the wet season, describe what activities will continue during the wet season and how the transport of sediment from the construction site to receiving waters will be prevented.
- **Financial/Ownership Responsibilities** – Describe ownership and obligations for the project. Include bond forms and other evidence of financial responsibility for environmental liabilities associated with construction.
- **Engineering Calculations** – Attach any calculations made for the design of BMPs such as sediment ponds, diversions, and waterways, as well as calculations for runoff and stormwater detention design (if applicable). Engineering calculations must bear the signature and stamp of an engineer licensed in the state of Washington. Provide references for all variables used and clearly state any assumptions.

2.2.3.2 Erosion and Sediment Control Drawings

See the City of Auburn Engineering Design Standard 3.04 for plan sheet requirements.

2.3 Construction SWPPP Checklists

The following checklists provide a tool to the applicant to determine if all the major items are included in the Construction SWPPP. The checklist will be used by reviewers to determine that SWPPPs meet all requirements and are complete. Applicants are encouraged to complete and submit this form with their application.

Construction Stormwater Pollution Prevention Plan Checklist

Project Name: ____

Address: ____

Parcel No.: _____________ Section: _________ Township: __________ Range: ________

City Reference/Permit No.: ____

Responsible Parties: Owner:__________________ Engineer:_____________________

Section I – Construction SWPPP Narrative

1. Project Description

☐ A. Total project area.
☐ B. Total proposed impervious area.
☐ C. Total proposed area to be disturbed, including off-site borrow and fill areas.
☐ D. Total volumes of proposed cut and fill.

2. Existing Site Conditions

☐ A. Description of the existing topography.
☐ B. Description of the existing vegetation.
☐ C. Description of the existing drainage.

3. Adjacent Areas

☐ A. Description of adjacent areas which may be affected by site disturbance

- ☐ 1. Streams
- ☐ 2. Lakes
- ☐ 3. Wetlands
- ☐ 4. Residential areas
- ☐ 5. Roads
- ☐ 6. Ditches, pipes, culverts
- ☐ 7. Other

☐ B. Description of the downstream drainage path leading from the site to the receiving body
of water (minimum distance of ¼ mile.)

4. Critical Areas

☐ A. Description of critical areas that are on or adjacent to the site.
☐ B. Description of special requirements for working in or near critical areas.

Construction Stormwater Pollution Prevention Plan Checklist

Project Name: ____________________

Address: ____________________ Parcel No: ____________________

City Reference/Permit No.: ____________________

5. Soils

☐ Description of on-site soils.
- ☐ 1. Soil name(s)
- ☐ 2. Soil mapping unit

The following information may be required:
- Erodibility
- Settleability
- Permeability
- Depth
- Texture
- Soil structure

6. Potential Erosion Problem Areas

☐ Description of potential erosion problems on site.

7. Construction Stormwater Pollution Prevention Elements

☐ A. Describe how each of the Construction Stormwater Pollution Prevention Elements has
been addressed though the Construction SWPPP.
☐ B. Identify the type and location of BMPs used to satisfy the required element.
☐ C. Written justification identifying the reason an element is not applicable to the proposal.

12 Required Elements - Construction Stormwater Pollution Prevention Plan:

☐ 1. Mark Clearing Limits
☐ 2. Establish Construction Access
☐ 3. Control Flow Rates
☐ 4. Install Sediment Controls
☐ 5. Stabilize Soils
☐ 6. Protect Slopes
☐ 7. Protect Drain Inlets
☐ 8. Stabilize Channels and Outlets
☐ 9. Control Pollutants
☐ 10. Control Dewatering
☐ 11. Maintain BMPs
☐ 12. Manage the Project

Construction Stormwater Pollution Prevention Plan Checklist

Project Name: ____________________

Address: ____________________ Parcel No: ____________________

City Reference/Permit No.: ____________________

8. Construction Phasing

☐ A. Construction sequence
☐ B. Construction phasing (if proposed)

9. Construction Schedule

☐ A. Provide a proposed construction schedule.
☐ B. Wet Season Construction Activities
- ☐ 1. Proposed wet season construction activities.
- ☐ 2. Proposed wet season construction restraints for environmentally sensitive/critical areas.

10. Financial/Ownership Responsibilities

☐ A. Identify the property owner responsible for the initiation of bonds and/or other financial securities.
☐ B. Describe bonds and/or other evidence of financial responsibility for liability associated with erosion and sedimentation impacts.
☐ C. Maintenance bond.

11. Engineering Calculations

☐ Provide Design Calculations.
- ☐ 1. Sediment ponds/traps
- ☐ 2. Diversions
- ☐ 3. Waterways
- ☐ 4. Runoff/stormwater detention calculations

Construction Stormwater Pollution Prevention Plan Checklist

Project Name: ____

Address: ______________________________ Parcel No.: ________________

City Reference/Permit No.: ______________________________________

Responsible Parties: Owner: ________________ Engineer: ______________

Section II - Erosion and Sediment Control Drawings

1. General

☐ A. Vicinity map with roads and waters of the state within one mile of the site.
☐ B. Address, Parcel Number, and Street names labels
☐ C. Erosion and Sediment Control Notes

2. Site Plan

☐ A. Legal description of subject property.
☐ B. North Arrow
☐ C. Indicate boundaries of existing vegetation, e.g. tree lines, pasture areas, etc.
☐ D. Identify and label areas of potential erosion problems.
☐ E. Identify any on-site or adjacent surface waters, critical areas and associated buffers.
☐ F. Identify FEMA base flood boundaries and Shoreline Management boundaries (if applicable).
☐ G. Show existing and proposed contours.
☐ H. Indicate drainage basins and direction of flow for individual drainage areas.
☐ I. Label final grade contours and identify developed condition drainage basins.
☐ J. Delineate areas that are to be cleared and graded.
☐ K. Show all cut and fill slopes indicating top and bottom of slope catch lines.

3. Conveyance Systems

☐ A. Designate locations for swales, interceptor trenches, or ditches.
☐ B. Show all temporary and permanent drainage pipes, ditches, or cut-off trenches required for erosion and sediment control.
☐ C. Provide minimum slope and cover for all temporary pipes or call out pipe inverts.
☐ D. Show grades, dimensions, and direction of flow in all ditches, swales, culverts and pipes.
☐ E. Provide details for bypassing offsite runoff around disturbed areas.
☐ F. Indicate locations and outlets of any dewatering systems.

4. Location of Detention BMPs

☐ Identify location of detention BMPs.

Construction Stormwater Pollution Prevention Plan Checklist

Project Name: ____

Address: ______________________________ Parcel No.: ________________

City Reference/Permit No.: ____________________________________

5. Erosion and Sediment Control Facilities

☐ Show the locations of all ESC facilities with dimensions and details as appropriate.

6. Detailed Drawings

☐ Any best management practices used that are not referenced in the SWMM should be explained and illustrated with detailed drawings.

7. Other Pollutant BMPs

☐ Indicate on the site plan the location of BMPs to be used for the control of pollutants other than sediment, e.g. concrete wash water.

8. Monitoring Locations

☐ Indicate on the site plan the water quality sampling locations to be used for monitoring water quality on the construction site, if applicable.

☐ Describe inspection reporting responsibility, documentation, and filing.

Chapter 3 Standards and Specifications for Best Management Practices (BMPs)

BMPs are defined as schedules of activities, prohibitions of practices, maintenance procedures, and structural and/or managerial practices, that when used singly or in combination, prevent or reduce the release of pollutants to waters of Washington State. This chapter contains standards and specifications for temporary BMPs to be used as applicable during the construction phase of a project.

Section 3.1 contains the standards and specifications for Source Control BMPs specific to construction operations.

Section 3.2 contains the standards and specifications for Runoff Conveyance and Treatment BMPs.

The standards for each individual BMP are divided into four sections:

1. Purpose
2. Conditions of Use
3. Design and Installation Specifications
4. Maintenance Standards

Note that the “Conditions of Use” always refers to site conditions. As site conditions change, BMPs must be changed to remain in compliance.

Information on stream bank stabilization is available in the Integrated Streambank Protection Guidelines, Washington State Department of Fish and Wildlife, 2003.

3.1 Source Control BMPs

3.1.1 BMP C101: Preserving Natural Vegetation

3.1.1.1 Purpose

The purpose of preserving natural vegetation is to reduce erosion wherever practicable. Limiting site disturbance is the single most effective method for reducing erosion. For example, conifers can hold up to about 50 percent of all rain that falls during a storm. Up to 20-30 percent of this rain may never reach the ground but is taken up by the tree or evaporates. Another benefit is that the rain held in the tree can be released slowly to the ground after the storm.

3.1.1.2 Conditions of Use

Natural vegetation should be preserved on steep slopes, near perennial and intermittent watercourses or swales, in wooded areas, and any other location practicable.

3.1.1.3 Design and Installation Specifications

Natural vegetation can be preserved in natural clumps or as individual trees, shrubs and vines.

The preservation of individual plants is more difficult because heavy equipment is generally used to remove unwanted vegetation. The points to remember when attempting to save individual plants are:

- Is the plant worth saving? Consider the location, species, size, age, vigor, and the work involved. The City of Auburn encourages the preservation of natural vegetation and trees.
- Fence or clearly mark areas around trees that are to be saved. Keep ground disturbance away from the trees as far out as the dripline (at a minimum).

Plants need protection from three kinds of injuries:

- ***Construction Equipment*** - This injury can be above or below the ground level. Damage results from scarring, cutting of roots, and compaction of the soil. Placing a fenced buffer zone around plants to be saved prior to construction can prevent construction equipment injuries.
- ***Grade Changes*** - Changing the natural ground level will alter grades, which affects the plant's ability to obtain the necessary air, water, and minerals. Minor fills usually do not cause problems although sensitivity between species does vary and should be checked. Trees can tolerate fill of 6 inches or less. For shrubs and other plants, the fill should be less.

  When there are major changes in grade, it may become necessary to supply air to the roots of plants. This can be done by placing a layer of gravel and a tile system over the roots before the fill is made. A tile system protects a tree from a raised grade. The tile system should be laid out on the original grade leading from a dry well around the tree trunk. The system should then be covered with small stones to allow air to circulate over the root area.

Lowering the natural ground level can seriously damage trees and shrubs. The highest percentage of the plant roots are in the upper 12 inches of the soil and cuts of only 2-3 inches can cause serious injury. To protect the roots, it may be necessary to terrace the immediate area around the plants to be saved. If roots are exposed, construction of retaining walls may be needed to keep the soil in place. Plants can also be preserved by leaving them on an undisturbed, gently sloping mound. To increase the chances for survival, it is best to limit grade changes and other soil disturbances to areas outside the dripline of the plant.

- ***Excavations* -** Protect trees and other plants when excavating for drainfields, power, water, and sewer lines. Where possible, route the trenches around trees and large shrubs. When this is not possible, it is best to tunnel under them. This can be done with hand tools or power augers. If it is not possible to route the trench around plants to be saved, then the following methods should be observed:
  - Cut as few roots as possible. When you have to cut, cut clean. Paint cut root ends with a wood dressing like asphalt base paint.
  - Backfill the trench as soon as possible.
  - Tunnel beneath root systems as close to the center of the main trunk as possible to preserve most of the important feeder roots.

Some problems that can be encountered with a few specific trees are:

- Maple, Dogwood, Red alder, Western hemlock, Western red cedar, and Douglas fir do not readily adjust to changes in environment and special care should be taken to protect these trees.
- The windthrow hazard of Pacific silver fir and madrona is high, while that of Western hemlock is moderate. The danger of windthrow increases where dense stands have been thinned. Other species (unless they are in shallow, wet soils less than 20 inches deep) have a low windthrow hazard.
- Cottonwoods, maples, and willows have water-seeking roots. These species thrive in high moisture conditions that other trees would not. Roots of these plants can cause problems in sewer lines and infiltration fields.
- Thinning operations in pure or mixed stands of Grand fir, Pacific silver fir, Noble fir, Sitka spruce, Western red cedar, Western hemlock, Pacific dogwood, and Red alder can cause serious disease problems. Disease can become established through damaged limbs, trunks, roots, and freshly cut stumps. Diseased and weakened trees are also susceptible to insect attack.

3.1.1.4 Maintenance Standards

- Inspect flagged and/or fenced areas regularly to make sure flagging or fencing has not been removed or damaged. If the flagging or fencing has been damaged or visibility reduced, it shall be repaired or replaced immediately and visibility restored.
- If tree roots have been exposed or injured, “prune” cleanly with an appropriate pruning saw or loppers directly above the damaged roots and recover with native soils. Treatment of sap flowing trees (fir, hemlock, pine, soft maples) is not advised as sap forms a natural healing barrier.

3.1.2 BMP C102: Buffer Zone

3.1.2.1 Purpose

An undisturbed area or strip of natural vegetation or an established suitable planting that will provide a living filter to reduce soil erosion and runoff velocities.

3.1.2.2 Conditions of Use

Natural buffer zones are used along streams, wetlands and other bodies of water that need protection from erosion and sedimentation. Vegetative buffer zones can be used to protect natural swales and can be incorporated into the natural landscaping of an area.

Critical-areas buffer zones should not be used as sediment treatment areas. Do not disturb critical area buffers. The City may expand the buffer widths temporarily to allow the use of the expanded area for removal of sediment.

3.1.2.3 Design and Installation Specifications

- Preserve natural vegetation or plantings in clumps, blocks, or strips as this is generally the easiest and most successful method. However, single specimen trees and plants should also be preserved.
- Leave all unstable slopes in their natural, undisturbed state.
- Mark clearing limits and keep all equipment and construction debris out of the natural areas. Steel construction fencing is the most effective method of protecting sensitive areas and buffers. Alternatively, wire-backed silt fence on steel posts is marginally effective. Flagging alone is typically not effective and will not be allowed.
- Keep all excavations outside the dripline of trees and shrubs.
- Do not push debris or extra soil into the buffer zone area because it will cause damage from burying and smothering.
- Vegetative buffer zones for streams, lakes or other waterways shall be established by the City or other state or federal permits or approvals.

3.1.2.4 Maintenance Standards

- Inspect the area frequently to make sure flagging remains in place and the area remains undisturbed.

3.1.3 BMP C103: High Visibility Plastic or Metal Fence

3.1.3.1 Purpose

Fencing is intended to:

- Restrict clearing to approved limits.
- Prevent disturbance of sensitive areas, their buffers, and other areas required to be left undisturbed.
- Limit construction traffic to designated construction entrances or roads.
- Protect areas where marking with survey tape may not provide adequate protection.

3.1.3.2 Conditions of Use

To establish clearing limits, plastic or metal fence may be used:

- At the boundary of sensitive areas, their buffers, and other areas required to be left uncleared.
- As necessary to control vehicle access to and on the site.

3.1.3.3 Design and Installation Specifications

- High visibility plastic fence shall be composed of a high-density polyethylene material and shall be at least four feet in height. Posts for the fencing shall be steel or wood and placed every 6 feet on center (maximum) or as needed to ensure rigidity. The fencing shall be fastened to the post every six inches with a polyethylene tie. On long continuous lengths of fencing, a tension wire or rope shall be used as a top stringer to prevent sagging between posts. See City of Auburn Construction Standards for high visibility fence specifications.
- Design and install metal fences according to the manufacturer's specifications.
- Metal fences shall be at least 3 feet high and must be highly visible.
- Do not wire or staple fences to trees.

3.1.3.4 Maintenance Standards

- If the fence has been damaged or visibility reduced, it shall be repaired or replaced immediately and visibility restored.

3.1.4 BMP C104: Stake and Wire Fence

3.1.4.1 Purpose

Fencing is intended to:

- Restrict clearing to approved limits.
- Prevent disturbance of sensitive areas, their buffers, and other areas required to be left undisturbed.
- Limit construction traffic to designated construction entrances or roads.
- Protect areas where marking with survey tape may not provide adequate protection.

3.1.4.2 Conditions of Use

To establish clearing limits, stake or wiring fence may be used:

- At the boundary of sensitive areas, their buffers, and other areas required to be left uncleared.
- As necessary to control vehicle access to and on the site.

3.1.4.3 Design and Installation Specifications

- See Figure II-3-1 for details.
- Use more substantial fencing if the fence does not prevent encroachment into those areas that are not to be disturbed.

3.1.4.4 Maintenance Standards

- If the fence has been damaged or visibility reduced, it shall be repaired or replaced immediately and visibility restored.

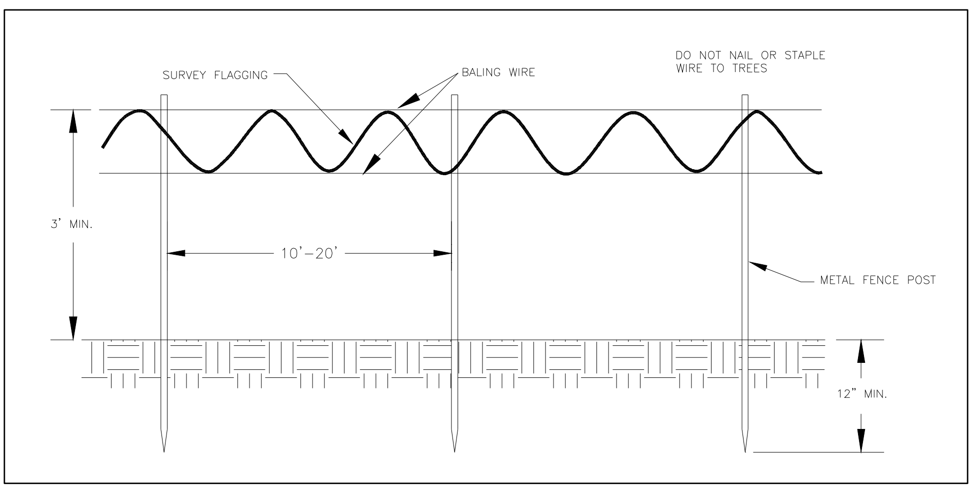


Figure II-3-1. Stake and Wire Fence

3.1.5 BMP C105: Stabilized Construction Entrance

3.1.5.1 Purpose

Construction entrances are stabilized to reduce the amount of sediment transported onto paved roads by vehicles or equipment by constructing a stabilized pad of quarry spalls at entrances to construction sites.

3.1.5.2 Conditions of Use

Construction entrances shall be stabilized wherever traffic will be leaving a construction site and traveling on paved roads or other paved areas within 1,000 feet of the site.

On large commercial, highway, and road projects, the designer should include enough extra materials in the contract to allow for additional stabilized entrances not shown in the initial Construction SWPPP. It is difficult to determine exactly where access to these projects will take place; additional materials will enable the contractor to install them where needed.

3.1.5.3 Design and Installation Specifications

- See Figure II-3-2 for details.

  NOTE: Reduce the length of the entrance to the maximum practicable size when the size or configuration of the site does not allow the full 100-foot length.

- Place a separation geotextile under the spalls to prevent fine sediment from pumping up into the rock pad. The geotextile shall meet the following standards:
  - Grab Tensile Strength (ASTM D4751) – 200 psi min.
  - Grab Tensile Elongation (ASTM D4632) – 30% max.
  - Mullen Burst Strength (ASTM D3786-80a) – 400 psi min.
  - AOS (ASTM D4751) – 20 to 45 (U.S. standard sieve size)
- Consider early installation of the first lift of asphalt in areas that will be paved; this can be used as a stabilized entrance. Also consider the installation of excess concrete as a stabilized entrance. During large concrete pours, excess concrete is often available for this purpose.
- Install fencing (see BMPs C103 and C104) as necessary to restrict traffic to the construction entrance.
- Whenever possible, construct the entrance on a firm, compacted subgrade. This can substantially increase the effectiveness of the pad and reduce the need for maintenance.

3.1.5.4 Maintenance Standards

- Add quarry spalls if the pad is no longer in accordance with the specifications.
- If the entrance is not preventing sediment from being tracked onto pavement, then alternative measures to keep the streets free of sediment shall be used. This may

include street sweeping, an increase in the dimensions of the entrance, or the installation of a wheel wash.

- No tracking of sediment onto the roadway is allowed. If sediment is tracked onto the road, clean the road thoroughly by shoveling or pickup sweeping. Transport sediment to a controlled sediment disposal area.
- Keep streets clean at ALL times. Clean tracked sediment immediately.
- Street washing of sediment to the storm drain system is not allowed.
- Immediately remove any quarry spalls that are loosened from the pad and end up on the roadway.
- Install fencing (BMPs C103 and C104) to control traffic if vehicles are entering or exiting the site at points other than the construction entrance(s).
- Upon project completion and site stabilization, permanently stabilize all construction accesses intended as permanent access for maintenance.

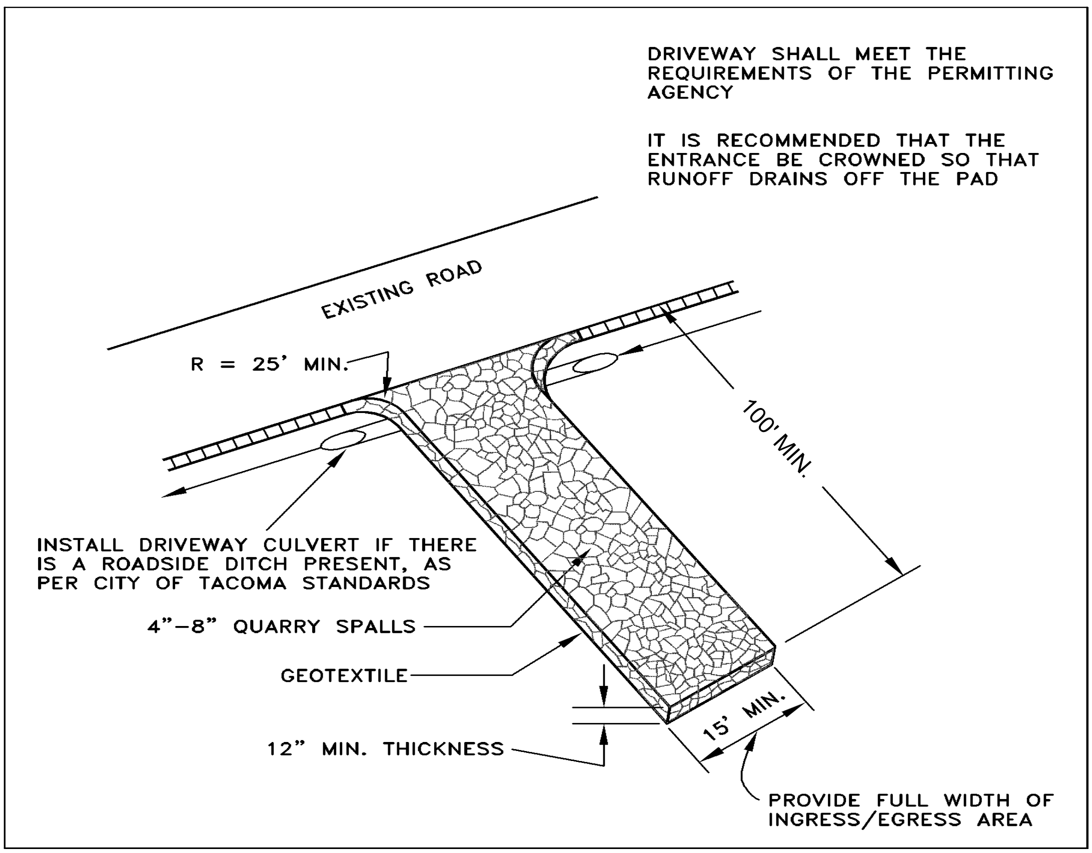


Figure II-3-2. Stabilized Construction Entrance

Figure II-3-3 shows a small site, stabilized construction entrance.

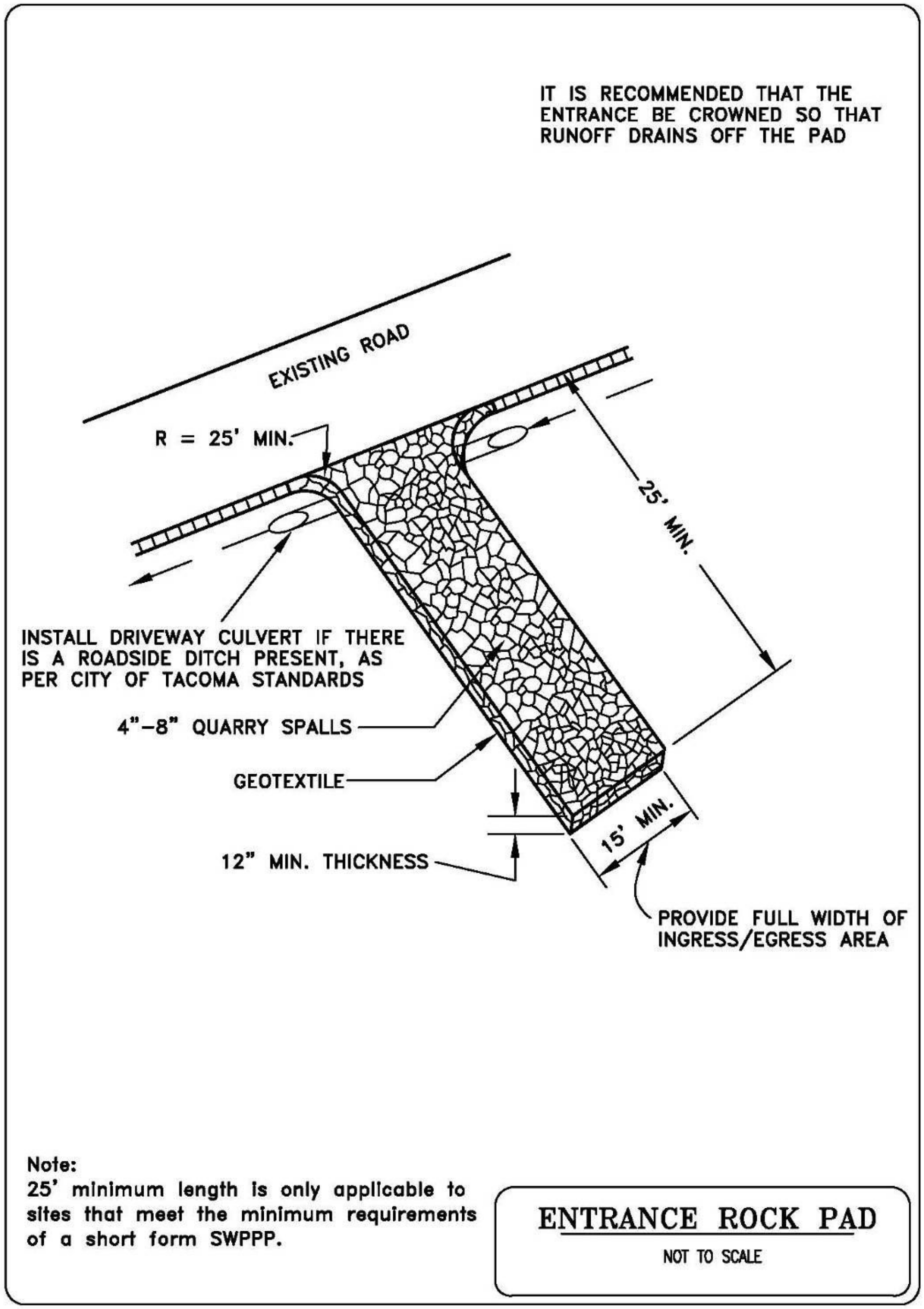


Figure II-3-3. Small-Site Stabilized Construction Entrance

3.1.6 BMP C106: Wheel Wash

3.1.6.1 Purpose

Wheel washes reduce the amount of sediment transported onto paved roads by motor vehicles.

3.1.6.2 Conditions of Use

Can be used when a stabilized construction entrance (see BMP C105) is not preventing sediment from being tracked onto pavement.

- Wheel washing is generally an effective BMP when installed with careful attention to topography. For example, a wheel wash can be detrimental if installed at the top of a slope abutting a right-of-way where the water from the dripping truck can run unimpeded into the street.
- Pressure washing combined with an adequately sized and surfaced pad with direct drainage to a large 10-foot x 10-foot sump can be very effective.

3.1.6.3 Design and Installation Specifications

Suggested details are shown in Figure II-3-4. The City may allow other designs. A minimum of 6 inches of asphalt treated base (ATB) over crushed base material or 8 inches over a good subgrade is recommended to pave the wheel wash.

Use a low clearance truck to test the wheel wash before paving. Either a belly dump or lowboy will work well to test clearance.

Keep the water level from 12 to 14 inches deep to avoid damage to truck hubs and filling the truck tongues with water.

Midpoint spray nozzles are only needed in extremely muddy conditions.

Design wheel wash systems with a small grade change, 6 to 12 inches for a 10-foot-wide pond, to allow sediment to flow to the low side of pond to help prevent re-suspension of sediment. A drainpipe with a 2- to 3-foot riser should be installed on the low side of the pond to allow for easy cleaning and refilling. Polymers may be used to promote coagulation and flocculation in a closed-loop system. Polyacrylamide (PAM) added to the wheel wash water at a rate of 0.25 - 0.5 pounds per 1,000 gallons of water increases effectiveness and reduces cleanup time. If PAM is already being used for dust or erosion control and is being applied by a water truck, the same truck can be used to change the wash water.

3.1.6.4 Maintenance Standards

The wheel wash should start out the day with fresh water.

The wash water should be changed a minimum of once per day. On large earthwork jobs where more than 10 to 20 trucks per hour are expected, the wash water will need to be changed more often.

Wheel wash or tire bath wastewater shall be discharged to a separate on-site treatment system, such as closed-loop recirculation or land application, or to the sanitary sewer with a King County – Metro wastewater discharges from construction sites permit.

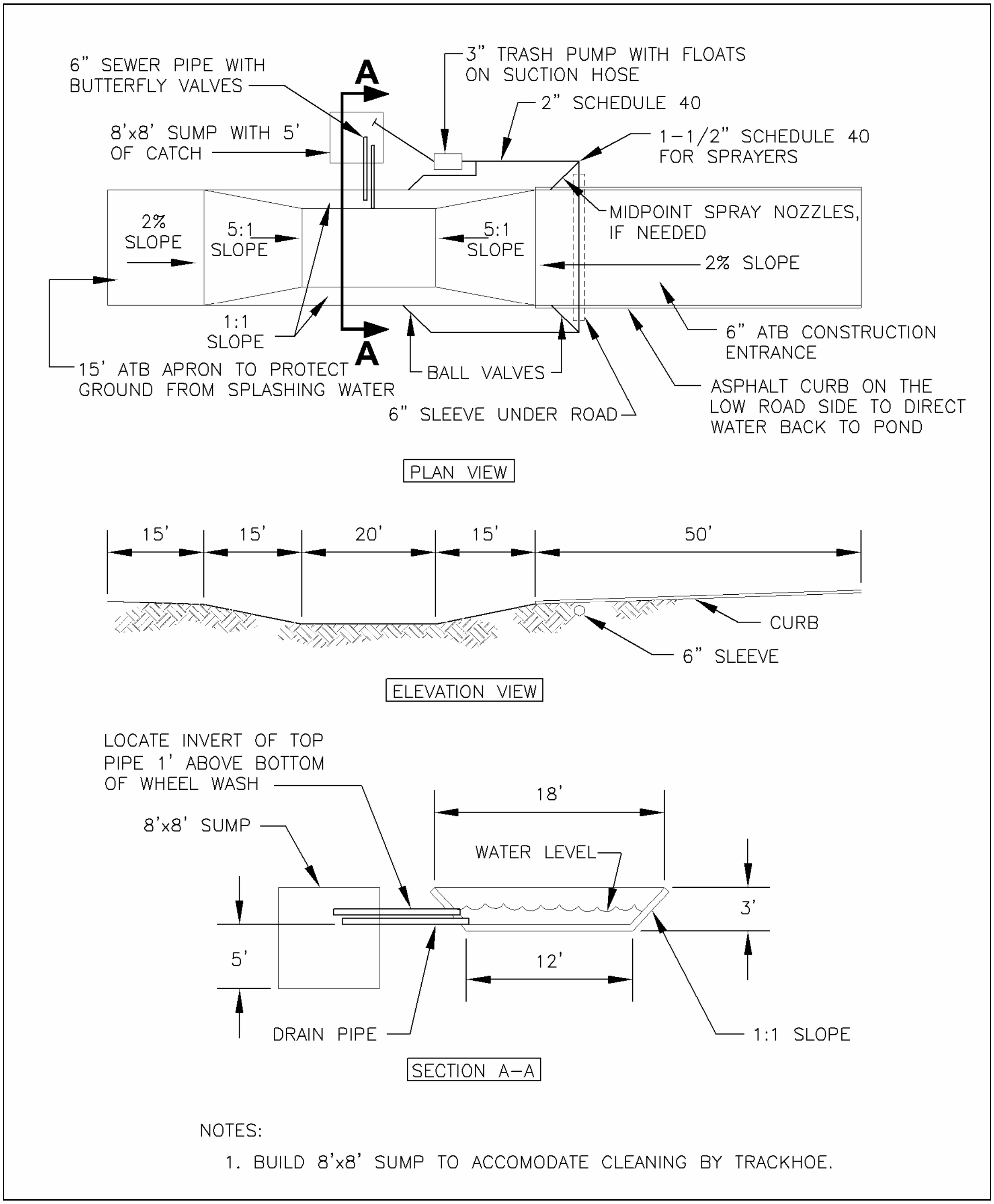


Figure II-3-4. Wheel Wash

3.1.7 BMP C107: Construction Road/Parking Area Stabilization

3.1.7.1 Purpose

Stabilizing subdivision roads, parking areas and other onsite vehicle transportation routes immediately after grading reduces erosion caused by construction traffic or runoff.

3.1.7.2 Conditions of Use

- Stabilize roads or parking areas wherever they are constructed, whether permanent or temporary, for use by construction traffic.
- Install fencing (see BMPs C103 and C104), if necessary, to limit the access of vehicles to only those roads and parking areas that are stabilized.

3.1.7.3 Design and Installation Specifications

- On areas that will receive asphalt as part of the project, install the first lift as soon as possible.
- Apply a 6-inch depth of 2- to 4-inch crushed rock, gravel base, or crushed surfacing base course immediately after grading or utility installation. A 4-inch course of asphalt treated base (ATB) may also be used, or the road/parking area may be paved. It may also be possible to use cement or calcium chloride for soil stabilization. If cement or cement kiln dust is used for roadbase stabilization, pH monitoring and BMPs are necessary to evaluate and minimize the effects on stormwater. If the area will not be used for permanent roads, parking areas, or structures, a 6-inch depth of hog fuel may also be used, but this is likely to require more maintenance. Whenever possible, place construction roads and parking areas on a firm, compacted subgrade.
- Temporary road gradients shall not exceed 15 percent. Carefully grade roadways to drain. Provide drainage ditches on each side of the roadway in the case of a crowned section, or on one side in the case of a super-elevated section. Direct drainage ditches to a sediment control BMP.
- Rather than relying on ditches, it may also be possible to grade the road so that runoff sheet-flows into a heavily vegetated area with a well-developed topsoil. Landscaped areas are not adequate. If this area has at least 50 feet of vegetation, then it is generally preferable to use the vegetation to treat runoff, rather than a sediment pond or trap. The 50 feet shall not include wetlands. If runoff is allowed to sheetflow through adjacent vegetated areas, it is vital to design the roadways and parking areas so that no concentrated runoff is created.
- Protect storm drain inlets to prevent sediment-laden water entering the storm drain system (see BMP C220).

3.1.7.4 Maintenance Standards

- Inspect stabilized areas regularly, especially after large storm events.
- Add crushed rock, gravel base, hog fuel, etc. as required to maintain a stable driving surface and to stabilize any eroded areas.
- Following construction, restore all areas to preconstruction condition or better to prevent future erosion.

3.1.8 BMP C120: Temporary and Permanent Seeding

3.1.8.1 Purpose

Seeding is intended to reduce erosion by stabilizing exposed soils. A well-established vegetative cover is one of the most effective methods of reducing erosion.

3.1.8.2 Conditions of Use

- Seeding may be used throughout the project on disturbed areas that have reached final grade or that will remain unworked for more than 30 days.
- Channels that will be vegetated should be installed before major earthwork and hydroseeded with a Bonded Fiber Matrix. The vegetation should be well established (i.e., 75 percent cover) before water is allowed to flow in the ditch. With channels that will have high flows, install erosion control blankets over the hydroseed. If vegetation cannot be established from seed before water is allowed in the ditch, sod should be installed in the bottom of the ditch over hydromulch and blankets.
- Seed retention/detention ponds as required.
- Mulch is required at all times because it protects seeds from heat, moisture loss, and transport due to runoff.
- All disturbed areas shall be reviewed in late August to early September and all seeding shall be completed by the end of September. Otherwise, vegetation will not establish itself enough to provide more than average protection.
- At final site stabilization, seed and mulch all disturbed areas not otherwise vegetated or stabilized. Final stabilization means the completion of all soil disturbing activities at the site and the establishment of a permanent vegetative cover, or equivalent permanent stabilization measures (such as pavement, riprap, gabions, or geotextiles) which will prevent erosion.

3.1.8.3 Design and Installation Specifications

- Seed during seasons most conducive to plant growth. The optimum seeding windows for western Washington are April 1 through June 30 and September 1 through October 1. Seeding that occurs between July 1 and August 30 will require irrigation until 75 percent grass cover is established. Seeding that occurs between October 1 and March 30 will require a mulch or plastic cover until 75 percent grass cover is established.
- Deviation from these specifications shall be allowed if alternatives are developed by a licensed Landscape Professional and approved by the City.
- To prevent seed from being washed away, confirm that all required surface water control measures have been installed.
- The seedbed should be firm and rough. All soil should be roughened no matter what the slope. If compaction is required for engineering purposes, track walk slopes before seeding. Backblading or smoothing of slopes greater than 4:1 is not allowed if they are to be seeded.

- New and more effective restoration-based landscape practices rely on deeper incorporation than that provided by a simple single-pass rototilling treatment. Wherever practical, the subgrade should be initially ripped to improve long-term permeability, infiltration, and water inflow qualities. At a minimum for permanent areas, use soil amendments to achieve organic matter and permeability performance defined in engineered soil/landscape systems. For systems that are deeper than 8 inches, complete the rototilling process in multiple lifts, or prepare the soil system properly and then place it to achieve the specified depth.
- Organic matter is the most appropriate form of “fertilizer” because it provides nutrients (including nitrogen, phosphorus, and potassium) in the least water-soluble form. A natural system typically releases 2-10 percent of its nutrients annually. Chemical fertilizers have since been formulated to simulate what organic matter does naturally.
- In general, 10-4-6 N-P-K (nitrogen-phosphorus-potassium) fertilizer can be used at a rate of 90 pounds per acre. Always use slow-release fertilizers because they are more efficient and have fewer environmental impacts. It is recommended that soils tests are conducted in areas being seeded for final landscaping to determine the exact type and quantity of fertilizer needed. This will prevent the over-application of fertilizer. Fertilizer should not be added to the hydromulch machine and agitated more than 20 minutes before it is to be used. If agitated too much, the slow-release coating is destroyed.
- There are numerous products available on the market that take the place of chemical fertilizers. These include several with seaweed extracts that are beneficial to soil microbes and organisms. If 100 percent cottonseed meal is used as the mulch in hydroseed, chemical fertilizer may not be necessary. Cottonseed meal is a good source of long-term, slow-release, available nitrogen.
- Hydroseed applications shall include a minimum of 1,500 pounds per acre of mulch with 3 percent tackifier. Mulch may be made up of 100 percent: cottonseed meal; fibers made of wood, recycled cellulose, hemp, and kenaf; compost; or blends of these. Tackifier shall be plant-based, such as guar or alpha plantago, or chemical-based such as polyacrylamide or polymers. Any mulch or tackifier product used shall be installed per manufacturer’s instructions. Generally, mulches come in 40-50 pound bags. Seed and fertilizer are added at time of application.
- Mulch is always required for seeding. Mulch can be applied on top of the seed or simultaneously by hydroseeding.
- On steep slopes, Bonded Fiber Matrix (BFM) or Mechanically Bonded Fiber Matrix (MBFM) products should be used. BFM/MBFM products are applied at a minimum rate of 3,000 pounds per acre of mulch with approximately 10 percent tackifier. Application is made so that a minimum of 95 percent soil coverage is achieved. Numerous products are available commercially and should be installed per manufacturer’s instructions. Most products require 24 to 36 hours to cure before a rainfall and cannot be installed on wet or saturated soils. Generally, these products come in 40 to 50 pound bags and include all necessary ingredients except for seed and fertilizer.

- BFMs and MBFMs have some advantages over blankets:
  - No surface preparation required;
  - On slopes steeper than 2.5:1, blanket installers may need to be roped and harnessed for safety;
- In most cases, the shear strength of blankets is not a factor when used on slopes, only when used in channels. BFMs and MBFMs are good alternatives to blankets in most situations where vegetation establishment is the goal.
- When installing seed via hydroseeding operations, only about 1/3 of the seed actually ends up in contact with the soil surface. This reduces the ability to establish a good stand of grass quickly. One way to overcome this is to increase seed quantities by up to 50 percent.
- Vegetation establishment can also be enhanced by dividing the hydromulch operation into two phases:
  - Phase 1- Install all seed and fertilizer with 25 to 30 percent mulch and tackifier onto soil in the first lift;
  - Phase 2- Install the rest of the mulch and tackifier over the first lift.
- An alternative is to install the mulch, seed, fertilizer, and tackifier in one lift. Then, spread or blow straw over the top of the hydromulch at a rate of about 800 to 1,000 pounds per acre. Hold straw in place with a standard tackifier. Both of these approaches will increase cost moderately but will greatly improve and enhance vegetative establishment. The increased cost may be offset by the reduced need for:
  - Irrigation
  - Reapplication of mulch
  - Repair of failed slope surfaces
  - This technique works with standard hydromulch (1,500 pounds per acre minimum) and BFM/MBFMs (3,000 pounds per acre minimum).
- Provide a healthy topsoil to areas to be permanently landscaped. This will reduce the need for fertilizers, improve overall topsoil quality, provide for better vegetal health and vitality, improve hydrologic characteristics, and reduce the need for irrigation. See the Post-Construction Soil Quality and Depth BMP in Volume VI for more information. Areas that will be seeded only and not landscaped may need compost or meal-based mulch included in the hydroseed in order to establish vegetation. Replace native topsoil on the disturbed soil surface before application.
- Seed that is installed as a temporary measure may be installed by hand if it will be covered by straw, mulch, or topsoil. Seed that is installed as a permanent measure may be installed by hand on small areas (usually less than 1 acre) that will be covered with mulch, topsoil, or erosion blankets. The seed mixes listed below include recommended mixes for both temporary and permanent seeding. These mixes, with the exception of the wetland mix, shall be applied at a rate of 120 pounds per acre. This rate can be reduced if soil amendments or slow-release fertilizers are used. Local suppliers or the local conservation district should be consulted for their

recommendations because the appropriate mix depends on a variety of factors, including location, exposure, soil type, slope, and expected foot traffic. Alternative seed mixes approved by the City of Auburn may be used.

- Table II-3-1 represents the standard mix for those areas where just a temporary vegetative cover is required.
- Table II-3-2 provides just one recommended possibility for landscaping seed.
- The turf seed mix in Table II-3-3 is for dry situations. The advantage is that this mix requires very little maintenance.
- Table II-3-4 presents a mix recommended for bioswales and other intermittently wet areas.
- The seed mix shown in Table II-3-5 is a recommended low-growing, relatively non-invasive seed mix appropriate for very wet areas that are not regulated wetlands. Other mixes may be appropriate, depending on the soil type and hydrology of the area. Recent research suggests that bentgrass (agrostis sp.) should be emphasized in wet-area seed mixes. Apply this mixture at a rate of 60 pounds per acre.
- The meadow seed mix in Table II-3-6 is recommended for areas that will be maintained infrequently or not at all and where colonization by native plants is desirable. Likely applications include rural road and utility right-of-way. Seeding should take place in September or very early October in order to obtain adequate establishment prior to the winter months. The appropriateness of clover in the mix may need to be considered, as this can be a fairly invasive species. If the soil is amended, the addition of clover may not be necessary.

3.1.8.4 Maintenance Standards

- Reseed any seeded areas that fail to establish at least 80 percent cover within 6 weeks from the initial seeding (100 percent cover for areas that receive sheet or concentrated flows). If reseeding is ineffective, use an alternate method, such as sodding, mulching, or nets/blankets. If winter weather prevents adequate grass growth, this time limit may be relaxed at the discretion of the City.
- After adequate cover is achieved, reseed and protect with mulch any areas that experience erosion. If the erosion problem is drainage related, the problem shall be fixed and the eroded area reseeded and protected by mulch.
- Water seeded areas if necessary. Watering shall not cause runoff.

Table II-3-1. Temporary Erosion Control Seed Mix

	% Weight	% Purity	% Germination
Chewings or annual bluegrass *Festuca rubra var. commutate or Poa anna*	40	98	90
Perennial rye *Lolium perenne*	50	98	90
Redtop or colonial bentgrass *Agrostis alba or Agrostis tenuis*	5	92	85
White Dutch clover *Trifolium repens*	5	98	90

Table II-3-2. Landscaping Seed Mix

	% Weight	% Purity	% Germination
Perennial rye *Lolium perenne*	70	98	90
Chewings and red fescue blend *Festuca rubra var commutate or Festuca rubra*	30	98	90

Table II-3-3. Low-Growing Turf Seed Mix

	% Weight	% Purity	% Germination
Dwarf tall fescue (several varieties) *Festuca arundinacea var.*	45	98	90
Dwarf perennial rye (Barclay) *Lolium perenne var. barclay*	30	98	90
Red fescue *Festuca rubra*	20	98	90
Colonial bentgrass *Agrostis tenuis*	5	98	90

Table II-3-4. Bioswale Seed Mix[1]

	% Weight	% Purity	% Germination
Tall or meadow fescue *Festuca arundinacea or Festuca elatior*	75-80	98	90
Seaside/Creeping bentgrass *Agrostis palustriis*	1-15	92	85
Redtop bentgrass *Agrostis alba or Agrostis gigantea*	5-10	90	80

[1]Modified Briargreen, Inc. Hydroseeding Guide Wetlands Seed Mix

Table II-3-5. Wet Area Seed Mix

	% Weight	% Purity	% Germination
Tall or meadow fescue *Festuca arundinacea or Festuca elatior*	60-70	98	90
Seaside/Creeping bentgrass *Agrostis palustriis*	10-15	98	85
Meadow foxtail *Alepocurus pratensis*	10-15	90	80
Alsike clover *Trifolium hybridium*	1-6	98	90
Redtop bentgrass *Agrostis alba or Agrostis gigantea*	106	92	85

Table II-3-6. Meadow Seed Mix

	% Weight	% Purity	% Germination
Redtop or Oregon bentgrass *Agrostis alba or Agrostis oregonensis*	20	92	85
Red fescue *Festuca rubra*	70	98	90
White Dutch clover *Trifolium repens*	10	98	90

3.1.9 BMP C121: Mulching

3.1.9.1 Purpose

The purpose of mulching soils is to provide immediate temporary protection from erosion. Mulch also enhances plant establishment by conserving moisture, holding fertilizer, seed, and topsoil in place, and moderating soil temperatures. There is an enormous variety of mulches that can be used. Only the most common types are discussed in this section.

3.1.9.2 Conditions of Use

As a temporary cover measure, mulch should be used:

- On disturbed areas that require cover measures for less than 30 days.
- As a cover for seed during the wet season and during the hot summer months.
- During the wet season on slopes steeper than 3H:1V with more than 10 feet of vertical relief.
- Mulch may be applied at any time of the year and must be refreshed periodically.

3.1.9.3 Design and Installation Specifications

For mulch materials, application rates, and specifications, see Table II-3-7.

NOTE: Thicknesses may be increased for disturbed areas in or near sensitive areas or other areas highly susceptible to erosion.

Mulch used within the ordinary high-water mark of surface waters should be selected to minimize potential flotation of organic matter. Composted organic materials have higher specific gravities (densities) than straw, wood, or chipped material.

3.1.9.4 Maintenance Standards

- The thickness of the cover must be maintained.
- Re-mulch and/or protect with a net or blanket any areas that experience erosion. If the erosion problem is drainage related, then fix the problem and remulch the eroded area.

Table II-3-7. Mulch Standards and Guidelines

Mulch Material	Quality Standards	Application Rates	Remarks
Straw	Air-dried; free from undesirable seed and coarse material.	3" thick; 5 bales per 1000 sf or 2 to 3 tons per acre.	Cost-effective protection when applied with adequate thickness. Hand-application generally requires greater thickness than blown straw. The thickness of straw may be reduced by half when used in conjunction with seeding. In windy areas, straw must be held in place by crimping, using a tackifier, or covering with netting. Blown straw always has to be held in place with a tackifier as even light winds will blow it away. Straw, however, has several deficiencies that should be considered when selecting mulch materials. If often introduces and/or encourages the propagation of weed species and it has no significant long-term benefits. Straw should be used only if mulches with long-term benefits are unavailable locally. It should also not be used within the ordinary high-water elevation of surface waters (due to flotation).
Hydro-mulch	No growth inhibiting factors.	Approx. 25-30 lbs per 1000 sf or 1500-2000 lbs per acre.	Shall be applied with hydromulcher. Shall not be used without seed and tackifier unless the application rate is at least doubled. Fibers longer than about ¾ - 1 inch clog hydromulch equipment. Fibers should be kept to less than ¾ inch.
Composted Mulch and Compost	No visible water or dust during handling. Must be purchased from supplier with a Solid Waste Handling permit (unless exempt)	3" thick, min.; approx. 100 tons per acre (approx. 800 lbs. per yard).	Mulch is excellent for protecting final grades until landscaping because it can be directly seeded or tilled into soil as an amendment. Composted mulch has a coarser size gradation than compost. It is more stable and practical to use in wet areas and during rainy weather conditions.
Chipped Site Vegetation	Average size shall be several inches. Gradations from fine to 6-inches in length for texture, variation, and interlocking properties.	3" minimum thickness	This is a cost-effective way to dispose of debris from clearing and grubbing, and it eliminates the problems associated with burning. Generally, it should not be used on slopes above approx. 10% because of its tendency to be transported by runoff. It is not recommended within 200 feet of surface waters. If seeding is expected shortly after mulch, the decomposition of the chipped vegetation may tie up nutrients important to grass establishment.
Wood-based mulch	No visible water or dust during handling. Must be purchased from a supplier with a Solid Waste Handling permit or one exempt from solid waste regulations.	3" thick; approx. 100 tons per acre (approx. 800 lbs. per yard).	This material is often called "hog" or "hogged fuel". It is usable as a material for Stabilized Construction Entrances (BMP C105) and as a mulch. The use of mulch ultimately improves the organic matter in the soil. Special caution is advised regarding the source and composition of wood-based mulches. Its preparation typically does not provide any weed seed control, so evidence of residual vegetation in its composition or known inclusion of weed plants or seeds should be monitored and prevented (or minimized).

3.1.10 BMP C122: Nets and Blankets

3.1.10.1 Purpose

Erosion control nets and blankets are intended to prevent erosion and hold seed and mulch in place on steep slopes and in channels so that vegetation can become well established. In addition, some nets and blankets can be used to reinforce turf permanently to protect drainage ways during high flows. Nets (commonly called matting) are strands of material woven into an open, but high-tensile strength net (for example, coconut fiber matting). Blankets are strands of material that are not tightly woven, but instead form a layer of interlocking fibers, typically held together by a biodegradable or photodegradable netting (for example, excelsior or straw blankets). They generally have lower tensile strength than nets, but cover the ground more completely. Coir (coconut fiber) fabric comes as both nets and blankets.

3.1.10.2 Conditions of Use

Erosion control nets and blankets should be used:

- To aid permanent vegetated stabilization of slopes 2H:1V or greater and with more than 10 feet of vertical relief.
- For drainage ditches and swales (highly recommended). The application of appropriate netting or blanket to drainage ditches and swales can protect bare soil from channelized runoff while vegetation is established. Nets and blankets also can capture a great deal of sediment due to their open, porous structure. Synthetic nets and blankets can be used to stabilize channels permanently and may provide a cost-effective, environmentally preferable alternative to riprap. 100 percent synthetic blankets manufactured for use in ditches may be easily reused as temporary ditch liners.
- Disadvantages of blankets include:
    - Surface preparation required;
    - On slopes steeper than 2.5:1, blanket installers may need to be roped and harnessed for safety;
- Advantages of blankets include:
    - Can be installed without mobilizing special equipment;
    - Can be installed by anyone with minimal training;
    - Can be installed in stages or phases as the project progresses;
    - Seed and fertilizer can be hand-placed by the installers as they progress down the slope;
    - Can be installed in any weather;
    - There are numerous types of blankets that can be designed with various parameters in mind. Those parameters include: fiber blend, mesh strength, longevity, biodegradability, cost, and availability.

3.1.10.3 Design and Installation Specifications

- See Figure II-3-5 and Figure II-3-6 for typical orientation and installation of blankets used in channels and as slope protection. Note: these are typical only; all blankets must be installed per manufacturer's installation instructions.
- Installation is critical to the effectiveness of these products. If good ground contact is not achieved, runoff can concentrate under the product, resulting in significant erosion.

Installation of Blankets on Slopes:

- Complete final grade and track walk up and down the slope.
- Install hydromulch with seed and fertilizer.
- Dig a small trench, approximately 12 inches wide by 6 inches deep along the top of the slope.
- Install the leading edge of the blanket into the small trench and staple approximately every 18 inches.

  NOTE: Staples are metal. ”U”-shaped, and a minimum of 6 inches long. Longer staples are used in sandy soils. Biodegradable stakes are also available and should be used where applicable.
- Roll the blanket slowly down the slope as the installer walks backwards.
- **NOTE:** The blanket rests against the installer's legs. Staples are installed as the blanket is unrolled. It is critical that the proper staple pattern in used for the blanket being installed. The blanket should not be allowed to roll down the slope on its own as this stretches the blanket, making it impossible to maintain soil contact. In addition, no one should be allowed to walk on the blanket after it is in place.
- If the blanket is not long enough to cover the entire slope length, the trailing edge of the upper blanket should overlap the leading edge of the lower blanket and be stapled. On steeper slopes, this overlap should be installed in a small trench, stapled, and covered with soil.
- With the variety of products available, it is impossible to cover all the details of appropriate use and installation. Therefore, it is critical that the design engineer consults the manufacturer's information and that a site visit takes place in order to insure that the product specified is appropriate. Information is also available at the following websites:
  - WSDOT: http://www.wsdot.wa.gov/eesc/environmental/
  - Texas Transportation Institute: http://www.dot.state.tx.us/insdtdot/orgchart/cmd/erosion/contents.htm

- Jute matting must be used in conjunction with mulch (BMP C121). Excelsior, woven straw blankets, and coir (coconut fiber) blankets may be installed without mulch. There are many other types of erosion control nets and blankets on the market that may be appropriate in certain circumstances.
- In general, most nets (e.g., jute matting) require mulch in order to prevent erosion because they have a fairly open structure. Blankets typically do not require mulch because they usually provide complete protection of the surface.
- Extremely steep, unstable, wet, or rocky slopes are often appropriate candidates for use of synthetic blankets, as are riverbanks, beaches, and other high-energy environments. If synthetic blankets are used, the soil should be hydromulched first.
- 100 percent biodegradable blankets are available for use in sensitive areas. These organic blankets are usually held together with a paper or fiber mesh and stitching which may last up to a year.
- Most netting used with blankets is photodegradable, meaning it will break down under sunlight (not UV stabilized). However, this process can take months or years even under bright sun. Once vegetation is established, sunlight does not reach the mesh. It is not uncommon to find non-degraded netting still in place several years after installation. This can be a problem if maintenance requires the use of mowers or ditch cleaning equipment. In addition, birds and small animals can become trapped in the netting.

3.1.10.4 Maintenance Standards

- Good contact with the ground must be maintained, and erosion must not occur beneath the net or blanket.
- Repair or staple any areas of the net or blanket that are damaged or not in close contact with the ground.
- If erosion occurs due to poorly controlled drainage, fix the problem and protect the eroded area.

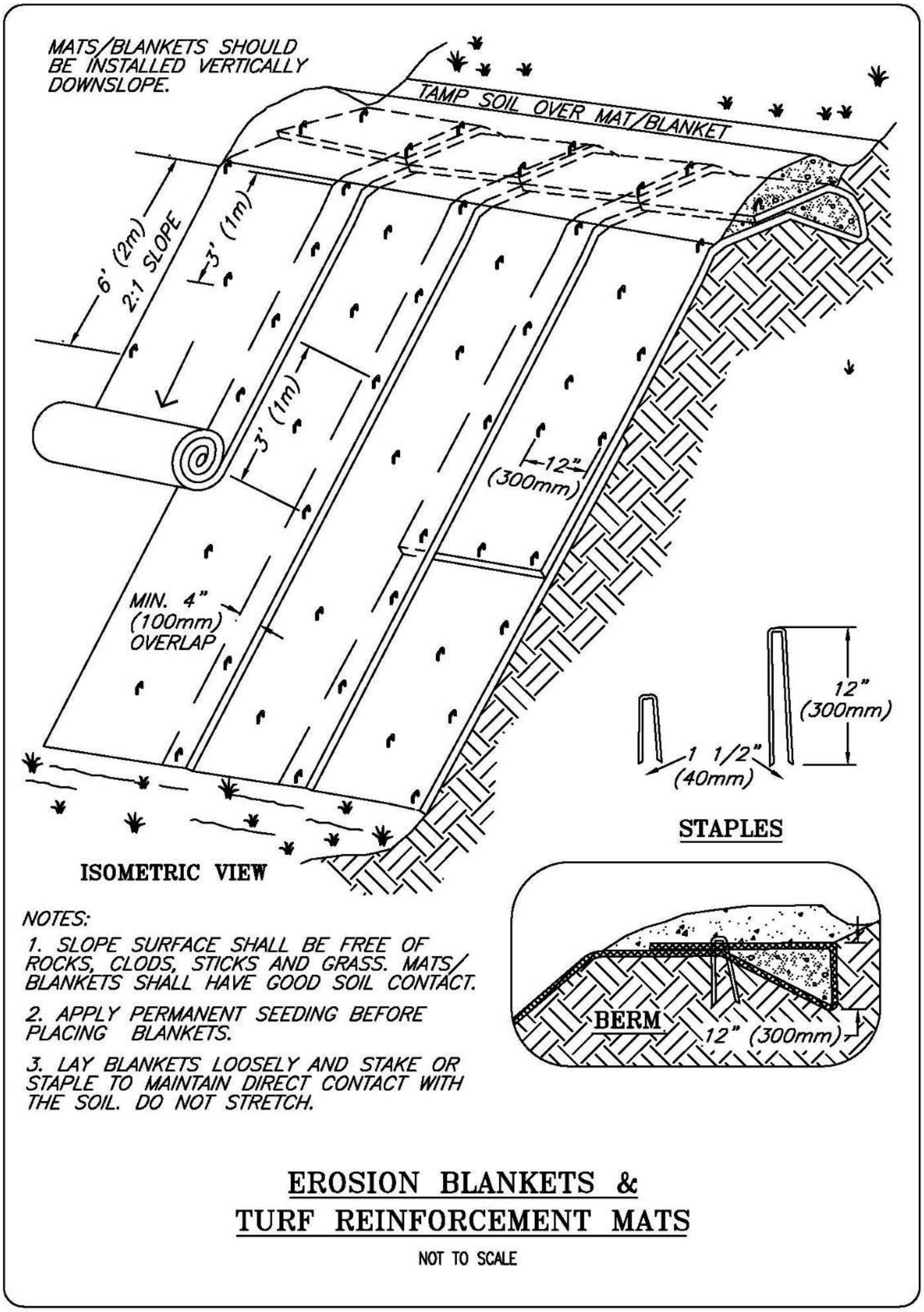


Figure II-3-5. Nets and Blankets – Slope Installation

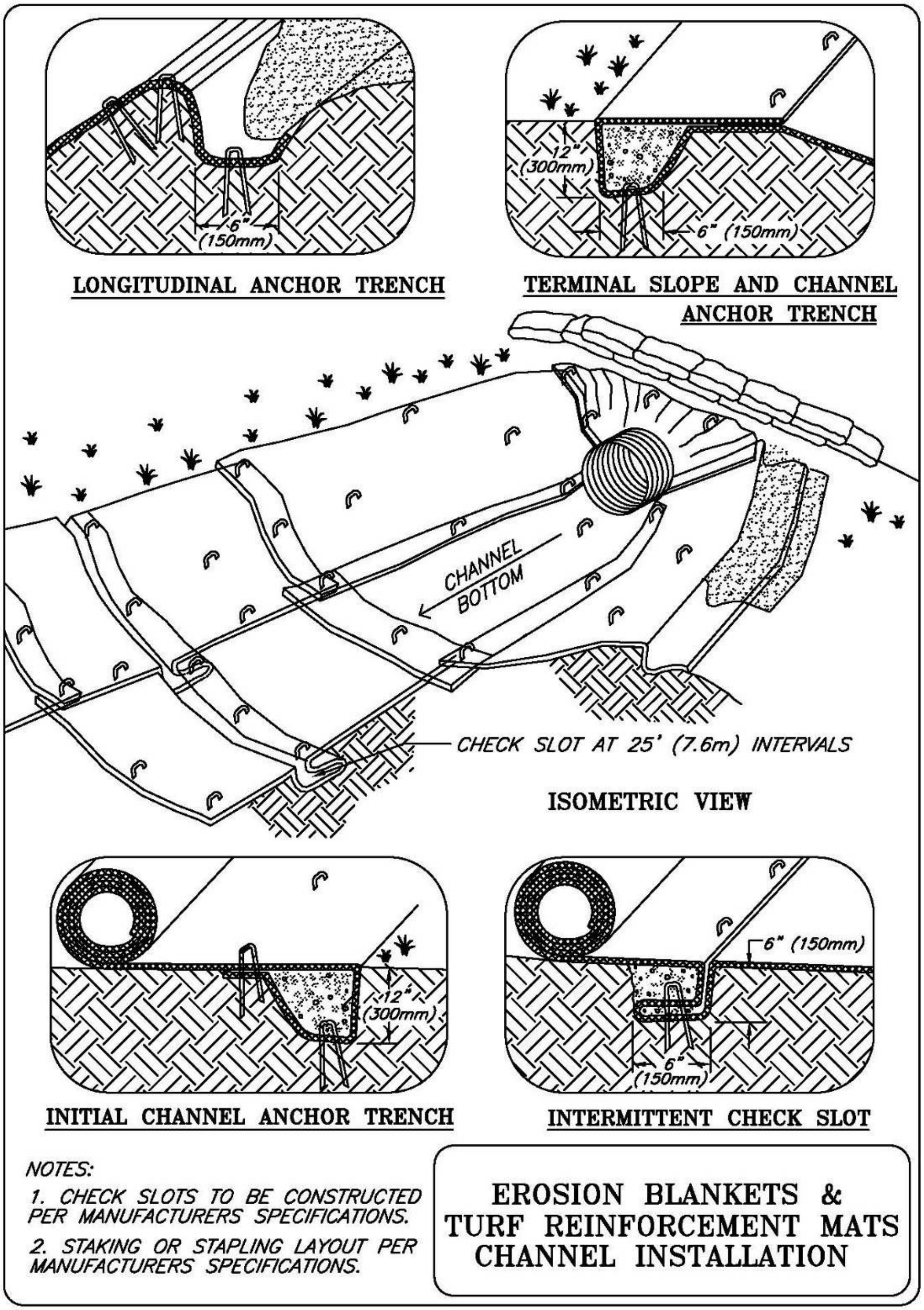


Figure II-3-6. Nets and Blankets – Channel Installation

3.1.11 BMP C123: Plastic Covering

3.1.11.1 Purpose

Plastic covering provides immediate, short-term erosion protection to slopes and disturbed areas.

3.1.11.2 Conditions of Use

See Figure II-3-7.

- Plastic covering may be used on disturbed areas that require cover measures for less than 30 days, except as stated below.
- Plastic is particularly useful for protecting cut and fill slopes and stockpiles. Note: The relatively rapid breakdown of most polyethylene sheeting makes it unsuitable for long-term (greater than six months) applications.
- Clear plastic sheeting can be used over newly-seeded areas to create a greenhouse effect and encourage grass growth if the hydroseed was installed too late in the season to establish 75 percent grass cover, or if the wet season started earlier than normal. Clear plastic should not be used for this purpose during the summer months because the resulting high temperatures can kill the grass.
- Due to rapid runoff caused by plastic sheeting, this method shall not be used upslope of areas that might be adversely impacted by concentrated runoff. Such areas include steep and/or unstable slopes.
- While plastic is inexpensive to purchase, the added cost of installation, maintenance, removal, and disposal can make this an expensive material.
- Whenever plastic is used to protect slopes, water collection measures must be installed at the base of the slope. These measures include plastic-covered berms, channels, and pipes used to convey clean rainwater away from bare soil and disturbed areas. At no time is clean runoff from a plastic covered slope to be mixed with dirty runoff from a project.
- Other uses for plastic include:
  - Temporary ditch liner;
  - Pond liner in temporary sediment pond;
  - Liner for bermed temporary fuel storage area if plastic is not reactive to the type of fuel being stored;
  - Emergency slope protection during heavy rains; and
  - Temporary drainpipe (“elephant trunk”) used to direct water.

3.1.11.3 Design and Installation Specifications

Plastic slope cover must be installed as follows:

- Run plastic up and down slope, not across slope.

- Plastic may be installed perpendicular to a slope if the slope length is less than 10 feet.
- Minimum of 8-inch overlap at seams.
- On long or wide slopes, or slopes subject to wind, all seams should be taped.
- Place plastic into a small (12-inch wide by 6-inch deep) slot trench at the top of the slope and backfill with soil to keep water from flowing underneath.
- Place sand filled burlap or geotextile bags every 3 to 6 feet along seams and pound a wooden stake through each to hold them in place. Alternative options for holding plastic in place exist and may be considered with City of Auburn approval.
- Inspect plastic for rips, tears, and open seams regularly and repair immediately. This prevents high velocity runoff from contacting bare soil, which causes extreme erosion;
- Sandbags may be lowered into place tied to ropes. However, all sandbags must be staked in place.

  NOTE: Methods other than staking down plastic with sandbags may be used with City of Auburn approval.

- Plastic sheeting shall have a minimum thickness of 0.06 millimeters.
- If erosion at the toe of a slope is likely, a gravel berm, riprap, or other suitable protection shall be installed at the toe of the slope in order to reduce the velocity of runoff.

3.1.11.4 Maintenance Standards

- Torn sheets must be replaced and open seams repaired.
- If the plastic begins to deteriorate due to ultraviolet radiation, it must be completely removed and replaced.
- When the plastic is no longer needed, it shall be completely removed.

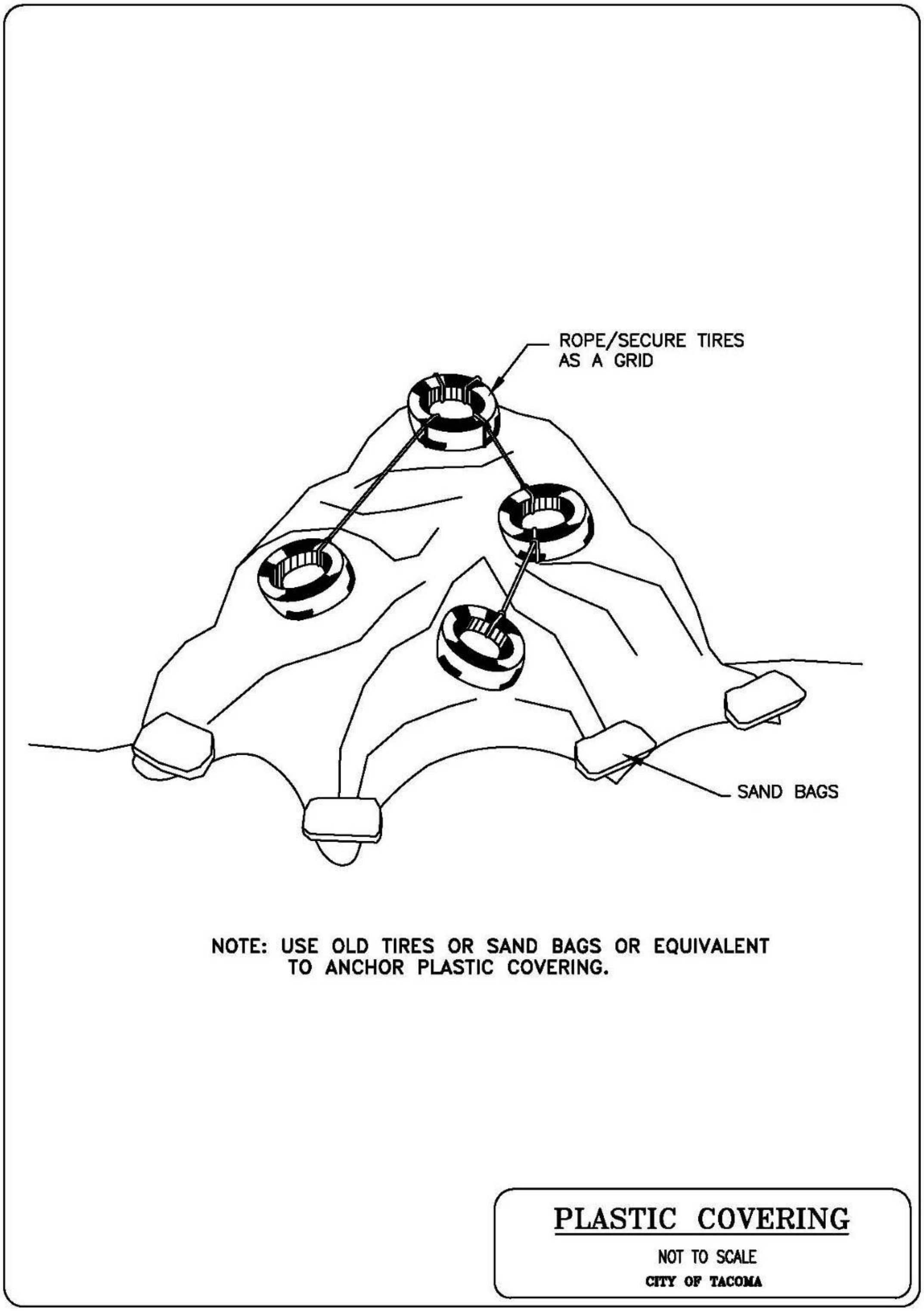


Figure II-3-7. Soil Erosion Protection – Plastic Covering

3.1.12 BMP C124: Sodding

3.1.12.1 Purpose

The purpose of sodding is to establish permanent turf for immediate erosion protection and to stabilize drainage ways where concentrated overland flow will occur.

3.1.12.2 Conditions of Use

Sodding may be used in the following areas:

- Disturbed areas that require short-term or long-term cover.
- Disturbed areas that require immediate vegetative cover.
- All waterways that require vegetative lining. Waterways may also be seeded rather than sodded, and protected with a net or blanket.

3.1.12.3 Design and Installation Specifications

Sod shall be free of weeds, of uniform thickness (approximately 1-inch thick), and shall have a dense root mat for mechanical strength.

The following steps are recommended for sod installation:

- Shape and smooth the surface to final grade in accordance with the approved grading plan. Overexcavate the swale 4 to 6 inches below design elevation to allow room for placing soil amendment and sod.
- Amend 4 inches (minimum) of compost into the top 8 inches of the soil if the organic content of the soil is less than ten percent or the permeability is less than 0.6 inches per hour. Compost used should meet Ecology specifications for Grade A quality compost. See http://www.ecy.wa.gov/programs/swfa/compost/
- Fertilize according to the supplier's recommendations.
- Work lime and fertilizer 1 to 2 inches into the soil, and smooth the surface.
- Lay strips of sod beginning at the lowest area to be sodded and perpendicular to the direction of water flow. Wedge strips securely into place. Square the ends of each strip to provide for a close, tight fit. Stagger joints at least 12 inches. Staple on slopes steeper than 3H:1V. Staple the upstream edge of each sod strip.
- Roll the sodded area and irrigate.
- When sodding is carried out in alternating strips or other patterns, seed the areas between the sod immediately after sodding.

3.1.12.4 Maintenance Standards

If the grass is unhealthy, the cause shall be determined and appropriate action taken to reestablish a healthy groundcover. If it is impossible to establish a healthy groundcover due to frequent saturation, instability, or some other cause, the sod shall be removed, the area seeded with an appropriate mix, and protected with a net or blanket.

3.1.13 BMP C125: Compost

3.1.13.1 Purpose

The purpose of compost is to help establish vegetation and filter stormwater thus removing fine sediment and other contaminants. Compost can be used alone as a compost blanket, as a berm, or inside a sock.

3.1.13.2 Conditions of Use

- Do not use if stormwater will discharge to a nutrient sensitive waterbody.
- Do not use as a storm drain inlet protection measure.

3.1.13.3 Design and Installation Specifications

Compost Blankets

Compost blankets are simply compost blanketed over an area.

- Place compost 3” thick.
- Compost can be blown onto slopes up to 2:1 or spread by hand on shallower slopes.
- Compost must be ¾ to 1 inch-minus screened compost meeting Ecology’s requirements for Grade A quality compost. See http://www.ecy.wa.gov/programs/swfa/compost for more information on compost quality.
- Compost can be mixed with a seed mix to ensure rapid vegetation.
- Compost does not need to be removed after construction phase unless required by the project engineer or geotechnical professional.

Compost Berms

Compost berms are a perimeter sediment control that can be used instead of silt fence.

- Do not use compost berms on steep slopes.
- Berm width shall be a minimum of 2 feet.
- Berm height shall be a minimum of 12 inches.
- Berm width shall be twice the berm height.

Compost can be blown in place or placed by front-end loader. Compost must be ¾ to 1 inch-minus screened compost meeting Ecology’s requirements for Grade A quality compost. See http://www.ecy.wa.gov/programs/swfa/compost for more information on compost quality.

Compost should be spread over proposed landscaped section when construction is complete to aid in revegetation.

Compost Socks

Compost socks are similar to straw wattles.

- Sock material that is biodegradable will last up to 6 months and can be used for soil amendment after 6 months.
- Sock material that is non-biodegradable must be removed after construction is complete.
- Place socks perpendicular to flow.
- Walk socks in place to ensure good soil contact.
- Install wooden stakes every 12" on steep slopes or every 24" on shallow slopes

3.1.13.4 Maintenance Standards

Compost Blankets

- Inspect compost regularly.
- Ensure a 3" thick blanket.

Compost Berms

- Inspect compost berm regularly.
- Ensure vehicular traffic does not cross berm and track compost off-site. If this occurs, sweep compost immediately.

Compost Socks

- Do not allow erosion or concentrated runoff under or around the barrier.
- Inspect the socks after each rainfall and repair any socks that tear or are not abutting the ground.

3.1.14 BMP C126: Topsoiling

3.1.14.1 Purpose

To provide a suitable growth medium for final site stabilization with vegetation. While not a permanent cover practice in itself, topsoiling is an integral component of providing permanent cover in those areas where there is an unsuitable soil surface for plant growth. Native soils and disturbed soils that have been organically amended not only retain much more stormwater, but they also serve as effective biofilters for urban pollutants and, by supporting more vigorous plant growth, reduce the amount of water, fertilizer, and pesticides needed to support installed landscapes. Topsoil does not include any subsoils, only the material from the top several inches, including organic debris.

3.1.14.2 Conditions of Use

Native soils should be left undisturbed to the maximum extent practicable. Native soils disturbed during clearing and grading should be restored, to the maximum extent practicable, to a condition where moisture-holding capacity is equal to or better than the original site conditions. This criterion can be met by using on-site native topsoil, incorporating amendments into on-site soil, or importing blended topsoil.

- Topsoiling is a required procedure when establishing vegetation on shallow soils, and soils of critically low pH (high acid) levels.
- Stripping of the existing, properly functioning soil system and vegetation for the purpose of topsoiling during construction is not acceptable. If an existing soil system is functioning properly, it shall be preserved in its undisturbed and uncompacted condition.
- Depending on where the topsoil comes from, or what vegetation was on site before disturbance, invasive plant seeds may be included and could cause problems for establishing native plants, landscaped areas, or grasses.
- Topsoil from the site will contain mycorrhizal bacteria that are necessary for healthy root growth and nutrient transfer. These native mycorrhiza are acclimated to the site and will provide optimum conditions for establishing grasses. Commercially available mycorrhiza products should be used when topsoil is brought in from off-site.

3.1.14.3 Design and Installation Specifications

If topsoiling is to be done, the following items should be considered:

- Maximize the depth of the topsoil wherever possible to provide the maximum possible infiltration capacity and beneficial growth medium. Topsoil depth shall be at least 8 inches with a minimum organic content of 10 percent dry weight and pH between 6.0 and 8.0 or matching the pH of the undisturbed soil. This can be accomplished either by returning native topsoil to the site and/or incorporating organic amendments. Organic amendments should be incorporated to a minimum 8-inch depth except where tree roots or other natural features limit the depth of incorporation. Subsoils below the 12-inch depth should be scarified at least 4 inches to avoid stratified layers, where feasible. The decision to either layer topsoil over a subgrade or incorporate topsoil into the underlying layer may vary depending on the planting specified.

- If blended topsoil is imported, fines should be limited to 25 percent passing through a 200 sieve.
- The final composition and construction of the soil system will result in a natural selection or favoring of certain plant species over time. For example, recent practices have shown that incorporation of topsoil may favor grasses, while layering with mildly acidic, high-carbon amendments may favor more woody vegetation.
- Locate the topsoil stockpile so it meets specifications and does not interfere with work on the site. It may be possible to locate more than one pile in proximity to areas where topsoil will be used.
- Allow sufficient time in scheduling for topsoil to be spread prior to seeding, sodding, or planting.
- Care must be taken not to apply topsoil over subsoil if the two soils have contrasting textures. Sandy topsoil over clayey subsoil is a particularly poor combination, as water creeps along the junction between the soil layers and causes the topsoil to slough.
- If topsoil and subsoil are not properly bonded, water will not infiltrate the soil profile evenly and it will be difficult to establish vegetation. The best method to prevent a lack of bonding is to work the topsoil into the layer below for a depth of at least 6 inches.
- Ripping or re-structuring the subgrade may also provide additional benefits regarding the overall infiltration and interflow dynamics of the soil system.
- Field exploration of the site shall be made to determine if there is surface soil of sufficient quantity and quality to justify stripping. Topsoil shall be friable and loamy (loam, sandy loam, silt loam, sandy clay loam, clay loam). Areas of natural groundwater recharge should be avoided.
- Confine stripping to the immediate construction area. A 4- to 6- inch stripping depth is common, but depth may vary depending on the particular soil. Place all surface runoff control structures in place prior to stripping.

Stockpile topsoil in the following manner:

- Side slopes of the stockpile shall not exceed 2:1.
- Surround all topsoil stockpiles between October 1 and April 30 with an interceptor dike with gravel outlet and silt fence. Between May 1 and September 30, install an interceptor dike with gravel outlet and silt fence if the stockpile will remain in place for a longer period of time than active construction grading.
- Complete erosion control seeding or covering with clear plastic or other mulching materials of stockpiles within 2 days (October 1 through April 30) or 7 days (May 1 through September 30) of the formation of the stockpile. Do not cover native topsoil stockpiles with plastic.

- Topsoil shall not be placed while in a frozen or muddy condition, when the subgrade is excessively wet, or when conditions exist that may otherwise be detrimental to proper grading or proposed sodding or seeding.
- Maintain previously established grades on the areas to be topsoiled according to the approved plan.
- When native topsoil is to be stockpiled and reused, the following should apply to ensure that the mycorrhizal bacterial, earthworms, and other beneficial organisms will not be destroyed:
    - Topsoil is to be re-installed within 4 to 6 weeks;
    - Topsoil is not to become saturated with water;
    - Plastic cover is not allowed.

3.1.14.4 Maintenance Standards

Inspect stockpiles regularly, especially after large storm events. Stabilize any areas that have eroded.

3.1.15 BMP C127: Polyacrylamide for Soil Erosion Protection

3.1.15.1 Purpose

Polyacrylamide (PAM) is used on construction sites to prevent soil erosion.

Applying PAM to bare soil in advance of a rain event significantly reduces erosion and controls sediment in two ways. PAM helps maintain soil structure, which increases the ability to infiltrate.

3.1.15.2 Conditions of Use

Do not apply PAM directly to water or allow it to enter a water body. In areas that drain to a sediment pond, PAM can be applied to bare soil under the following conditions:

- During rough grading operations.
- Staging areas.
- Balanced cut and fill earthwork.
- Haul roads prior to placement of crushed rock surfacing.
- Compacted soil roadbase.
- Stockpiles.
- After final grade and before paving or final seeding and planting.
- Pit sites.
- Sites having a winter shut down. In the case of winter shut down, or where soil will remain unworked for several months, PAM should be used together with mulch.

3.1.15.3 Design and Installation Specifications

PAM may be applied in dissolved form with water, or it may be applied in dry, granular or powdered form. The preferred application method is the dissolved form.

PAM is to be applied at a maximum rate of 2/3 pound PAM per 1,000 gallons water (80 mg/L) per 1 acre of bare soil. Higher concentrations of PAM **do not** provide any additional effectiveness.

The Preferred Method:

- Pre-measure the area where PAM is to be applied and calculate the amount of product and water necessary to provide coverage at the specified application rate (2/3 pound PAM per 1,000 gallons per acre).
- PAM has infinite solubility in water, but dissolves very slowly. Dissolve pre-measured dry granular PAM with a known quantity of clean water in a bucket several hours or overnight. Mechanical mixing will help dissolve the PAM. Always add PAM to water - not water to PAM.
- Pre-fill the water truck about 1/8 full with water. The water does not have to be potable, but it must have relatively low turbidity – in the range of 20 NTU or less.
- Add PAM and water mixture to the truck.

- Completely fill the water truck to specified volume.
- Spray PAM and water mixture onto dry soil until the soil surface is uniformly and completely wetted.

An Alternate Method:

PAM may also be applied as a powder at the rate of 5 pounds per acre. This must be applied on a day that is dry. For areas less than 5 to 10 acres, a hand-held “organ grinder” fertilizer spreader set to the smallest setting will work. Tractor-mounted spreaders will work for larger areas.

Benefits and Limitations:

The following benefits and limitations should be considered:

- PAM shall be used in conjunction with other BMPs and not in place of other BMPs.
- The steeper the slope, the less benefit PAM will provide and the more critical it is to use proper groundcover for erosion control.
- Do not use PAM on a slope that flows directly into a stream or wetland or any other waterbody.
- PAM has little to no effect on sandy soils with little clay content.
- Do not add PAM to water discharging from site.
- When the total drainage area is greater than or equal to 5 acres, PAM treated areas shall drain to a sediment pond.
- Areas less than 5 acres shall drain to sediment control BMPs, such as a minimum of 3 check dams per acre. The total number of check dams used shall be maximized to achieve the greatest amount of settlement of sediment prior to discharging from the site. Each check dam shall be spaced evenly in the drainage channel through which stormwater flows are discharged off-site.
- On all sites, use silt fences to limit the discharges of sediment from the site.
- Cover and protect all areas not being actively worked from rainfall. PAM shall not be the only cover BMP used.
- PAM can be applied to wet soil, but dry soil is preferred due to less sediment loss.
- PAM will work when applied to saturated soil but is not as effective as applications to dry or damp soil.
- Keep the granular PAM supply out of the sun. Granular PAM loses its effectiveness in three months after exposure to sunlight and air.
- Proper application and re-application plans are necessary to ensure total effectiveness of PAM usage.
- PAM, combined with water, is very slippery and can be a safety hazard. Care must be taken to prevent spills of PAM powder onto paved surfaces. During an application of PAM, prevent over-spray from reaching pavement, as pavement will become

slippery. If PAM powder gets on skin or clothing, wipe it off with a rough towel rather than washing with water, which makes cleanup messier and take longer.

- Some PAMs are more toxic and carcinogenic than others. Only the most environmentally safe PAM products should be used.
- The specific PAM copolymer formulation must be anionic. **Cationic PAM shall not be used in any application because of known aquatic toxicity problems.** Only the highest drinking water grade PAM, certified for compliance with ANSI/NSF Standard 60 for drinking water treatment, will be used for soil applications. PAM use shall be reviewed and approved by the City. The Washington State Department of Transportation (WSDOT) has listed approved PAM products on its web page.
- PAM designated for these uses should be "water soluble", "linear", or "non-crosslinked". Cross-linked or water absorbent PAM, polymerized in highly acidic (pH<2) conditions, are used to maintain soil moisture content.
- The PAM anionic charge density may vary from 2 to 30 percent; a value of 18 percent is typical. Studies conducted by the United States Department of Agriculture (USDA)/ARS demonstrated that soil stabilization was optimized by using very high molecular weight (12-15 mg/mole), highly anionic (>20% hydrolysis) PAM.
- PAM tackifiers are available and being used in place of guar and alpha plantago. Typically, PAM tackifiers should be used at a rate of no more than 0.5 to 1 pounds per 1,000 gallons of water in a hydromulch machine. Some tackifier product instructions say to use at a rate of 3 to 5 pounds per acre, which can be too much. In addition, pump problems can occur at higher rates due to increased viscosity.

3.1.15.4 Maintenance Standards

- PAM may be reapplied on actively worked areas after a 48-hour period.
- Reapplication is not required unless PAM treated soil is disturbed or turbidity levels show the need for an additional application. If PAM treated soil is left undisturbed, a reapplication may be necessary after two months. When PAM is applied first to bare soil and then covered with straw, a reapplication may not be necessary for several months.
- Loss of sediment and PAM may be a basis for penalties per RCW 90.48.080.

3.1.16 BMP C130: Surface Roughening

3.1.16.1 Purpose

Surface roughening aids in the establishment of vegetative cover, reduces runoff velocity, increases infiltration, and provides for sediment trapping through the provision of a rough soil surface. Horizontal depressions are created by operating a tiller or other suitable equipment on the contour or by leaving slopes in a roughened condition by not fine grading them.

3.1.16.2 Conditions for Use

All slopes steeper than 3H:1V and greater than 5 vertical feet require surface roughening.

- Areas with grades steeper than 3H:1V should be roughened to a depth of 2 to 4 inches prior to seeding.
- Areas that will not be stabilized immediately may be roughened to reduce runoff velocity until seeding takes place.
- Slopes with a stable rock face do not require roughening.
- Slopes where mowing is planned should not be excessively roughened.

3.1.16.3 Design and Installation Specifications

There are different methods for achieving a roughened soil surface on a slope, and the selection of an appropriate method depends upon the type of slope. Roughening methods include stair-step grading, grooving, contour furrows, and tracking. See Figure II-3-8 for tracking and contour furrows. Factors to be considered in choosing a method are slope steepness, mowing requirements, and whether the slope is formed by cutting or filling.

- Graded areas with slopes greater than 3:1 but less than 2:1 should be roughened before seeding. This can be accomplished in a variety of ways, including "track walking," or driving a crawler tractor up and down the slope, leaving a pattern of cleat imprints parallel to slope contours.
- Tracking is done by operating equipment up and down the slope to leave horizontal depressions in the soil.

3.1.16.4 Maintenance Standards

- Areas that are graded in this manner should be seeded as quickly as possible.
- Regular inspections should be made of the area. If rills appear, they should be re-graded and re-seeded immediately.

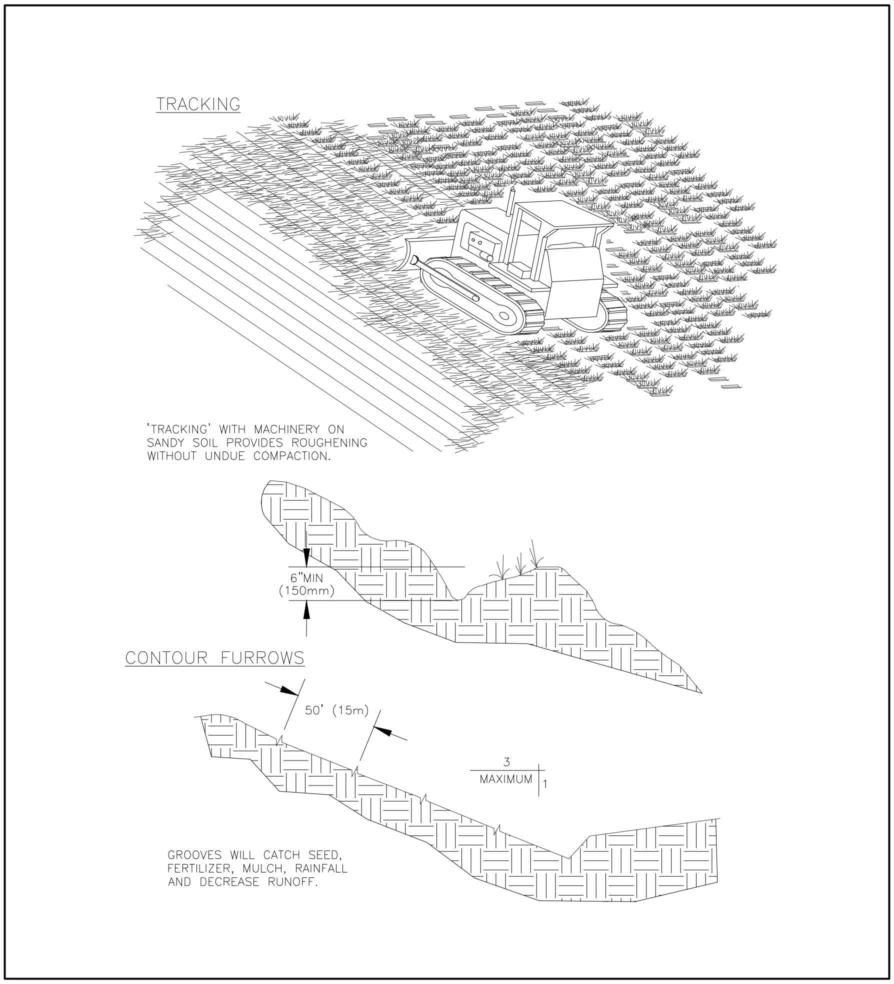


Figure II-3-8. Surface Roughening by Tracking and Contour Furrows

3.1.17 BMP C131: Gradient Terraces

3.1.17.1 Purpose

Gradient terraces reduce erosion damage by intercepting surface runoff and conducting it to a stable outlet at a non-erosive velocity.

3.1.17.2 Conditions of Use

Gradient terraces normally are limited to denuded land having a water erosion problem. They should not be constructed on deep sands or on soils that are too stony, steep, or shallow to permit practical and economical installation and maintenance. Gradient terraces may be used only where suitable outlets are or will be made available. See Figure II-3-9 for gradient terraces.

3.1.17.3 Design and Installation Specifications

The maximum spacing of gradient terraces should be determined by the following method:

$$VI = (0.8)s + y$$

Where:

VI = vertical interval in feet
s = land rise per 100 feet, expressed in feet
y = a soil and cover variable with values from 1.0 to 4.0

Values of “y” are influenced by soil erodibility and cover practices. The lower values are applicable to erosive soils where little to no residue is left on the surface. The higher value is applicable only to erosion-resistant soils where a large amount of residue (1½ tons of straw/acre equivalent) is on the surface.

- The minimum constructed cross-section should meet the design dimensions.
- The top of the constructed ridge should not be lower at any point than the design elevation plus the specified overfill for settlement. The opening at the outlet end of the terrace should have a cross section equal to that specified for the terrace channel.
- Channel grades may be either uniform or variable with a maximum grade of 0.6 feet per 100 feet length. For short distances, terrace grades may be increased to improve alignment. The channel velocity should not exceed that which is non-erosive for the soil type with the planned treatment.
- All gradient terraces should have adequate outlets. Such an outlet may be a grassed waterway, vegetated area, or tile outlet. In all cases, the outlet must convey runoff from the terrace or terrace system to a point where the outflow will not cause damage. Vegetative cover should be used in the outlet channel.
- The design elevation of the water surface of the terrace should not be lower than the design elevation of the water surface in the outlet at their junction, when both are operating at design flow.

- Vertical spacing determined by the above methods may be increased as much as 0.5 feet or 10 percent, whichever is greater, to provide better alignment or location, avoid obstacles, adjust for equipment size, or reach a satisfactory outlet.
- The drainage area above the top should not exceed the area that would be drained by a terrace with normal spacing.
- The terrace should have enough capacity to handle the peak runoff expected from a 2-year, 24-hour design storm without overtopping.
- The terrace cross-section should be proportioned to fit the land slope. The ridge height should include a reasonable settlement factor. The ridge should have a minimum top width of 3 feet at the design height. The minimum cross-sectional area of the terrace channel should be 8 square feet for land slopes of 5 percent or less, 7 square feet for slopes from 5 to 8 percent, and 6 square feet for slopes steeper than 8 percent. The terrace can be constructed wide enough to be maintained using a small cat.

3.1.17.4 Maintenance Standards

Maintenance should be performed as needed. Terraces should be inspected regularly, at least once a year, and after large storm events.

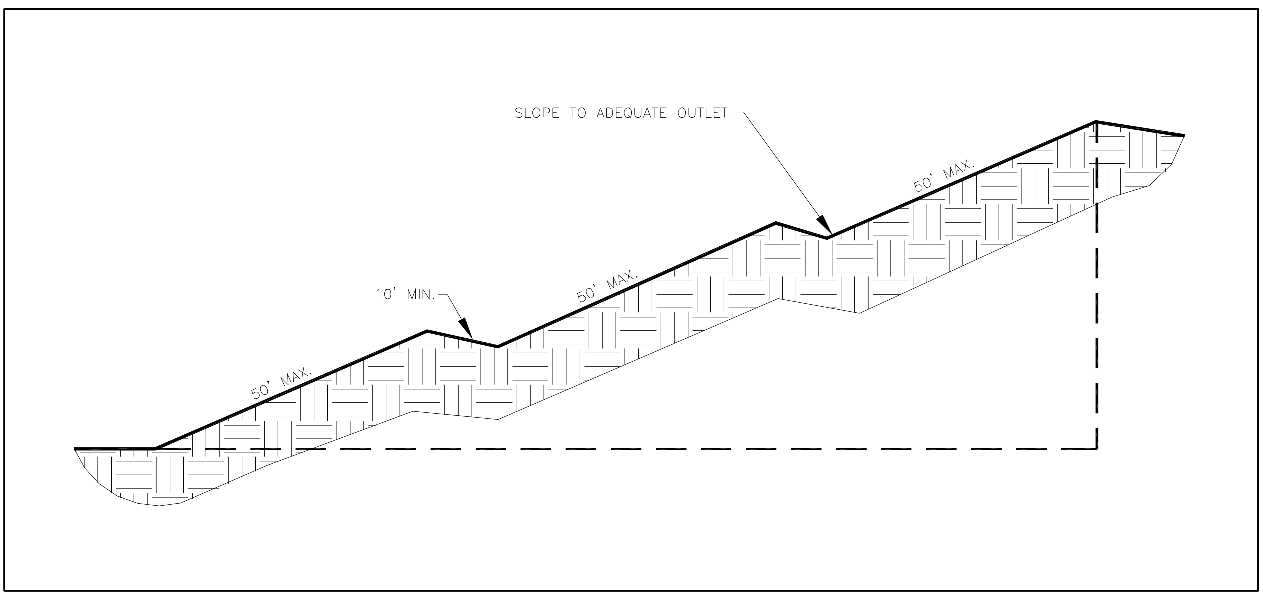


Figure II-3-9. Gradient Terraces

3.1.18 BMP C140: Dust Control

3.1.18.1 Purpose

Dust control prevents wind transport of dust from disturbed soil surfaces onto roadways, drainage ways, and surface waters.

3.1.18.2 Conditions of Use

Use dust control practices in areas (including roadways) subject to surface and air movement of dust where on-site and off-site impacts to roadways, drainage ways, or surface waters are likely.

3.1.18.3 Design and Installation Specifications

- Vegetate or mulch areas that will not receive vehicle traffic. In areas where planting, mulching, or paving is impractical, apply gravel or landscaping rock.
- Limit dust generation by clearing only to those areas where immediate activity will take place, leaving the remaining area(s) in the original condition, if stable. Maintain the original ground cover as long as practical.
- Construct natural or artificial windbreaks or windscreens. These may be designed as enclosures for small dust sources.
- Sprinkle the site with water until surface is wet. Repeat as needed. To prevent carryout of mud onto street, refer to Stabilized Construction Entrance (BMP C105).
- Irrigation water can be used for dust control. Install irrigation systems as a first step on sites where dust control is a concern.
- Spray exposed soil areas with a dust palliative, following the manufacturer's instructions and cautions regarding handling and application. Used oil is prohibited from use as a dust suppressant. The City may approve other dust palliatives such as calcium chloride or PAM.
- PAM (BMP C127) added to water at a rate of 2/3 pounds per 1,000 gallons of water per acre and applied from a water truck is more effective than water alone. This is due to the increased infiltration of water into the soil and reduced evaporation. In addition, small soil particles are bonded together and are not as easily transported by wind. Adding PAM may actually reduce the quantity of water needed for dust control. There are concerns with the proper use of PAM, refer to BMP C127 for more information on PAM application. PAM use requires City approval.
- Lower speed limits. High vehicle speed increases the amount of dust stirred up from unpaved roads and lots.
- Upgrade the road surface strength by improving particle size, shape, and mineral types that make up the surface and base materials.
- Add surface gravel to reduce the source of dust emission. Limit the amount of fine particles to 10 to 20 percent.
- Use geotextile fabrics to increase the strength of new roads or roads undergoing reconstruction.

- Encourage the use of alternate, paved routes, if available.
- Restrict use by tracked vehicles and heavy trucks to prevent damage to road surfaces and bases.
- Apply chemical dust suppressants using the admix method, blending the product with the top few inches of surface material. Suppressants may also be applied as surface treatments.
- Pave unpaved permanent roads and other trafficked areas.
- Use vacuum street sweepers.
- Remove mud and other dirt promptly so it does not dry and then turn into dust.
- Limit dust-causing work on windy days.
- Contact the Puget Sound Clean Air Agency for guidance and training on other dust control measures. Compliance with the Puget Sound Clean Air Agency's recommendations/requirements constitutes compliance with this BMP.

3.1.18.4 Maintenance Standards

Evaluate the potential for dust generation frequently during dry periods. Complete the actions outlines above as needed to limit the dust.

3.1.19 BMP C150: Materials On Hand

3.1.19.1 Purpose

Quantities of erosion prevention and sediment control materials should be kept on the project site at all times to be used for emergency situations such as unexpected heavy summer rains. Having these materials on-site reduces the time needed to implement BMPs when inspections indicate that existing BMPs are not meeting the Construction SWPPP requirements. In addition, it may be more economical to buy some materials in bulk and store them at the office or yard for future use.

3.1.19.2 Conditions of Use

Construction projects of any size or type can benefit from having materials on hand. A small commercial development project could have a roll of plastic and some gravel available for immediate protection of bare soil and temporary berm construction. A large earthwork project, such as highway construction, might have several tons of straw, several rolls of plastic, flexible pipe, sandbags, geotextile fabric, and steel “T” posts.

- Materials are stockpiled and readily available before any site clearing, grubbing, or earthwork begins. A large contractor or developer could keep a stockpile of materials that are available to be used on several projects.
- If storage space at the project site is at a premium, the contractor could maintain the materials at their office or yard. The office or yard must be less than an hour from the project site.

3.1.19.3 Design and Installation Specifications

Depending on project type, size, complexity, and length, materials and quantities will vary. Table II-3-8 provides a good minimum that will cover numerous situations.

Table II-3-8. Materials on Hand

Material	Measure	Quantity
Clear Plastic, 6 mil	100 foot roll	1-2
Drainpipe, 6 or 8 inch diameter	25 foot section	4-6
Sandbags, filled	each	25-50
Straw Bales for mulching,	approx. 50# each	10-20
Quarry Spalls	ton	2-4
Washed Gravel	cubic yard	2-4
Geotextile Fabric	100 foot roll	1-2
Catch Basin Inserts	each	2-4
Steel “T” Posts	each	12-24

3.1.19.4 Maintenance Standards

- All materials with the exception of the quarry spalls, steel “T” posts, and gravel should be kept covered and out of both sun and rain.
- Re-stock materials used as needed.

3.1.20 BMP C151: Concrete Handling

3.1.20.1 Purpose

Concrete work can generate process water and slurry that contain fine particles and high pH, both of which can violate water quality standards in the receiving water. This BMP is intended to minimize and eliminate concrete process water and slurry from entering waters of the state.

3.1.20.2 Conditions of Use

Utilize these management practices any time concrete is used.

Concrete construction projects include, but are not limited to, the following:

- Curbs
- Sidewalks
- Roads
- Bridges
- Foundations
- Floors
- Runways

3.1.20.3 Design and Installation Specifications

- Concrete truck chutes, pumps, and internals shall be washed out only into formed areas awaiting installation of concrete or asphalt.
- When no formed areas are available, contain washwater and leftover product in a lined container. Dispose of washwater in a manner that does not violate groundwater or surface water quality standards.
- Unused concrete remaining in the truck and pump shall be returned to the originating batch plant for recycling.
- Hand tools including, but not limited to, screeds, shovels, rakes, floats, and trowels shall be washed off only into formed areas awaiting installation of concrete or asphalt.
- Equipment that cannot be easily moved, such as concrete pavers, shall only be washed in areas that do not directly drain to natural or constructed stormwater conveyances.
- Washdown from areas such as concrete aggregate driveways shall not drain directly to natural or constructed stormwater conveyances.

3.1.20.4 Maintenance Standards

Containers shall be checked for holes in the liner daily during concrete pours and repaired the same day.

3.1.21 BMP C152: Sawcutting and Surfacing Pollution Prevention

3.1.21.1 Purpose

Sawcutting and surfacing operations generate slurry and process water that contains fine particles and high pH (concrete cutting), both of which can violate water quality standards in the receiving water. This BMP is intended to minimize and eliminate process water and slurry from entering waters of the State

3.1.21.2 Conditions of Use

Anytime sawcutting or surfacing operations take place, use these management practices. Sawcutting and surfacing operations include, but are not limited to, the following:

- Sawing
- Coring
- Grinding
- Roughening
- Hydro-demolition
- Bridge and road surfacing

3.1.21.3 Design and Installation Specifications

- Vacuum slurry and cuttings during cutting and surfacing operations.
- Do not leave slurry and cuttings on permanent concrete or asphalt pavement overnight.
- Do not drain slurry and cuttings to any natural or constructed drainage conveyance.
- Dispose of collected slurry and cuttings in a manner that does not violate groundwater or surface water quality standards.
- Do not drain process water that is generated during hydro-demolition, surface roughening, or similar operations to any natural or constructed drainage conveyance and dispose of it in a manner that does not violate groundwater or surface water quality standards.
- Handle and dispose of cleaning waste material and demolition debris in a manner that does not cause contamination of water. If the area is swept with a pick-up sweeper, haul the material out of the area to an appropriate disposal site.

3.1.21.4 Maintenance Standards

Continually monitor operations to determine whether slurry, cuttings, or process water could enter waters of the state. If inspections show that a violation of water quality standards could occur, stop operations and immediately implement preventive measures such as berms, barriers, secondary containment, and vacuum trucks.

3.1.22 BMP C153: Material Delivery, Storage and Containment

3.1.22.1 Purpose

Prevent, reduce, or eliminate the discharge of pollutants from material delivery and storage to the stormwater system or watercourses by minimizing the storage of hazardous materials onsite, storing materials in a designated area, and installing secondary containment.

3.1.22.2 Conditions of Use

These procedures are suitable for use at all construction sites with delivery and storage of the following materials:

- Petroleum products such as fuel, oil, and grease
- Soil stabilizers and binders (e.g. Polyacrylamide)
- Fertilizers, pesticides, and herbicides
- Detergents
- Asphalt and concrete compounds
- Hazardous chemicals such as acids, lime, adhesives, paints, solvents, and curing compounds
- Any other material that may be detrimental if released to the environment

3.1.22.3 Design and Installation Specifications

The following steps should be taken to minimize risk:

- Locate temporary storage area away from vehicular traffic, near the construction entrance(s), and away from waterways or storm drains.
- Supply Material Safety Data Sheets (MSDS) for all materials stored. Keep chemicals in their original labeled containers.
- Surrounding materials with earth berms is an option for temporary secondary containment.
- Minimize hazardous material storage on-site.
- Handle hazardous materials as infrequently as possible.
- During the wet weather season (October 1 through April 30), consider storing materials in a covered area.
- Store materials in secondary containment, such as an earthen dike, a horse trough, or a children’s wading pool for non-reactive materials such as detergents, oil, grease, and paints. “Bus boy” trays or concrete mixing trays may be used as secondary containment for small amounts of material.
- Do not store chemicals, drums, or bagged materials directly on the ground. Place these items on a pallet and, when possible, in secondary containment.
- If drums cannot be stored under a roof, domed plastic covers are inexpensive and snap to the top of drums, preventing water from collecting.

3.1.22.4 Material Storage Areas and Secondary Containment Practices:

- Store liquids, petroleum products, and substances listed in 40 CFR Parts 110, 117, or 302 in approved containers and drums and do not overfill the containers or drums. Store containers and drums in temporary secondary containment facilities.
- Temporary secondary containment facilities shall provide for a spill containment volume able to contain precipitation from a 25 year, 24 hour storm event plus 10% of the total enclosed container volume of all containers, or 110% of the capacity of the largest container within its boundary, whichever is greater.
- Secondary containment facilities shall be impervious to the materials stored therein for a minimum contact time of 72 hours.
- Secondary containment facilities shall be maintained free of accumulated rainwater and spills. In the event of spills or leaks, collect accumulated rainwater and spills and place into drums. Handle these liquids as hazardous waste unless testing determines them to be non-hazardous.
- Provide sufficient separation between stored containers to allow for spill cleanup and emergency response access.
- During the wet weather season (October 1 through April 30), cover each secondary containment facility during non-working days, prior to and during rain events.
- Keep material storage areas clean, organized, and equipped with an ample supply of appropriate spill clean-up material.
- The spill kit should include, at a minimum:
  - 1 water resistant nylon bag
  - 3 oil absorbent socks (3-inches by 4-feet)
  - 2 oil absorbent socks (3-inches by 10-feet)
  - 12 oil absorbent pads (17-inches by 19-inches)
  - 1 pair splash resistant goggles
  - 3 pairs nitrile gloves
  - 10 disposable bags with ties
  - Instructions

3.1.23 BMP C154: Concrete Washout Area

3.1.23.1 Purpose

Prevent or reduce the discharge of pollutants to stormwater from concrete waste by conducting washout offsite, or performing onsite washout in a designated area to prevent pollutants from entering surface waters or groundwater.

3.1.23.2 Conditions of Use

Use concrete washout best management practices on construction projects where:

- Concrete is used as a construction material.
- It is not possible to dispose of all concrete wastewater and washout offsite (ready mix plant, etc.)
- Concrete trucks, pumpers, or other concrete coated equipment are washed onsite.

NOTE: If less than 3 concrete trucks or pumpers need to be washed on-site, the washwater may be disposed of in a formed area awaiting concrete or an upland disposal area where it cannot contaminate surface or groundwater. The upland disposal area must be at least 50 feet from sensitive areas such as storm drains, open ditches, or waterbodies, including wetlands. Do not allow dirty water to enter storm drains, open ditches, or any waterbody.

3.1.23.3 Implementation

The following steps will help reduce stormwater pollution from concrete wastes:

- Perform washout of concrete trucks offsite or in designated concrete washout areas only.
- Do not wash out concrete trucks onto the ground, or into storm drains, open ditches, streets, or streams.
- Do not allow excess concrete to be dumped onsite, except in designated concrete washout areas.
- Concrete washout areas may be prefabricated concrete washout containers, or self-installed structures (above-grade or below-grade).
  - Prefabricated containers are most resistant to damage and protect against spills and leaks. Companies may offer delivery service and provide regular maintenance and disposal of solid and liquid waste.
  - If self-installed concrete washout areas are used, below-grade structures are preferred over above-grade structures because they are less prone to spills and leaks.
  - Self-installed above-grade structures should only be used if excavation is not practical.

3.1.23.4 Education

- Discuss the concrete management techniques described in this BMP with the ready-mix concrete supplier before any deliveries are made.
- Educate employees and subcontractors on the concrete waste management techniques described in this BMP.
- Arrange for contractor's superintendent or Certified Erosion and Sediment Control Lead (CESCL) to oversee and enforce concrete waste management procedures.
- Install a sign adjacent to each temporary concrete washout facility to inform concrete equipment operators to utilize the proper facilities.

3.1.23.5 Contracts

Incorporate requirements for concrete waste management into concrete supplier and subcontractor agreements.

3.1.23.6 Location and Placement Considerations:

- Locate washout area at least 50 feet from sensitive areas such as storm drains, open ditches, or water bodies, including wetlands.
- Allow convenient access for concrete trucks, preferably near the area where the concrete is being poured.
- If trucks need to leave a paved area to access washout, prevent track-out with a pad of rock or quarry spalls (BMP C105). These areas should be far enough away from other construction traffic to reduce the likelihood of accidental damage and spills.
- The number of facilities you install should depend on the expected demand for storage capacity.
- On large sites with extensive concrete work, washouts should be placed in multiple locations for ease of use by concrete truck drivers.

3.1.23.7 Onsite Temporary Concrete Washout Facility, Transit Truck Washout Procedures:

- Locate temporary concrete washout facilities a minimum of 50 ft from sensitive areas including storm drain inlets, open drainage facilities, and watercourses.
- Construct and maintain concrete washout facilities in order to contain all liquid and concrete waste generated by washout operations.
    - Approximately 7 gallons of wash water are used to wash one truck chute.
    - Approximately 50 gallons are used to wash out the hopper of a concrete pump truck.
- Washout of concrete trucks shall be performed in designated areas only.
- Concrete washout from concrete pumper bins can be washed into concrete pumper trucks and discharged into designated washout area or properly disposed of offsite.

- Once concrete wastes are washed into the designated area and allowed to harden, the concrete should be broken up, removed, and disposed of per applicable solid waste regulations. Dispose of hardened concrete on a regular basis.

Temporary Above-Grade Concrete Washout Facility

- Temporary concrete washout facility (type above grade) should be constructed as shown on the details at the end of this BMP, with a recommended minimum length and minimum width of 10 ft, but with sufficient quantity and volume to contain all liquid and concrete waste generated by washout operations.
- Plastic lining material should be a minimum of 10 mil polyethylene sheeting and should be free of holes, tears, or other defects that compromise the impermeability of the material.

Temporary Below-Grade Concrete Washout Facility

- Temporary concrete washout facilities (type below grade) should be constructed as shown on the details at the end of this BMP, with a recommended minimum length and minimum width of 10 ft. The quantity and volume should be sufficient to contain all liquid and concrete waste generated by washout operations.
- Lath and flagging should be commercial type.
- Plastic lining material shall be a minimum of 10 mil polyethylene sheeting and should be free of holes, tears, or other defects that compromise the impermeability of the material.
- Liner seams shall be installed in accordance with manufacturers' recommendations.
- Soil base shall be prepared free of rocks or other debris that may cause tears or holes in the plastic lining material.

3.1.23.8 Inspection and Maintenance

- Inspect and verify that concrete washout BMPs are in place prior to the commencement of concrete work.
- During periods of concrete work, inspect daily to verify continued performance.
  - Check overall condition and performance.
  - Check remaining capacity (% full).
  - If using self-installed washout facilities, verify plastic liners are intact and sidewalls are not damaged.
  - If using prefabricated containers, check for leaks.

- Maintain washout facilities to provide adequate holding capacity with a minimum freeboard of 12 inches.
- Washout facilities must be cleaned, or new facilities must be constructed and ready for use once the washout is 75% full.

- If the washout is nearing capacity, vacuum and dispose of the waste material in an approved manner.
    - Do not discharge liquid or slurry to waterways, storm drains or directly onto ground.
    - Do not use sanitary sewer without local approval.
    - Place a secure, non-collapsing, non-water collecting cover over the concrete washout facility prior to predicted wet weather to prevent accumulation and overflow of precipitation.
    - Remove and dispose of hardened concrete and return the structure to a functional condition. Concrete may be reused onsite or hauled away for disposal or recycling.
- When you remove materials from the self-installed concrete washout, build a new structure; or, if the previous structure is still intact, inspect for signs of weakening or damage, and make any necessary repairs. Re-line the structure with new plastic after each cleaning.

3.1.23.9 Removal of Temporary Concrete Washout Facilities

- When temporary concrete washout facilities are no longer required for the work, remove and properly dispose of the hardened concrete, slurries and liquids.
- Remove materials used to construct temporary concrete washout facilities from the site of the work and dispose of or recycle it.
- Holes, depressions or other ground disturbance caused by the removal of the temporary concrete washout facilities shall be backfilled, repaired, and stabilized to prevent erosion.

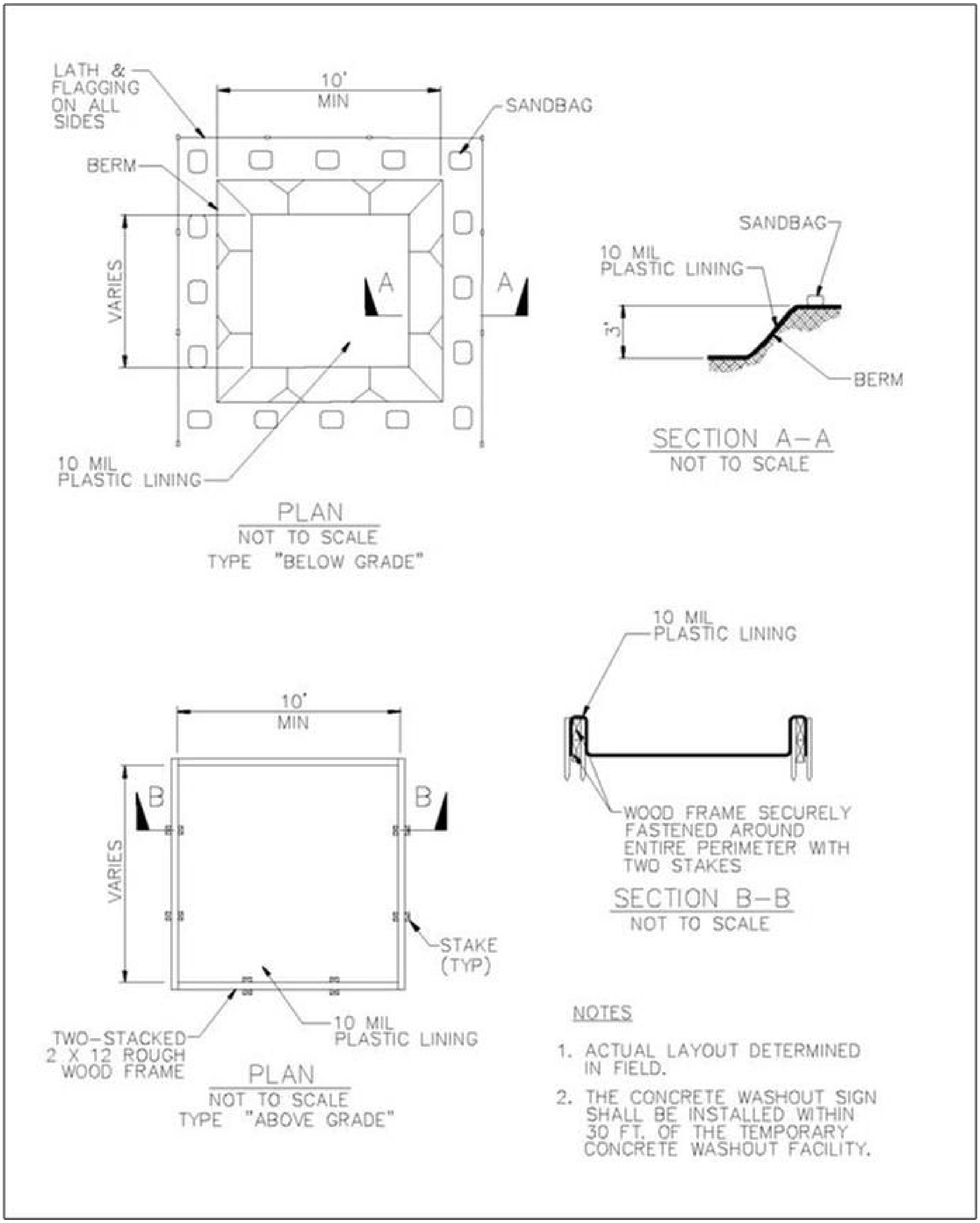


Figure II-3-10. Temporary Concrete Washout Facility

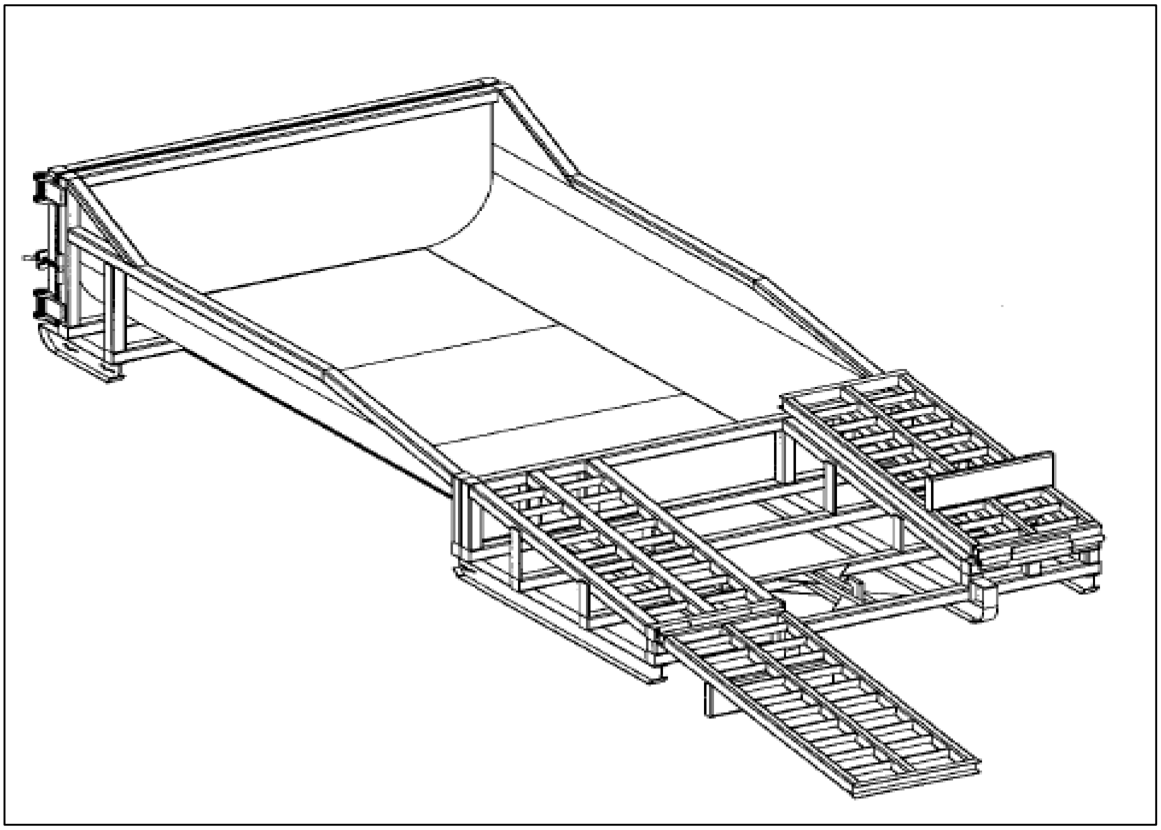


Figure II-3-11. Prefabricated Concrete Washout Container with Ramp

3.1.24 BMP C160: Certified Erosion and Sediment Control Lead

3.1.24.1 Purpose

The project proponent designates at least one person as the responsible representative in charge of erosion and sediment control (ESC) and water quality protection. The designated person shall be the Certified Erosion and Sediment Control Lead (CESCL), who is responsible for ensuring compliance with all local, state, and federal erosion and sediment control and water quality requirements.

3.1.24.2 Conditions of Use

A CESCL should be made available on project types that include, but are not limited to, the following:

- Construction activity that disturbs one acre of land or more.
- Construction activity that disturbs less than one acre of land, but is part of a larger common plan of development or sale that will ultimately disturb one acre of land or more.
- Heavy construction of roads, bridges, highways, airports, buildings.
- Projects near wetlands and sensitive or critical areas.
- Projects in or over water.

3.1.24.3 Specifications

The CESCL shall:

- Have a current certificate proving attendance in an erosion and sediment control training course that meets the minimum ESC training and certification requirements established by Ecology. Ecology will maintain a list of ESC training and certification providers at: www.ecy.wa.gov/programs/wq/stormwater.

  OR

- Be a Certified Professional in Erosion and Sediment Control (CPESC). For additional information go to: www.cpesc.net

The CESCL shall have authority to act on behalf of the contractor or developer and shall be available, on call, 24 hours per day throughout the period of construction.

The Construction SWPPP shall include the name, telephone number, fax number, and address of the designated CESCL.

A CESCL may provide inspection and compliance services for multiple construction projects in the same geographic region.

Duties and responsibilities of the CESCL shall include, but are not limited to, the following:

- Maintaining a permit file on site at all times which includes the SWPPP and any associated permits and plans.
- Directing BMP installation, inspection, maintenance, modification, and removal.

- Updating all project drawings and the Construction SWPPP with changes made.
- Keeping daily logs and inspection reports. Inspection reports should include:
  - Inspection date/time.
  - Weather information, general conditions during inspection, and approximate amount of precipitation since the last inspection.
  - A summary or list of all BMPs implemented, including observations of all erosion/sediment control structures or practices. The following shall be noted:
    - ♦ Locations of BMPs inspected,
    - ♦ Locations of BMPs that need maintenance,
    - ♦ Locations of BMPs that failed to operate as designed or intended, and
    - ♦ Locations where additional or different BMPs are required.
  - Visual monitoring results, including a description of discharged stormwater. The presence of suspended sediment, turbid water, discoloration, and oil sheen shall be noted, as applicable.
  - Any water quality monitoring performed during inspection.
  - General comments and notes, including a brief description of any BMP repairs, maintenance, or installations made as a result of the inspection.
- Facilitate, participate in, and take corrective actions resulting from inspections performed by outside agencies or the owner.

3.1.25 BMP C161: Payment of Erosion Control Work

3.1.25.1 Purpose

As with any construction operation, the contractor should be paid for erosion control work. Address payment for erosion control during project development and design. Identify the method of payment in the SWPPP.

3.1.25.2 Conditions of Use

Erosion control work should never be "incidental" to the contract as it is extremely difficult for the contractor to bid the work. Work that is incidental to the contract is work where no separate measurement or payment is made. The cost for incidental work is included in payments made for applicable bid items in the Schedule of Unit Prices. For example, any erosion control work associated with an item called "Clearing and Grubbing" is bid and paid for as part of that item, not separately.

Two effective means for payment of erosion control work are described below. These include:

- TESC-Force Account
- Unit Prices

TESC Force Account

One good method for ensuring that contingency money is available to address unforeseen erosion and sediment control problems is to set up an item called "TESC-Force Account". For example, an amount such as $15,000 is written in both the Unit Price and Amount columns for the item. This requires all bidders to bid $15,000 for the item.

The Force Account is used only at the discretion of the contracting agency or developer. If there are no unforeseen erosion problems, the money is not used. If there are unforeseen erosion problems, the contracting agency would direct the work to be done and pay an agreed upon amount for the work (such as predetermined rates under a Time and Materials setting).

Contract language for this item could look like this:

Measurement and Payment for "TESC-Force Account" will be on a Force Account basis in accordance with_________(include appropriate section of the Contract Specifications). The amount entered in the Schedule of Unit Prices is an estimate.

Unit Prices

When the material or work can be quantified, it can be paid by Unit Prices. For example, the project designer knows that 2 acres will need to be hydroseeded and sets up an Item of Work for Hydroseed, with a Bid Quantity of 2, and a Unit for Acre. The bidder writes in the unit Prices and Amount.

Unit Price items can be used in conjunction with TESC-Force Account and TESC-Lump Sum.

3.1.26 BMP C162: Scheduling

3.1.26.1 Purpose

Sequencing a construction project reduces the amount and duration of soil exposed to erosion by wind, rain, runoff, and vehicle tracking.

3.1.26.2 Conditions of Use

The construction sequence schedule is an orderly listing of all major land-disturbing activities together with the necessary erosion and sedimentation control measures planned for the project. This type of schedule guides the contractor on work to be done before other work is started so serious erosion and sedimentation problems can be avoided.

Following a specified work schedule that coordinates the timing of land-disturbing activities and the installation of control measures is perhaps the most cost-effective way of controlling erosion during construction. The removal of surface ground cover leaves a site vulnerable to accelerated erosion. Construction procedures that limit land clearing, provide timely installation of erosion and sedimentation controls, and restore protective cover quickly can significantly reduce the erosion potential of a site.

3.1.26.3 Design Considerations

- Avoid rainy periods.
- Schedule projects to disturb only small portions of the site at any one time. Complete grading as soon as possible. Immediately stabilize the disturbed portion before grading the next portion. Practice staged seeding in order to revegetate cut and fill slopes as the work progresses.

3.1.27 BMP C180: Small Project Construction Stormwater Pollution Prevention

3.1.27.1 Purpose

To prevent the discharge of sediment and other pollutants to the maximum extent practicable from small construction projects.

3.1.27.2 Conditions of Use

Can be used on small construction projects that:

- Add or replace between 2,000 and 5,000 square feet of impervious surfaces, or
- Clear/disturb between 7,000 square feet and 1 acre of land, or
- Grade/fill less than 500 cubic yards of material.

3.1.27.3 Design and Installation Specifications

- Plan and implement proper clearing and grading of the site. It is most important to clear only the areas needed, thus keeping exposed areas to a minimum. Phase clearing so that only those areas actively being worked are uncovered.

  NOTE: Clearing limits should be flagged in the lot or area prior to initiating clearing.

- Manage soil in a manner that does not permanently compact or deteriorate the final soil and landscape system. If disturbance and/or compaction occur, the impact must be corrected at the end of the construction activity. This shall include restoration of soil depth, soil quality, permeability, and percent organic matter. Construction practices must not cause damage to or compromise the design of permanent landscape or infiltration areas.
- Locate excavated basement soil a reasonable distance behind the curb, such as in the backyard or side yard area. This will increase the distance eroded soil must travel to reach the storm sewer system. Cover soil piles until the soil is either used or removed. Situate piles so sediment does not run into the street or adjoining yards.
- Backfill basement walls as soon as possible and rough grade the lot. This will eliminate large soil mounds, which are highly erodible, and prepares the lot for temporary cover, which will further reduce erosion potential.
- Remove excess soil from the site as soon as possible after backfilling. This will eliminate any sediment loss from surplus fill.
- If a lot has a soil bank higher than the curb, install a trench or berm, moving the bank several feet behind the curb. This will reduce the occurrence of gully and rill erosion while providing a storage and settling area for stormwater.
- Stabilize the construction entrance where traffic will be leaving the construction site and traveling on paved roads or other paved areas within 1,000 feet of the site.

- Provide for periodic street cleaning to remove any sediment that may have been tracked out. Remove sediment by shoveling or sweeping and carefully move it to a suitable disposal area where it will not be re-eroded.
- Backfill utility trenches that run up and down slopes within seven days. Cross-slope trenches may remain open throughout construction to provide runoff interception and sediment trapping, provided that they do not convey turbid runoff off site.

3.2 Runoff, Conveyance and Treatment BMPs

3.2.1 BMP C200: Interceptor Dike and Swale

3.2.1.1 Purpose

Provide a ridge of compacted soil, or a ridge with an upslope swale, at the top or base of a disturbed slope or along the perimeter of a disturbed construction area to convey stormwater. Use the dike and/or swale to intercept the runoff from unprotected areas and direct it to areas where erosion can be controlled. This can prevent storm runoff from entering the work area or sediment-laden runoff from leaving the construction site.

3.2.1.2 Conditions of Use

Where the runoff from an exposed site or disturbed slope must be conveyed to an erosion control facility that can safely convey the stormwater.

- Locate upslope of a construction site to prevent runoff from entering disturbed area.
- When placed horizontally across a disturbed slope, it reduces the amount and velocity of runoff flowing down the slope.
- Locate downslope to collect runoff from a disturbed area and direct it to a sediment basin.

3.2.1.3 Design and Installation Specifications

- Stabilize dike and/or swale and channel with temporary or permanent vegetation or other channel protection during construction.
- Channel requires a positive grade for drainage; steeper grades require channel protection and check dams.
- Review construction for areas where overtopping may occur.
- Can be used at the top of new fill before vegetation is established.
- May be used as a permanent diversion channel to carry the runoff.
- Sub-basin tributary area should be one acre or less.
- Design capacity for the peak flow from a 10-year, 24-hour storm assuming a Type 1A rainfall distribution (3-inches) for temporary facilities. Alternatively, use 1.6 times the 10-year, 1-hour flow indicated by WWHM. Design capacity for the peak flow from a 25-year, 24-hour storm for permanent facilities.

Interceptor Dikes

- Interceptor dikes shall meet the following criteria:

Top Width	2 feet minimum.
Height	1.5 feet minimum on berm.
Side Slope	2:1 or flatter.
Grade	Depends on topography, however, dike system minimum is 0.5% and maximum is 1%
Compaction	Minimum of 90 percent ASTM D698 standard proctor.

- Horizontal Spacing of Interceptor Dikes:

Average Slope	**Slope Percent**	**Flowpath Length**
20H:1V or less	3-5%	300 feet
(10 to 20)H:1V	5-10%	200 feet
(4 to 10)H:1V	10-25%	100 feet
(2 to 4)H:1V	25-50%	50 feet

- Stabilization depends on velocity and reach.

Slopes <5%	Seed and mulch applied within 5 days of dike construction (see BMP C121, Mulching).
Slopes 5 - 40%	Dependent on runoff velocities and dike materials. Stabilization should be done immediately using either sod or riprap or other measures to avoid erosion.

- The upslope side of the dike shall provide positive drainage to the dike outlet. No erosion shall occur at the outlet. Provide energy dissipation measures as necessary. Sediment-laden runoff must be released through a sediment trapping facility.
- Minimize construction traffic over temporary dikes. Use temporary cross culverts for channel crossing.

Interceptor Swales

- Interceptor swales shall meet the following criteria:

Bottom Width	2 feet minimum; the bottom shall be level.
Depth	1-foot minimum.
Side Slope	2H:1V or flatter
Grade	Maximum 5 percent, with positive drainage to a suitable outlet (such as a sediment pond).
Stabilization	Seed as per *BMP C120*, *Temporary and Permanent Seeding*, or *BMP C202*, *Channel Lining*, 12 inches thick of riprap pressed into the bank and extending at least 8 inches vertical from the bottom.

- Inspect diversion dikes and interceptor swales once a week and after every rainfall. Immediately remove sediment from the flow area.
- Repair damage caused by construction traffic or other activity before the end of each working day.
- Check outlets and make timely repairs as needed to avoid gully formation. When the area below the temporary diversion dike is permanently stabilized, remove the dike and fill and stabilize the channel to blend with the natural surface.

3.2.2 BMP C201: Grass-Lined Channels

3.2.2.1 Purpose

To provide a channel with a vegetative lining for conveyance of runoff. See Figure II-3-12 for typical grass-lined channels.

3.2.2.2 Conditions of Use

This practice applies to construction sites where concentrated runoff needs to be contained to prevent erosion or flooding.

- When a vegetative lining can provide sufficient stability for the channel cross section and lower velocities of water (normally dependent on grade). This means that the channel slopes are generally less than 5 percent and space is available for a relatively large cross section.
- Typical uses include roadside ditches, channels at property boundaries, outlets for diversions, and other channels and drainage ditches in low areas.
- Channels that will be vegetated should be installed before major earthwork and hydroseeded with a bonded fiber matrix (BFM). The vegetation should be well established (i.e., 75 percent cover) before water is allowed to flow in the ditch. With channels that will have high flows, erosion control blankets should be installed over the hydroseed. If vegetation cannot be established from seed before water is allowed in the ditch, sod should be installed in the bottom of the ditch in lieu of hydromulch and blankets.

3.2.2.3 Design and Installation Specifications

Locate the channel where it can conform to the topography and other features such as roads.

- Locate them to use natural drainage systems to the greatest extent possible.
- Avoid sharp changes in alignment or bends and changes in grade.
- Do not reshape the landscape to fit the drainage channel.
- Base the maximum design velocity on soil conditions, type of vegetation, and method of revegetation, but at no times shall velocity exceed 5 feet/second. The channel shall not be overtopped by the peak runoff from a 10-year, 24–hour storm, assuming a type 1A rainfall distribution (3.0-inches). Alternatively, use 1.6 times the 10-year, 1-hour flow indicated by an approved continuous runoff model to determine a flow rate which the channel must contain.
- An **established** grass or vegetated lining is required before the channel can be used to convey stormwater, unless stabilized with nets or blankets.
- If design velocity of a channel to be vegetated by seeding exceeds 2 ft/sec, a temporary channel liner is required. Geotextile or special mulch protection, such as fiberglass roving or straw and netting, provides stability until the vegetation is fully established. See Figure II-3-13.

- Remove check dams when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4 percent. Seed and mulch the area beneath the check dams immediately after dam removal.
- If vegetation is established by sodding, the permissible velocity for established vegetation may be used and no temporary liner is needed.
- Do not subject grass-lined channel to sedimentation from disturbed areas. Use sediment-trapping BMPs upstream of the channel.
- **V-shaped grass channels** generally apply where the quantity of water is small, such as in short reaches along roadsides. The V-shaped cross section is least desirable because it is difficult to stabilize the bottom where velocities may be high.
- **Trapezoidal grass channels** are used where runoff volumes are large and slope is low so that velocities are non-erosive to vegetated linings. (Note: it is difficult to construct small parabolic shaped channels.)
- Subsurface drainage, or riprap channel bottoms, may be necessary on sites that are subject to prolonged wet conditions due to long duration flows or a high water table.
- Provide outlet protection at culvert ends and at channel intersections.
- Grass channels, at a minimum, should carry peak runoff for temporary construction drainage facilities from the 10-year, 24-hour storm (3.0 inches) without eroding. Where flood hazard exists, increase the capacity according to the potential damage.
- Grassed channel side slopes generally are constructed 3:1 or flatter to aid in the establishment of vegetation and for maintenance.
- Construct channels a minimum of 0.2 foot larger around the periphery to allow for soil bulking during seedbed preparations and sod buildup.

3.2.2.4 Maintenance Standards

During the establishment period, check grass-lined channels after every rainfall.

- After grass is established, periodically check the channel; check the channel after every heavy rainfall event. Immediately make repairs.
- It is particularly important to check the channel outlet and all road crossings for bank stability and evidence of piping or scour holes.
- Remove all significant sediment accumulations to maintain the designed carrying capacity. Keep the grass in a healthy, vigorous condition at all times, since it is the primary erosion protection for the channel.

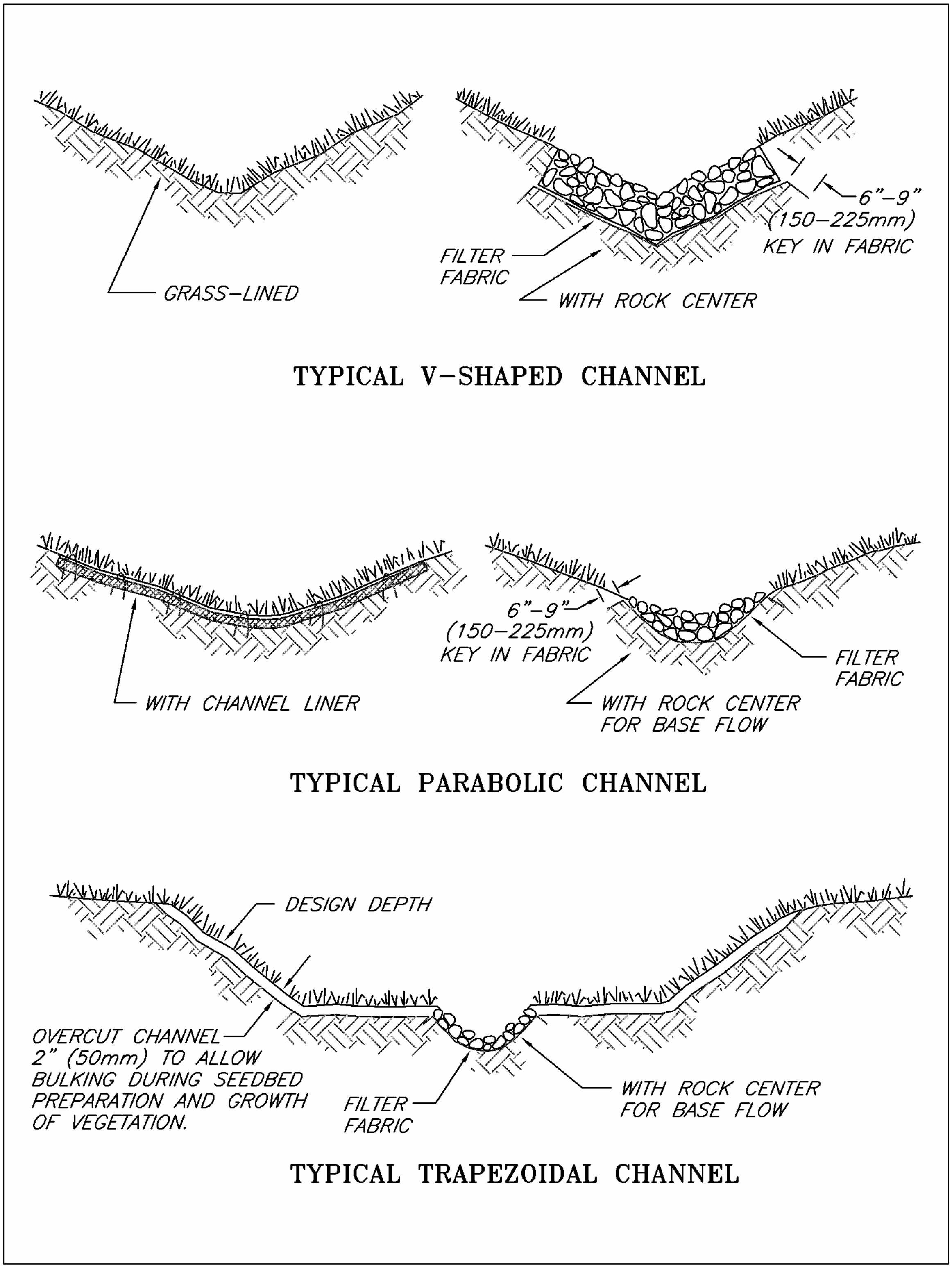
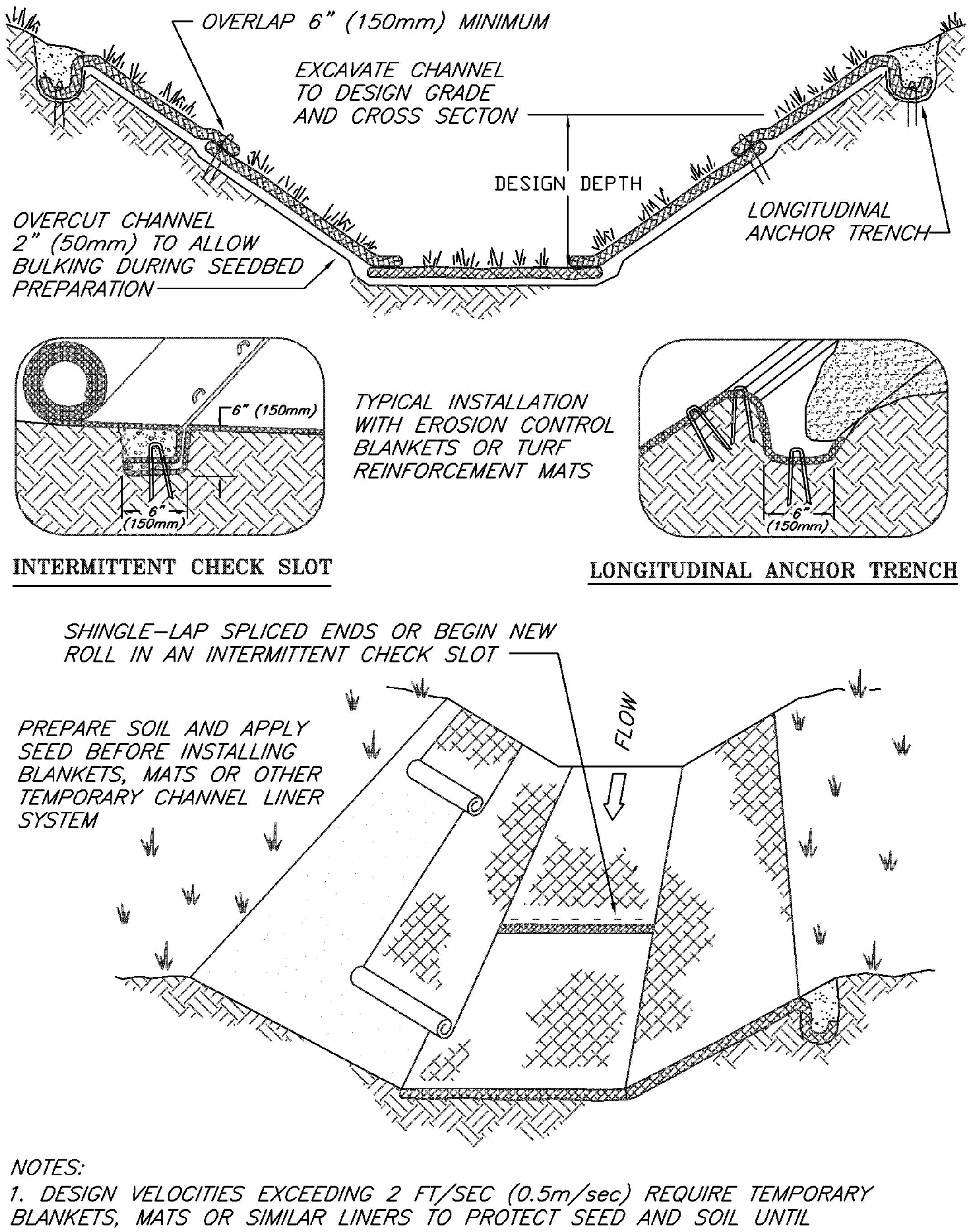


Figure II-3-12. Typical Grass-Lined Channels



NOTES:

1. DESIGN VELOCITIES EXCEEDING 2 FT/SEC (0.5m/sec) REQUIRE TEMPORARY BLANKETS, MATS OR SIMILAR LINERS TO PROTECT SEED AND SOIL UNTIL VEGETATION BECOMES ESTABLISHED.

2. GRASS-LINED CHANNELS WITH DESIGN VELOCITIES EXCEEDING 6 FT/SEC (2m/sec) SHOULD INCLUDE TURF REINFORCEMENT MATS.

Figure II-3-13. Temporary Channel Liners

3.2.3 BMP C202: Channel Lining

3.2.3.1 Purpose

To protect erodible channels by providing a channel liner using either blankets or riprap.

3.2.3.2 Conditions of Use

- When natural soils or vegetated stabilized soils in a channel are not adequate to prevent channel erosion.
- When a permanent ditch or pipe system is to be installed and a temporary measure is needed.
- In almost all cases, synthetic and organic coconut blankets are more effective than riprap for protecting channels from erosion. Blankets can be used with and without vegetation. Blanketed channels can be designed to handle any expected flow and longevity requirement. Some synthetic blankets have a predicted life span of 50 years or more, even in sunlight.
- The Federal Highway Administration recommends not using flexible liners whenever the slope exceeds 10 percent or the shear stress exceeds 8 pounds per square foot.

3.2.3.3 Design and Installation Specifications

See BMP C122 for information on blankets.

Since riprap is used where erosion potential is high, construction must be sequenced so the riprap is put in place with the minimum possible delay (see Figure II-3-14).

- Only disturb areas where riprap is to be placed if final preparation and placement of the riprap can immediately follow the initial disturbance. Where riprap is used for outlet protection, place the riprap before or in conjunction with the construction of the pipe or channel so it is in place when the pipe or channel begins to operate.
- The designer, after determining the appropriate riprap size for stabilization, shall consider that size to be a minimum size and then, based on riprap gradations actually available in the area, select the size or sizes that equal or exceed the minimum size. Consider the possibility of drainage structure damage by children when selecting a riprap size, especially if there is nearby water or a gully in which to toss the stones.
- Use field stone or quarry stone of approximately rectangular shape for the riprap. The stone shall be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering and shall be suitable in all respects for the purpose intended.
- Rubble concrete may be used, provided it has a density of at least 150 pounds per cubic foot and otherwise meets the requirement of this standard and specification.
- Place a lining of engineering filter fabric (geotextile) between the riprap and the underlying soil surface to prevent soil movement into or through the riprap. The geotextile should be keyed in at the top of the bank.

- Do not use filter fabric on slopes steeper than 1-1/2H:1V as slippage may occur. It should be used in conjunction with a layer of coarse aggregate (granular filter blanket) when the riprap to be placed is 12 inches and larger.

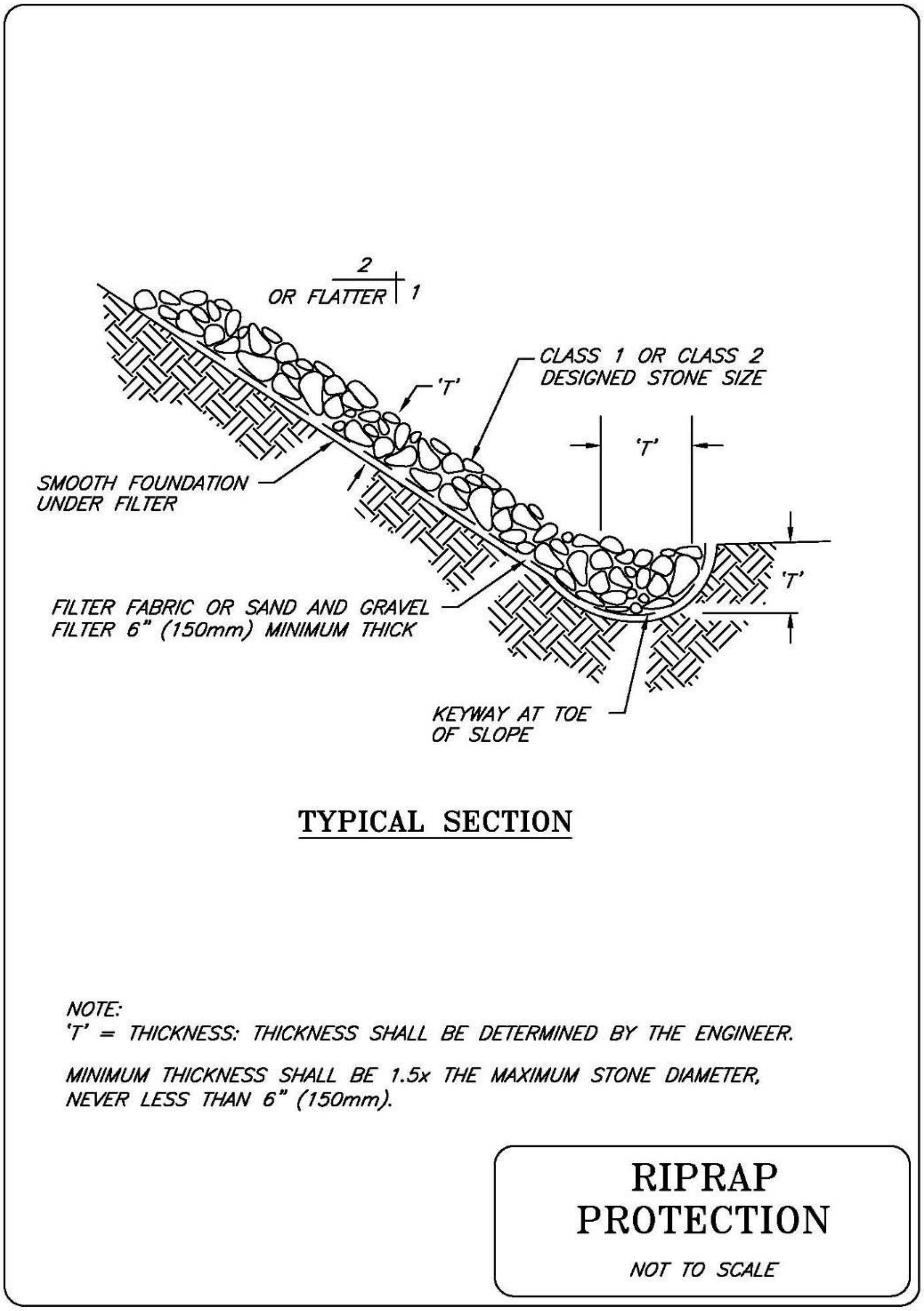


Figure II-3-14. Soil Erosion Protection – Rip Rap Protection

3.2.4 BMP C203: Water Bars

3.2.4.1 Purpose

A small ditch or ridge of material is constructed diagonally across a road or right-of-way to divert stormwater runoff from the road surface, wheel tracks, or a shallow road ditch.

3.2.4.2 Conditions of Use

Clearing right-of-way and construction of access for power lines, pipelines, and other similar installations often require long, narrow right-of-ways over sloping terrain. Disturbance and compaction promotes gully formation in these cleared strips by increasing the volume and velocity of runoff. Gully formation may be especially severe in tire tracks and ruts. To prevent gullying, runoff can often be diverted across the width of the right-of-way to undisturbed areas by using small predesigned diversions.

Give special consideration to each individual outlet area, as well as to the cumulative effect of added diversions. Use gravel to stabilize the diversion where significant vehicular traffic is anticipated.

3.2.4.3 Design and Installation Specifications

Height: 8-inch minimum measured from the channel bottom to the top of the ridge.

- Side slope of channel: 2H:1V maximum; 3H:1V or flatter when vehicles will cross.
- Base width of ridge: 6-inch minimum.
- Locate them to use natural drainage systems and to discharge into well vegetated stable areas.
- Guideline for Spacing:

Slope %	Spacing (ft)
< 5	125
5 - 10	100
10 - 20	75
20 – 35	50
> 35	Use rock lined ditch

- Grade of water bar and angle: Select angle that results in ditch slope of less than 2 percent.
- Install as soon as clearing and grading is complete. Reconstruct when construction is complete on a section when utilities are being installed.
- Compact the ridge when installed.
- Stabilize, seed, and mulch portions that are not subject to traffic. Gravel areas crossed by vehicles.

3.2.4.4 Maintenance Standards

Periodically inspect right-of-way diversions for wear and after every heavy rainfall inspect for erosion damage.

- Immediately remove sediment from the flow area and repair the dike.
- Check outlet areas and make timely repairs as needed.
- When permanent road drainage is established and the area above the temporary right-of-way diversion is permanently stabilized, remove the dike and fill the channel to blend with the natural ground, and appropriately stabilize the disturbed area.

3.2.5 BMP C204: Pipe Slope Drains

3.2.5.1 Purpose

To use a pipe to convey stormwater anytime water needs to be diverted away from or over bare soil to prevent gullies, channel erosion, and saturation of slide-prone soils.

3.2.5.2 Conditions of Use

Pipe slope drains should be used when a temporary or permanent stormwater conveyance is needed to move the water down a steep slope to avoid erosion (Figure II-3-15).

On highway projects, pipe slope drains should be used at bridge ends to collect runoff and pipe it to the base of the fill slopes along bridge approaches. These can be designed into a project and included as bid items. Another use on road projects is to collect runoff from pavement and pipe it away from side slopes. These are useful because there is generally lag time between having the first lift of asphalt installed and the curbs, gutters, and permanent drainage installed. Used in conjunction with sand bags or other temporary diversion devices, these will prevent massive amounts of sediment from leaving a project.

Water can be collected; channeled with sand bags, Triangular Silt Dikes, berms, or other material; and piped to temporary sediment ponds.

Pipe slope drains can be:

- Connected to new catch basins and used temporarily until all permanent piping is installed;
- Used to drain water collected from aquifers exposed on cut slopes and convey it to the base of the slope;
- Used to collect clean runoff from plastic sheeting and direct it away from exposed soil;
- Installed in conjunction with silt fence to drain collected water to a controlled area;
- Used to divert small seasonal streams away from construction. They have been used successfully on culvert replacement and extension jobs. Large flex pipe can be used on larger streams during culvert removal, repair, or replacement; and,
- Connected to existing down spouts and roof drains and used to divert water away from work areas during building renovation, demolition, and construction projects.

There are now several commercially available collectors that are attached to the pipe inlet and help prevent erosion at the inlet.

3.2.5.3 Design and Installation Specifications

Size the pipe to convey the flow. The capacity for temporary drains shall be sufficient to handle the peak flow from a 10-year, 24-hour storm event assuming a Type 1A rainfall distribution (3.0-inches). Alternatively, use 1.6 times the 10-year, 1-hour flow indicated by WWHM. Size permanent pipe slope drains for the 25-year, 24-hour peak flow.

- Use care in clearing vegetated slopes for installation.
- Re-establish cover immediately on areas disturbed by installation.
- Use temporary drains on new cut or fill slopes.
- Use diversion dikes or swales to collect water at the top of the slope.
- Ensure that the entrance area is stable and large enough to direct flow into the pipe.
- Piping of water through the berm at the entrance area is a common failure mode.
- The entrance shall consist of a standard flared end section for culverts 12 inches and larger with a minimum 6-inch metal toe plate to prevent runoff from undercutting the pipe inlet. The slope of the entrance shall be at least 3 percent. Sand bags may also be used at pipe entrances as a temporary measure.
- Thoroughly compact the soil around and under the pipe and entrance section to prevent undercutting.
- Securely connect the flared inlet section to the slope drain and have watertight connecting bands.
- Securely fasten, fuse or have gasketed, watertight fittings for the slope drain sections, and securely anchor them into the soil.
- Install thrust blocks anytime 90 degree bends are utilized. Depending on size of pipe and flow, these can be constructed with sand bags, straw bales staked in place, “T” posts and wire, or ecology blocks.
- Pipe needs to be secured along its full length to prevent movement. This can be done with steel “T” posts and wire. A post is installed on each side of the pipe and the pipe is wired to them. This should be done every 10-20 feet of pipe length, depending on the size of the pipe and quantity of water to be diverted.
- Use interceptor dikes to direct runoff into a slope drain. Ensure the height of the dike is at least 1 foot higher at all points than at the top of the inlet pipe.
- Stabilize the area below the outlet with a riprap apron (see BMP C209 Outlet Protection for the appropriate outlet material).
- If the pipe slope drain is conveying sediment-laden water, direct all flows into the sediment trapping facility.
- Materials specifications for any permanent piped system shall be set by the local government.

3.2.5.4 Maintenance Standards

Check inlet and outlet points regularly, especially after storms.

The inlet should be free of undercutting, and no water should be going around the point of entry. If there are problems, the headwall should be reinforced with compacted earth or sand bags.

- The outlet point should be free of erosion and installed with appropriate outlet protection.
- For permanent installations, inspect pipe periodically for vandalism and physical distress such as slides and wind-throw.
- Normally the pipe slope is so steep that clogging is not a problem with smooth wall pipe; however, debris may become lodged in the pipe.

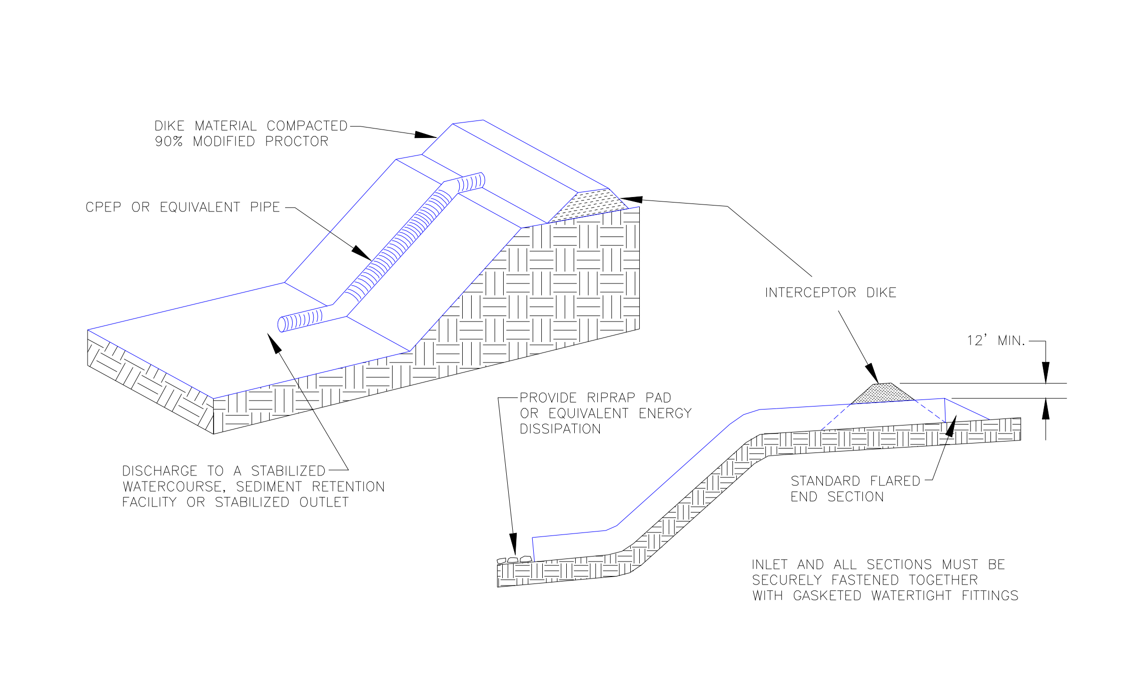


Figure II-3-15. Pipe Slope Drains

3.2.6 BMP C205: Subsurface Drains

3.2.6.1 Purpose

To intercept, collect, and convey groundwater to a satisfactory outlet, using a perforated pipe or conduit below the ground surface. Subsurface drains are also known as “French drains.” The perforated pipe provides a dewatering mechanism to drain excessively wet soils, provide a stable base for construction, improve stability of structures with shallow foundations, or to reduce hydrostatic pressure to improve slope stability.

3.2.6.2 Conditions of Use

Use when excessive water must be removed from the soil. The soil permeability, depth to water table, and impervious layers are all factors which may govern the use of subsurface drains.

3.2.6.3 Design and Installation Specifications

- **Relief drains**
  - Are used either to lower the water table in large, relatively flat areas, improve the growth of vegetation, or to remove surface water.
  - Are installed along a slope and drain in the direction of the slope.
  - Can be installed in a grid pattern, a herringbone pattern, or a random pattern.
- **Interceptor drains**
  - Are used to remove excess groundwater from a slope, stabilize steep slopes, and lower the water table immediately below a slope to prevent the soil from becoming saturated.
  - Are installed perpendicular to a slope and drain to the side of the slope.
  - Usually consist of a single pipe or series of single pipes instead of a patterned layout.
- **Depth and spacing considerations for interceptor drains**
  - The depth of an interceptor drain is determined primarily by the depth to which the water table is to be lowered or the depth to a confining layer. For practical reasons, the maximum depth is usually limited to 6 feet, with a minimum cover of 2 feet to protect the conduit.
  - The soil should have depth and sufficient permeability to permit installation of an effective drainage system at a depth of 2 to 6 feet.
  - An adequate outlet for the drainage system must be available either by gravity or pumping.
  - The quantity and quality of discharge needs to be accounted for in the receiving stream (additional detention may be required).
  - This standard does not apply to subsurface drains for building foundations or deep excavations.

- The capacity of an interceptor drain is determined by calculating the maximum rate of groundwater flow to be intercepted. Therefore, it is good practice to make complete subsurface investigations, including hydraulic conductivity of the soil, before designing a subsurface drainage system.
- **Drain sizing considerations**
  - Size subsurface drains to carry the required capacity without pressure flow. The minimum diameter for a subsurface drain is 4 inches.
  - The minimum velocity required to prevent silting is 1.4 feet per second. Grade the line to achieve this velocity at a minimum. The maximum allowable velocity using a sand-gravel filter or envelope is 9 feet per second.
- Use filter material and fabric around all drains for proper bedding and filtration of fine materials. Envelopes and filters should surround the drain to a minimum of 3-inch thickness.
- Empty the outlet of the subsurface drain into a sediment pond through a catch basin. If free of sediment, it can then empty into a receiving channel, swale, or stable vegetated area adequately protected from erosion and undermining.
- Construct the trench on a continuous grade with no reverse grades or low spots.
- Stabilize soft or yielding soils under the drain with gravel or other suitable material.
- Backfill immediately after placement of the pipe. Do not allow sections of pipe to remain uncovered overnight or during a rainstorm. Place backfill material in the trench in such a manner that the drain pipe is not displaced or damaged.
- Do not install permanent drains near trees as tree roots may clog the lines. Use solid pipe with watertight connections where necessary to pass a subsurface drainage system through a stand of trees.
- **Outlet considerations**
  - Ensure that the outlet of a drain empties into a channel or other watercourse above the normal water level.
  - Secure an animal guard to the outlet end of the pipe to keep out rodents.
  - Use at least 10 feet of corrugated metal, cast iron, or heavy-duty plastic without perforations outlet pipe. Do not use an envelope or filter material around the outlet pipe, and bury at least two-thirds of the pipe length.
  - When outlet velocities exceed those allowable for the receiving stream, provide outlet protection.

3.2.6.4 Maintenance Standards

Check the subsurface drains periodically to ensure that they are free-flowing and not clogged with sediment or roots.

- Keep the outlet clean and free of debris.
- Keep surface inlets open and free of sediment and other debris.
- Trees located too close to a subsurface drain often clog the system with their roots. If a drain becomes clogged, relocate the drain or remove the trees as a last resort. Plan the placement of the drain to minimize this problem.
- Where drains are crossed by heavy vehicles, check the line to ensure that it is not crushed and use pipe material that can handle traffic loads.

3.2.7 BMP C206: Level Spreader

3.2.7.1 Purpose

To provide a temporary outlet for dikes and diversions consisting of an excavated depression constructed at zero grade across a slope. To convert concentrated runoff to sheet flow and release it onto areas stabilized by existing vegetation or an engineered filter strip.

3.2.7.2 Conditions of Use

Used when a concentrated flow of water needs to be dispersed over a large area with existing stable vegetation.

- Items to consider are:
  - What is the risk of erosion or damage if the flow may become concentrated?
  - Is an easement required if discharged to adjoining property?
  - Most of the flow should be as groundwater and not as surface flow.
  - Is there an unstable area downstream that cannot accept additional groundwater?
- Use only where the slopes are gentle, the water volume is relatively low, and the soil will adsorb most of the low flow events.

3.2.7.3 Design and Installation Specifications

Use above undisturbed areas that are stabilized by existing vegetation.

If the level spreader has any low points, flow will concentrate, create channels and may cause erosion.

- Discharge area below the outlet must be uniform with a slope of less than 5H:1V.
- Construct outlet level in a stable, undisturbed soil profile (not on fill).
- Do not allow the runoff to reconcentrate after release unless intercepted by another downstream measure.
- The grade of the channel for the last 20 feet of the dike or interceptor entering the level spreader shall be less than or equal to 1 percent. The grade of the level spreader shall be 0 percent to ensure uniform spreading of storm runoff.
- A 6-inch high gravel berm placed across the level lip shall consist of washed crushed rock, 2- to 4-inch or 3/4-inch to 1½-inch size.
- Calculate the spreader length by estimating the peak flow expected from the 10-year, 24-hour design storm (3.0-inches). The length of the spreader shall be a minimum of 15 feet for 0.1 cubic feet per second and shall be 10 feet for each 0.1 cubic feet per second there after to a maximum of 0.5 cubic feet per second per spreader. Use multiple spreaders for higher flows.
- The width of the spreader should be at least 6 feet.

- The depth of the spreader as measured from the lip should be at least 6 inches and it should be uniform across the entire length.
- Level spreaders shall be setback from the property line unless there is an easement for flow.
- Level spreaders, when installed every so often in grassy swales, keep the flows from concentrating. Materials that can be used include sand bags, lumber, logs, concrete, and pipe. To function properly, the material needs to be installed level and on contour. Figure II-3-16 and Figure II-3-17 provide a cross-section and a detail of a level spreader.

3.2.7.4 Maintenance Standards

The spreader should be inspected after every runoff event to ensure proper function.

- The contractor should avoid the placement of any material on the structure and should prevent construction traffic from crossing over the structure.
- If the spreader is damaged by construction traffic, immediately repair it.

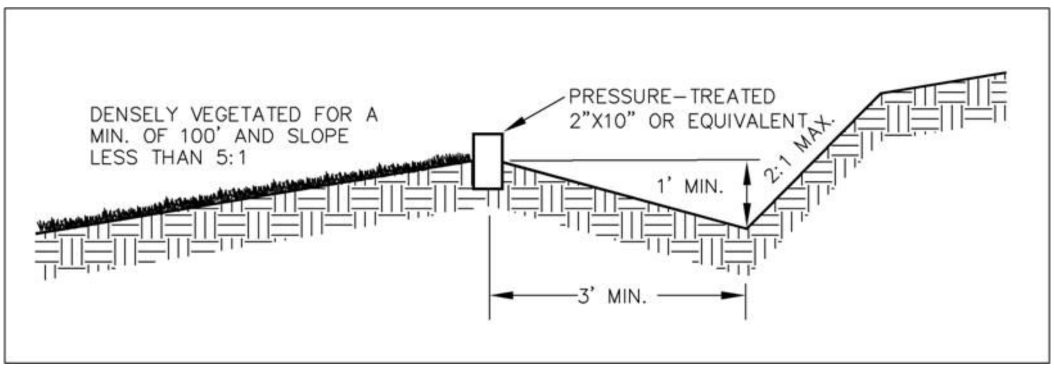


Figure II-3-16. Cross-Section of a Level Spreader

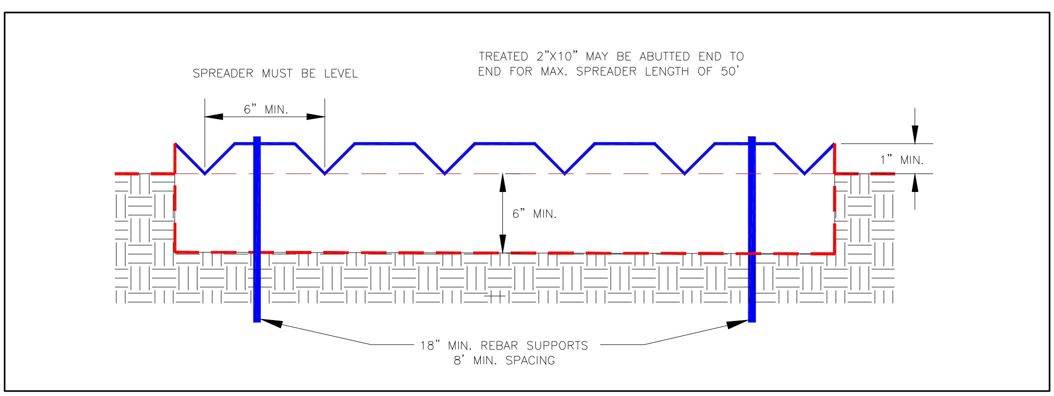


Figure II-3-17. Detail of a Level Spreader

3.2.8 BMP C207: Check Dams

3.2.8.1 Purpose

Construction of small dams across a swale or ditch reduces the velocity of concentrated flow and dissipates energy at the check dam.

3.2.8.2 Conditions of Use

Where temporary channels or permanent channels are not yet vegetated, channel lining is infeasible, and velocity checks are required.

- Do not place check dams in streams unless approved by the State Department of Fish and Wildlife. Do not place check dams in wetlands without approval from a permitting agency.
- Do not place check dams below the expected backwater from any salmonid bearing water between September 15 and June 15 to ensure that there is no loss of high flow refuge habitat for overwintering juvenile salmonids and emergent salmonid fry.

3.2.8.3 Design and Installation Specifications

Whatever material is used, the dam should form a triangle when viewed from the side. This prevents undercutting as water flows over the face of the dam rather than falling directly onto the ditch bottom.

Check dams in association with sumps work more effectively at slowing flow and retaining sediment than just a check dam alone. A deep sump should be provided immediately upstream of the check dam.

- In some cases, if carefully located and designed, check dams can remain as permanent installations with very minor regrading. They may be left as either spillways, in which case accumulated sediment would be graded and seeded, or as check dams to prevent further sediment from leaving the site.
- Check dams can be constructed of either rock or pea-gravel filled bags. Numerous new products are also available for this purpose. They tend to be re-usable, quick and easy to install, effective, and cost efficient.
- Check dams should be placed perpendicular to the flow of water.
- The maximum spacing between the dams shall be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam.
- Keep a maximum height of 2 feet at the center of the dam.
- Keep the center of the check dam at least 12 inches lower than the outer edges at natural ground elevation.
- Keep the side slopes of the check dam at 2H:1V or flatter.
- Key the stone into the ditch banks and extend it beyond the abutments a minimum of 18 inches to avoid washouts from overflow around the dam.

- Use filter fabric foundation under a rock or sand bag check dam. If a blanket ditch liner is used, this is not necessary. A piece of organic or synthetic blanket cut to fit will also work for this purpose.
- Construct rock check dams of appropriately sized rock. Place the rock by hand or by mechanical means (no dumping of rock to form dam) to achieve complete coverage of the ditch or swale and to ensure that the center of the dam is lower than the edges. The rock used must be large enough to stay in place given the expected design flow through the channel.
- In the case of grass-lined ditches and swales, remove all check dams and accumulated sediment when the grass has matured sufficiently to protect the ditch or swale - unless the slope of the swale is greater than 4 percent. Seed and mulch the area beneath the check dams immediately after dam removal.
- Ensure that channel appurtenances, such as culvert entrances below check dams, are not subject to damage or blockage from displaced stones. Figure II-3-18 depicts a typical rock check dam.

3.2.8.4 Maintenance Standards

Monitor check dams for performance and sediment accumulation during and after each runoff producing rainfall. Remove sediment when it reaches one half the sump depth.

- Anticipate submergence and deposition above the check dam and erosion from high flows around the edges of the dam.
- If significant erosion occurs between dams, install a protective riprap liner in that portion of the channel.

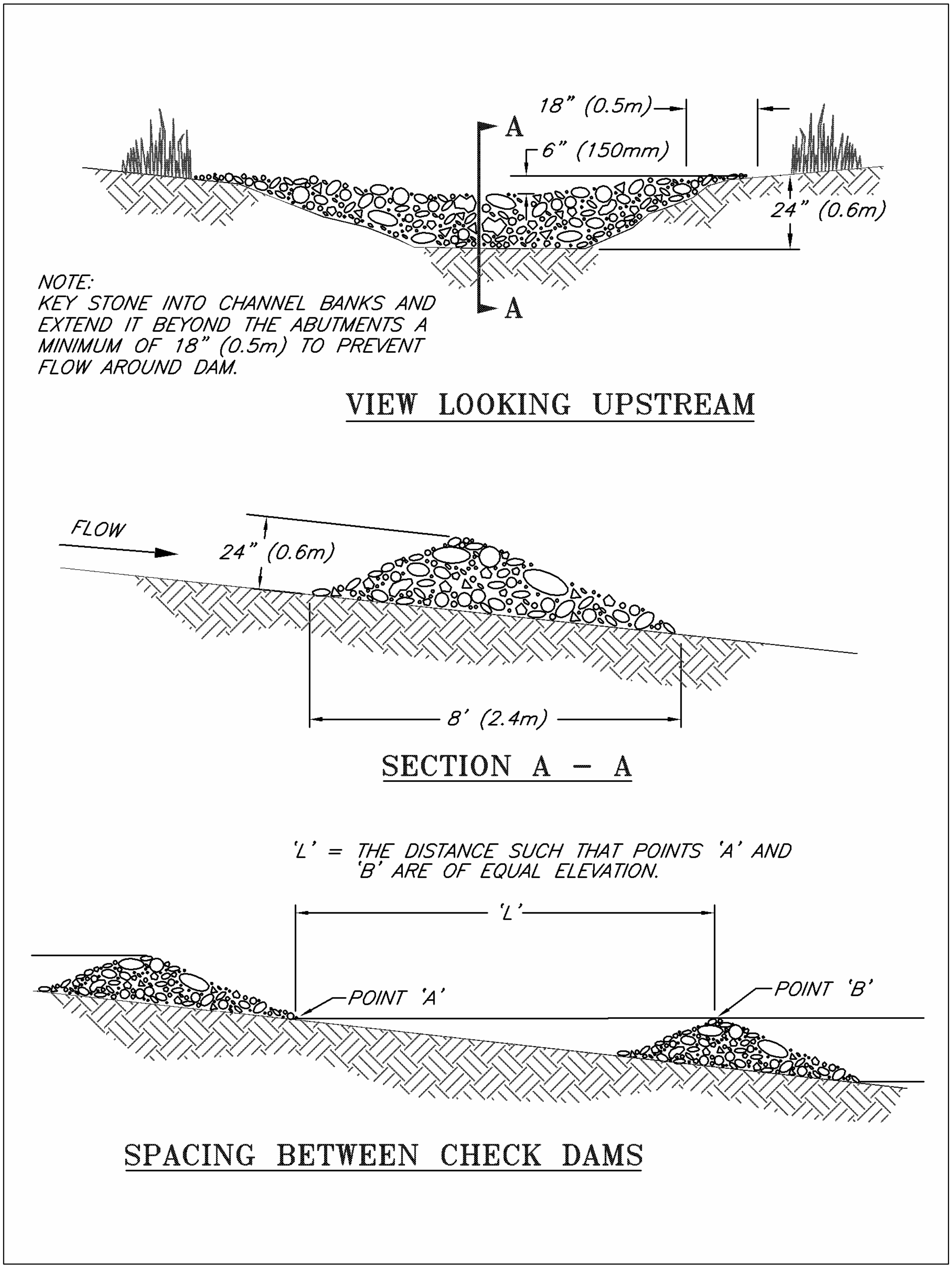


Figure II-3-18. Check Dams

3.2.9 BMP C208: Triangular Silt Dike (Geotextile-Encased Check Dam)

3.2.9.1 Purpose

Triangular silt dikes (TSDs) may be used as check dams, for perimeter protection, for temporary soil stockpile protection, for drop inlet protection, or as a temporary interceptor dike (see Figure II-3-19 and Figure II-3-20).

3.2.9.2 Conditions of Use

May be used in place of straw bales for temporary check dams in ditches of any dimension.

- May be used on soil or pavement with adhesive or staples.
- TSDs have been used to build temporary:
    - sediment ponds
    - diversion ditches
    - concrete wash out facilities
    - curbing
    - water bars
    - level spreaders
    - berms

3.2.9.3 Design and Installation Specifications

Made of urethane foam sewn into a woven geosynthetic fabric.

It is triangular, 10 inches to 14 inches high in the center, with a 20-inch to 28-inch base. A 2–foot apron extends beyond both sides of the triangle along its standard section of 7 feet. A sleeve at one end allows attachment of additional sections as needed.

- Install with ends curved up to prevent water from flowing around the ends.
- The fabric flaps and check dam units are attached to the ground with wire staples. Wire staples should be No. 11 gauge wire and should be 200 mm to 300 mm in length.
- When multiple units are installed, the sleeve of fabric at the end of the unit shall overlap the abutting unit and be stapled.
- Check dams should be located and installed as soon as construction will allow.
- Check dams should be placed perpendicular to the flow of water.
- When used as check dams, the leading edge must be secured with rocks, sandbags, or a small key slot and staples.

3.2.9.4 Maintenance Standards

Monitor triangular silt dikes for performance and sediment accumulation during and after each runoff producing rainfall. Remove sediment when it reaches one half the height of the dam.

Anticipate submergence and deposition above the triangular silt dam and erosion from high flows around the edges of the dam. Immediately repair any damage or undercutting of the dam.

In the case of grass-lined ditches and swales, remove check dams and accumulated sediment when the grass has matured sufficiently to protect the ditch or swale, unless the slope of the swale is greater than 4 percent. Seed and mulch the area beneath the check dams immediately after dam removal.

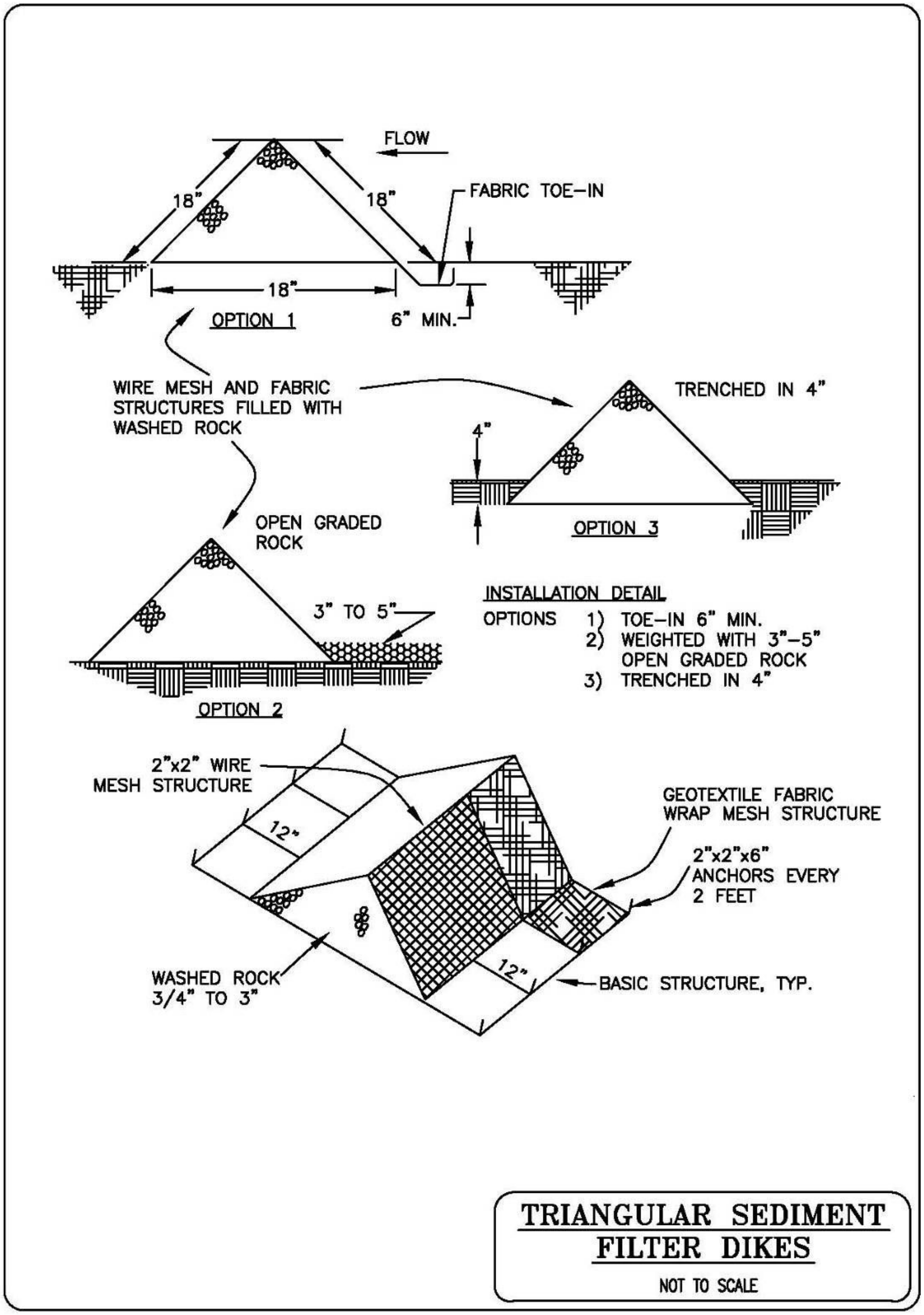


Figure II-3-19. Sediment Barrier – Triangular Sediment Filter Dikes

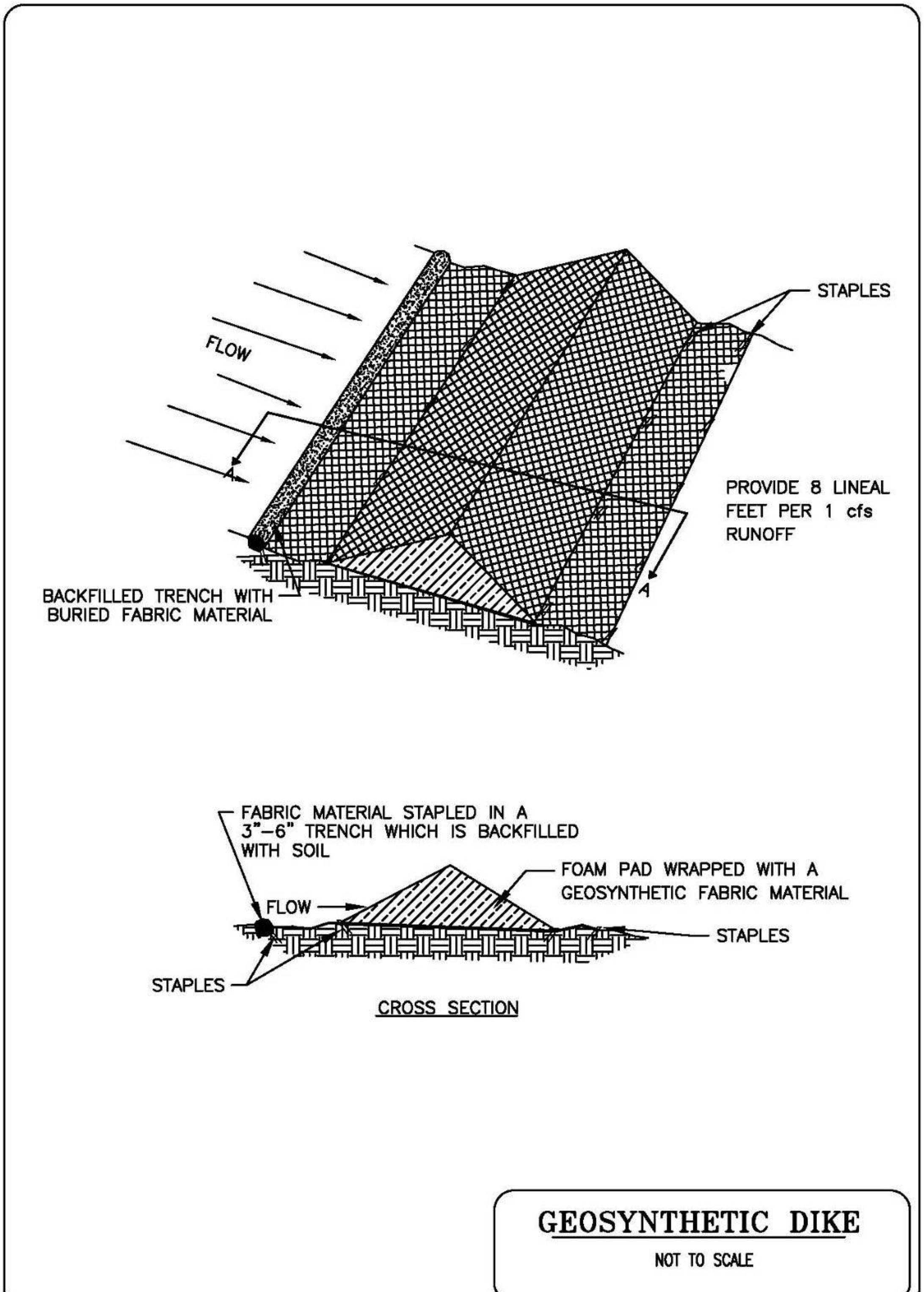


Figure II-3-20. Sediment Barrier – Geosynthetic Dike

3.2.10 BMP C209: Outlet Protection

3.2.10.1 Purpose

Outlet protection prevents scour at conveyance outlets and minimizes the potential for downstream erosion by reducing the velocity of concentrated stormwater flows.

3.2.10.2 Conditions of Use

Outlet protection is required at the outlets of all ponds, pipes, ditches, or other conveyances, and where runoff is conveyed to a natural or manmade drainage feature such as a stream, wetland, lake, or ditch.

3.2.10.3 Design and Installation Specifications

Protect the receiving channel at the outlet of a culvert from erosion by rock lining a minimum of 6 feet downstream and extending rock lining up the channel sides a minimum of 1–foot above the maximum tailwater elevation or 1-foot above the crown, whichever is higher. For large pipes (more than 18 inches in diameter), the outlet protection lining of the channel is lengthened to four times the diameter of the culvert.

- Standard wingwalls, and tapered outlets and paved channels should also be considered when appropriate for permanent culvert outlet protection. (See the WSDOT Hydraulic Manual, available through WSDOT Engineering Publications).
- Organic or synthetic erosion blankets, with or without vegetation, may be, cheaper, and easier to install than rock. Materials can be chosen using manufacturer product specifications. ASTM test results are available for most products and the designer can choose the correct material for the expected flow.
- With low flows, vegetation (including sod) can be effective.
- Use the following guidelines for riprap outlet protection:
  - If the discharge velocity at the outlet is less than 5 feet per second (pipe slope less than 1 percent), use 2-inch to 8-inch riprap. Minimum thickness is 1-foot.
  - For 5 to 10 feet per second discharge velocity at the outlet (pipe slope less than 3 percent), use 24-inch to 4-foot riprap. Minimum thickness is 2 feet.
  - For outlets at the base of steep slope pipes (pipe slope greater than 10 percent), an engineered energy dissipater shall be used.
- Always use filter fabric or erosion control blankets under riprap to prevent scour and channel erosion.
- New pipe outfalls can provide an opportunity for low-cost fish habitat improvements. For example, an alcove of low-velocity water can be created by constructing the pipe outfall and associated energy dissipater back from the stream edge and digging a channel, over-widened to the upstream side, from the outfall. Overwintering juvenile and migrating adult salmonids may use the alcove as shelter during high flows. Bank

stabilization, bioengineering, and habitat features may be required for disturbed areas. See Volume V for more information on outfall system design.

3.2.10.4 Maintenance Standards

- Inspect and repair as needed.
- Add rock as needed to maintain the intended function.
- Clean energy dissipater if sediment builds up.

Figure II-3-21. No Figure Placeholder

3.2.11 BMP C220: Storm Drain Inlet Protection

3.2.11.1 Purpose

To prevent coarse sediment from entering drainage systems prior to permanent stabilization of the disturbed area.

3.2.11.2 Conditions of Use

Where storm drain inlets are to be made operational before permanent stabilization of the disturbed drainage area.

Provide protection for all storm drain inlets downslope and within 500 feet of a disturbed or construction area, unless the runoff that enters the catch basin will be conveyed to a sediment pond or trap. Inlet protection may be used anywhere to protect the drainage system. It is likely that the drainage system will still require cleaning.

Table II-3-9 lists several options for inlet protection. All of the methods for storm drain inlet protection are prone to plugging and require a high frequency of maintenance. Drainage areas should be limited to 1 acre or less. Emergency overflows may be required where stormwater ponding would cause a hazard. If an emergency overflow is provided, additional end-of-pipe treatment may be required.

Only bag filter type catch basin filters (per Section 3.2.11.3) are allowed within the right of way.

Table II-3-9. Storm Drain Inlet Protection

Type of Inlet Protection	Emergency Overflow	Applicable for Paved/Earthen Surfaces	Conditions of Use
Excavated drop inlet protection	Yes, temporary flooding will occur	Earthen	Applicable for heavy flows. Easy to maintain. Large area requirement: 30' x 30' per acre.
Block and gravel drop filter	Yes	Paved or earthen	Applicable for heavy concentrated flows. Will not pond.
Gravel and mesh filter	No	Paved	Applicable for heavy concentrated flows. Will pond. Can withstand traffic.
Catch basin filters	Yes	Paved or earthen	Frequent maintenance required.
Curb inlet protection with a wooden weir	Small capacity overflow	Paved	Used for sturdy, more compact installation.
Block and gravel curb inlet protection	Yes	Paved	Sturdy, but limited filtration.

3.2.11.3 Design and Installation Specifications

Excavated Drop Inlet Protection

An excavated impoundment around the storm drain. Sediment settles out of the stormwater prior to entering the storm drain.

- Depth 1 to 2 feet, as measured from the crest of the inlet structure.
- Side slopes of excavation no steeper than 2H:1V.
- Minimum volume of excavation 35 cubic yards.
- Shape basin to fit site with longest dimension oriented toward the longest inflow area.
- Install provisions for draining to prevent standing water problems.
- Clear the area of all debris.
- Grade the approach to the inlet uniformly.
- Drill weep holes into the side of the inlet.
- Protect weep holes with screen wire and washed aggregate.
- Seal weep holes when removing structure and stabilizing area.
- It may be necessary to build a temporary dike to the down slope side of the structure to prevent bypass flow.

Block and Gravel Filter

A barrier formed around the storm drain inlet with standard concrete blocks and gravel. See Figure II-3-22.

- Height 1 to 2 feet above inlet.
- Recess the first row 2 inches into the ground for stability.
- Support subsequent courses by placing a piece of 2x4 lumber through the block opening.
- Do not use mortar.
- Lay some blocks in the bottom row on their side for dewatering the pool.
- Place hardware cloth or comparable wire mesh with ½-inch openings over all block openings.
- Place gravel just below the top of blocks on slopes of 2H:1V or flatter.
- An alternative design is a gravel donut.
- Inlet slope of 3H:1V.
- Outlet slope of 2H:1V.

- 1-foot wide level stone area between the structure and the inlet.
- Inlet slope stones 3 inches in diameter or larger.
- Outlet slope use gravel ½- to ¾-inch at a minimum thickness of 1-foot.

Gravel and Wire Mesh Filter

A gravel barrier placed over the top of the inlet (see Figure II-3-23). This structure does not provide an overflow.

- Hardware cloth or comparable wire mesh with ½-inch openings.
- Coarse aggregate.
- Height 1-foot or more, 18 inches wider than inlet on all sides.
- Place wire mesh over the drop inlet so that the wire extends a minimum of 1-foot beyond each side of the inlet structure.
- If more than one strip of mesh is necessary, overlap the strips.
- Place coarse aggregate over the wire mesh.
- The depth of the gravel should be at least 12 inches over the entire inlet opening and extend at least 18 inches on all sides.

Catchbasin Filters

Inserts (Figure II-3-24) shall be designed by the manufacturer for use at construction sites. The limited sediment storage capacity increases the frequency of inspection and maintenance required, which may be daily for heavy sediment loads. The maintenance requirements can be reduced by combining a catchbasin filter with another type of inlet protection. This type of inlet protection provides flow bypass without overflow and therefore may be a better method for inlets located along active rights-of-way. See Figure II-C-46 for one example.

- Should have a minimum of 5 cubic feet of storage.
- Dewatering provisions.
- High-flow bypass that will not clog under normal use at a construction site.
- The catchbasin filter is inserted in the catchbasin just below the grating.
- Only bag filter type catch basin filters are allowed in the City right-of-way.

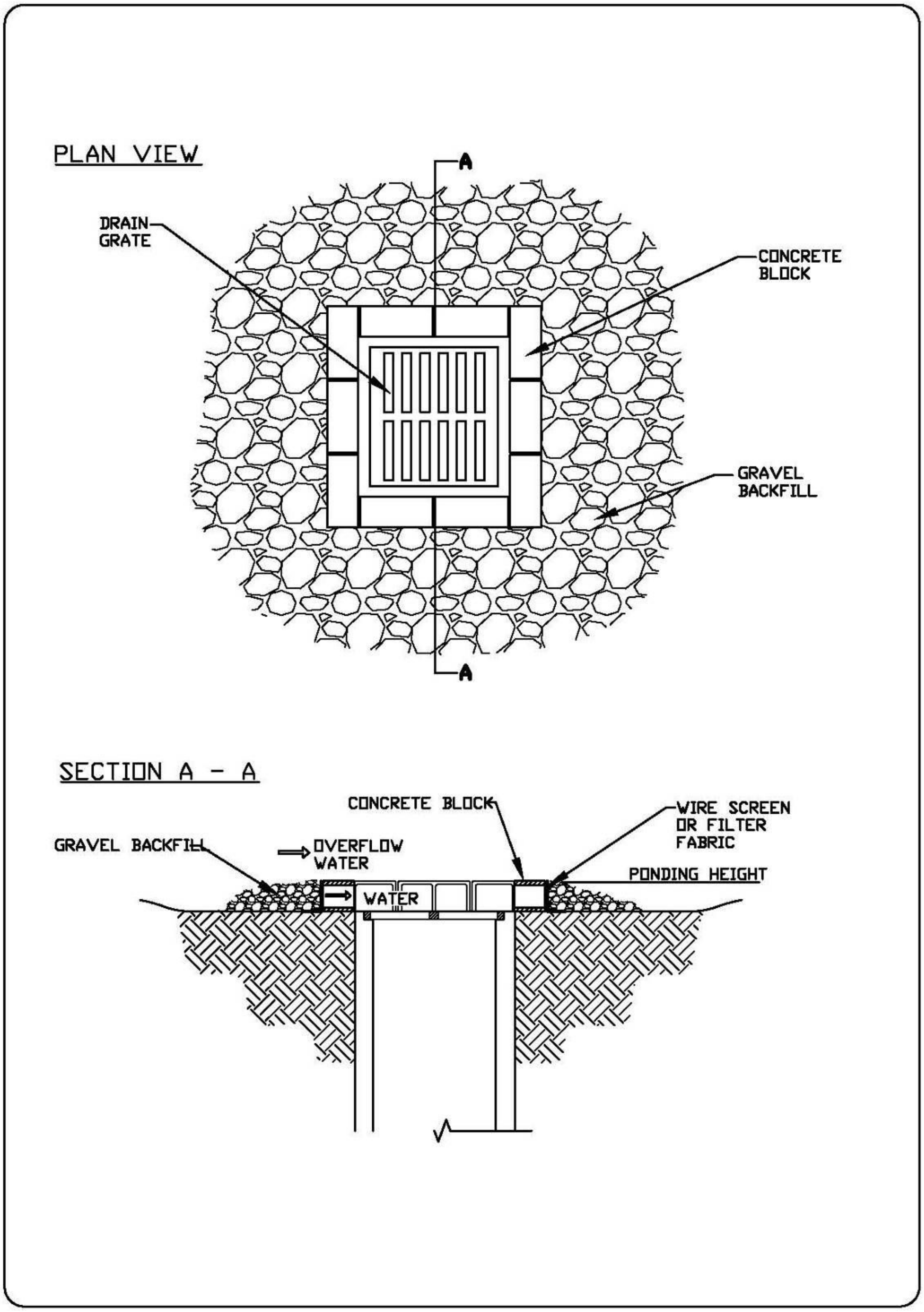


Figure II-3-22. Drop Inlet with Block and Gravel Filter

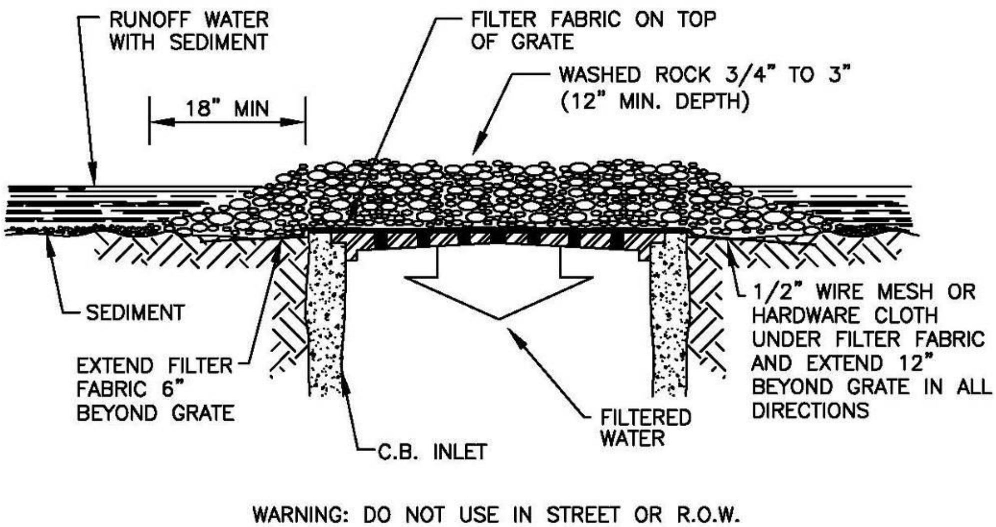
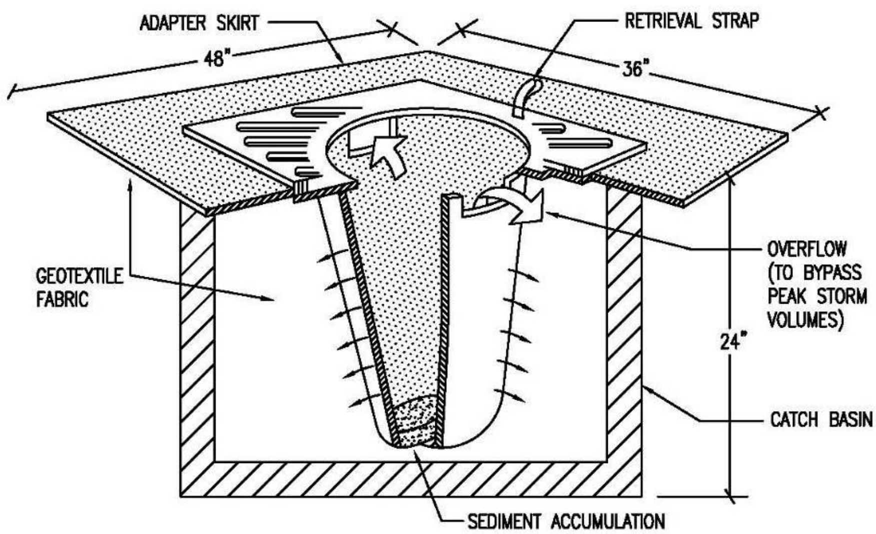


Figure II-3-23. Gravel and Wire Mesh Filter



INLET PROTECTION NOTES:

1. FILTERS SHALL BE INSPECTED AFTER EACH STORM EVENT AND CLEANED OR REPLACED WHEN 1/3 FULL.

BAG FILTER

NOT TO SCALE

Figure II-3-24. Catchbasin Filter

Curb Inlet Protection with Wooden Weir

Barrier formed around a curb inlet with a wooden frame and gravel.

- Wire mesh with ½-inch openings.
- Extra strength filter cloth.
- Construct a frame.
- Attach the wire and filter fabric to the frame.
- Pile coarse washed aggregate against the wire and fabric.
- Place weight on frame anchors.

Block and Gravel Curb Inlet Protection

Barrier formed around an inlet with concrete blocks and gravel. See Figure II-3-25.

- Wire mesh with ½-inch openings.
- Place two concrete blocks on their sides abutting the curb at either side of the inlet opening. These are spacer blocks.
- Place a 2x4 stud through the outer holes of each spacer block to align the front blocks.
- Place blocks on their sides across the front of the inlet and abutting the spacer blocks.
- Place wire mesh over the outside vertical face.
- Pile coarse aggregate against the wire to the top of the barrier.

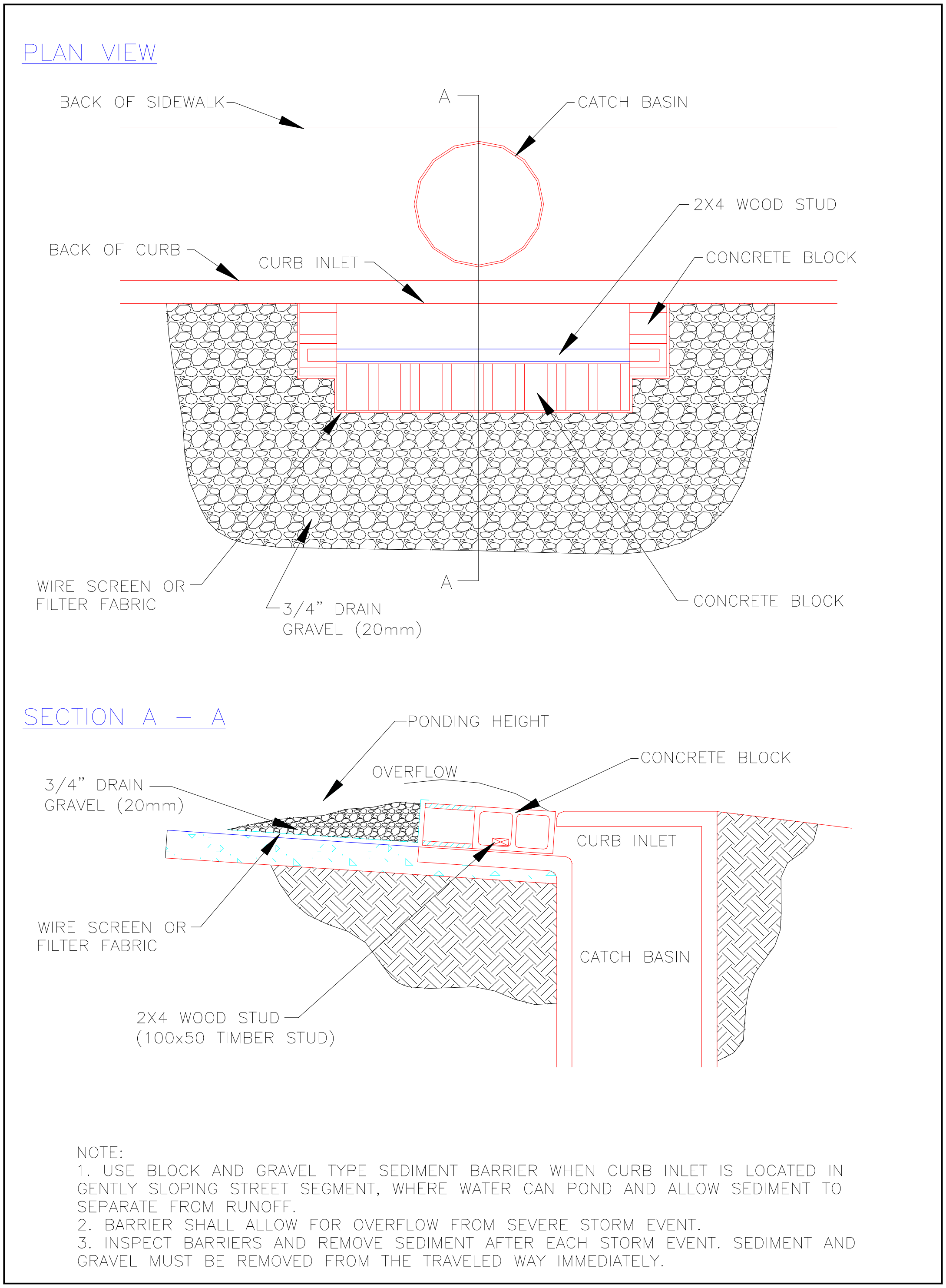


Figure II-3-25. Block and Gravel Curb Inlet Protection

Curb and Gutter Sediment Barrier

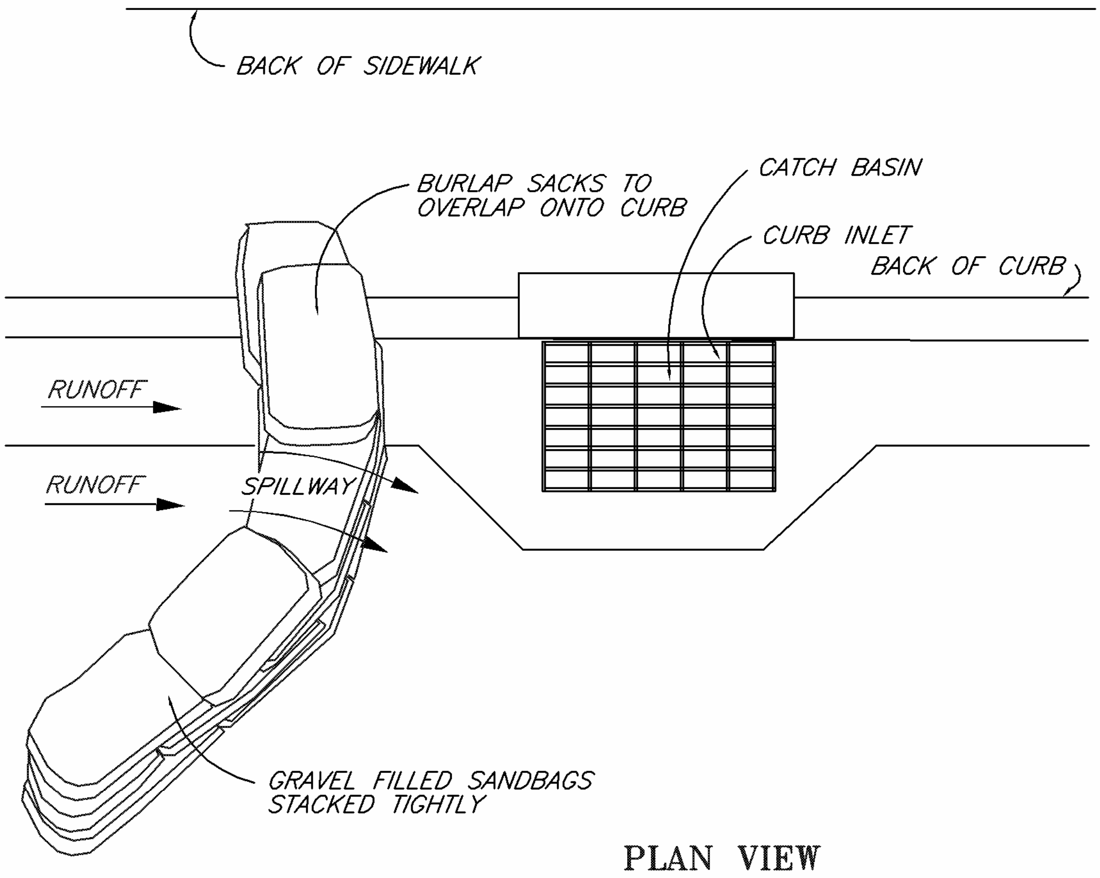
Sandbag or rock berm (riprap and aggregate) 3 feet high and 3 feet wide in a horseshoe shape. See Figure II-3-26.

- Construct a horseshoe shaped berm, faced with coarse aggregate if using riprap, 3 feet high and 3 feet wide, at least 2 feet from the inlet.
- Construct a horseshoe shaped sedimentation trap on the outside of the berm sized to sediment trap standards for protecting a culvert inlet.

3.2.11.4 Maintenance Standards

Inspect catch basin filters frequently, especially after storm events. If the insert becomes clogged, clean or replace it.

- For systems using stone filters: If the stone filter becomes clogged with sediment, the stones must be pulled away from the inlet and cleaned or replaced. Since cleaning of gravel at a construction site may be difficult, an alternative approach would be to use the clogged stone as fill and put fresh stone around the inlet.
- Do not wash sediment into storm drains while cleaning. Spread all excavated material evenly over the surrounding land area or stockpile and stabilize as appropriate.



NOTES:

1. PLACE CURB TYPE SEDIMENT BARRIERS ON GENTLY SLOPING STREET SEGMENTS, WHERE WATER CAN POND AND ALLOW SEDIMENT TO SEPARATE FROM RUNOFF.
2. SANDBAGS OF EITHER BURLAP OR WOVEN 'GEOTEXTILE' FABRIC, ARE FILLED WITH GRAVEL, LAYERED AND PACKED TIGHTLY.
3. LEAVE A ONE SANDBAG GAP IN THE TOP ROW TO PROVIDE A SPILLWAY FOR OVERFLOW.
4. INSPECT BARRIERS AND REMOVE SEDIMENT AFTER EACH STORM EVENT. SEDIMENT AND GRAVEL MUST BE REMOVED FROM THE TRAVELED WAY IMMEDIATELY.

Figure II-3-26. Curb and Gutter Sediment Barrier

3.2.12 BMP C231: Brush Barrier

3.2.12.1 Purpose

The purpose of brush barriers is to reduce the transport of coarse sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow.

3.2.12.2 Conditions of Use

- Brush barriers may be used downslope of all disturbed areas of less than one-quarter acre.
- Brush barriers are not intended to treat concentrated flows, nor are they intended to treat substantial amounts of overland flow. Any concentrated flows must be conveyed through the drainage system to a sediment pond. The only circumstance in which overland flow can be treated solely by a barrier, rather than by a sediment pond, is when the area draining to the barrier is small.
- Only install brush barriers on contours.

3.2.12.3 Design and Installation Specifications

- Height 2 feet (minimum) to 5 feet (maximum).
- Width 5 feet at base (minimum) to 15 feet (maximum).
- Filter fabric (geotextile) may be anchored over the brush berm to enhance the filtration ability of the barrier. Ten-ounce burlap is an adequate alternative to filter fabric.
- Chipped site vegetation, composted mulch, or wood-based mulch (hog fuel) can be used to construct brush barriers.
- A 100 percent biodegradable installation can be constructed using 10-ounce burlap held in place by wooden stakes. Figure II-3-27 depicts a typical brush barrier.

3.2.12.4 Maintenance Standards

- Do not allow erosion or concentrated runoff under or around the barrier. If concentrated flows are bypassing the barrier, it must be expanded or augmented by toed-in filter fabric.
- Maintain the dimensions of the barrier.

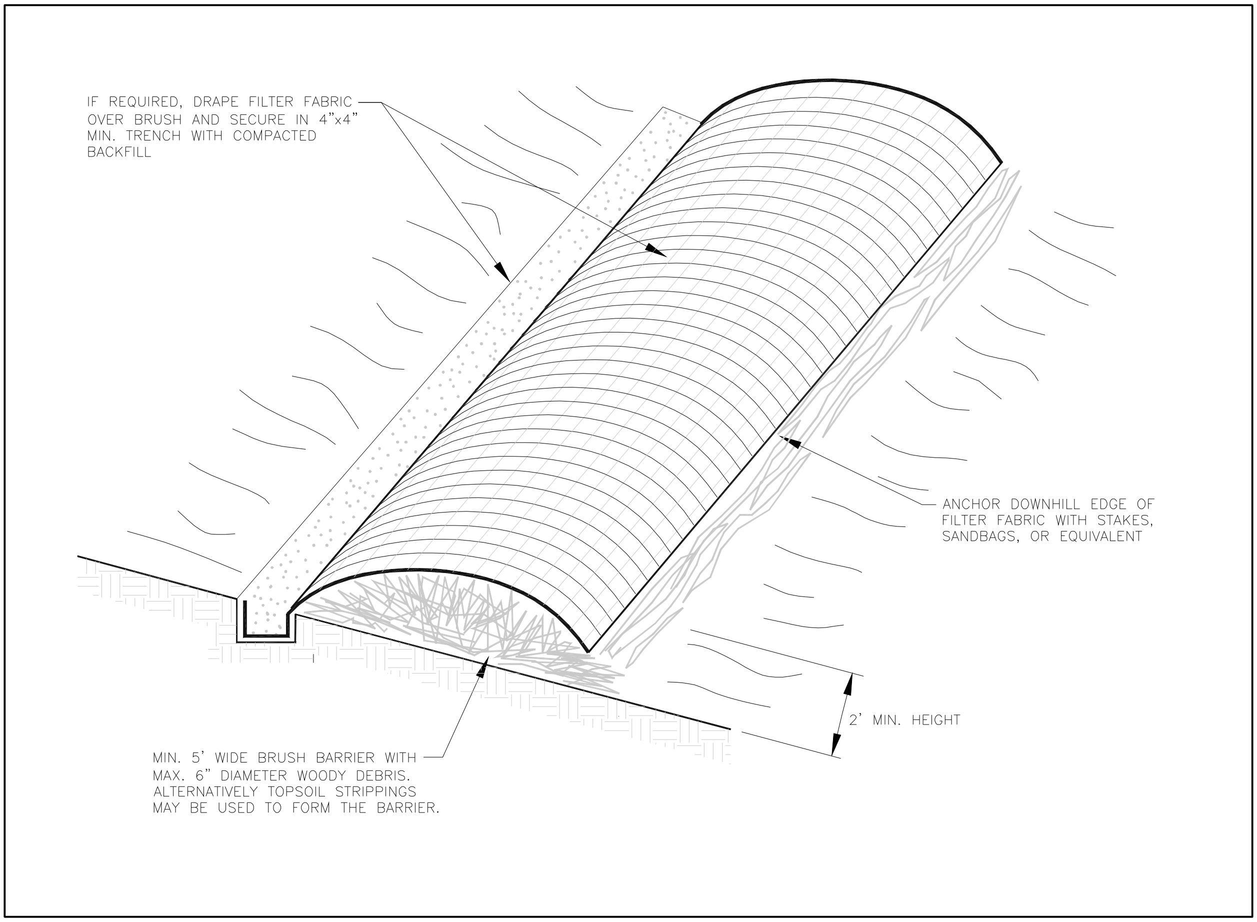


Figure II-3-27. Brush Barrier

3.2.13 BMP C232: Gravel Filter Berm

3.2.13.1 Purpose

A gravel filter berm is constructed on rights-of-way or traffic areas within a construction site to retain sediment by using a filter berm of gravel or crushed rock.

3.2.13.2 Conditions of Use

Where a temporary measure is needed to retain sediment from rights-of-way or in traffic areas on construction sites.

3.2.13.3 Design and Installation Specifications

Berm material shall be ¾ to 3 inches in size, washed well-graded gravel or crushed rock, with less than 5 percent fines.

- Space berms:
  - Every 300 feet on slopes less than 5 percent
  - Every 200 feet on slopes between 5 percent and 10 percent
  - Every 100 feet on slopes greater than 10 percent
- Berm dimensions:
  - 1 foot high with 3:1 side slopes
  - 8 linear feet per 1 cubic foot per second runoff based on the 10-year, 24-hour design storm (3.0-inches)

3.2.13.4 Maintenance Standards

Regular inspection is required. Remove sediment and replace filter material as needed.

3.2.14 BMP C233: Silt Fence

3.2.14.1 Purpose

Use of a silt fence reduces the transport of coarse sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow. See Figure II-3-28 for details on silt fence construction.

3.2.14.2 Conditions of Use

Silt fence may be used downslope of all disturbed areas.

- Silt fence is not intended to treat concentrated flows, nor is it intended to treat substantial amounts of overland flow. Convey any concentrated flows through the drainage system to a sediment pond. The only circumstance in which overland flow can be treated solely by a silt fence, rather than by a sediment pond, is when the area draining to the fence is one acre or less and flow rates are less than 0.5 cfs.
- Do not construct silt fences in streams or use them in V-shaped ditches. They are not an adequate method of silt control for anything deeper than sheet or overland flow.

3.2.14.3 Design and Installation Specifications

Drainage area of 1 acre or less or in combination with sediment basin on a larger site.

Maximum slope steepness (perpendicular to fence line) 1H:1V.

- Maximum sheet or overland flow path length to the fence of 100 feet.
- No flows greater than 0.5 cubic feet per second.
- The geotextile used shall meet the following standards. All geotextile properties listed below are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values shown in Table II-3-10).

Table II-3-10. Geotextile Standards

Polymeric Mesh AOS (ASTM D4751)	0.60 mm maximum for slit film wovens (#30 sieve). 0.30 mm maximum for all other geotextile types (#50 sieve). 0.15 mm minimum for all fabric types (#100 sieve).
Water Permittivity (ASTM D4491)	0.02 sec^{-1} minimum
Grab Tensile Strength (ASTM D4632)	180 lbs. minimum for extra strength fabric. 100 lbs. minimum for standard strength fabric.
Grab Tensile Strength (ASTM D4632)	30% maximum
Ultraviolet Resistance (ASTM D4355)	70% minimum

- Support standard strength fabrics with wire mesh, chicken wire, 2-inch x 2-inch wire, safety fence, or jute mesh to increase the strength of the fabric. Silt fence materials are available that have synthetic mesh backing attached.
- Filter fabric material shall contain ultraviolet ray inhibitors and stabilizers to provide a minimum of six months of expected usable construction life at a temperature range of 0° to 120° Fahrenheit.
- 100 percent biodegradable silt fence is available that is strong and long lasting.
- The following are standard design and installation methods. Refer to Figure II-3-28 for standard silt fence details.
  - Install and maintain temporary silt fences at the locations shown in the plans. Install the silt fences in the areas of clearing, grading, or drainage prior to starting those activities. Do not consider a silt fence temporary if the silt fence must function beyond the life of the contract. The silt fence shall prevent soil carried by runoff water from going beneath, through, or over the top of the silt fence, but shall allow the water to pass through the fence.
  - The minimum height of the top of silt fence shall be 2 feet and the maximum height shall be 2½ feet above the original ground surface.
  - Sew the geotextile together at the point of manufacture, or at an approved location as determined by the Engineer, to form geotextile lengths as required. Locate all sewn seams at a support post. Alternatively, two sections of silt fence can be overlapped, provided the Contractor can demonstrate, to the satisfaction of the Engineer, that the overlap is long enough and adjacent fence sections are close enough together to prevent silt laden water from escaping through the fence at the overlap.
  - Attach the geotextile on the up-slope side of the posts and support system with staples, wire, or in accordance with the manufacturer's recommendations. Attach the geotextile to the posts in a manner that reduces the potential for geotextile tearing at the staples, wire, or other connection device. Silt fence back-up support for the geotextile in the form of a wire or plastic mesh is dependent on the properties of the geotextile selected for use. If wire or plastic back-up mesh is used, fasten the mesh securely to the up-slope of the posts with the geotextile being up-slope of the mesh back-up support.
  - Bury the geotextile at the bottom of the fence in a trench to a minimum depth of 4 inches below the ground surface. Backfill the trench and tamp the soil in place over the buried portion of the geotextile, such that no flow can pass beneath the fence and scouring can not occur. When wire or polymeric back-up support mesh is used, the wire or polymeric mesh shall extend into the trench a minimum of 3 inches.
  - Drive fence posts in to a minimum depth of 18 inches. A minimum depth of 12 inches is allowed if topsoil or other soft subgrade soil is not present and a minimum depth of 18 inches cannot be reached. Increase fence post depths by 6 inches if the fence is located on slopes of 3H:1V or steeper and the

slope is perpendicular to the fence. If required post depths cannot be obtained, adequately secure the posts by bracing or guying to prevent overturning of the fence due to sediment loading.

- Locate the silt fences on contour as much as possible, except at the ends of the fence, where the fence shall be turned uphill such that the silt fence captures the runoff water and prevents water from flowing around the end of the fence.
- If the fence must cross contours, with the exception of the ends of the fence, place gravel check dams perpendicular to the back of the fence to minimize concentrated flow and erosion along the back of the fence. The gravel check dams shall be approximately 1-foot deep at the back of the fence and be perpendicular to the fence at the same elevation until the top of the check dam intercepts the ground surface behind the fence. The gravel check dams shall consist of crushed surfacing base course, gravel backfill for walls, or shoulder ballast. Locate the gravel check dams every 10 feet along the fence where the fence must cross contours. The slope of the fence line where contours must be crossed shall not be steeper than 3H:1V.
- Use wood, steel or equivalent posts. Wood posts shall have minimum dimensions of 2 inches by 2 inches by 3 feet minimum length, and shall be free of defects such as knots, splits, or gouges. Steel posts shall consist of either size No. 6 rebar or larger; ASTM A120 steel pipe with a minimum diameter of 1-inch; U, T, L, or C shape steel posts with a minimum weight of 1.35 pounds per foot; or other steel posts having equivalent strength and bending resistance to the post sizes listed. The spacing of the support posts shall be a maximum of 6 feet.
- Fence back-up support, if used, shall consist of steel wire with a maximum mesh spacing of 2 inches, or a prefabricated polymeric mesh. The strength of the wire or polymeric mesh shall be equivalent to or greater than 180 pounds grab tensile strength. The polymeric mesh must be as resistant to ultraviolet radiation as the geotextile it supports.

- Specification details for silt fence installation using the slicing method follow. Refer to Figure II-3-29 for slicing method details.
  - The base of both end posts must be at least 2 to 4 inches above the top of the silt fence fabric on the middle posts for ditch checks to drain properly. Use a hand level or string level, if necessary, to mark base points before installation.
  - Install posts 3 to 4 feet apart in critical retention areas and a minimum of 6 feet apart in standard applications.
  - Install posts 24 inches deep on the downstream side of the silt fence, and as close as possible to the fabric, enabling posts to support the fabric from upstream water pressure.
  - Install posts with the nipples facing away from the silt fence fabric.

- Attach the fabric to each post with three ties, all spaced within the top 8 inches of the fabric. Attach each tie diagonally 45 degrees through the fabric, with each puncture at least 1 inch vertically apart. In addition, each tie should be positioned to hang on a post nipple when tightening to prevent sagging.
- Wrap approximately 6 inches of fabric around the end posts and secure with 3 ties.
- No more than 24 inches of a 36-inch fabric is allowed above ground level.
- The rope lock system must be used in all ditch check applications.
- The installation should be checked and corrected for any deviation before compaction. Use a flat-bladed shovel to tuck fabric deeper into the ground, if necessary.
- Compaction is vitally important for effective results. Compact the soil immediately next to the silt fence fabric with the front wheel of a tractor, skid steer, or roller exerting at least 60 pounds per square inch. Compact the upstream side first and then each side twice for a total of four trips.

3.2.14.4 Maintenance Standards

- Repair any damage immediately.
- If concentrated flows are evident uphill of the fence, intercept and convey them to a sediment pond.
- It is important to check the uphill side of the fence for signs of the fence clogging, acting as a barrier to flow, and then causing channelization of flows parallel to the fence. If this occurs, replace the fence or remove the trapped sediment.
- Remove sediment deposits when the deposit reaches approximately one-third the height of the silt fence, or install a second silt fence.
- If the filter fabric (geotextile) has deteriorated due to ultraviolet breakdown, replace it.

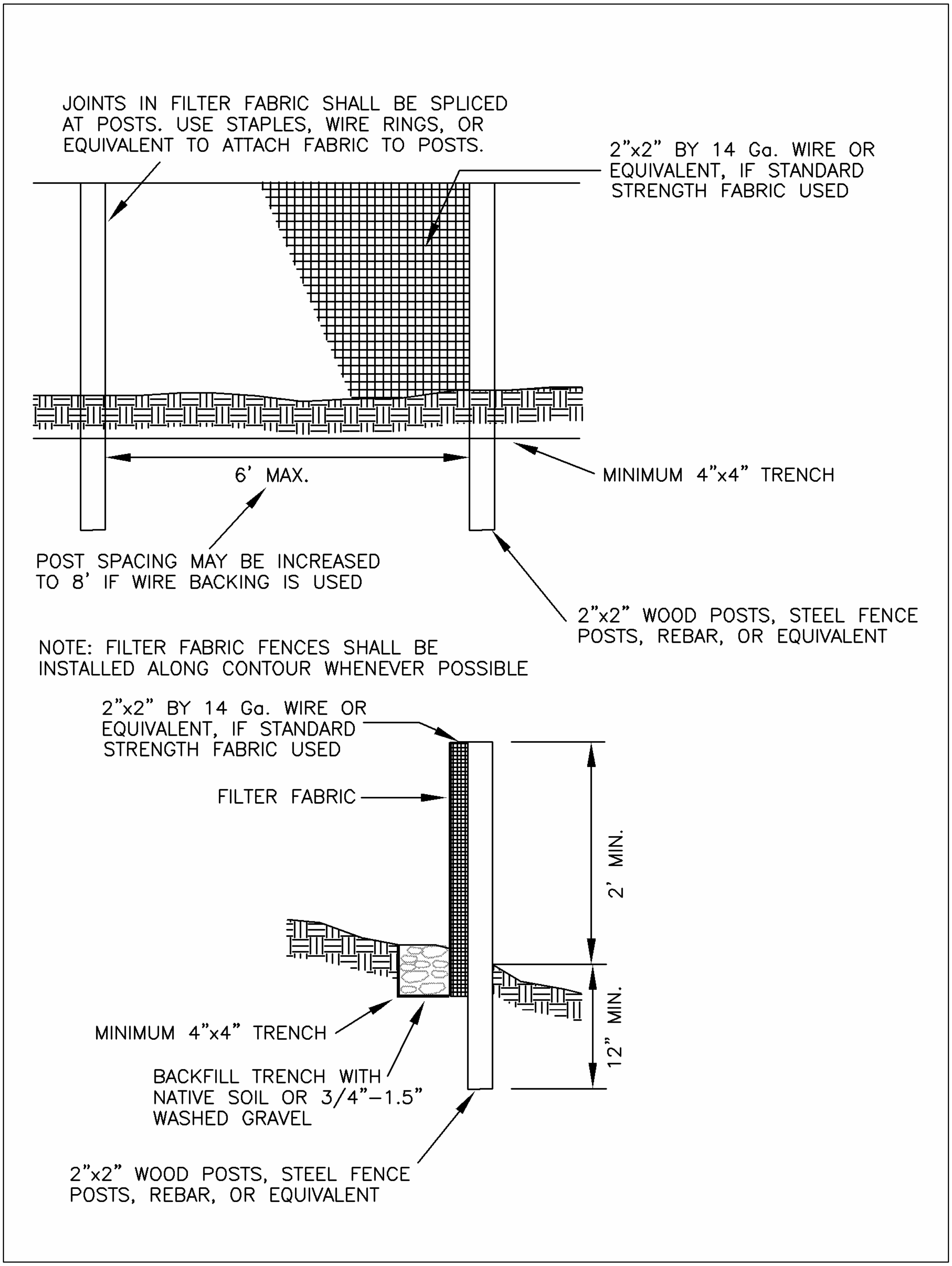


Figure II-3-28. Silt Fence

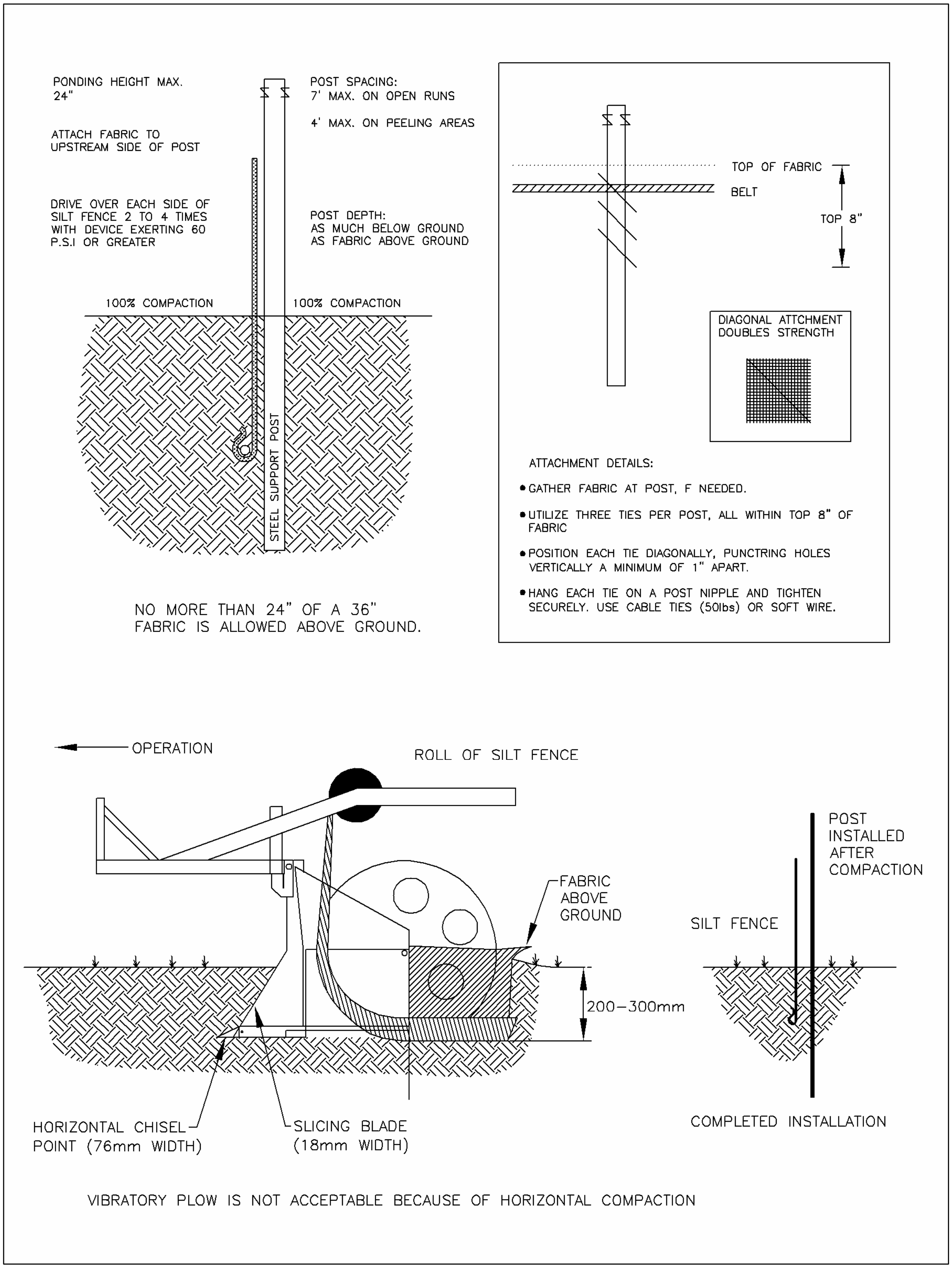


Figure II-3-29. Silt Fence Installation by Slicing

3.2.15 BMP C234: Vegetated Strip

3.2.15.1 Purpose

Vegetated strips reduce the transport of coarse sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow.

3.2.15.2 Conditions of Use

Vegetated strips may be used downslope of all disturbed areas.

Vegetated strips are not intended to treat concentrated flows, nor are they intended to treat substantial amounts of overland flow. Convey any concentrated flows through the drainage system to a sediment pond. The only circumstance in which overland flow can be treated solely by a strip, rather than by a sediment pond, is when the criteria shown in Table II-3-11 are met.

Table II-3-11. Vegetated Strips

Average Slope	Slope Percent	Flowpath Length
1.5H:1V or less	67% or less	100 feet
2H:1V or less	50% or less	115 feet
4H:1V or less	25% or less	150 feet
6H:1V or less	16.7% or less	200 feet
10H:1V or less	10% or less	250 feet

3.2.15.3 Design and Installation Specifications

The vegetated strip shall consist of a minimum of a 25-foot wide continuous strip of dense vegetation with permeable topsoil. Grass-covered, landscaped areas are generally not adequate because the volume of sediment overwhelms the grass. Ideally, vegetated strips shall consist of undisturbed native growth with a well-developed soil that allows for infiltration of runoff.

- The slope within the strip shall not exceed 4H:1V.
- Delineate the uphill boundary of the vegetated strip with clearing limits.

3.2.15.4 Maintenance Standards

- Seed any areas damaged by erosion or construction activity immediately and protected with mulch.
- If more than 5 feet of the original vegetated strip width has had vegetation removed or is being eroded, install sod.
- If there are indications that concentrated flows are traveling across the vegetated strip, surface water controls must be installed to reduce the flows entering the vegetated strip, or install additional perimeter protection.

3.2.16 BMP C235: Straw Wattles

3.2.16.1 Purpose

Straw wattles are temporary erosion and sediment control barriers consisting of straw that is wrapped in biodegradable tubular plastic or similar encasing material. They reduce the velocity and can spread the flow of rill and sheet runoff, and can capture and retain sediment. Straw wattles are typically 8 to 10 inches in diameter and 25 to 30 feet in length. The wattles are placed in shallow trenches and staked along the contour of disturbed or newly constructed slopes. See Figure II-3-30 for typical construction details.

3.2.16.2 Conditions of Use

- Disturbed areas that require immediate erosion protection.
- Exposed soils during the period of short construction delays.
- On slopes requiring stabilization until permanent vegetation can be established.
- Straw wattles are effective for one to two seasons.
- If conditions are appropriate, wattles can be staked to the ground using live cuttings for added revegetation.

3.2.16.3 Design Criteria

- It is critical that wattles are installed perpendicular to the flow direction and parallel to the slope contour.
- Dig narrow trenches across the slope on contour to a depth of 3 to 5 inches on clay soils and soils with gradual slopes. On loose soils, steep slopes, and areas with high rainfall, dig the trenches to a depth of 5 to 7 inches, or 1/2 to 2/3 of the thickness of the wattle.
- Start building trenches and installing wattles from the base of the slope and work up. Excavated material should be spread evenly along the uphill slope and compacted using hand tamping or other methods.
- Construct trenches at contour intervals of 3 to 30 feet apart depending on the steepness of the slope, soil type, and rainfall. The steeper the slope, the closer together the trenches shall be.
- Install the wattles snugly into the trenches and abut tightly end to end. Do not overlap the ends. Rilling can occur beneath wattles if not properly entrenched, and water can pass between wattles if not tightly abutted.
- Install stakes at each end of the wattle, and at 4-foot centers along entire length of wattle.
- If required, install pilot holes for the stakes using a straight bar to drive holes through the wattle and into the soil.
- At a minimum, wooden stakes should be approximately 3/4 x 3/4 x 24 inches. Live cuttings or 3/8-inch rebar can also be used for stakes.

- Stakes should be driven through the middle of the wattle, leaving 2 to 3 inches of the stake protruding above the wattle.

3.2.16.4 Maintenance Standards

- Wattles may require maintenance to ensure they are in contact with soil and thoroughly entrenched, especially after significant rainfall on steep sandy soils.
- Inspect the slope after significant storms and repair any areas where wattles are not tightly abutted or water has scoured beneath the wattles.

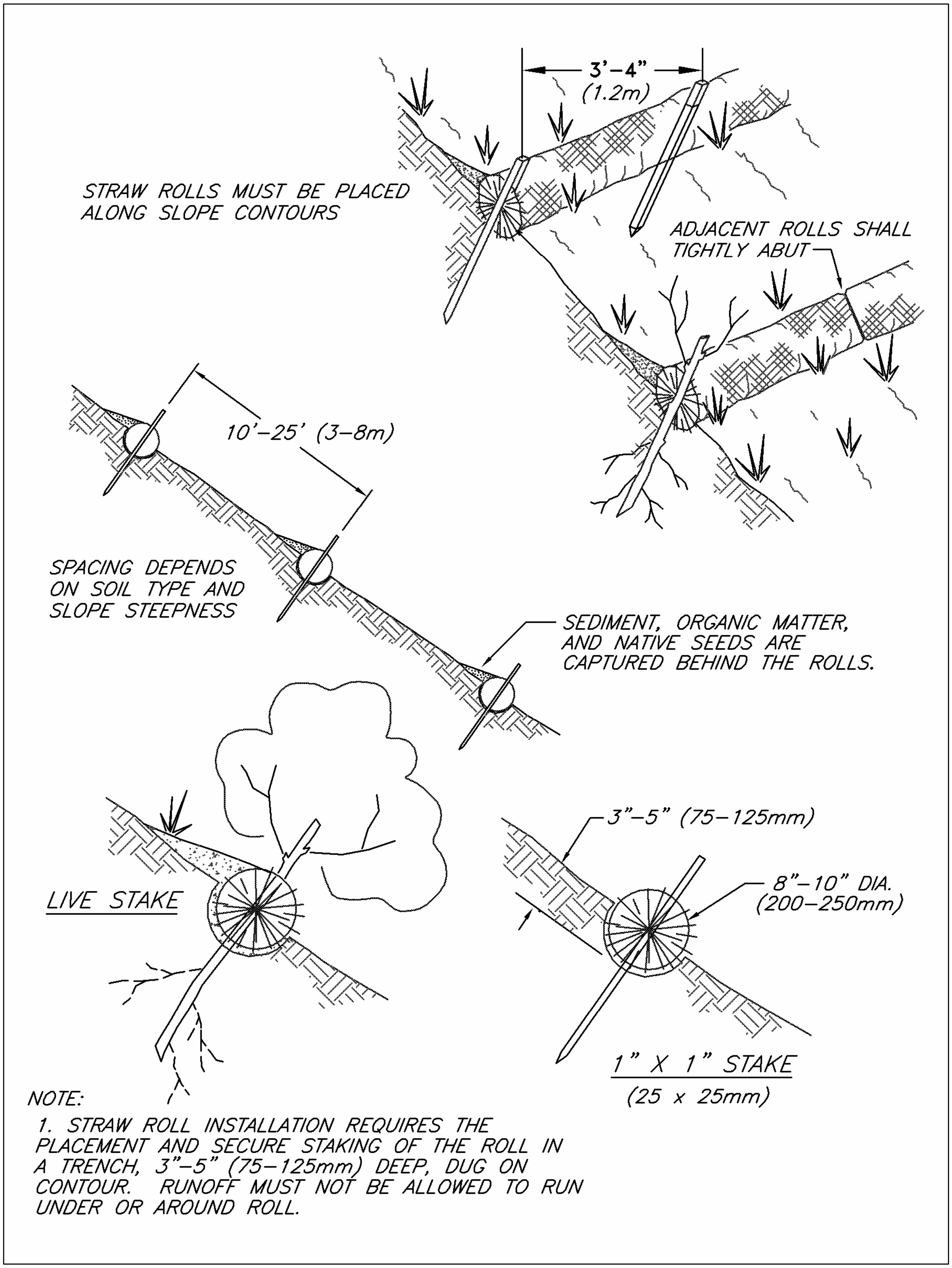


Figure II-3-30. Straw Wattles

3.2.17 BMP C240: Sediment Trap

3.2.17.1 Purpose

A sediment trap is a small temporary ponding area with a gravel outlet used to collect and store sediment from sites cleared and/or graded during construction. Install sediment traps, along with other perimeter controls, before any land disturbance takes place in the drainage area.

3.2.17.2 Conditions of Use

Prior to leaving a construction site, stormwater runoff must pass through a sediment pond or trap or other appropriate sediment removal best management practice. Non-engineered sediment traps may be used on-site prior to an engineered sediment trap or sediment pond to provide additional sediment removal capacity.

Sediment traps are intended for use on sites where the tributary drainage area is less than 3 acres, with no unusual drainage features, and a projected build-out time of six months or less. The sediment trap is a temporary measure (with a design life of approximately 6 months) and shall be maintained until the site area is permanently protected against erosion by the installation of vegetation and/or structures.

Sediment traps and ponds are only effective in removing sediment down to about the medium silt size fraction. Runoff with sediment of finer grades (fine silt and clay) will pass through untreated, emphasizing the need to control erosion to the maximum extent first.

Whenever possible, discharge sediment-laden water into onsite, relatively level, vegetated areas (see BMP C234 – Vegetated Strip). Do not use vegetated wetlands for this purpose. All projects that are constructing permanent detention facilities for runoff quantity control should use the rough-graded or final-graded permanent facilities for traps and ponds. This includes combined facilities and infiltration facilities. When permanent facilities are used as temporary sedimentation facilities, the surface area requirement of a sediment trap or pond must be met. If the surface area requirements are larger than the surface area of the permanent facility, then the trap or pond shall be enlarged to comply with the surface area requirement. The permanent pond shall also be divided into two cells as required for sediment ponds.

Use of infiltration facilities for sedimentation basins during construction tends to clog the soils and reduce their capacity to infiltrate. If infiltration facilities are to be used, the sides and bottom of the facility must only be rough excavated to a minimum of 2 feet above final grade. Final grading of the infiltration facility shall occur only when all contributing drainage areas are fully stabilized. The infiltration pretreatment facility should be fully constructed and used with the sedimentation basin to help prevent clogging.

Either a permanent control structure or the temporary control structure described in BMP C241 - Temporary Sediment Pond can be used. If a permanent control structure is used, it may be advisable to partially restrict the lower orifice with gravel to increase residence time while still allowing dewatering of the pond. A shut-off valve may be added to the control structure to allow complete retention of stormwater in emergency situations. In this case, add an emergency overflow weir.

A skimmer may be used for the sediment trap outlet if approved by the City.

3.2.17.3 Design and Installation Specifications

See Figure II-3-31 and Figure II-3-32 for details.

If permanent runoff control facilities are part of the project, they should be used for sediment retention.

- To determine the sediment trap geometry, first calculate the design surface area (*SA*) of the trap, measured at the invert of the weir. Use the following equation:

  $SA = FS(Q_2/V_S)$

  Where:

  SA = Design surface area, in square feet, of the sediment trap measured at the invert of the weir.

  Q_2 = Design inflow, in cubic feet per second, based on the peak discharge from the developed 2-year runoff event from the contributing drainage area as computed in the hydrologic analysis. The 10-year peak flow shall be used if the project size, expected timing and duration of construction, or downstream conditions warrant a higher level of protection. If no hydrologic analysis is required, the Rational Method may be used.

  Alternatively, Q_2 = Design inflow (cfs) based on the 2-year, 1-hour flowrate predicted by WWHM for the developed (unmitigated site) multiplied by 1.3. Use the 10-year peak flow if the project size, expected timing and duration of construction, or downstream conditions warrant a higher level of protection. Q_{10} is the 10-year, 1-hour flowrate predicted by WWHM multiplied by 1.6.

  V_S = The settling velocity of the soil particle of interest. The 0.02 millimeter (medium silt) particle with an assumed density of 2.65 grams per cubic centimeter has been selected as the particle of interest and has a settling velocity (V_S) of 0.00096 feet per second.

  FS = A safety factor of 2 to account for non-ideal settling.

  Therefore, the equation for computing surface area becomes:

  $SA = 2 \times Q_2/0.00096$ or

  $= 2080\ (Q_2)$

NOTE: Even if permanent facilities are used, they must still have a surface area that is at least as large as that derived from the above formula. If they do not, the pond must be enlarged.

- Smaller sites may use the minimum pond sizes in Table II-3-12 instead of providing calculations.

Table II-3-12. Sediment Trap Sizing

Contributing Area (Acres)	Required Surface Area of Pond (sq. ft.)
1/8 acre or less	130
¼ acre or less	260
½ acre or less	520
¾ acre or less	780
1 acre or less	1040

- To aid in determining sediment depth, all sediment traps shall have a staff gauge with a prominent mark 1-foot above the bottom of the trap.
- Sediment traps may not be feasible on utility projects due to the limited work space or short-term nature of the work. Portable tanks may be used in place of sediment traps for utility projects.
- The basic geometry of the pond can now be determined using the following design criteria:
    - Required surface area SA (from the equation above) at top of riser.
    - Minimum 3.5-foot depth from top of riser to bottom of pond.
    - Maximum 3H:1V interior side slopes and maximum 2H:1V exterior slopes. The interior slopes can be increased to a maximum of 2H:1V if fencing is provided at or above the maximum water surface.
    - One foot of freeboard between the top of the riser and the crest of the emergency spillway.
    - Flat bottom.
    - Minimum 1-foot deep spillway.
    - Length-to-width ratio between 3:1 and 6:1.

3.2.17.4 Maintenance Standards

- Remove sediment from the trap when it reaches 1-foot in depth.
- Repair any damage to the pond embankments or slopes.

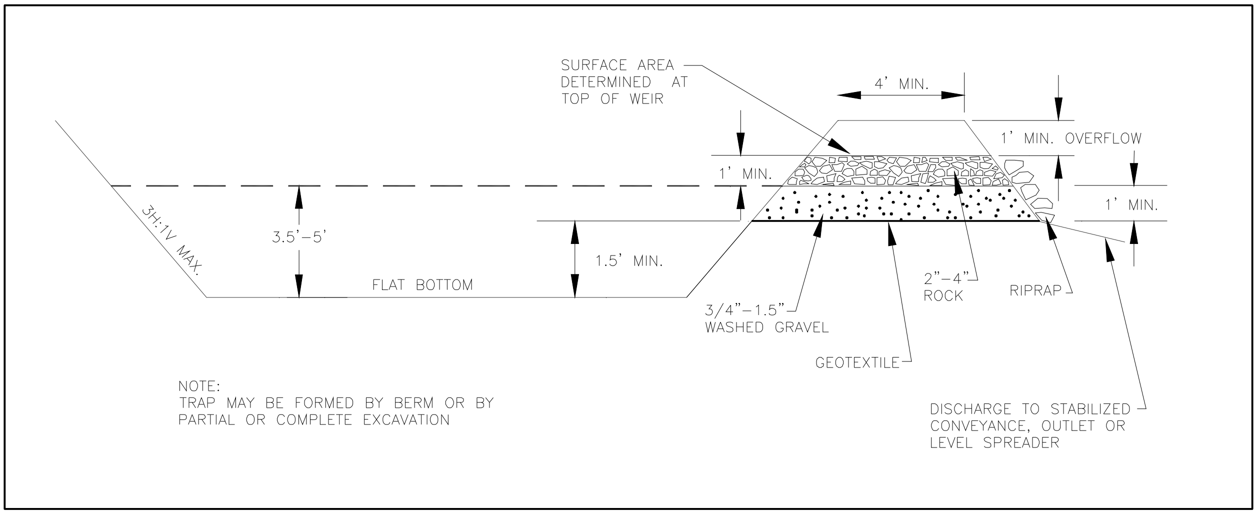


Figure II-3-31. Cross-Section of a Sediment Trap

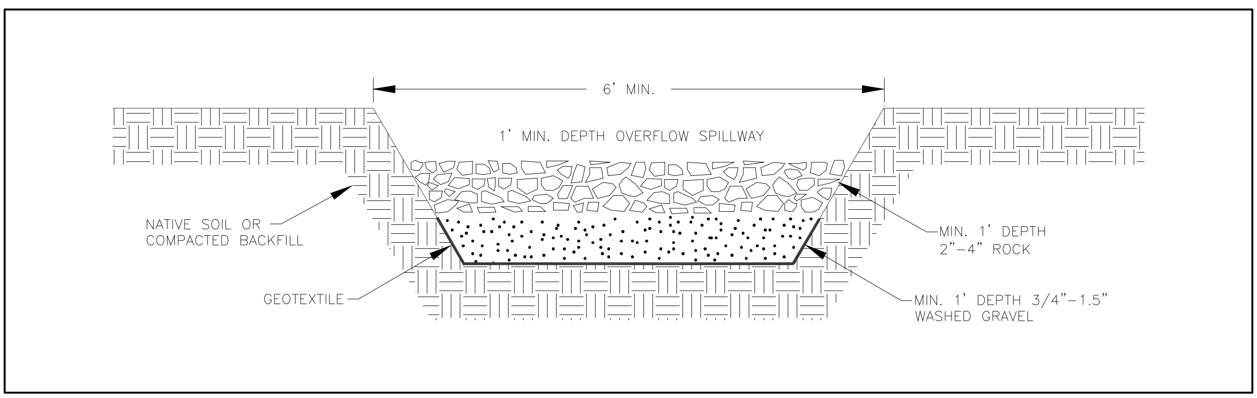


Figure II-3-32. Sediment Trap Outlet

3.2.18 BMP C241: Temporary Sediment Pond

3.2.18.1 Purpose

Sediment ponds remove sediment from runoff originating from disturbed areas of the site. Sediment ponds are typically designed to remove sediment no smaller than medium silt (0.02 mm). Consequently, they usually reduce turbidity only slightly.

3.2.18.2 Conditions of Use

Prior to leaving a construction site, stormwater runoff must pass through a sediment pond or other appropriate sediment removal best management practice.

Use a sediment pond where the contributing drainage area is 3 acres or more. Ponds must be used in conjunction with erosion control practices to reduce the amount of sediment flowing into the basin.

3.2.18.3 Design and Installation Specifications

Only install sediment basins on sites where failure of the structure would not result in loss of life, damage to homes or buildings, or interruption of use or service of public roads or utilities. Also, sediment traps and ponds are attractive to children and can be very dangerous. Compliance with local ordinances regarding health and safety must be addressed. If fencing of the pond is required, show the type of fence and its location on the ESC plan.

- Structures having a maximum storage capacity at the top of the dam of 10 acre-feet (435,600 cubic feet) or more are subject to the Washington Dam Safety Regulations (Chapter 173-175 WAC).
- See Figure II-3-33, Figure II-3-34 and Figure II-3-35 for details.
- If permanent detention facilities are part of the project, they may be used for sediment retention. The surface area requirements of the sediment basin must be met. This may require enlarging the permanent basin to comply with the surface area requirements. If a permanent control structure is used, it may be advisable to partially restrict the lower orifice with gravel to increase residence time while still allowing dewatering of the basin.
- Use of infiltration facilities for sedimentation basins during construction tends to clog the soils and reduce their capacity to infiltrate. If infiltration facilities are to be used, the sides and bottom of the facility must only be rough excavated to a minimum of 2 feet above final grade. Final grading of the infiltration facility shall occur only when all contributing drainage areas are fully stabilized. The infiltration pretreatment facility should be fully constructed and used with the sedimentation basin to help prevent clogging.

Determining Pond Geometry

- Determine the required surface area at the top of the riser pipe with the equation:

  SA = $2 \times Q_2/0.00096$ or

  SA = $2080 (Q_2)$

  Where:

  SA = Design surface area, in square feet, of the sediment trap measured at the invert of the weir.

  Q_2 = Design inflow, in cubic feet per second, based on the peak discharge from the developed 2-year runoff event from the contributing drainage area as computed in the hydrologic analysis. The 10-year peak flow shall be used if the project size, expected timing and duration of construction, or downstream conditions warrant a higher level of protection. If no hydrologic analysis is required, the Rational Method may be used.

  Alternatively, Q_2 = Design inflow (cfs) based on the 2-year, 15-minute flowrate predicted by WWHM for the developed (unmitigated site). Use the 10-year peak flow if the project size, expected timing and duration of construction, or downstream conditions warrant a higher level of protection. Q_{10} is the 10-year, 15-minute flowrate predicted by WWHM. Note: WWHM 2 and 3 do not use 15 minute time steps for 2 or 10 year flow rates, they use 1-hour time steps. The 2-year flowrate predicted by WWHM 2 or 3 must be multiplied by 1.3 and the 10-year flowrate predicted by WWHM 2 or 3 must be multiplied by 1.6. Currently it is unknown what time steps future versions of WWHM will use.

- See BMP C240 for more information on the derivation of the surface area calculation.
- The basic geometry of the pond can now be determined using the following design criteria:
  - Required surface area SA (from the equation above) at top of riser.
  - Minimum 3.5-foot depth from top of riser to bottom of pond.
  - Maximum 3H:1V interior side slopes and maximum 2H:1V exterior slopes. The interior slopes can be increased to a maximum of 2H:1V if fencing is provided at or above the maximum water surface.
  - One foot of freeboard between the top of the riser and the crest of the emergency spillway.
  - Flat bottom.
  - Minimum 1-foot deep spillway.
  - Length-to-width ratio between 3:1 and 6:1.

Sizing of Discharge Mechanisms

The outlet for the basin consists of a combination of principal and emergency spillways. These outlets must pass the peak runoff expected from the contributing drainage area for a 100-year storm. If, due to site conditions and basin geometry, a separate emergency spillway is not feasible, the principal spillway must pass the entire peak runoff expected from the 100-year storm. However, an attempt to provide a separate emergency spillway should always be made. The runoff calculations shall be based on the site conditions during construction. The flow through the dewatering orifice cannot be utilized when calculating the 100-year storm elevation because of its potential to become clogged; therefore, available spillway storage must begin at the principal spillway riser crest.

The principal spillway designed by the procedures contained in this standard will result in some reduction in the peak rate of runoff. However, the riser outlet design will not adequately control the basin discharge to the predevelopment discharge limitations as stated in Minimum Requirement #7: Flow Control. However, if the basin for a permanent stormwater detention pond is used for a temporary sedimentation basin, the control structure for the permanent pond can be used to maintain predevelopment discharge limitations. The size of the basin, the expected life of the construction project, the anticipated downstream effects, and the anticipated weather conditions during construction should be considered to determine the need of additional discharge control. See Figure II-3-36 for riser inflow curves.

Principal Spillway: Determine the required diameter for the principal spillway (riser pipe). The diameter shall be the minimum necessary to pass the pre-developed 10-year peak flow (Q_{10}). Use Figure II-3-36 to determine this diameter (h = 1-foot).

NOTE: A permanent control structure may be used instead of a temporary riser.

Emergency Overflow Spillway: Determine the required size and design of the emergency overflow spillway for the developed 100-year peak flow using the method contained in Volume III. Alternatively, the 100-year peak flow as determined by WWHM multiplied by 1.6 can be used to size the emergency overflow.

Dewatering Orifice: Determine the size of the dewatering orifice(s) (minimum 1-inch diameter) using a modified version of the discharge equation for a vertical orifice and a basic equation for the area of a circular orifice. Determine the required area of the orifice with the following equation:

$$A_o = \frac{A_s (2h)^{0.5}}{0.6\text{x}3600 T g^{0.5}}$$

Where:

A_O	=	orifice area (square feet)
A_S	=	pond surface area (square feet)
h	=	head of water above orifice (height of riser in feet)
T	=	dewatering time (24 hours)
g	=	acceleration of gravity (32.2 feet per second squared)
D	=	orifice diameter (inches)

Convert the required surface area to the required diameter *D* of the orifice:

$$D = 24\text{x}\sqrt{\frac{A_o}{\pi}} = 13.54\text{x}\sqrt{A_o}$$

The vertical, perforated tubing connected to the dewatering orifice must be at least 2 inches larger in diameter than the orifice to improve flow characteristics. The size and number of perforations in the tubing shall be large enough so the tubing does not restrict flow. The orifice shall control the flow rate.

Additional Design Specifications

The **pond shall be divided** into two roughly equal volume cells by a permeable divider that will reduce turbulence while allowing movement of water between cells. The divider shall be at least one-half the height of the riser and a minimum of one foot below the top of the riser. Wire-backed, 2- to 3-foot high, extra strength filter fabric supported by treated 4"x4"s can be used as a divider. If the pond is more than 6 feet deep, a different mechanism must be proposed. A riprap embankment is one acceptable method of separation for deeper ponds. Other designs that satisfy the intent of this provision are allowed as long as the divider is permeable, structurally sound, and designed to prevent erosion under or around the barrier.

To aid in determining sediment depth, prominently mark **one-foot intervals** on the riser.

If an **embankment height** of more than 6 feet is proposed, the pond must comply with the criteria contained in Volume III regarding dam safety for detention BMPs.

The most common structural failure of sedimentation basins is caused by piping. Piping refers to two phenomena: (1) water seeping through fine-grained soil, eroding the soil grain by grain and forming pipes or tunnels and (2) water under pressure flowing upward through a granular soil with a head of sufficient magnitude to cause soil grains to lose contact and capability for support.

The most critical construction sequences to prevent piping will be:

- Tight connections between the riser and barrel and other pipe connections.
- Adequate anchoring of the riser.
- Proper soil compaction of the embankment and riser footing.
- Proper construction of anti-seep devices.

3.2.18.4 Maintenance Standards

- Remove sediment from the pond when it reaches 1–foot in depth.
- Repair any damage to the pond embankments or slopes.

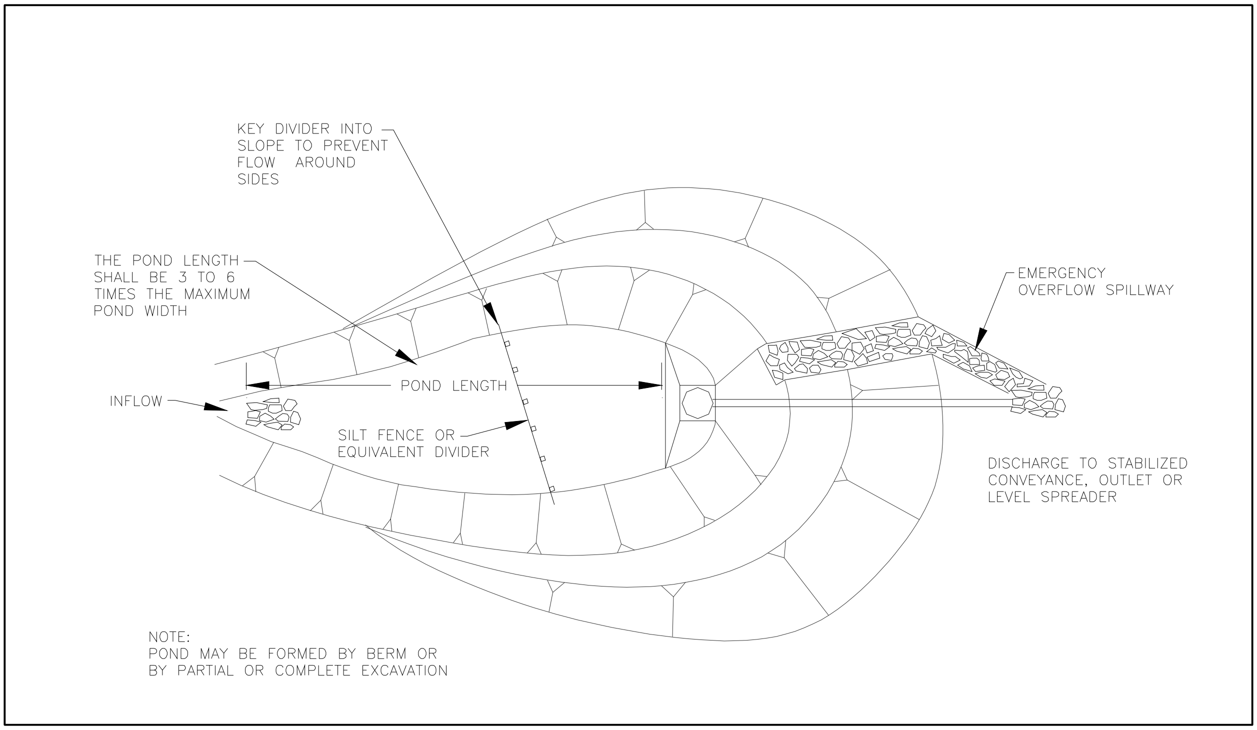


Figure II-3-33. Sediment Pond

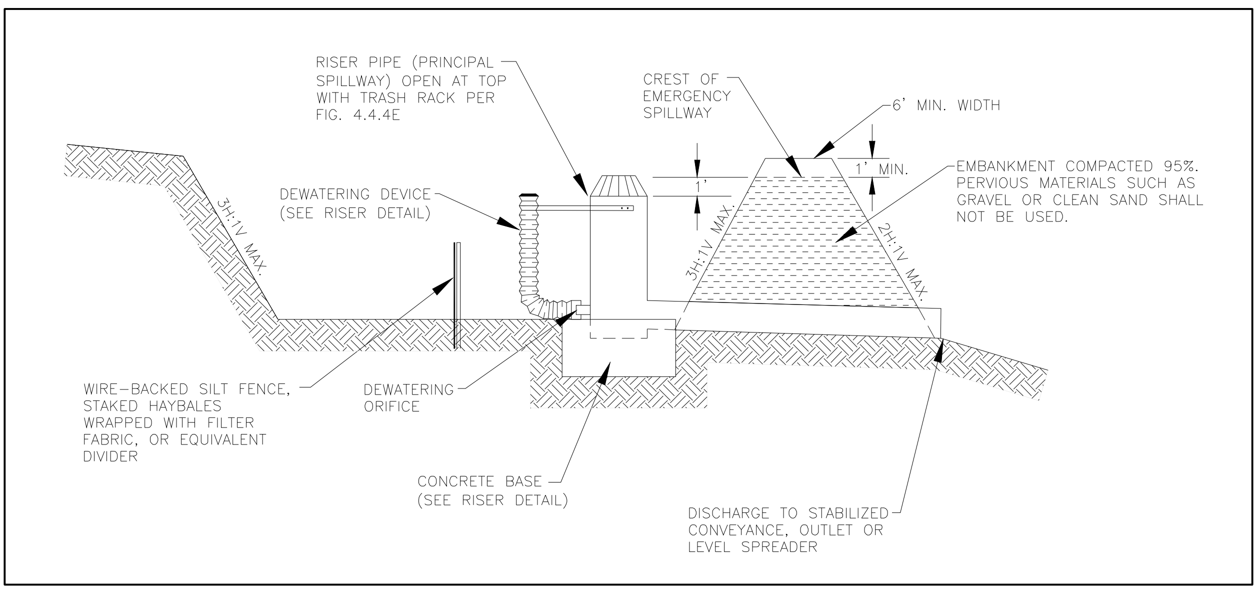


Figure II-3-34. Sediment Pond Cross Section

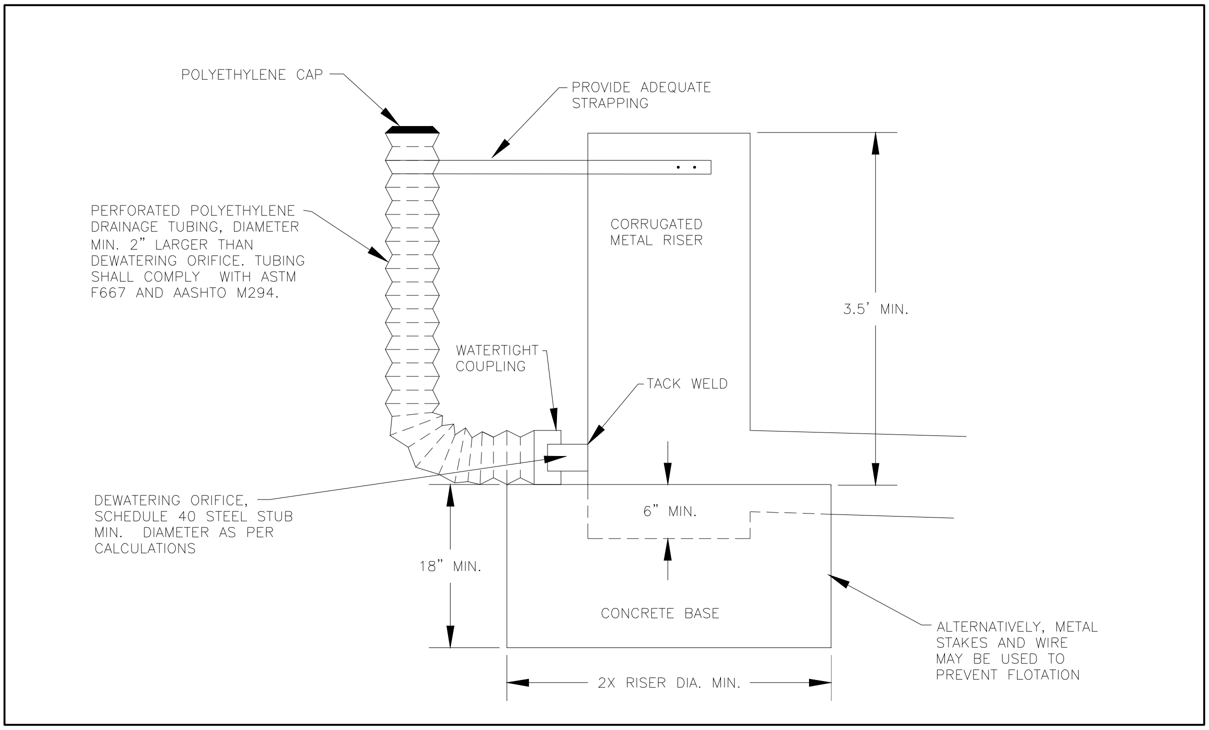


Figure II-3-35. Sediment Pond Riser Detail

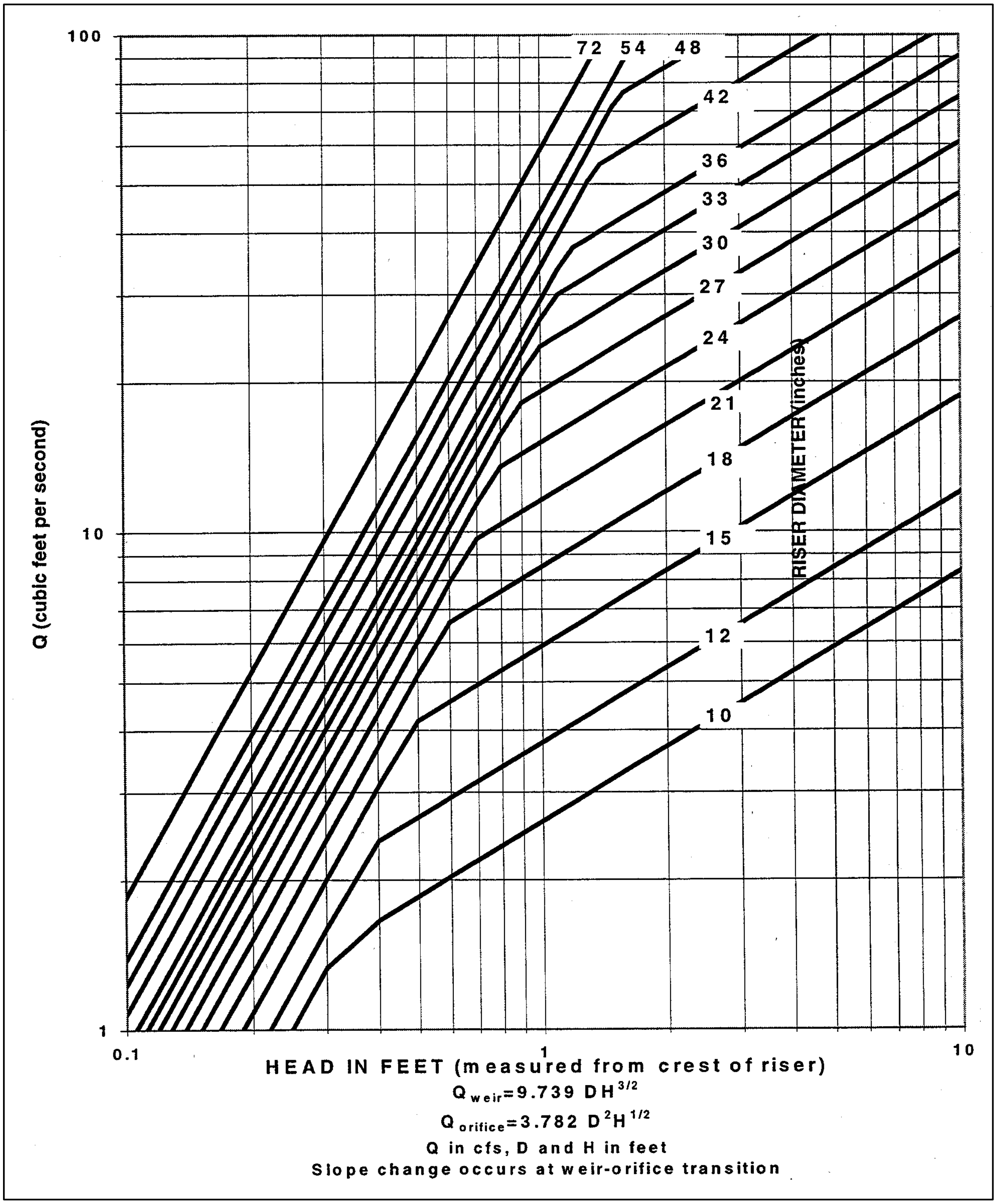


Figure II-3-36. Riser Inflow Curves

3.2.19 BMP C250: Construction Stormwater Chemical Treatment

3.2.19.1 Purpose

This BMP applies when using stormwater chemicals in batch treatment or flow-through treatment.

Turbidity is difficult to control once fine particles are suspended in stormwater runoff from a construction site. Sedimentation ponds are effective at removing larger particulate matter by gravity settling, but are ineffective at removing smaller particulates such as clay and fine silt. Traditional erosion and sediment control BMPs may not be adequate to ensure compliance with the water quality standards for turbidity in the receiving water.

3.2.19.2 Conditions of Use

Formal written approval from Ecology and the City is required for the use of chemical treatment regardless of site size. When approved, include the chemical treatment system in the Stormwater Pollution Prevention Plan (SWPPP).

3.2.19.3 Design and Installation Specifications

See Appendix B for background information on chemical treatment.

Criteria for Chemical Treatment Product Use

Chemically treated stormwater discharged from construction sites must be nontoxic to aquatic organisms. The Chemical Technology Assessment Protocol (CTAPE) must be used to evaluate chemicals proposed for stormwater treatment. **Only chemicals approved by Ecology under the CTAPE may be used for stormwater treatment.** The approved chemicals, their allowable application techniques (batch treatment or flow-through treatment), allowable application rates, and conditions of use can be found at the Department of Ecology Emerging Technologies website: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html

Treatment System Design Considerations

The design and operation of a chemical treatment system should take into consideration the factors that determine optimum, cost-effective performance. It is important to recognize the following:

- Only Ecology approved chemicals may be used and must follow approved dose rates.
- The pH of the stormwater must be in the proper range for the polymers to be effective, which is typically 6.5 to 8.5.
- The coagulant must be mixed rapidly into the water to ensure proper dispersion.
- A flocculation step is important to increase the rate of settling, to produce the lowest turbidity, and to keep the dosage rate as low as possible.
- Too little energy input into the water during the flocculation phase results in flow that are too small and/or insufficiently dense. Too much energy can rapidly destroy floc as it is formed.

- Care must be taken in the design of the withdrawal system to minimize outflow velocities and to prevent floc discharge. Discharge from a batch treatment system should be directed through a physical filter such as a vegetated swale that would catch any unintended floc discharge. Currently, flow-through systems always discharge through the chemically enhanced sand filtration system.
- System discharge rates must take into account downstream conveyance integrity.

Polymer Batch Treatment Process Description

A batch chemical treatment system consists of the stormwater collection system (either temporary diversion or the permanent site drainage system), an untreated stormwater storage pond, pumps, a chemical feed system, treatment cells, and interconnecting piping.

The batch treatment system shall use a minimum of two lined treatment cells in addition to the untreated stormwater storage pond. Multiple treatment cells allow for clarification of treated water while other cells are being filled or emptied. Treatment cells may be ponds or tanks. Ponds with constructed earthen embankments greater than six feet high require special engineering analyses.

Stormwater is collected at interception point(s) on the site and is diverted by gravity or by pumping to an untreated stormwater storage pond or other untreated stormwater holding area. The stormwater is stored until treatment occurs. It is important that the holding pond be large enough to provide adequate storage.

The first step in the treatment sequence is to check the pH of the stormwater in the untreated stormwater storage pond. The pH is adjusted by the application of carbon dioxide or a base until the stormwater in the storage pond is within the desired pH range, 6.5 to 8.5. When used, carbon dioxide is added immediately downstream of the transfer pump. Typically sodium bicarbonate (baking soda) is used as a base, although other bases may be used. When needed, base is added directly to the untreated stormwater storage pond. The stormwater is recirculated with the treatment pump to provide mixing in the storage pond. Initial pH adjustments should be based on daily bench tests. Further, pH adjustments can be made at any point in the process.

Once the stormwater is within the desired pH range (dependant on polymer being used), the stormwater is pumped from the untreated stormwater storage pond to a treatment cell as polymer is added. The polymer is added upstream of the pump to facilitate rapid mixing.

After polymer addition, the water is kept in a lined treatment cell for clarification of the sediment-floc. In a batch mode process, clarification typically takes from 30 minutes to several hours. Prior to discharge samples are withdrawn for analysis of pH and turbidity. If both are acceptable, the treated water is discharged.

Several configurations have been developed to withdraw treated water from the treatment cell. The original configuration is a device that withdraws the treated water from just beneath the water surface using a float with adjustable struts that prevent the float from settling on the cell bottom (Figure II-3-37). This reduces the possibility of picking up sediment-floc from the bottom of the pond. The struts are usually set at a minimum clearance of about 12 inches; that is, the float will come within 12 inches of the bottom of the cell. Other systems have used vertical guides or cables which constrain the float, allowing it to drift up and down with the water level. More recent designs have an H-shaped array of pipes, set on the horizontal.

Figure II-3-37. Floating Platform with Struts

This scheme provides for withdrawal from four points rather than one. This configuration reduces the likelihood of sucking settled solids from the bottom. It also reduces the tendency for a vortex to form. Inlet differs, a long floating or fixed pipe with many small holes in it, are also an option.

Safety is a primary concern. Design should consider the hazards associated with operations, such as sampling. Facilities should be designed to reduce slip hazards and drowning. Tanks and ponds should have life rings, ladder, or steps extending from the bottom to the top.

Polymer Flow-Through Treatment Process Description

At a minimum, a flow-through chemical treatment system consists of the stormwater collection system (either temporary diversion or the permanent site drainage system), an untreated stormwater storage pond, and the chemically enhanced sand filtration system.

Stormwater is collected at interception point(s) on the site and is diverted by gravity or by pumping to an untreated stormwater storage pond or other untreated stormwater holding area. The stormwater is stored until treatment occurs. It is important that the holding pond be large enough to provide adequate storage.

Stormwater is then pumped from the untreated stormwater storage pond to the chemically enhanced sand filtration system where polymer is added. Adjustments to pH may be necessary before chemical addition. The sand filtration system continually monitors the stormwater for turbidity and pH. If the discharge water is ever out of an acceptable range for turbidity or pH, the water is recycled to the untreated stormwater pond where it can be retreated.

Equipment

For batch treatment and flow-through treatment, the following equipment should be located in a lockable shed:

- The chemical injector
- Secondary non-corrosive containment for acid, caustic, buffering compound, and treatment chemical
- Emergency shower and eyewash
- Monitoring equipment

System Sizing

Certain sites are required to implement flow control for the developed sites. These sites must also control stormwater release rates during construction. Generally, these are sites that discharge stormwater directly or indirectly, through a conveyance system, into a freshwater. System sizing is dependent on flow control requirements.

Sizing Criteria for Batch Treatment Systems for Flow Control Exempt Water Bodies

- The total volume of the untreated stormwater storage pond and treatment ponds or tanks must be large enough to treat the volume of stormwater that is produced during multiple day storm events. At a minimum, size the untreated storage pond to hold 1.5 times the runoff volume of the 10-year, 24-hour storm event. Provide bypass around the chemical treatment system to accommodate extreme storm events. Calculate runoff volumes using the methods in Volume III, Chapter 3. Use worst-case land cover conditions (i.e., producing the most runoff) for analyses (in most cases, this would be the land cover conditions just prior to final landscaping).
- Primary settling should be encouraged in the untreated stormwater storage pond. A forebay with access for maintenance is beneficial.
- There are two opposing considerations in sizing the treatment cells. A larger cell is able to treat a larger volume of water each time a batch is processed. However, the larger the cell the longer the time is required to empty the cell. A larger cell may also be less effective at flocculation and therefore require a longer settling time. The simplest approach to sizing the treatment cell is to multiply the allowable discharge flowrate times the desired drawdown time. A 4-hour drawdown time allow one batch per cell per 8-hour work period, given 1 hour of flocculation followed by 2 hours of settling.
- If the discharge is directly to a lake, flow control exempt receiving water, or to an infiltration system, there is no discharge flow limit.
- Ponds sized for flow control water bodies must at a minimum meet the sizing criteria for flow control exempt waters.

Sizing Criteria for Flow-Through Treatment Systems for Flow Control Exempt Water Bodies:

- Sites that must implement flow control for the developed site condition must also control stormwater release rates during construction. Construction site stormwater discharges shall not exceed the discharge durations of the predeveloped condition for the range of predeveloped discharge rates from ½ of the 2-year flow through the 10-year flow as predicted by WWHM. The predeveloped condition to be matched shall be the land cover condition immediately prior to the development project. This restriction on release rates can affect the size of the storage pond and treatment cells.
- The following is how WWHM can be used to determine the release rates from the chemical treatment systems:
    1. Determine the predeveloped flow durations to be matched by entering the land use area under the "Predeveloped" scenario in WWHM. The default flow range is from ½ of the 2-year flow through the 10-year flow.
    2. Enter the post developed land use area in the "Developed Unmitigated" scenario in WWHM.
    3. Copy the land use information for the "Developed Unmitigated" to "Developed Mitigated" scenario.
    4. While in the "Developed Mitigated" scenario, add a pond element under the basin element containing the post-developed land use areas. This pond element represents information on the available untreated stormwater storage and discharge from the chemical treatment system. In cases where the discharge from the chemical treatment is controlled by a pump, a stage/storage/discharge (SSD) table representing the pond must be generated outside WWHM and imported into WWHM. WWHM can route the runoff from the post-developed condition through this SSD table (the pond) and determine compliance with the flow duration standard. This would be an iterative design procedure where if the initial SSD table proved to be inadequate, the designer would have to modify the SSD table outside WWHM and reimport in WWHM and route the runoff through it again. The iteration will continue until a pond that complies with the flow duration standard is correctly sized.

Notes on SSD table characteristics:

- The pump discharge rate would likely be initially set at just below ½ of the 2-year flow from the pre-developed condition. As runoff coming into the untreated stormwater storage pond increases and the available untreated stormwater storage volume gets used up, it would be necessary to increase the pump discharge rate above ½ of the 2-year. The increase(s) above ½ of the 2-year must be such that they provide some relief to the untreated stormwater storage needs but at the same time will not cause violations of the flow duration standard at the higher flows. The final design SSD table will identify the appropriate pumping rates and the corresponding stage and storages.
- When building such a flow control system, the design must ensure that any automatic adjustments to the pumping rates will be as a result of the changes to the available storage in accordance with the final design SSD table.

- It should be noted that the above procedures would be used to meet the flow control requirements. The chemical treatment system must be able to meet the runoff treatment requirements. It is likely that the discharge flowrate of ½ of the 2-year or more may exceed the treatment capacity of the system. If that is the case, the untreated stormwater discharge rate(s) (i.e., influent to the treatment system) must be reduced to allow proper treatment. Any reduction in the flows will likely result in the need for a larger untreated stormwater storage volume.
- If the discharge is to a municipal storm drainage system, the allowable discharge rate may be limited by the capacity of the public system. It may be necessary to clean the municipal storm drainage system prior to the start of the discharge to prevent scouring solids from the drainage system. If the municipal storm drainage system discharges to a water body that is not flow control exempt, the project site is subject to flow control requirements.
- If system design does not allow you to discharge at the slower rates as described above and if the site had a retention or detention pond that will serve the planned development, the discharge from the treatment system may be directed to the permanent retention/detention pond to comply with the flow control requirement. In this case, the untreated stormwater storage pond and treatment system will be sized according to the sizing criteria for flow-through system for flow control exempt water bodies described earlier except all discharge (water passing through the treatment system and stormwater bypassing the treatment system) will be directed into the permanent retention/detention pond. If site constraints make locating the untreated stormwater storage pond difficult, the permanent retention/detention pond may be divided to serve as the untreated stormwater storage pond and the post-treatment flow control pond. A berm or barrier must be used in this case so the untreated water does not mix with the treated water. Both untreated stormwater storage requirements, and adequate post-treatment flow control must be achieved. The post-treatment flow control pond's revised dimensions must be entered into the WWHM and the WWHM must be run to confirm compliance with the flow control requirements.

3.2.19.4 Monitoring

Conduct the following monitoring. Record test results on a daily log kept on site. Additional testing may be required by the NPDES permit based on site conditions.

Operational Monitoring:

- Total volume treated and discharged
- Flow must be continuously monitored and recorded at not greater than 15-minute intervals
- Type and amount of chemical used for pH adjustment, if any
- Quantity of chemical used for treatment
- Settling time

Compliance Monitoring

- Influent and effluent pH and turbidity must be continuously monitored and recorded at not greater than 15-minute intervals.
- pH and turbidity of the receiving water

Biomonitoring

- Treated stormwater must be non-toxic to aquatic organisms. Treated stormwater must be tested for aquatic toxicity or residual chemical content. Frequency of biomonitoring will be determined by Ecology.
- Residual chemical tests must be approved by Ecology prior to their use.
- If testing treated stormwater for aquatic toxicity, you must test for acute (lethal) toxicity. Bioassays shall be conducted by a laboratory accredited by Ecology, unless otherwise approved by Ecology. Acute toxicity tests shall be conducted per the CTAPE protocol.

Discharge Compliance

- **Prior to discharge, treated stormwater must be sampled and tested for compliance with pH and turbidity limits**. These limits may be established by the Construction Stormwater General Permit, or a site-specific discharge permit. Sampling and testing for other pollutants may also be necessary at some sites. pH must be within the range of 6.5 to 8.5 standard units and not cause a change in the pH of the receiving water of more than 0.2 standard units.
- Treated stormwater samples and measurements shall be taken from the discharge pipe or another location representative of the nature of the treated stormwater discharge. Samples used for determining compliance with the water quality standards in the receiving water shall not be taken from the treatment pond prior to decanting. Compliance with the water quality standards is determined in the receiving water.

Operator Training

- Each contractor who intends to use chemical treatment shall be trained by an experienced contractor on an active site.

Standard BMPs

- Surface stabilization BMPs should be implemented on site to prevent significant erosion. All sites shall use a truck wheel wash to prevent tracking of sediment off site.

Sediment Removal and Disposal:

- Remove sediment from the storage or treatment cells as necessary. Typically, sediment removal is required at least once during a wet season and at the decommissioning of the cells. Sediment remaining in the cells between batches may enhance the settling process and reduce the required chemical dosage.
- Sediment that is known to be non-toxic may be incorporated into the site away from drainages.

3.2.20 BMP C251: Construction Stormwater Filtration

3.2.20.1 Purpose

Filtration removes sediment from runoff originating from disturbed areas of the site.

3.2.20.2 Conditions of Use

Traditional BMPs used to control soil erosion and sediment loss from sites under development may not be adequate to ensure compliance with the water quality standard for turbidity in the receiving water. Filtration may be used in conjunction with gravity settling to remove sediment as small as fine silt (0.5 µm). The reduction in turbidity will be dependent on the particle size distribution of the sediment in the stormwater. In some circumstances, sedimentation and filtration may achieve compliance with the water quality standard for turbidity.

The use of construction stormwater filtration does not require approval from Ecology as long as treatment chemicals are not used. Filtration in conjunction with polymer treatment requires testing under the Chemical Technology Assessment Protocol – Ecology (CTAPE) before it can be initiated. Approval from the appropriate regional Ecology office must be obtained at each site where polymers use is proposed prior to use. For more guidance on stormwater chemical treatment see BMP C250.

3.2.20.3 Background Information

Filtration with sand media has been used for over a century to treat water and wastewater. The use of sand filtration for treatment of stormwater has developed recently, generally to treat runoff from streets, parking lots, and residential areas. The application of filtration to construction stormwater is currently under development.

3.2.20.4 Design and Installation Specifications

Two types of filtration systems may be applied to construction stormwater treatment: rapid and slow. Rapid sand filters are the typical system used for water and wastewater treatment. They can achieve relatively high hydraulic flow rates, on the order of 2 to 20 gpm/sf, because they have automatic backwash systems to remove accumulated solids. In contrast, slow sand filters have very low hydraulic rates, on the order of 0.02 gpm/sf, because they do not have backwash systems. To date, slow sand filtration has generally been used to treat stormwater. Slow sand filtration is mechanically simple in comparison to rapid sand filtration but requires a much larger filter area.

Filtration Equipment

Sand media filters are available with automatic backwashing features that can filter to 50 µm particle size. Screen or bag filters can filter down to 5 µm. Fiber wound filters can remove particles down to 0.5 µm. Filters should be sequenced from the largest to the smallest pore opening. Sediment removal efficiency will be related to particle size distribution in the stormwater.

Treatment Process Description

Stormwater is collected at interception point(s) on the site and is diverted to an untreated stormwater sediment pond or tank for removal of large sediment and storage of the stormwater before it is treated by the filtration system. The stormwater is pumped from the trap, pond, or tank through the filtration system in a rapid sand filtration system. Slow sand filtration systems are designed as flow through systems using gravity.

Sizing Criteria for Flow-Through Treatment Systems for Flow Control Exempt Water Bodies

When sizing storage ponds or tanks for flow-through systems for flow control exempt water bodies, the treatment system capacity should be a factor. The untreated stormwater storage pond or tank should be sized to hold 1.5 times the runoff volume of the 10-year, 24-hour storm event minus the treatment system flowrate for an 8-hour period. For a chitosan-enhanced sand filtration system, the treatment flowrate should be sized using a hydraulic loading rate between 6-8 gpm/ft^2. Other hydraulic loading rates may be more appropriate for other systems. Bypass should be provided around the chemical treatment system to accommodate extreme storms. Runoff volumes shall be calculated using the methods presented in Volume III, Chapter 3. Worst-case conditions (i.e., producing the most runoff) should be used for analyses (most likely conditions present prior to final landscaping).

Sizing Criteria for Flow Control Waters:

Sites that must implement flow control for the developed site condition must also control stormwater release rates during construction. Construction site stormwater discharges shall not exceed the discharge durations of the pre-developed condition for the range of pre-developed discharge rates from ½ of the 2-year flow through the 10-year flow as predicted by WWHM. The pre-developed condition to be matched shall be the land cover condition immediately prior to the development project. This restriction on release rates will affect the size of the sediment pond, the filtration system, and the flow rate through the filter system.

The following is how WWHM can be used to determine the release rates from the filtration systems:

1. Determine the pre-developed flow durations to be matched by entering the land use area under the “Pre-developed” scenario in WWHM. The default flow range is from ½ of the 2-year flow through the 10-year flow.
2. Enter the post developed land use area in the “Developed Unmitigated” scenario in WWHM.
3. Copy the land use information from the “Developed Unmitigated” to “Developed Mitigated” scenario.
4. There are two possible ways to model stormwater filtration systems:
    a. The stormwater filtration system uses a storage pond/tank and the discharge from this pond/tank is pumped to one or more filters. In-line filtration chemicals would be added to the flow right after the pond/tank and before the filter(s). Because the discharge is pumped, WWHM cannot generate a stage/storage/discharge (SSD) table for this system. This system is modeled the same way as described in BMP C250 and is as follows:

        While in the “Developed Mitigated” scenario, add a pond element under the basin element containing the post-developed land use areas. This pond element represents information on the available storage and discharge from the filtration system. In cases where the discharge from the filtration system is controlled by a pump, a stage/storage/discharge (SSD) table representing the pond must be generated outside WWHM and imported into WWHM. WWHM can route the runoff from the post-developed condition through this SSD table (the pond) and determine compliance with the flow duration standard. This would be an iterative design procedure where if the initial SSD table proved to be out of compliance, the designer would have to modify the SSD table outside WWHM and re-import in WWHM and route the runoff through it again. The iteration will continue until a pond that enables compliance with the flow duration standard is designed.

Notes on SSD Table Characteristics

- The pump discharge rate would likely be initially set at just below ½ if the 2-year flow from the pre-developed condition. As runoff coming to the storage pond increases and the available storage volume gets used up, it would be necessary to increase the pump discharge rate above ½ of the 2-year. The increase(s) above ½ of the 2-year must be such that they provide some relief to the storage needs but at the same time they will not cause violations of the flow duration standard at the higher flows. The final design SSD table will identify the appropriate pumping rates and the corresponding stage and storages.
- When building such a flow control system, the design must ensure that any automatic adjustments to the pumping rates will be as a result of changes to the available storage in accordance with the final design SSD table.

b. The stormwater filtration system uses a storage pond/tank and the discharge from this pond/tank gravity flows to the filter. This is usually a slow sand filter system and it is possible to model it in WWHM as a Filter element or as a combination of Pond and Filter element placed in series. The stage/storage/discharge table(s) may then be generated within WWHM as follows:

(i) While in the "Developed Mitigated" scenario, add a Filter element under the basin element containing the post-developed land use areas. The length and width of this filter element would have to be the same as the bottom length and width of the upstream storage pond/tank.

(ii) In cases where the length and width of the filter is not the same as those for the bottom of the upstream storage tank/pond, the treatment system may be modeled as a Pond element followed by a Filter element. By having these two elements, WWHM would then generate a SSD table for the storage pond which then gravity flows to the Filter element. The Filter element downstream of the storage pond would have a storage component through the media, and an overflow component for when the filtration capacity is exceeded.

WWHM can route the runoff from the post-developed condition through the treatment systems in 4b and determine compliance with the flow duration standard. This would be an iterative design procedure where if the initial sizing estimates for the treatment system proved to be inadequate, the designer would have to modify the system and route the runoff through it again. The iteration would continue until compliance with the flow duration standard is achieved.

5. It should be noted that the above procedures would be used to meet the flow control requirements. The filtration system must be able to meet the runoff treatment requirements. It is likely that the discharge flow rate of ½ of the 2-year or more may exceed the treatment capacity of the system. If that is the case, the discharge rate(s) must be reduced to allow proper treatment. Any reduction in the flows would likely result in the need for a larger storage volume.

   If the system does not allow you to discharge at the slower rate as described above and if the site has a retention or detention pond that will serve the planned development, the discharge from the treatment system may be directed to the permanent retention/detention pond to comply with the flow control requirements. In this case, the untreated stormwater storage pond and treatment system will be sized according to the sizing criteria for flow-through treatment systems for flow control exempt waterbodies except all discharges (water passing through the treatment system and stormwater bypassing the treatment system) will be directed into the permanent retention/detention pond. If site constraints make locating the untreated stormwater storage pond difficult, the permanent retention/detention pond may be divided to serve as the untreated stormwater discharge pond and the post-treatment flow control pond. A berm or barrier must be used in this case so the untreated water does not mix with the treated water. Both untreated stormwater storage requirements, and adequate post-treatment flow control must be achieved. The post-treatment flow control pond's revised dimensions must be entered into the WWHM and the WWHM must be run to confirm compliance with the flow control requirements.

3.2.20.5 Maintenance Standards

Rapid sand filters typically have automatic backwash systems that are triggered by a pre-set pressure drop across the filter. If the backwash water volume is not large or substantially more turbid than the stormwater stored in the holding pond or tank, backwash return to the pond or tank may be appropriate. However, land application or another means of treatment and disposal may be necessary.

- Clean and/or replace screen, bag, and fiber filters when they become clogged.
- Remove sediment from the storage and/or treatment ponds as necessary. Typically, sediment removal is required once or twice during a wet season and at the decommissioning of the ponds.

3.2.21 BMP C252: High pH Neutralization using CO_2

3.2.21.1 Description

When pH levels in stormwater rise above 8.5 it is necessary to lower the pH levels to the acceptable range of 6.5 to 8.5, this process is called pH neutralization. pH neutralization involves the use of solid or compressed carbon dioxide gas in water requiring neutralization. Neutralized stormwater may be discharged to surface waters under the General Construction NPDES permit but neutralized process wastewater must be managed to prevent discharge to surface waters. Process wastewater includes wastewaters such as concrete truck wash-out, hydro-demolition, or saw-cutting slurry.

Reason for pH neutralization

A pH level range of 6.5 to 8.5 is typical for most natural watercourses, and this neutral pH is required for the survival of aquatic organisms. Should the pH rise or drop out of this range, fish and other aquatic organisms may become stressed and may die.

Calcium hardness can contribute to high pH values and cause toxicity that is associated with high pH conditions. A high level of calcium hardness in waters of the state is not allowed.

The water quality standard for pH in Washington State is in the range of 6.5 to 8.5.

Groundwater standard for calcium and other dissolved solids in Washington State is less than 500 mg/l.

Causes of high pH

High pH at construction sites is most commonly caused by the contact of stormwater with poured or recycled concrete, cement, mortars, and other Portland cement or lime-containing construction materials. (See BMP C151: Concrete Handling for more information on concrete handling procedures). The principal caustic agent in cement is calcium hydroxide (free lime).

Advantages of CO_2 Sparging

- Rapidly neutralizes high pH water.
- Cost effective and safer to handle than acid compounds.
- CO_2 is self-buffering. It is difficult to overdose and create harmfully low pH levels.
- Material is readily available.

The Chemical Process

When carbon dioxide (CO_2) is added to water (H_2O), carbonic acid (H_2CO_3) is formed which can further dissociate into a proton (H^+) and a bicarbonate anion (HCO_3^-) as shown below:

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

The free proton is a weak acid that can lower the pH.

Water temperature has an effect on the reaction as well. The colder the water temperature is the slower the reaction occurs and the warmer the water temperature is the quicker the reaction occurs. Most construction applications in Washington State have water temperatures in the 50°F or higher range so the reaction is almost simultaneous.

3.2.21.2 Treatment Procedures

High pH water may be treated using continuous treatment, continuous discharge systems. These manufactured systems continuously monitor influent and effluent pH to ensure that pH values are within an acceptable range before being discharged. All systems must have fail safe automatic shut off switches in the event that pH is not within the acceptable discharge range. Only trained operators may operate manufactured systems. System manufacturers often provide trained operators or training on their devices.

The following procedure may be used when not using a continuous discharge system:

- Prior to treatment, the appropriate jurisdiction should be notified in accordance with the regulations set by the jurisdiction.
- Every effort should be made to isolate the potential high pH water in order to treat it separately from other stormwater on-site.
- Water should be stored in an acceptable storage facility, detention pond, or containment cell prior to treatment.
- Transfer water to be treated to the treatment structure. Ensure that treatment structure size is sufficient to hold the amount of water that is to be treated. Do not fill tank completely, allow at least 2 feet of freeboard.
- The operator samples the water for pH and notes the clarity of the water. As a rule of thumb, less CO_2 is necessary for clearer water. This information should be recorded.
- In the pH adjustment structure, add CO_2 until the pH falls in the range of 6.9-7.1. Remember that pH water quality standards apply so adjusting pH to within 0.2 pH units of receiving water (background pH) is recommended. It is unlikely that pH can be adjusted to within 0.2 pH units using dry ice. Compressed carbon dioxide gas should be introduced to the water using a carbon dioxide diffuser located near the bottom of the tank, this will allow carbon dioxide to bubble up through the water and diffuse more evenly.
- Slowly release the water to discharge making sure water does not get stirred up in the process. Release about 80% of the water from the structure leaving any sludge behind.
- Discharge treated water through a pond or drainage system.
- Excess sludge needs to be disposed of properly as concrete waste. If several batches of water are undergoing pH treatment, sludge can be left in treatment structure for the next batch treatment. Dispose of sludge when it fills 50% of tank volume.

Sites that must implement flow control for the developed site must also control stormwater release rates during construction. All treated stormwater must go through a flow control facility before being released to surface waters which require flow control.

3.2.21.3 Safety and Materials Handling

- All equipment should be handled in accordance with OSHA rules and regulations.
- Follow manufacturer guidelines for materials handling.

3.2.21.4 Operator Records

Each operator should provide:

- A diagram of the monitoring and treatment equipment
- A description of the pumping rates and capacity the treatment equipment is capable of treating.

Each operator should keep a written record of the following:

- Client name and phone number
- Date of treatment
- Weather conditions
- Project name and location
- Volume of water treated
- pH of untreated water
- Amount of CO_2 needed to adjust water to a pH range of 6.9-7.1
- pH of treated water
- Discharge point location and description

A copy of this record should be given to the client/contractor who should retain the record for three years.

3.2.22 BMP C253: pH Control for High pH Water

3.2.22.1 Description

When pH levels in stormwater rise above 8.5 it is necessary to lower the pH levels to the acceptable range of 6.5 to 8.5, this process is called pH neutralization. Stormwater with pH levels exceeding water quality standards may be treated by infiltration, dispersion in vegetation or compost, pumping to a sanitary sewer, disposal at a permitted concrete batch plant with pH neutralization capabilities, or carbon dioxide sparging. BMP C252 provides guidance for carbon dioxide sparging.

Reason for pH neutralization

A pH level between 6.5 and 8.5 is typical for most natural watercourses, and this pH range is required for the survival of aquatic organisms. Should the pH rise or drop out of this range, fish and other aquatic organisms may become stressed and may die.

Causes of high pH

High pH levels at construction sites are most commonly caused by the contact of stormwater with poured or recycled concrete, cement, mortars, and other Portland cement or lime-containing construction materials. (See BMP C151: Concrete Handling for more information on concrete handling procedures). The principal caustic agent in cement is calcium hydroxide (free lime).

3.2.22.2 Disposal Methods

Infiltration

- Infiltration is only allowed if soil type allows all water to infiltrate (no surface runoff) without causing or contributing to a violation of surface or groundwater quality standards.
- Infiltration techniques should be consistent with Volume V, Chapter 5.

Dispersion

- Use BMP L614 Full Dispersion

Sanitary Sewer Disposal

- Local sewer authority approval is required prior to disposal via the sanitary sewer.

Concrete Batch Plant Disposal

- Only permitted facilities may accept high pH water.
- Facility should be contacted before treatment to ensure they can accept the high pH water.

Stormwater Discharge

Any pH treatment options that generate treated water that must be discharged off site are subject to flow control requirements. Sites that must implement flow control for the developed site must also control stormwater release rates during construction. All treated stormwater must go through a flow control facility before being released to surface waters which require flow control.

Appendix A Standard Notes for Erosion Control Plans

Use the following standard notes on project Stormwater Pollution Prevention Plan (SWPPP) and associated drawings. Other mandatory notes for construction plans may be applicable. Plans shall identify the name and phone number of the person or firm responsible for the preparation and maintenance of the erosion control plan.

Standard Notes

Approval of this erosion/sedimentation control (ESC) plan does not constitute an approval of permanent road or drainage design (e.g. size and location of roads, pipes, restrictors, channels, retention facilities, utilities, etc.).

The implementation of these ESC plans and the construction, maintenance, replacement, and upgrading of these ESC facilities is the responsibility of the applicant/contractor until all construction is completed and approved and vegetation/landscaping is established.

The boundaries of the clearing limits shown on this plan shall be clearly flagged in the field prior to construction. During the construction period, no disturbance beyond the flagged clearing limits shall be permitted. The flagging shall be maintained by the applicant/contractor for the duration of construction.

The ESC facilities shown on this plan must be constructed in conjunction with all clearing and grading activities, and in such a manner as to ensure that sediment and sediment laden water do not enter the drainage system or roadways, or violate applicable water standards.

The ESC facilities shown on this plan are the minimum requirements for anticipated site conditions. During the construction period, these ESC facilities shall be upgraded as needed for unexpected storm events and to ensure that sediment and sediment-laden water do not leave the site.

The ESC facilities shall be inspected daily by the applicant/contractor and maintained as necessary to ensure their continued functioning.

The ESC facilities on inactive sites shall be inspected and maintained a minimum of once a month or within the 48 hours following a major storm event.

At no time shall more than one foot of sediment be allowed to accumulate within a catch basin sediment trap. All catch basins and conveyance lines shall be cleaned prior to paving. The cleaning operation shall not flush sediment-laden water into the downstream system.

Stabilized construction entrances shall be installed at the beginning of construction and maintained for the duration of the project. Additional measures may be required to ensure that all paved areas are kept clean for the duration of the project.

Appendix B Background Information on Chemical Treatment

Coagulation and flocculation have been used for over a century to treat water. It is used less frequently for the treatment of wastewater. The use of coagulation and flocculation for treating stormwater is a very recent application. Experience with the treatment of water and wastewater has resulted in a basic understanding of the process, in particular factors that affect performance. This experience can provide insights as to how to most effectively design and operate similar systems in the treatment of stormwater.

Fine particles suspended in water give it a milky appearance, measured as turbidity. Their small size, often much less than 1 µm in diameter, give them a very large surface area relative to their volume. These fine particles typically carry a negative surface charge. Largely because of these two factors, small size and negative charge, these particles tend to stay in suspension for extended periods of time. Thus, removal is not practical by gravity settling. These are called stable suspensions. Polymers, as well as inorganic chemicals such as alum, speed the process of clarification. The added chemical destabilizes the suspension and causes the smaller particles to agglomerate. The process consists of three steps: coagulation, flocculation, and settling or clarification. Each step is explained below, as well as the factors that affect the efficiency of the process.

Coagulation: Coagulation is the first step. It is the process by which negative charges on the fine particles that prevent their agglomeration are disrupted. Chemical addition is one method of destabilizing the suspension, and polymers are one class of chemicals that are generally effective. Chemicals that are used for this purpose are called coagulants. Coagulation is complete when the suspension is destabilized by the neutralization of the negative charges. Coagulants perform best when they are thoroughly and evenly dispersed under relatively intense mixing. This rapid mixing involves adding the coagulant in a manner that promotes rapid dispersion, followed by a short time period for destabilization of the particle suspension. The particles are still very small and are not readily separated by clarification until flocculation occurs.

Flocculation: Flocculation is the process by which fine particles that have been destabilized bind together to form larger particles that settle rapidly. Flocculation begins naturally following coagulation, but is enhanced by gentle mixing of the destabilized suspension. Gentle mixing helps to bring particles in contact with one another such that they bind and continually grow to form "flocs." As the size of the flocs increases, they become heavier and tend to settle more rapidly.

Clarification: The final step is the settling of the particles. Particle density, size, and shape are important during settling. Dense, compact flocs settle more readily than less dense, fluffy flocs. Because of this, flocculation to form dense, compact flocs is particularly important during water treatment. Water temperature is important during settling. Both the density and viscosity of water are affected by temperature; these in turn affect settling. Cold temperatures increase viscosity and density, thus slowing down the rate at which the particles settle.

The conditions under which clarification is achieved can affect performance. Currents can affect settling. Currents can be produced by wind, by differences between the temperature of the incoming water and the water in the clarifier, and by flow conditions near the inlets and outlets.

Quiescent water, such as that which occurs during batch clarification, provides a good environment for effective performance, as many of these factors become less important in comparison to typical sedimentation basins. One source of currents that is likely important in batch systems is movement of the water leaving the clarifier unit. Given that flocs are relatively small and light, the exit velocity of the water must be as low as possible. Sediment on the bottom of the basin can be resuspended and removed by fairly modest velocities.

Coagulants: Polymers are large organic molecules that are made up of subunits linked together in a chain-like structure. Attached to these chain-like structures are other groups that carry positive or negative charges, or have no charge. Polymers that carry groups with positive charges are called cationic, those with negative charges are called anionic, and those with no charge (neutral) are called nonionic.

Cationic polymers can be used as coagulants to destabilize negatively charged turbidity particles present in natural waters, wastewater, and stormwater. Aluminum sulfate (alum) can also be used as this chemical becomes positively charged when dispersed in water. In practice, the only way to determine whether a polymer is effective for a specific application is to perform preliminary or on-site testing.

Polymers are available as powders, concentrated liquids, and emulsions (which appear as milky liquids). The latter are petroleum based, which are not allowed for construction stormwater treatment. Polymer effectiveness can degrade with time and from other influences. Thus, manufacturers' recommendations for storage should be followed. Manufacturers’ recommendations usually do not provide assurance of water quality protection or safety to aquatic organisms. Consideration of water quality protection is necessary in the selection and use of all polymers.

Application Considerations: Application of coagulants at the appropriate concentration or dosage rate for optimum turbidity removal is important for management of chemical cost, for effective performance, and to avoid aquatic toxicity. The optimum dose in a given application depends on several site-specific features. Turbidity of untreated water can be important with turbidities greater than 5,000 NTU. The surface charge of particles to be removed is also important. Environmental factors that can influence dosage rate are water temperature, pH, and the presence of constituents that consume or otherwise affect polymer effectiveness. Laboratory experiments indicate that mixing previously settled sediment (floc sludge) with untreated stormwater significantly improves clarification, therefore reducing the effective dosage rate. Preparation of working solutions and thorough dispersal of polymers in water to be treated is also important to establish the appropriate dosage rate.

For a given water sample, there is generally an optimum dosage rate that yields the lowest residual turbidity after settling. When dosage rates below this optimum value (underdosing) are applied, there is an insufficient quantity of coagulant to react with, and therefore destabilize, all of the turbidity present. The result is residual turbidity (after flocculation and settling) that is higher than with the optimum dose. Overdosing, application of dosage rates greater than the optimum value, can also negatively impact performance. Again, the result is higher residual turbidity than that with the optimum dose.

Mixing in Coagulation/Flocculation: The G-value, or just "G", is often used as a measure of the mixing intensity applied during coagulation and flocculation. The symbol G stands for “velocity gradient”, which is related in part to the degree of turbulence generated during mixing. High G-values mean high turbulence, and vice versa. High G-values provide the best conditions for coagulant addition. With high Gs, turbulence is high and coagulants are rapidly dispersed to their appropriate concentrations for effective destabilization of particle suspensions.

Low G-values provide the best conditions for flocculation. Here, the goal is to promote formation of dense, compact flocs that will settle readily. Low Gs provide low turbulence to promote particle collisions so that flocs can form. Low Gs generate sufficient turbulence such that collisions are effective in floc formation, but do not break up flocs that have already formed.

Design engineers wishing to review more detailed presentations on this subject are referred to the following textbooks:

- Fair, G., J. Geyer and D. Okun, Water and Wastewater Engineering, Wiley and Sons, NY, 1968.
- American Water Works Association, Water Quality and Treatment, McGraw-Hill, NY, 1990.
- Weber, W.J., Physiochemical Processes for Water Quality Control, Wiley and Sons, NY, 1972.

Adjustment of pH and Alkalinity: The pH must be in the proper range for the polymers to be effective, which is 6.5 to 8.5 for Calgon CatFloc 2953, the most commonly used polymer. As polymers tend to lower the pH, it is important that the stormwater have sufficient buffering capacity. Buffering capacity is a function of alkalinity. Without sufficient alkalinity, the application of the polymer may lower the pH to below 6.5. A pH below 6.5 not only reduces the effectiveness of the polymer, it may create a toxic condition for aquatic organisms. Stormwater may not be discharged without readjustment of the pH to above 6.5. The target pH should be within 0.2 standard units of the receiving water pH.

Experience gained at several projects in the City of Redmond has shown that the alkalinity needs to be at least 50 mg/L to prevent a drop in pH to below 6.5 when the polymer is added.

Appendix C Construction SWPPP Short Form

Projects falling within the thresholds listed below may use this short form instead of preparing a professionally-designed Construction Stormwater Pollution Prevention Plan (SWPPP). If your project meets the following thresholds and includes or may impact a critical area, please contact the City to determine if the SWPPP short form may be used.

The thresholds for using this form are projects that propose to:

- Add or replace between 2,000 and 5,000 square feet of impervious surface.

  OR
- Clear or disturb between 7,000 square feet and 1 acre of land.

  OR
- Grade/fill less than 500 cubic yards.

If project quantities exceed either of these thresholds, prepare a formal Construction SWPPP as described in Chapter 2 of this volume.

City of Auburn
Construction Stormwater Pollution Prevention Plan
Short Form

Project Name: ____
Address: ____
Contact/Owner: ______________________ Phone: ________________
Erosion Control Supervisor: ______________________________________
Phone:______________ Cell: __________ Pager: ________________
Emergency (After hour) contact: ____________ Phone: ________________
Permit No: ____
Parcel No.: ____

Required Submittals

1. Project Narrative

The Construction Stormwater Pollution Prevention Plan (SWPPP) Short-Form Narrative must be completed as part of this packet. Any information described, as part of the narrative, should be shown on the site plan.

NOTE: From October 1 thru April 30, clearing, grading, and other soil disturbing activities shall only be permitted by special authorization from the City of Auburn.

A. Project Description (Check all that apply)

☐ New Structure ☐ Building Addition ☐ Grading/Excavation ☐ Paving

☐ Utilities ☐ Other: ________________________________

1. Total project area__________ (square feet)
2. Total proposed impervious area__________(square feet)
3. Total existing impervious area _________(square feet)
4. Total proposed area to be disturbed __________(square feet)
5. Total volumes of proposed cuts/fill_________(cubic yards)

Additional Project Information: ____
____
____
____
____
____

B. Existing Site Conditions (Check all that apply)

- Describe the existing vegetation on the site. (Check all that apply)

  ☐ Forest ☐ Pasture/prairie grass ☐ Pavement ☐ Landscaping ☐ Brush

  ☐ Trees ☐ Other____

- Describe how surface water (stormwater) drainage flows across/from the site. (Check all that apply)

  ☐ Sheet Flow ☐ Gutter ☐ Catch Basin ☐ Ditch/Swale ☐ Storm sewer

  ☐ Stream ☐ Other ____

- Describe any unusual site condition(s) or other features of note.

  ☐ Steep Grades ☐ Large depression ☐ Underground tanks ☐ Springs

  ☐ Easements ☐ Existing Structures ☐ Existing Utilities

  ☐ Other____

C. Adjacent Areas (Check all that apply)

1. Check any adjacent areas that may be affected by site disturbance and describe in fully describe in item 2 below:

   ☐ Streams* ☐ Lakes* ☐ Wetlands* ☐ Steep Slopes*

   ☐ Residential Areas ☐ Roads ☐ Ditches, pipes, culverts

   ☐ Other ____

   ** If site is on or adjacent to a critical area, the City of Auburn may require additional information, engineering, and other permits to be submitted with this short-form.*

2. Describe how and where surface water enters the site from upstream properties: ____

   ____

   ____

   ____

   ____

   ____

   ____

3. Describe the downstream drainage path leading from the site to the receiving body of water. (Minimum distance of ¼-mile (1320 feet)) {E.g. water flows from site, into curb-line to catch basin at intersection of X and Y streets. A 10-inch pipe system conveys water another 1000 feet to a ravine/wetland.}

____

____

____

____

____

D. Soils (Check all that apply)

The intent of this section is to identify when additional soils information may be required for applicants using this short form. There are other site-specific issues that may necessitate a soils investigation or more extensive erosion control practices. The City will determine these situations on a case-by-case basis as part of their review.

1. Does the project propose infiltration? Infiltration systems require prior City approval.

   ☐ Yes ☐ No ☐ Groundwater Protection Zone 2

2. Does the project propose construction near or on steep slopes?

   ☐ Yes ☐ No

   If infiltration is proposed for the site or steep slopes have been identified, the City will require soils information as part of the project design. The applicant must contact a soil professional or civil engineer specializing in soil analysis to perform an in-depth soils investigation. If yes is checked for either question, the City may not permit the use of this short-form.

E. Construction Sequencing/Phasing

1. Construction sequence: The standard construction sequence is as follows:

   - Mark clearing/grading limits.
   - Call Building Inspector to inspect clearing/grading limits.
   - Install initial erosion control practices (construction entrance, silt fence, catch basin inserts).
   - Contact Building Inspector to inspect initial erosion control practices.
   - Clear, grade, and fill site as outlined in the site plan while implementing and maintaining temporary erosion and sediment control practices at the same time.
   - Install permanent erosion protection (impervious surface, landscaping, etc.).
   - Contact Building Inspector for approval of permanent erosion protection and site grades.
   - Remove erosion control methods as permitted by the Building Inspector and repair permanent erosion protection as necessary.

- Monitor and maintain permanent erosion protection until fully established.

List any changes from the standard construction sequence outlined above.

____

____

____

____

____

2. Construction phasing: If construction is going to occur in separate phases, describe:

____

____

____

____

F. Construction Schedule

1. Provide a proposed construction schedule (dates construction starts and ends, and dates for any construction phasing).

Start Date: _______________ End Date: _______________

Interim Phasing Dates: ______________________________

Wet Season Construction Activities: Wet season occurs from October 1 to April 30. Describe construction activities that will occur during this time period.

____

____

____

____

NOTE: Additional erosion control methods may be required during periods of increased surface water runoff.

2. Site Plan (See attached example)

A site plan, to scale, shall be included with this checklist that shows the following items:

___ a. Address, Parcel Number, Permit Number and Street names

___ b. North Arrow

___ c. Indicate boundaries of existing vegetation (e.g. tree lines, grassy areas, pasture areas, fields, etc.)

___ d. Identify any on-site or adjacent critical areas and associated buffers (e.g. wetlands, steep slopes, streams, etc.).

___ e. Identify any FEMA base flood boundaries and Shoreline Management boundaries.

___ f. Show existing and proposed contours.

___ g. Delineate areas that are to be cleared and graded.

___ h. Show all cut and fill slopes, indicating top and bottom of slope catch lines

___ i. Show locations where upstream runon enters the site and locations where runoff leaves the site.

___ j. Indicate existing surface water flow direction(s).

___ k. Label final grade contours and indicate proposed surface water flow direction and surface water conveyance systems (e.g. pipes, catch basins, ditches, etc.).

___ l. Show grades, dimensions, and direction of flow in all (existing and proposed) ditches, swales, culverts, and pipes.

__ m. Indicate locations and outlets of any dewatering systems (usually to sediment trap).

___ n. Identify and locate all erosion control techniques to be used during and after construction.

See attached: **Guidelines for Erosion Control Practices and sample Site Plan.**

Onsite field verification of actual conditions is required.

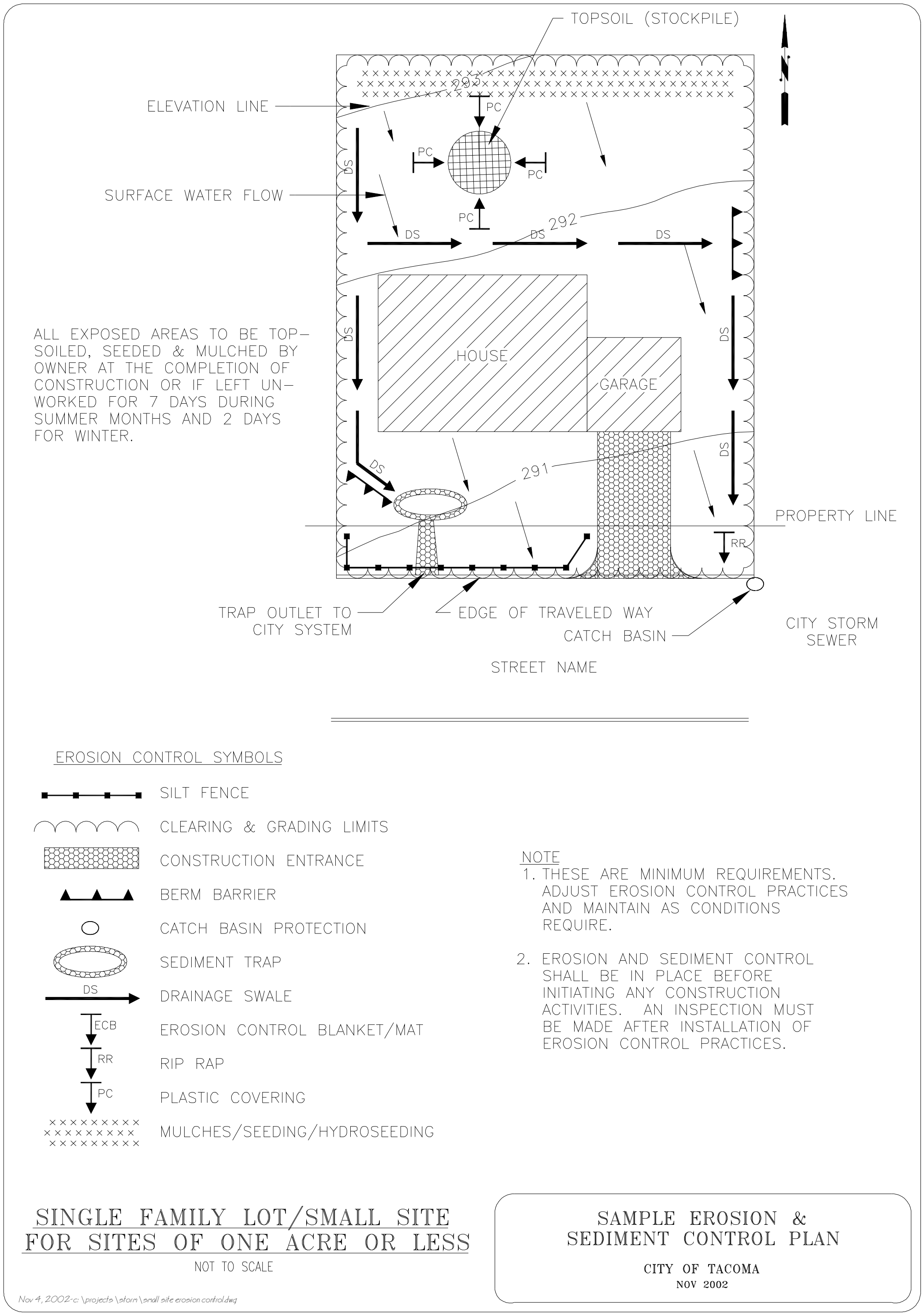


Figure II-C-38. Sample Erosion and Sediment Control Plan

Guidelines for Erosion Control Practices

As required by Ecology, this SWPPP must contain the 12 required elements. Check off each element as it is addressed in the SWPPP Short Form and/or on your site plan.

___ 1. Mark Clearing Limits (orange construction fence, staking with ribbon).
___ 2. Establish Construction Access (gravel entrance, tire wash area).
___ 3. Control Flow Rates (using pipe, drainage swales, berms).
___ 4. Install Sediment Controls (silt fence, sediment traps).
___ 5. Stabilize Soils (mulch, hydroseed, straw).
___ 6. Protect Slopes (divert water from top of slope, cover with plastic or erosion control blanket).
___ 7. Protect Drain Inlets (catch basin inserts).
___ 8. Stabilize Channels and Outlets (cover with grass, riprap).
___ 9. Control Pollutants (maintain equipment to prevent leaks).
___ 10. Control Dewatering (pump to sediment trap).
___ 11. Maintain BMPs (weekly maintenance/replacement, preparation for storm events).
___ 12. Manage the Project (establish construction schedule, phasing, contact numbers).

Several common erosion control techniques are explained and described in this section. Standard details for installation of these methods are included in this document. The applicant does not need to reproduce these drawings, but must indicate where each BMP will be used on a site plan and indicate which detail will be used. An example site plan and symbols list is provided to assist the applicant in preparation of their own site plan.

Only those erosion and sediment control techniques most pertinent to small construction sites are included here. More detailed information on construction BMPs can be found in Volume II of the City of Auburn Surface Water Management Manual. The BMP numbers referenced are BMPs located in the City of Auburn SWMM.

For phased construction plans, clearly indicate erosion control methods to be used for each phase of construction.

Mark Clearing Limits

All construction projects must clearly mark any clearing limits, sensitive areas and their buffers, and any trees that will be preserved prior to beginning any land disturbing activities, including clearing and grading. Clearly mark limits both in the field and on the plans. Plastic, metals, or stake wires may be used to mark the clearing limits. Do not staple or wire fences to trees. See Figure II-3-1 for Stake and Wire fencing

Applicable BMPs include:

- BMP C101: Preserving Natural Vegetation
- BMP C102: Buffer Zones
- BMP C103: High Visibility Plastic and Wire Fence
- BMP C104: Stake and Wire Fence

Construction Entrance

All construction projects subject to vehicular traffic shall provide a means of preventing vehicle “tracking” of soil from the site onto City streets. At a minimum, there shall be a rock pad construction entrance at every construction access point. *Note: The applicant should consider placing the entrance in the area for future driveway(s), as the rock can be used for driveway base material*. The entrance(s) shall be inspected weekly and if excessive sediment is found, more rock shall be added to ensure proper functioning.

If sediment is tracked off site, it shall be swept or shoveled from the paved surface on a daily basis. Washing of the streets to remove the sediment is not permitted because wash water can transport sediments to streams and other water courses via the City storm drainage system.

The entrance must be identified on the site plan and must conform to Figure II-C-39.

Applicable BMPs include:

- BMP C105: Stabilized Construction Entrance
- BMP C106: Wheel Wash
- BMP C107: Construction Road/Parking Area Stabilization

Sediment Barriers (Figure II-C-41 through Figure II-C-45)

Sediment barriers should be used downslope of disturbed areas. Sediment barriers are intended to create a barrier to slow the “sheet” flow of stormwater and allow the sediment to settle out behind the barrier. Do not use sediment barriers in streams, channels, ditches or around inlets/outlets of culverts. Sediment barriers selected shall be identified on the site plan and must conform to those shown in Figure II-C-41 through Figure II-C-45.

1. Silt fence

A silt fence is a temporary sediment barrier consisting of filter fabric, attached to supporting posts and entrenched into the soil. See Figure II-C-41.

2. Berm Barriers

A continuous berm is a temporary diversion dike or sediment barrier. It may be constructed with:

- Soil, sand, or aggregate encased within a geosynthetic fabric
  (see Figure II-C-42 and Figure II-C-43).
- Straw wattles (see Figure II-C-44).
- Sand bags (see Figure II-C-45).

Applicable BMPs include:

- BMP C231: Brush Barrier
- BMP C232: Gravel Filter Berm
- BMP C233: Silt Fence
- BMP C234: Vegetated Strip

- BMP C235: Straw Wattles

Catch Basin Protection (Figure II-C-46 and Figure II-C-47)

To prevent sediment from entering drainage systems prior to site stabilization, install catch basin protection within onsite and nearby downstream catch basins. Figure II-C-46 and Figure II-C-47 are acceptable methods of catch basin protection.

NOTE: Only Figure II-C-46 is approved for use in City of Auburn right of way.

Applicable BMPs include:

- BMP C220: Storm Drain Inlet Protection

Water Runoff Containment/Control

As an alternative to or in conjunction with sediment barriers, a combination of drainage swales and possibly a sediment trap may be used to control runoff and trap sediment before it leaves the construction site.

1. Sediment traps (Figure II-C-48 and Figure II-C-49)

Sediment traps are small temporary ponds (typically less than 3 feet deep) used to trap sediment suspended in site runoff before it leaves a construction site. As concentrated surface water pools within the pond, sediment is allowed to settle out of the water. Typically, a sediment trap will not be required for small sites as long as concentrated stormwater runoff (swales or ditches) does not occur.

Use Table II-C-13 for sizing your sediment trap.

Table II-C-13. Sediment Trap Sizing

Contributing Area (Acres)	Required Surface Area of Pond (sq. ft.)
1/8 acre or less	130
¼ acre or less	260
½ acre or less	520
¾ acre or less	780
1 acre or less	1040

If expected time of construction or downstream conditions warrant more protection, see BMP C240 for sizing information.

NOTE: If dewatering or significant stormwater runoff is expected, a sediment trap should be used to settle out solids before discharging to the City system.

2. Drainage Swales (Figure II-C-50)

Drainage swales are temporary ditches (minimum slope of 0.5% and a maximum of 10%) used to convey concentrated stormwater flows away from construction activities into a temporary sediment trap. Drainage swales carrying concentrated flows must discharge into a sediment trap or pond. Swales should be stabilized with erosion protection (see below). *Note: Swales should be completely stabilized before directing concentrated flows or they themselves will erode.*

Applicable BMPs include:

- BMP C240: Sediment Trap
- BMP C201: Grass-Lined Channels
- BMP C202: Channel Lining
- BMP C207: Check Dams

Soil Erosion Protection

Soil erosion protection is applied over the soil surface to reduce erosion from rainfall and wind. It can also be used to aid the establishment of vegetation. Between October 1st and April 30th, no soils shall remain exposed for more than 2 days unless they are being actively worked. From April 1st to September 30th, no soils shall remains exposed for more than 7 days unless they are being actively worked. See Table II-C-14, Table II-C-15 and Figure II-C-51 through Figure II-C-54.

1. Mulches/Seeding/Hydroseeding (Table II-C-14 and Table II-C-15)

Mulching is the application of a protective layer of straw or other suitable material to the soil surface. Mulch can be applied to any site where soil has been disturbed and the protective vegetation has been removed. Materials that may be used for mulching include:

- Straw or hay
- Compost material
- Wood or bark chips
- Hydraulically applied grass seed (Hydroseed)
- Bonded Fiber Matrix

Applicable BMPs include:

- BMP C121: Mulching
- BMP C120: Temporary and Permanent Seeding
- BMP C124: Sodding
- BMP C125: Compost
- BMP C126: Topsoiling
- BMP C130: Surface Roughening
- BMP C140: Dust Control

NOTE: The applicant may wish to mix in grass seed with the above practices to further aid in soil stabilization. Please refer to Table II-C-14 and Table II-C-15**.**

2. Erosion Control Blankets/ Mats (Figure II-C-51)

Erosion control blankets are suited for post-construction site stabilization, but may be used for temporary stabilization of highly erosive soils. Erosion control blankets are suitable for steep slopes, stream banks, and areas where vegetation will be slow to establish. These blankets are typically made from straw, coconut fiber, excelsior, or synthetic material that is enveloped in plastic, biodegradable netting, jute, polypropylene, or nylon.

Applicable BMPs include:

- BMP C122: Nets and Blankets

3. Gravel/Riprap (Figure II-C-52 and Figure II-C-53)

Gravel and Riprap are used to protect hillsides, drainage channels, stream banks, and pipe outlets from erosion due to surface water flow.

4. Plastic Sheeting (Figure II-C-54)

Plastic sheeting is a temporary method of erosion control. Plastic covering provides immediate, short-term erosion protection to slopes, soil stockpiles, and other disturbed areas. Unlike the other erosion protection techniques mentioned above, plastic sheeting shall be removed prior to applying permanent erosion protection.

Applicable BMPs include:

- BMP C123: Plastic Covering

Protect Slopes

Design, construct and phase projects in a manner that will minimize erosion. Protect slopes by diverting water at the top of the slope. Reduce slope velocities by minimizing the continuous length of slope. This can be accomplished by terracing and roughening slope sides. Seeding and establishing vegetation on slopes will help protect slopes as well.

Applicable BMPs include:

- BMP C120: Temporary and Permanent Seeding
- BMP C130: Surface Roughening
- BMP C131: Gradient Terraces
- BMP C200: Interceptor Dike and Swale
- BMP C204: Pipe Slope Drains

Control Pollutants Other Than Sediment

All pollutants must be disposed of in a manner that does not cause contamination of surface waters. Do not maintain or repair any heavy equipment or vehicles onsite. Clean any spills immediately. Handle concrete and concrete waste appropriately.

Applicable BMPs include:

- BMP C150: Materials on Hand
- BMP C151: Concrete Handling
- BMP C152: Sawcutting and Surfacing Pollution Prevention
- BMP C153: Materials Delivery, Storage and Containment
- BMP C154: Concrete Washout Area

Control Dewatering

All discharges to the City sewer system require City and King County approval. This approval process may be initiated by contacting the City. The City will coordinate the request for a letter of authorization from the King County Wastewater Treatment Division.

Any dewatering water must be discharged through a stabilized channel to a sediment pond.

Maintain BMPs

Maintain and repair temporary erosion and sediment control BMPs as needed. Inspect all BMPs at least weekly and after every storm event. Remove all temporary erosion and sediment control BMPs within 30 days after final site stabilization.

Table II-C-14. Temporary Erosion Control Seed Mix

	% Weight	% Purity	% Germination
Chewings or annual bluegrass *Festuca rubra var. commutate or Poa anna*	40	98	90
Perennial rye *Lolium perenne*	50	98	90
Redtop or colonial bentgrass *Agrostis alba or Agrostis tenuis*	5	92	85
White Dutch clover *Trifolium repens*	5	98	90

Table II-C-15. Mulch Standards and Guidelines

Mulch Material	Quality Standards	Application Rates	Remarks
Straw	Air-dried; free from undesirable seed and coarse material.	3” thick; 5 bales per 1000 sf or 2 to 3 tons per acre.	Cost-effective protection when applied with adequate thickness. Hand-application generally requires greater thickness than blown straw. The thickness of straw may be reduced by half when used in conjunction with seeding. In windy areas, straw must be held in place by crimping, using a tackifier, or covering with netting. Blown straw always has to be held in place with a tackifier as even light winds will blow it away. Straw, however, has several deficiencies that should be considered when selecting mulch materials. If often introduces and/or encourages the propagation of weed species and it has no significant long-term benefits. Straw should be used only if mulches with long-term benefits are unavailable locally. It should also not be used within the ordinary high-water elevation of surface waters (due to flotation).
Hydro-mulch	No growth inhibiting factors.	Approx. 25-30 lbs per 1000 sf or 1500-2000 lbs per acre.	Shall be applied with hydromulcher. Shall not be used without seed and tackifier unless the application rate is at least doubled. Fivers longer than about ¾ - 1 inch clog hydromulch equipment. Fibers should be kept to less than ¾ inch.
Composted Mulch and Compost	No visible water or dust during handling. Must be purchased from supplier with a Solid Waste Handling permit (unless exempt)	3” thick, min.; approx. 100 tons per acre (approx. 800 lbs. per yard).	More effective control can be obtained by increasing thickness to 3”. Excellent mulch for protecting final grades until landscaping because it can be directly seeded or tilled into soil as an amendment. Composted mulch has a coarser size gradation than compost. It is more stable and practical to use in wet areas and during rainy weather conditions.
Chipped Site Vegetation	Average size shall be several inches. Gradations from fine to 6-inches in length for texture, variation, and interlocking properties.	3” minimum thickness	This is a cost-effective way to dispose of debris from clearing and grubbing, and it eliminates the problems associated with burning. Generally, it should not be used on slopes above approx. 10% because of its tendency to be transported by runoff. It is not recommended within 200 feet of surface waters. If seeding is expected shortly after mulch, the decomposition of the chipped vegetation may tie up nutrients important to grass establishment.

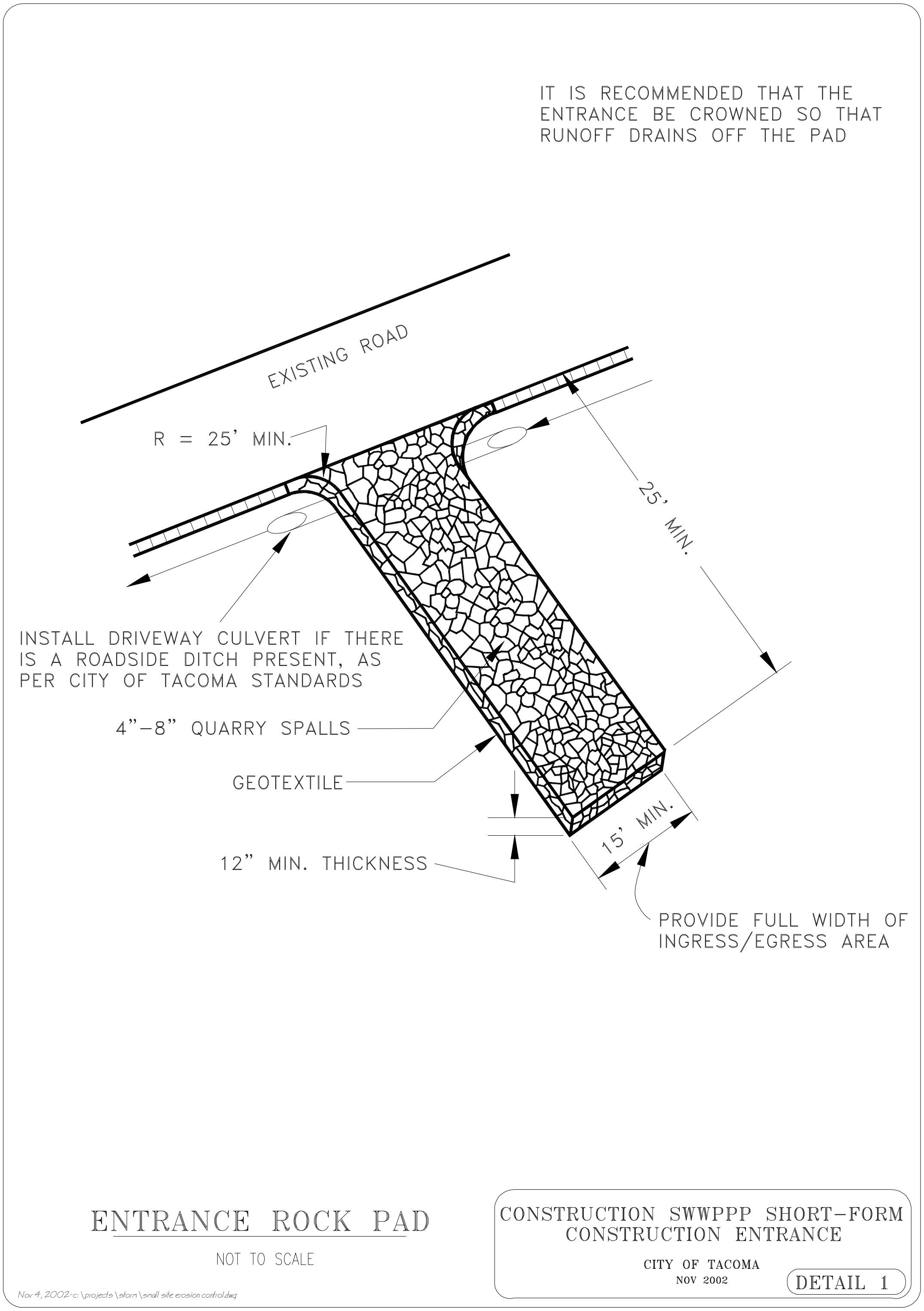


Figure II-C-39. Construction Entrance

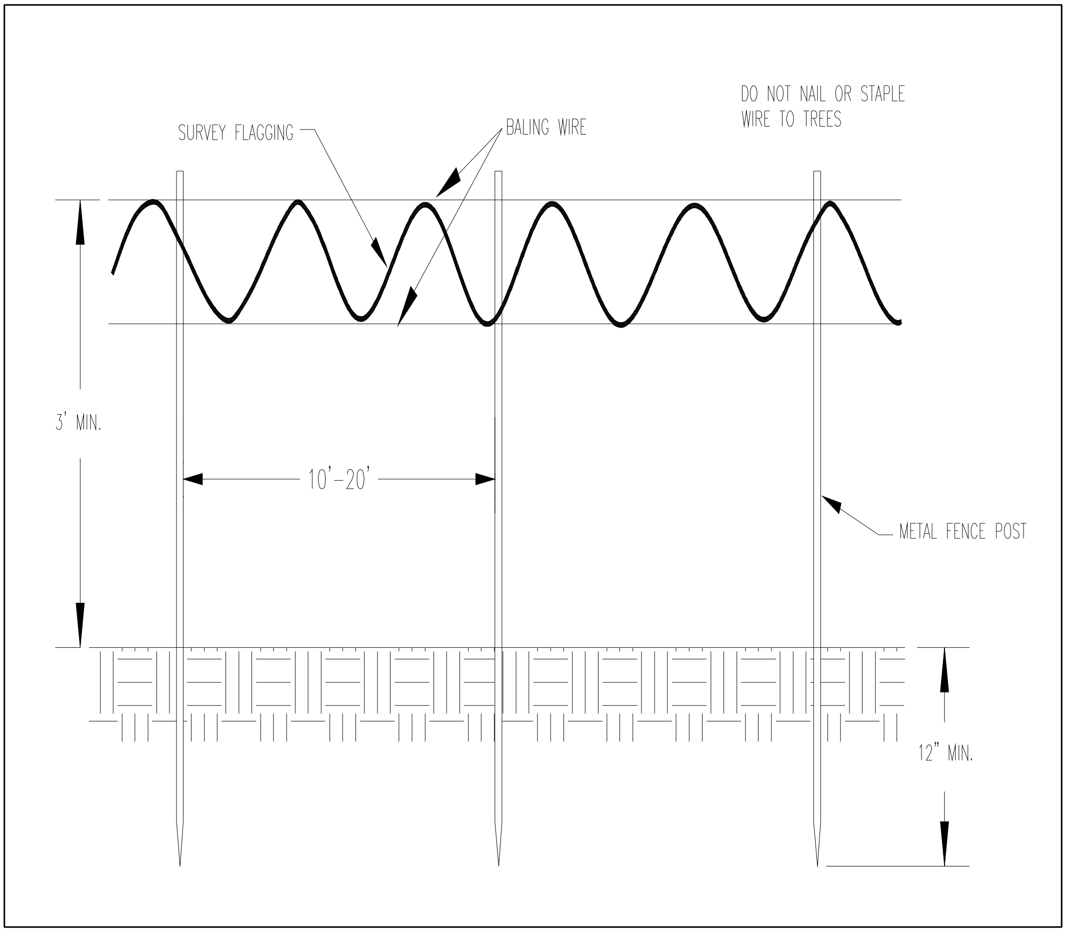


Figure II-C-40. Stake and Wire Fence

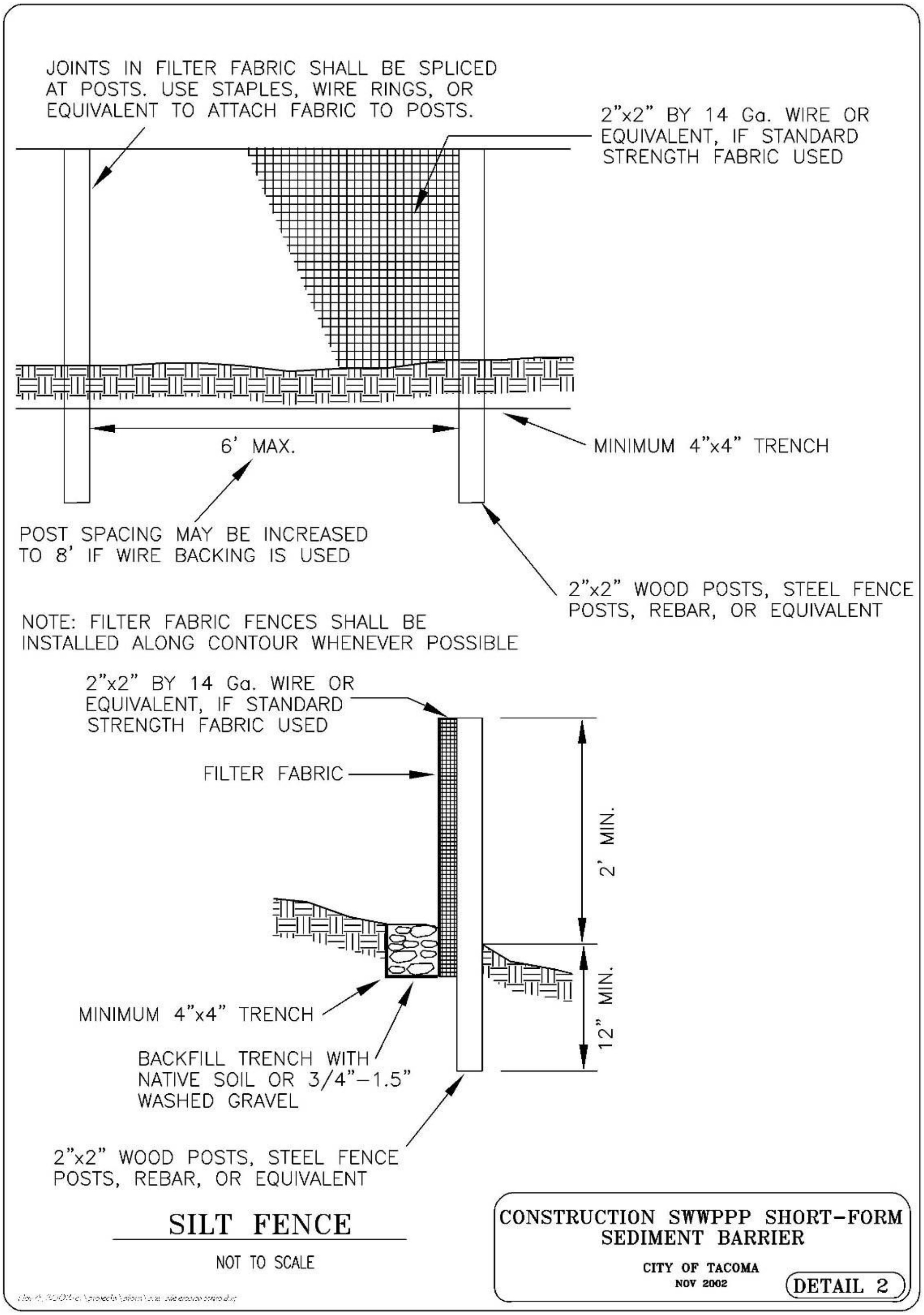


Figure II-C-41. Sediment Barrier – Silt Fence

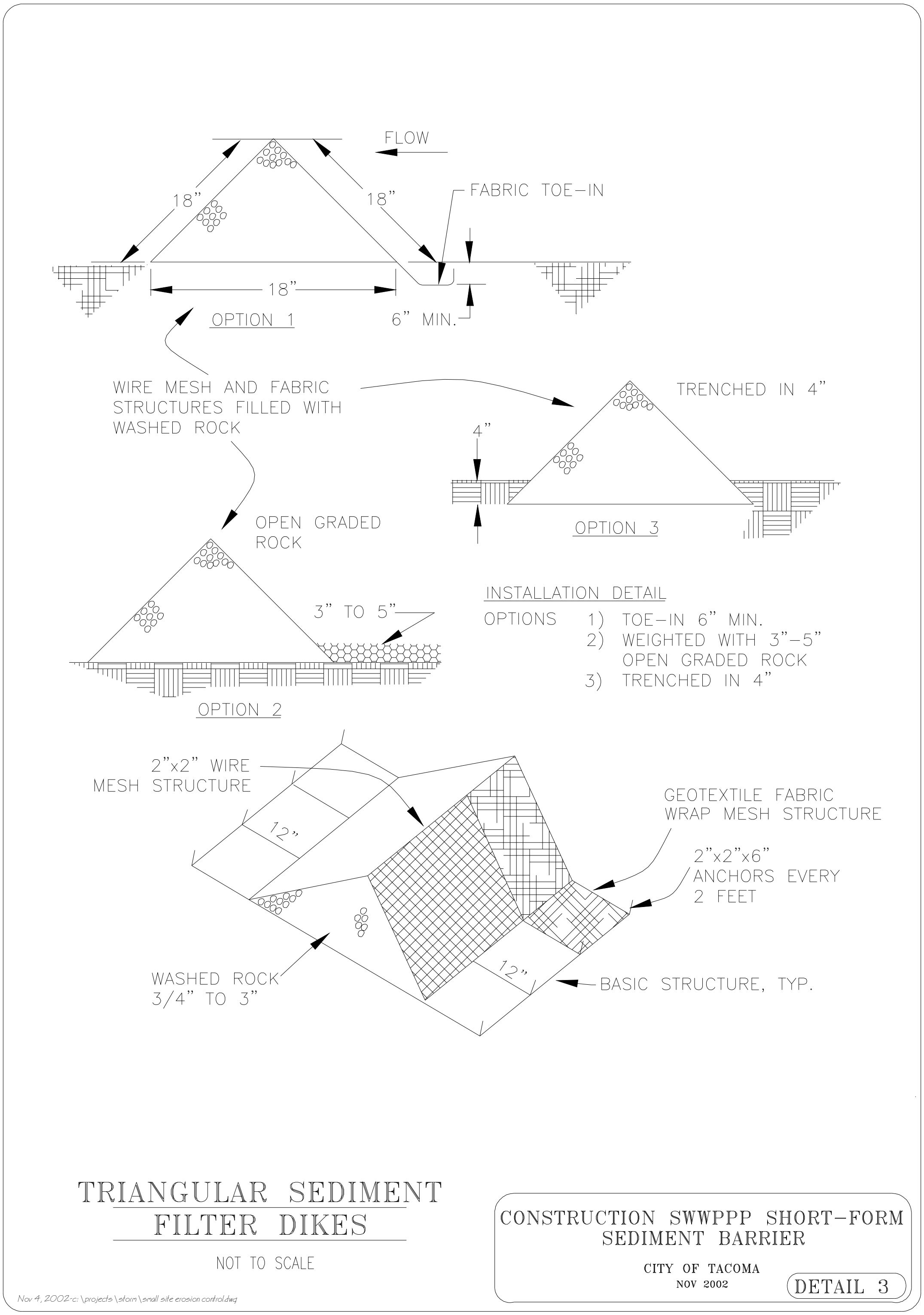


Figure II-C-42. Sediment Barrier – Triangular Sediment Filter Dikes

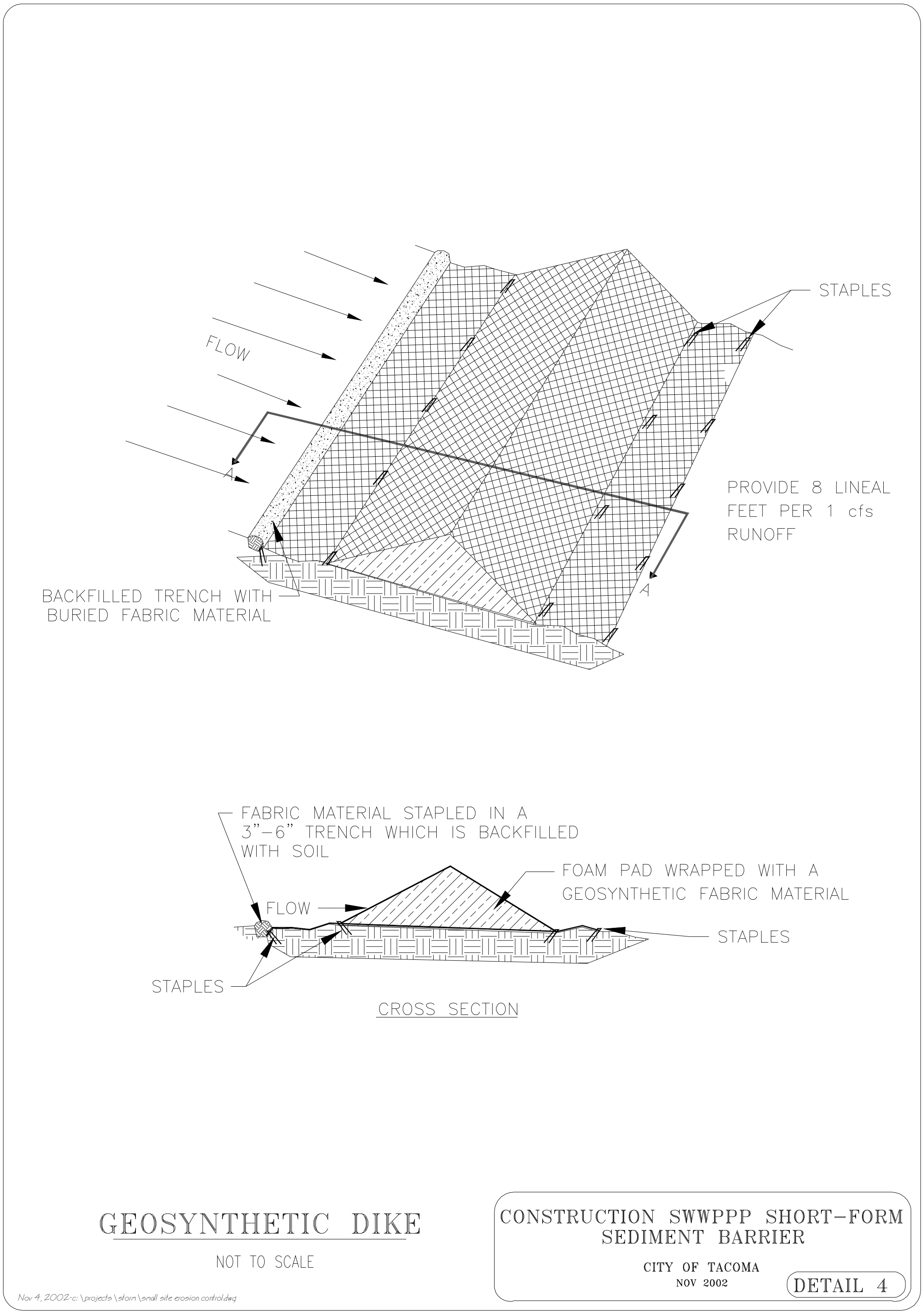


Figure II-C-43. Sediment Barrier – Geosynthetic Dike

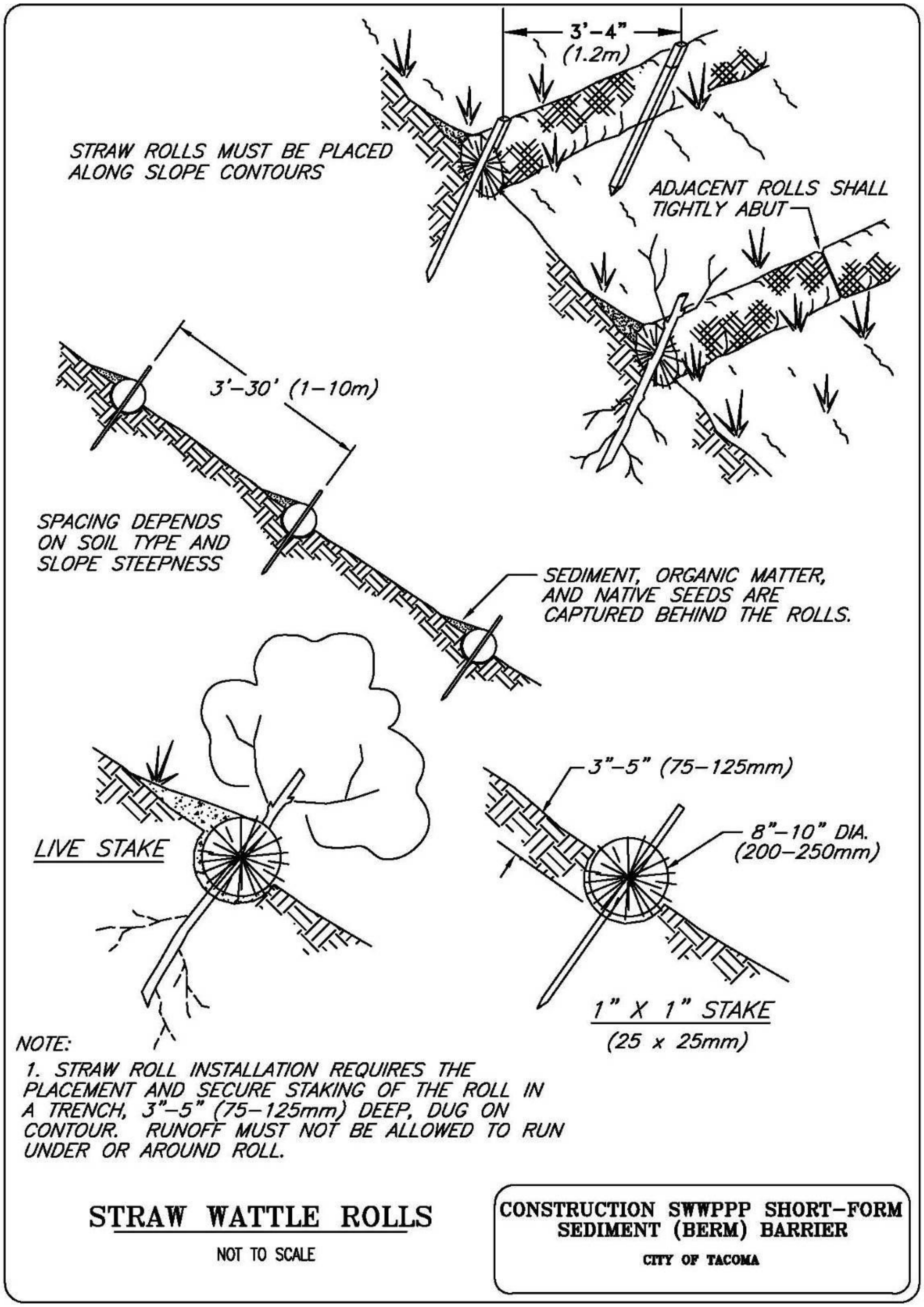
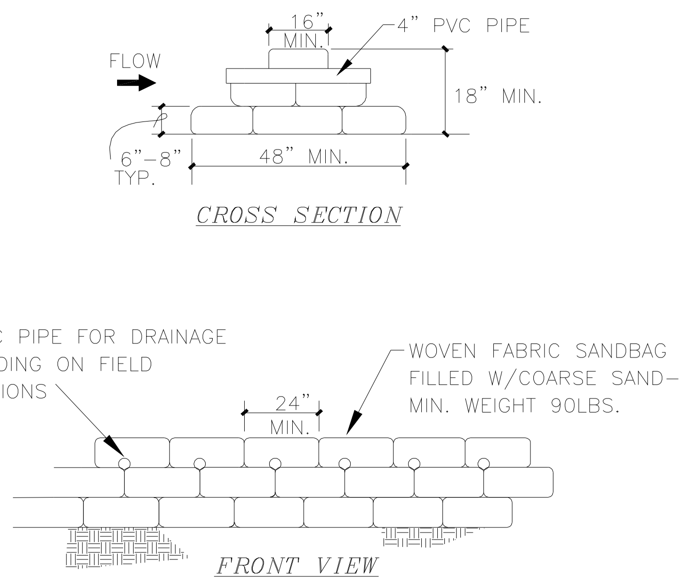


Figure II-C-44. Sediment (Berm) Barrier – Straw Wattle Rolls



1) WHEN SANDBAG IS FILLED WITH COARSE GRADE SAND MATERIAL, THE OPEN END SHOULD BE STAPLED OR TIED WITH NYLON OR POLY CORD. THE WEIGHT SHALL BE 90 – 125 LBS.

2) SANDBAGS SHOULD BE STACKED IN AT LEAST THREE VERTICAL ROWS ABUTTING EACH OTHER, AND IN STAGGERED ARRANGEMENT. (REFER TO FRONT VIEW).

3) THE BASE OF THE BERM SHOULD BE AT LEAST 3 SANDBAGS DEEP AND CAN BE REDUCED TO 2 AND 1 BAG IN THE SECOND AND THIRD ROWS RESPECTIVELY. (REFER TO CROSS SECTION).

SANDBAG BERM

NOT TO SCALE

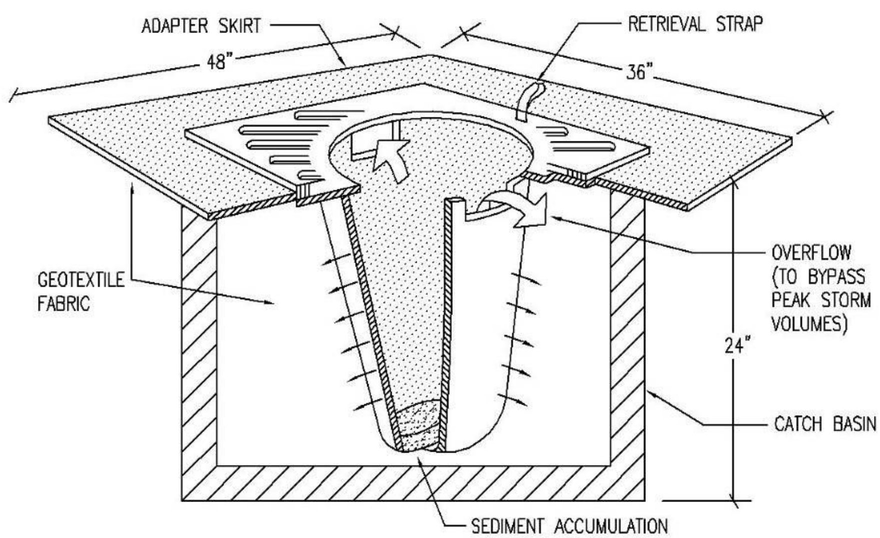
Nov 4, 2002-c:\projects\storm\small site erosion control.dwg

CONSTRUCTION SWWPPP SHORT–FORM
SEDIMENT (BERM) BARRIER

CITY OF TACOMA
NOV 2002

DETAIL 6

Figure II-C-45. Sediment (Berm) Barrier – Sandbag Berm



INLET PROTECTION NOTES:

1. FILTERS SHALL BE INSPECTED AFTER EACH STORM EVENT AND CLEANED OR REPLACED WHEN 1/3 FULL.

BAG FILTER

NOT TO SCALE

CONSTRUCTION SWWPPP SHORT–FORM
CATCH BASIN PROTECTION

CITY OF TACOMA

Figure II-C-46. Catch Basin Protection – Bag Filter

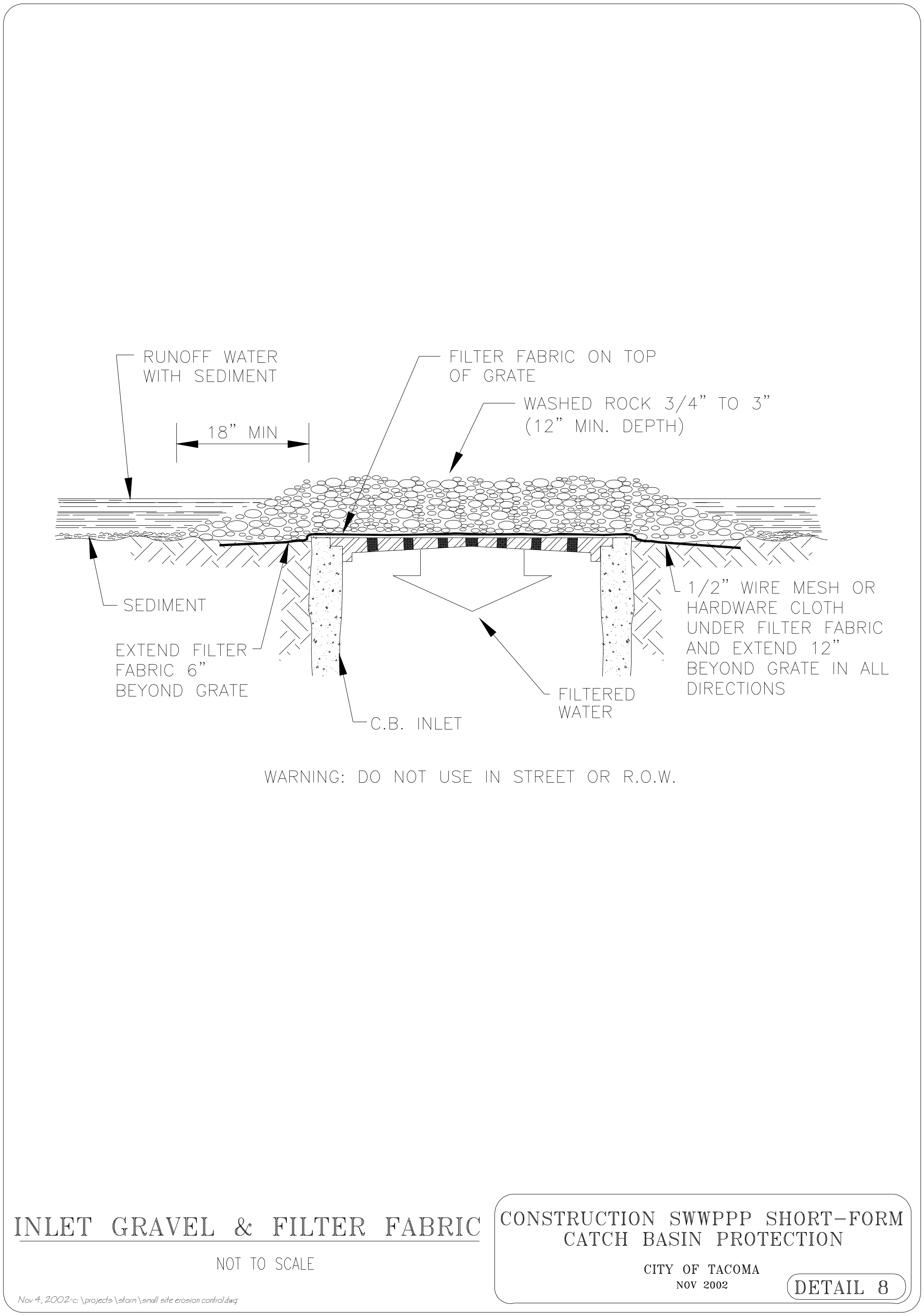


__Figure II-C-47. Catch Basin Protection – Inlet Gravel and Filter Fabric__

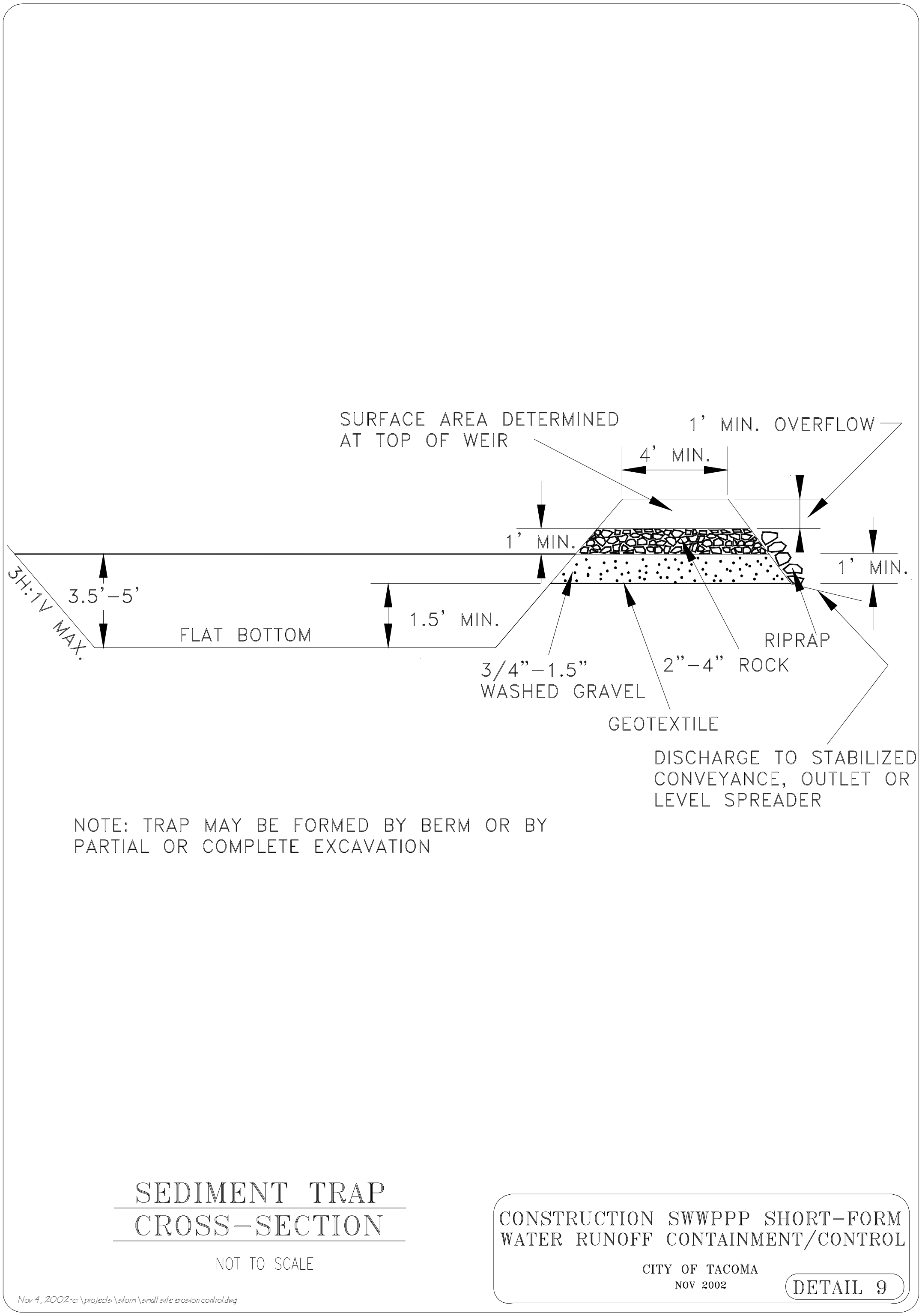


Figure II-C-48. Water Runoff Containment/Control – Sediment Trap Cross-Section

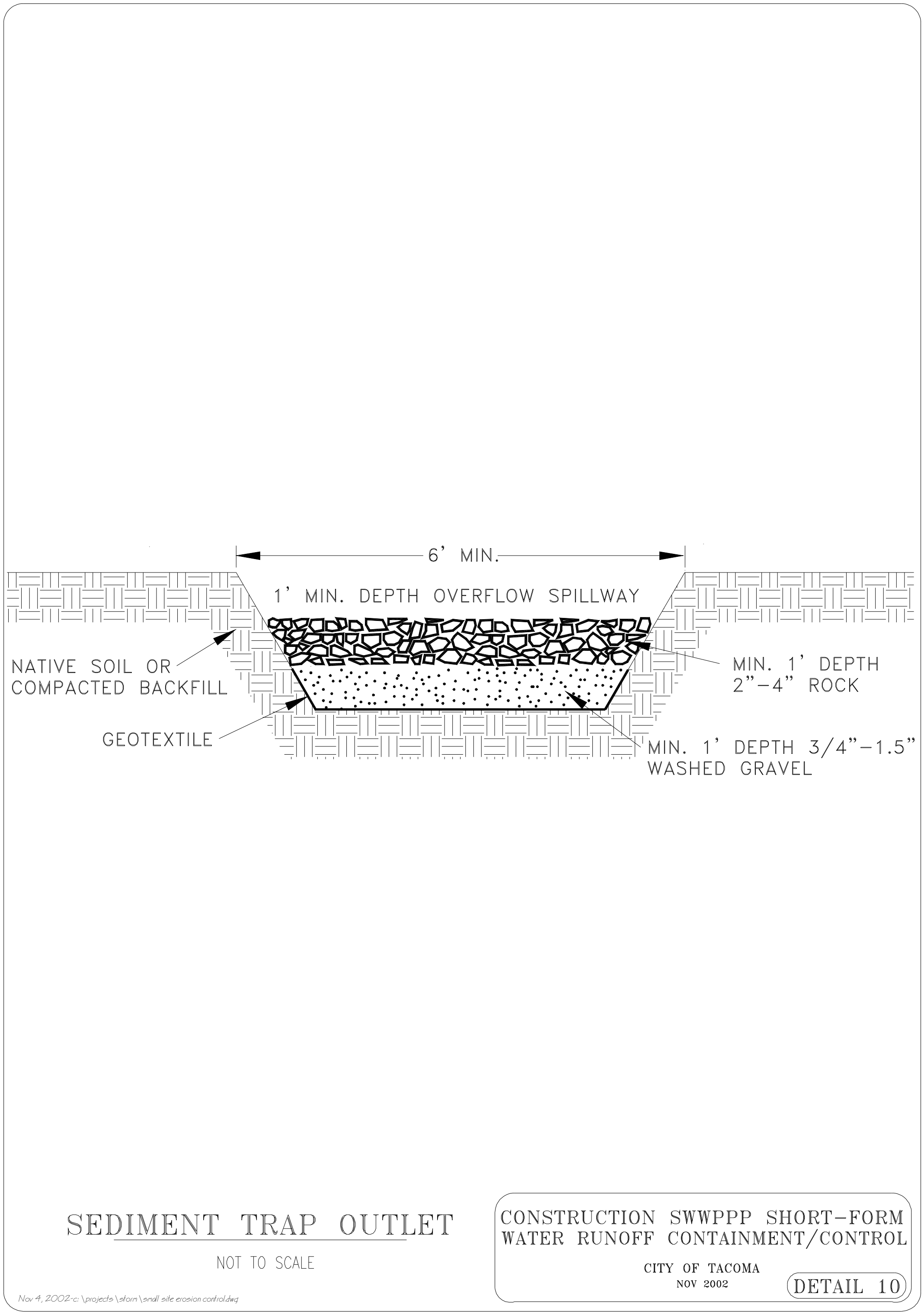


Figure II-C-49. Water Runoff Containment/Control – Sediment Trap Outlet

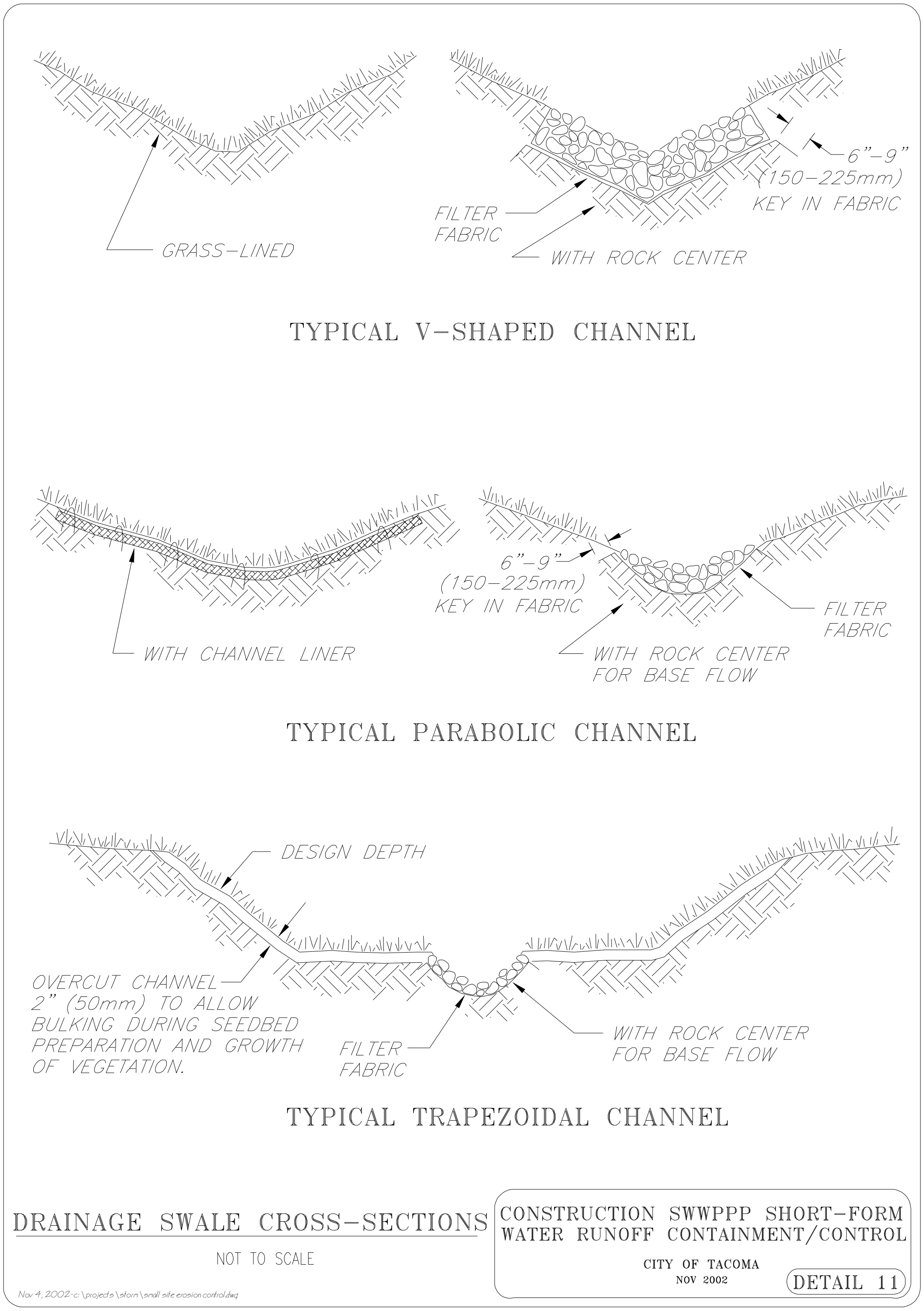


Figure II-C-50. Water Runoff Containment/Control – Drainage Swale Cross-Sections

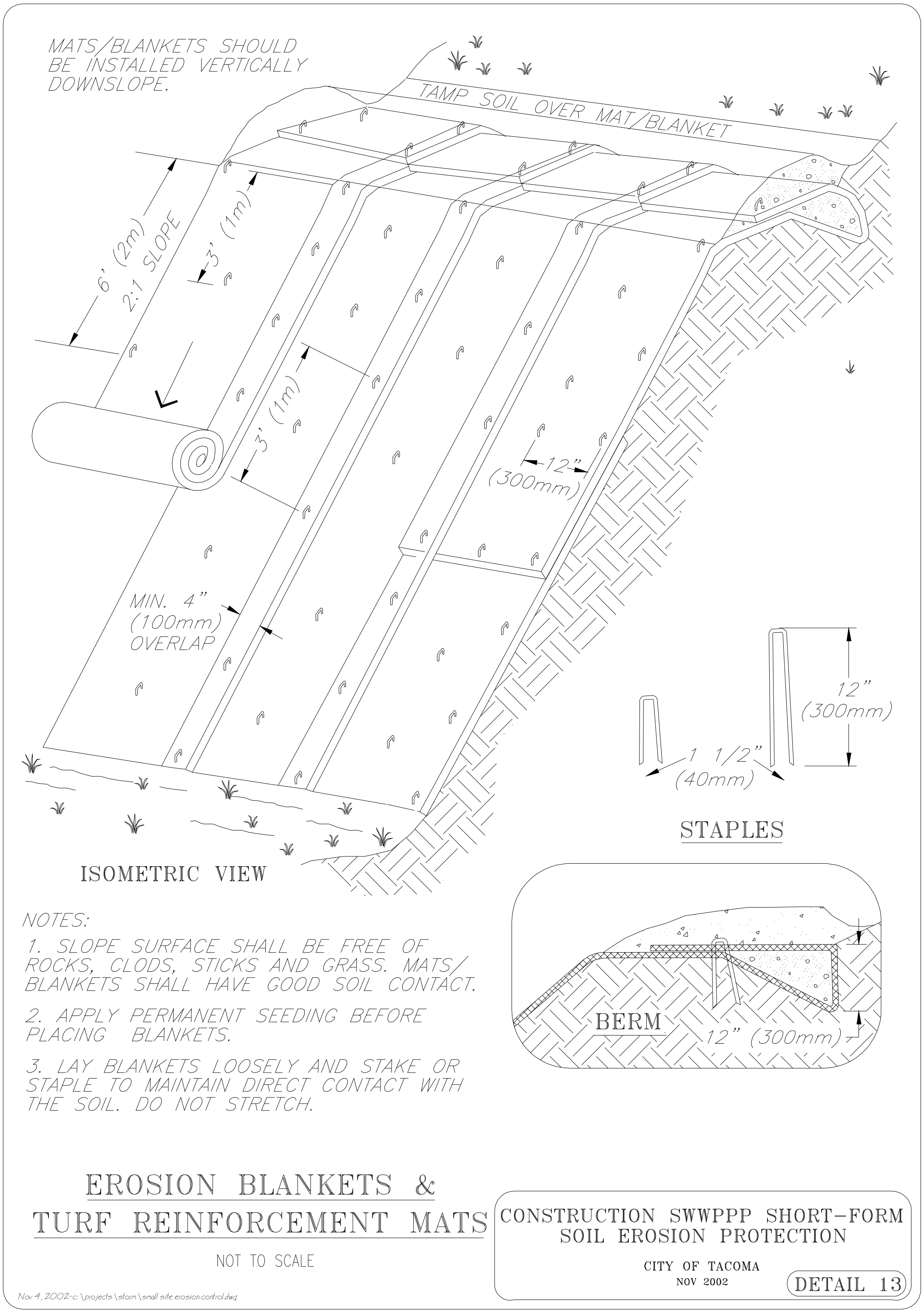


Figure II-C-51. Soil Erosion Protection – Erosion Blankets and Turf Reinforcement Mats

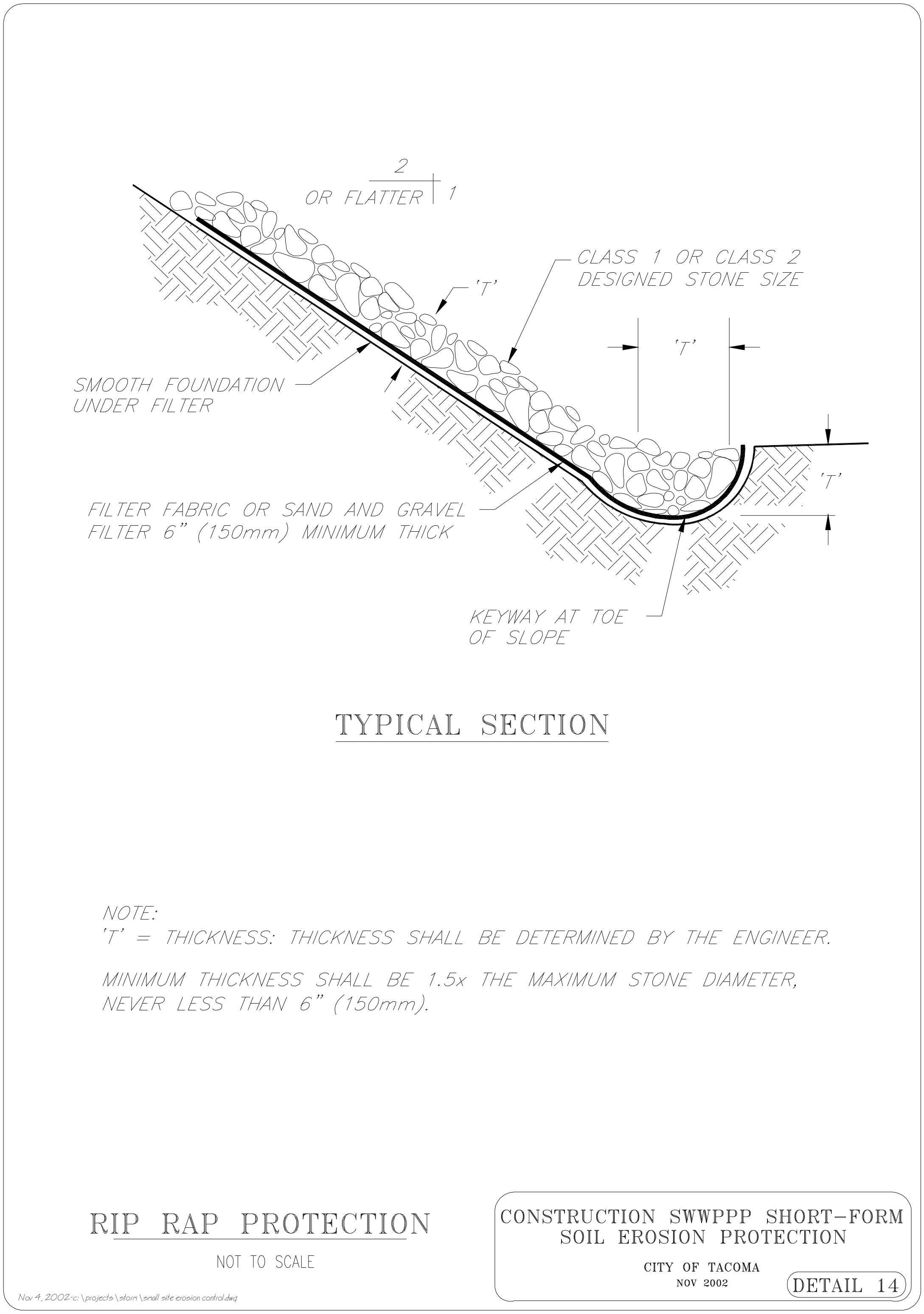


Figure II-C-52. Soil Erosion Protection – Rip Rap Protection

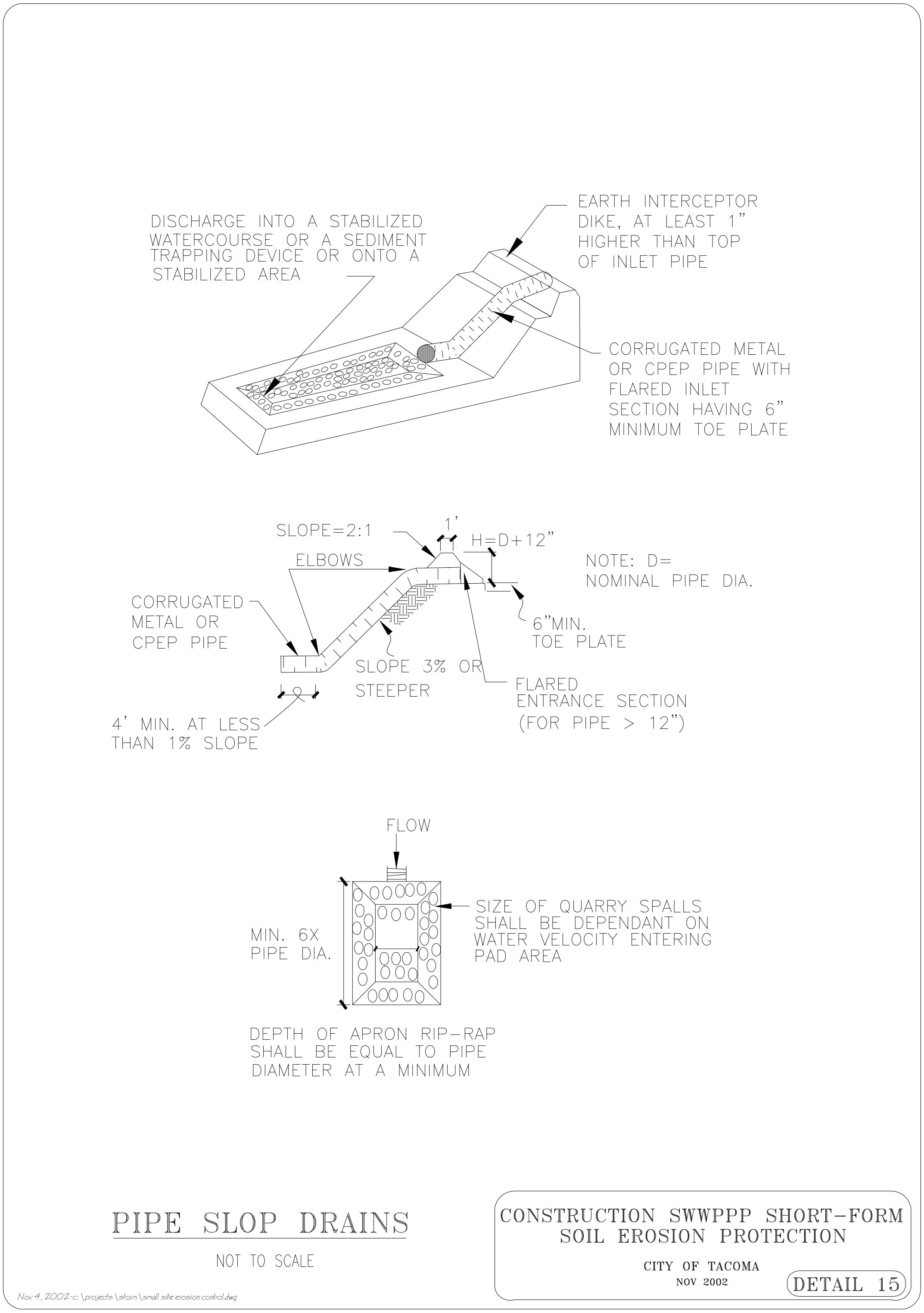


Figure II-C-53. Soil Erosion Protection – Pipe Slope Drains

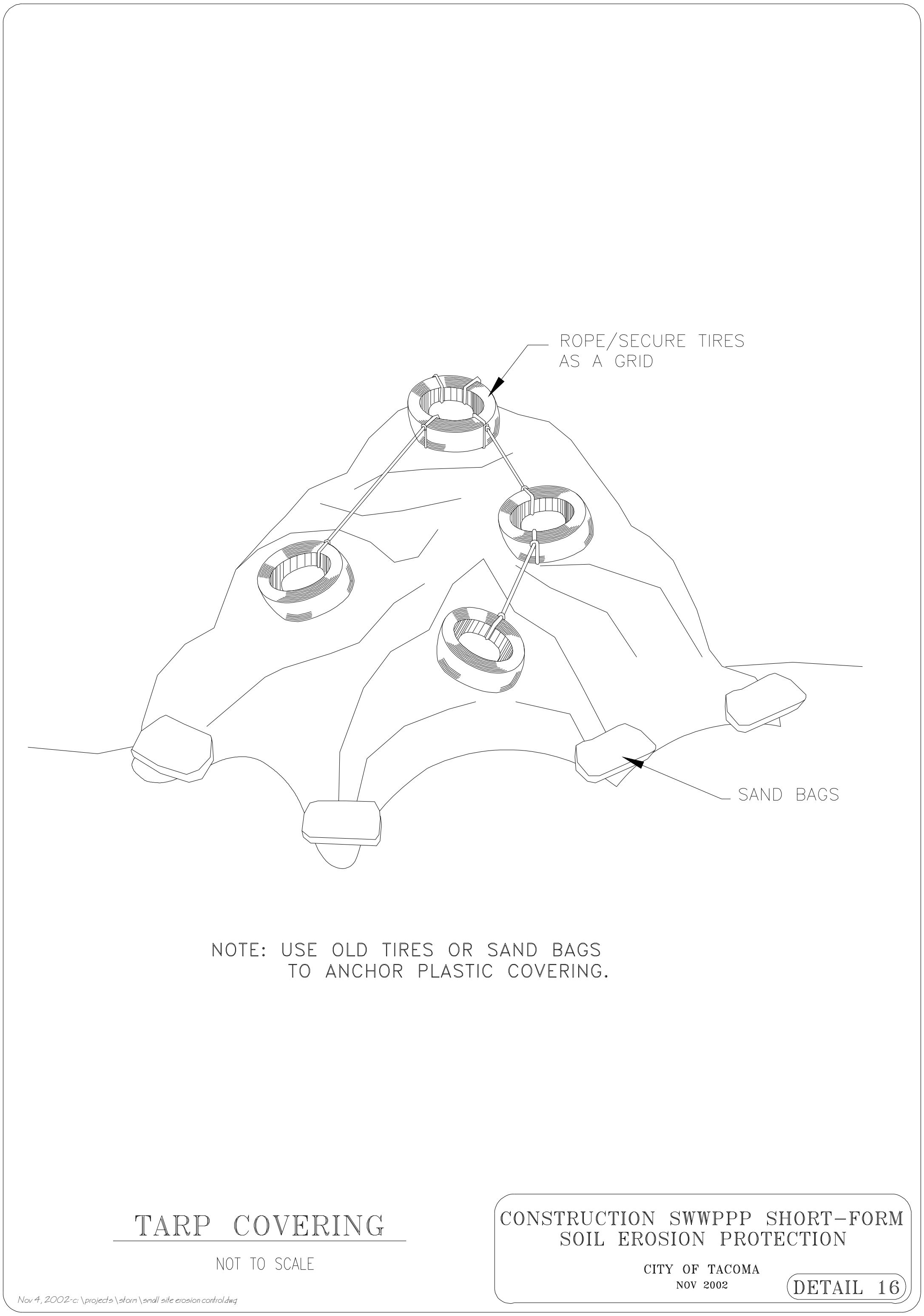


Figure II-C-54. Soil Erosion Protection – Tarp Covering

Volume III – Surface Water Quantity Control and Conveyance Table of Contents

Volume

III

Volume III: Surface Water Quantity Control and Conveyance

Purpose of this Volume

The purpose of this volume is to outline methods for calculating and designing methods to control the quantity of surface water runoff at developed sites. Quantity controls and on-site management for roof downspouts are described. Design criteria and methods of analysis for flow control BMPs are presented. Conveyance system requirements and design methods are also presented

Content and Organization of this Volume

Volume III of this manual contains three chapters and two appendices.

- Chapter 1 reviews methods of hydrologic analysis.
- Chapter 2 describes flow control design.
- Chapter 3 describes the requirements for analysis and design of surface water conveyance systems.
- Appendix A provides the Auburn Design Storm precipitation values.
- Appendix B describes the procedure for a Pilot Infiltration Test.

Chapter 1 Hydrologic Analysis

The purpose of this chapter is to define the minimum computational standards required, and outline how these computational standards may be applied.

1.1 Minimum Computational Standards

The minimum computational standards depend on the type of information required and the size of the drainage area to be analyzed, as follows:

- The most current software version of the Department of Ecology's Western Washington Hydrology Model (WWHM) model shall be used. Alternative models for sizing flow control and water quality facilities may be considered, provided they are Washington State Department of Ecology equivalent, and approved by the City of Auburn. Approval from the City shall be obtained prior to submittal of design documents.
- Model calibration shall be required for basins greater than 320 acres.

Exception: The Santa Barbara Urban Hydrograph method (SBUH) may be used to determine a water quality design storm volume for wetpond treatment facilities only.

Table III-1-1 summarizes the circumstances under which different design methodologies apply.

Table III-1-1. BMP Designs in Western Washington

Method		Treatment	Flow Control
Standard	Continuous Runoff Model (WWHM or approved equivalent)	Method applies to all BMPs.	Method applies throughout Auburn where flow control is required.
Alternative	SBUH	Wetpool water quality treatment facilities only.	Acceptable for City storm drainage system capacity problems.

1.2 Western Washington Hydrology Model

For most flow control design purposes, a continuous runoff model, such as the Western Washington Hydrology Model (WWHM), must be used. Information on the WWHM is provided in the Stormwater Management Manual for Western Washington (Washington State Department of Ecology, 2005). The software can be downloaded at the following website:

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

More WWHM information is available at http://www.clearcreeksolutions.com

Note: Pre-developed conditions shall be modeled as a forested land cover with either outwash (Hydrologic Soil Group A/ B) or till (Hydrologic Soil Group C/D) soils. Saturated soil conditions shall only be considered when determining existing wetland hydrology.

1.3 Single-Event Hydrograph Method

Hydrograph analysis with a single event hydrograph method utilizes the standard plot of runoff flow versus time for a given design storm, allowing the key characteristics of runoff such as peak, volume, and phasing to be considered in the design of drainage facilities. Single event methods are only acceptable for sizing wetpool treatment facilities or for determining pipe capacity.

All storm event hydrograph methods require input of parameters that describe physical drainage basin characteristics. These parameters provide the basis from which the runoff hydrograph is developed.

1.3.1 Design Storm

The total depth of rainfall for storms of 24-hour duration and 2, 5, 10, 25, 50, and 100-year recurrence intervals are published by the National Oceanic and Atmospheric Administration (NOAA). The information is presented in the form of “isopluvial” maps for each state. Isopluvial maps are maps where the contours represent total inches of rainfall for a specific duration. Isopluvial maps for the 2, 5, 10, 25, 50, and 100-year recurrence interval and 24-hour duration storm events can be found in the NOAA Atlas 2, “Precipitation - Frequency Atlas of the Western United States, Volume IX-Washington.” Based on these isopluvials, the following design storms shall be used for the City of Auburn:

6-month, 24-hour design storm:	1.44 inches
2-year, 24-hour design storm:	2.0 inches
10-year, 24-hour design storm:	3.0 inches
100-year, 24-hour design storm:	4.0 inches

1.3.2 Curve Number

Surface soils are classified by the National Resource Conservation Service into four hydrologic soil groups based on the soil’s runoff potential: A, B, C, and D. Group A soils generally have the lowest runoff potential while Group D soils have the highest. In Auburn the valley floor is mostly Group D soils, which typically have very low infiltration rates and high runoff potential. The West Hill, Lea Hill, and Lakeland Hills areas are predominately Group C soils, which have low infiltration rates and moderate to high runoff potential. The southeast area, Bowman Creek area, and valley area located between Highway 18 and the White River contain some Group A soils, which are characterized by high infiltration rates and low runoff potential. Soils within the City limits shall be assumed to fall in the Hydrologic Soils Groups as shown in figure 4-4 of the City of Auburn Comprehensive Drainage Plan unless grain size distribution and/or permeability testing indicate otherwise. Refer to Section 2.2.7.4 for details on appropriate soil testing methods.

Table III-1-2 shows the curve numbers (CNs), by land use description, for the four hydrologic soil groups. These numbers are for a 24-hour duration storm and the typical antecedent soil moisture condition preceding 24-hour storms.

The following are important criteria/considerations for selection of CN values.

Many factors may affect the CN value for a given land use. For example, the movement of heavy equipment over bare ground may compact the soil so that it has a lesser infiltration rate and greater runoff potential than would be indicated by strict application of the CN value to developed site conditions.

CN values can be area weighted when they apply to pervious areas of similar CNs (within 20 CN points). However, high CN areas should not be combined with low CN areas. In this case, separate estimates of S (potential maximum natural detention) and Qd (runoff depth) should be generated and summed to obtain the cumulative runoff volume unless the low CN areas are less than 15 percent of the sub-basin.

Separate CN values must be selected for the pervious and impervious areas of an urban basin or sub-basin. For residential districts, the percent impervious area given in Table III-1-2 must be used to compute the respective pervious and impervious areas. For proposed commercial areas, plats, etc., the percent impervious area must be computed from the site plan. For all other land uses, the percent impervious area must be estimated from best available aerial topography and/or field reconnaissance. The pervious area CN value must be a weighted average of all the pervious area CNs within the sub-basin. The impervious area CN value shall be 98.

1.4 Closed Depression Analysis

The analysis of closed depressions requires careful assessment of the existing hydrologic performance in order to evaluate the impacts of a proposed project. A calibrated continuous simulation hydrologic model must be used for closed depression analysis and design of mitigation facilities. The applicable requirements of this manual (see Minimum Requirement #7 and #8) and the City's Critical Areas Ordinance and Rules should be thoroughly reviewed prior to proceeding with the analysis.

Closed depressions generally facilitate infiltration of runoff. If a closed depression is classified as a wetland, then Minimum Requirement #8 for wetlands applies. If there is an outflow from the wetland to a surface water (such as a creek), then the flow from the wetland must also meet Minimum Requirement #7 for flow control. If a closed depression is not classified as a wetland, the ponding area at the bottom of the closed depression should be modeled as an infiltration pond.

Guidance for modeling closed depressions and model calibration shall be provided by the Department of Public Works.

Table III-1-2. Runoff Curve Numbers for Selected Agricultural, Suburban and Urban Areas

(Sources: TR 55, 1986, and Stormwater Management Manual, 1992. See Section 2.1.1 for explanation)					
		CNs for hydrologic soil group			
Cover type and hydrologic condition.		A	B	C	D
Curve Numbers for Pre-Development Conditions					
Pasture, grassland, or range-continuous forage for grazing:					
Fair condition (ground cover 50% to 75% and not heavily grazed).		49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)		39	61	74	80
Woods:					
Fair (Woods are grazed but not burned, and some forest litter covers the soil).		36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).		30	55	70	77
Curve Numbers for Post-Development Conditions					
Open space (lawns, parks, golf courses, cemeteries, landscaping, etc.)[1]					
Fair condition (grass cover on 50% - 75% of the area).		77	85	90	92
Good condition (grass cover on >75% of the area)		68	80	86	90
Impervious areas:					
Open water bodies: lakes, wetlands, ponds etc.		100	100	100	100
Paved parking lots, roofs[2], driveways, etc. (excluding right-of-way)		98	98	98	98
Permeable Pavement (see Appendix C of 2005 Ecology Manual to decide which condition applies)					
Landscaped area		77	85	90	92
50% landscaped area/50% impervious		87	91	94	96
100% impervious area		98	98	98	98
Paved		98	98	98	98
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Pasture, grassland, or range-continuous forage for grazing:					
Poor condition (ground cover <50% or heavily grazed with no mulch).		68	79	86	89
Fair condition (ground cover 50% to 75% and not heavily grazed).		49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)		39	61	74	80
Woods:					
Poor (Forest litter, small trees, brush are destroyed by heavy grazing or regular burning).		45	66	77	83
Fair (Woods are grazed but not burned, and some forest litter covers the soil).		36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).		30	55	70	77
Single family residential[3]**:**	Should only be used for	Average Percent			
Dwelling Unit/Gross Acre	subdivisions > 50 acres	impervious area[3,4]			
1.0 DU/GA		15	Separate curve number		
1.5 DU/GA		20	shall be selected for		
2.0 DU/GA		25	pervious & impervious		
2.5 DU/GA		30	portions of the site or		
3.0 DU/GA		34	basin		
3.5 DU/GA		38			
4.0 DU/GA		42			
4.5 DU/GA		46			
5.0 DU/GA		48			
5.5 DU/GA		50			
6.0 DU/GA		52			
6.5 DU/GA		54			
7.0 DU/GA		56			
7.5 DU/GA		58			
PUDs, condos, apartments, commercial	%impervious	Separate curve numbers shall			
businesses, industrial areas &	must be	be selected for pervious and			
& subdivisions < 50 acres	computed	impervious portions of the site			
For a more detailed and complete description of land use curve numbers refer to chapter two (2) of the Soil Conservation Service's Technical Release No. 55, (210-VI-TR-55, Second Ed., June 1986).					

[1] Composite CNs may be computed for other combinations of open space cover type.
[2] Where roof runoff and driveway runoff are infiltrated or dispersed according to the requirements in Chapter 2, the average percent impervious area may be adjusted in accordance with the procedure described under "Flow Credit for Roof Downspout Infiltration" and "Flow Credit for Roof Downspout Dispersion" in Volume 6, Chapter 2.
[3] Assumes roof and driveway runoff is directed into street/storm system.
[4] All the remaining pervious area (lawn) is considered to be in good condition for these curve numbers.

Chapter 2 Flow Control Design

2.1 Roof Downspout Controls

This section presents the criteria for design and implementation of roof downspout controls. *Roof downspout controls* are simple pre-engineered designs for infiltrating and/or dispersing runoff from roof areas for the purposes of increasing opportunities for groundwater recharge and reduction of runoff volumes from new development or redevelopment.

For roof areas below 10,000 square feet, these designs may typically be implemented with a single test pit, unless directed otherwise by the City. For designs other than those presented in Section 2.1, the requirements of Section 2.2 shall apply.

Roof downspout controls are used in conjunction with, and in addition to, any additional flow control facilities that may be necessary to mitigate stormwater impacts from the overall development. Implementation of roof downspout controls may reduce the total effective impervious area and result in less runoff from these surfaces. Flow credits for implementing infiltration and dispersion for controls are available as follows:

- If all the roof runoff is infiltrated according to the requirements of this section, the roof
- area may be discounted from the total project area used for determining project thresholds and sizing stormwater facilities.
- If roof runoff is dispersed according to the requirements of this section on lots greater than 22,000 square feet and the vegetative flow path is 50 feet or longer through undisturbed native landscape or lawn/landscape area that meets BMP L613, the roof area may be modeled as grassed surface.

Additional information on flow credits is available in Volume VI, Chapter 2.

2.1.1 Selection of Roof Downspout Controls

Large lots in rural areas (5 acres or greater) typically have enough area to disperse or infiltrate roof runoff. **Lots created in urban areas will typically be smaller and have a limited amount of area in which to infiltrate or disperse stormwater.** Downspout infiltration may be used in those soils that readily infiltrate (coarse sands and cobbles to medium sands). Dispersion BMPs may be used for urban lots located in less permeable soils, where infiltration is not feasible. **Where infiltration and/or dispersion is not feasible because of very small lot size, or where there is a potential for creating drainage problems on adjacent lots, downspouts shall be connected to the street storm drain system, which directs the runoff to a regional facility or receiving water.**

Where roof downspout controls are planned, the following methods should be considered in descending order of preference:

- Rain gardens (Section 2.1.4)
- Downspout infiltration systems (Section 2.1.2)
- Downspout dispersion systems (Section 2.1.3)

- Collect and convey to the City stormwater system – only allowed if it can be demonstrated that infiltration and dispersion are not feasible.

2.1.1.1 Roof Downspout Controls in Potential Landslide Hazard Areas

If or where the City has identified "geologically hazardous areas" (WAC 365-195-410), lots immediately adjacent to or within the hazard area shall collect roof runoff in a tightline system which conveys the runoff to the City system or to the base of the slope and then into the City system. Easements across adjacent properties may be necessary to convey drainage to the City system.

2.1.2 Downspout Infiltration Systems

Downspout infiltration systems are trenches designed for flow control and are intended only for use in infiltrating runoff from roof downspout drains. They are not designed to infiltrate directly runoff from pollutant-generating impervious surfaces. Volume V, Chapter 5 contains a discussion of infiltration trenches for water quality treatment.

2.1.2.1 Application

Use downspout infiltration on all sites that meet feasibility and setback requirements.

2.1.2.2 Flow Credit for Roof Downspout Infiltration

If roof runoff is infiltrated according to the requirements of this section, the roof area may be discounted from the project area used for determining project thresholds and sizing stormwater facilities.

2.1.2.3 Procedure for Evaluating Feasibility

A soils report to determine if soils suitable for infiltration are present on the site shall be prepared by a professional soil scientist certified by the Soil Science Society of America (or an equivalent national program), a locally licensed onsite sewage designer, other suitably trained professional engineer, geologist, hydrogeologist, or engineering geologist registered in the State of Washington, or persons working under the supervision of one of the soils professional listed here.

NOTE: On sites where soils are insufficient for infiltration, a downspout dispersion system per Section 2.1.3 may be feasible in lieu of infiltration.

1. Where downspout infiltration is being proposed, additional site-specific testing must be done. For single lots, at least one soils log at the location of the infiltration system is required. It must be a minimum of 4 feet deep (from proposed grade). Identify the SCS series of the soil and the USDA textural class of the soil horizon through the depth of the log, and note any evidence of high groundwater level, such as mottling.
2. If site-specific tests indicate less than 3 feet of permeable soil from the proposed final grade to the seasonal high groundwater table, a downspout infiltration system is not feasible and a downspout dispersion system per Section 2.1.3 may be feasible in lieu of infiltration.

3. On lots or sites with more than 3 feet of permeable soil from the proposed final grade to the seasonal high groundwater table, downspout infiltration is considered feasible if the soils are outwash type soils and the infiltration trench can be designed to meet the minimum design criteria specified below. Under no circumstances shall the seasonal high groundwater table be less then 1 foot from the bottom of the infiltration trench.

2.1.2.4 Design Criteria for Infiltration Trenches

Figure III-2-1 shows a typical downspout infiltration trench system, and Figure III-2-2 presents an alternative infiltration trench system for sites with coarse sand and cobble soils. These systems are designed as specified below. Alternate trench lengths require modeling per Section 2.2.

General

1. The following minimum lengths (in linear feet [LF]) per 1,000 square feet of roof area based on soil type may be used for sizing downspout infiltration trenches.

Coarse sands and cobbles	20 LF
Medium sand	30 LF
Fine sand, loamy sand	75 LF
Sandy loam	125 LF
Loam	190 LF

2. Maximum length of trench must not exceed 100 feet from the inlet sump.

3. Minimum spacing between trenches shall be 4 feet measured from the edge of trench.

4. Filter fabric must be placed over the drain rock as shown on Figure III-2-1 prior to backfilling.

5. Three feet of permeable soil, measured from the proposed final grade to the seasonal high groundwater table is required.

6. A minimum of 1 foot of separation is required from the bottom of the infiltration trench to the seasonal high groundwater table.

7. Infiltration trenches may be placed in fill material if the fill is placed and compacted under the direct supervision of a geotechnical engineer or professional civil engineer with geotechnical expertise, and if the measured infiltration rate is at least 8 inches per hour. Trench length in fill must be 60 linear feet per 1,000 square feet of roof area. Infiltration rates can be tested using the methods described in Section 2.2.7.3.

8. Infiltration trenches shall not be built on slopes steeper than 20 percent (5H:1V). A geotechnical analysis and report shall be required on slopes over 15 percent or if located within 200 feet of the top of steep slope (40% or greater) or landslide hazard area. More stringent setbacks may be required as described in Auburn City Code.

9. Trenches may be located under pavement if a small yard drain or catch basin with grate cover is placed at the end of the trench pipe such that overflow would occur out of the catch basin at an elevation at least one foot below that of the pavement, and in a location which can

accommodate the overflow without creating a significant adverse impact to downhill properties or drainage systems. This is intended to prevent saturation of the pavement in the event of system failure.

Setbacks

The City requires specific setbacks for sites with steep slopes, landslide areas, open water features, springs, wells, and septic tank drain fields. Adequate room for maintenance access and equipment shall also be considered. Project proponents should consult Auburn City Code to determine all applicable setback requirements. Where a conflict between setbacks occurs, the City shall require compliance with the most stringent of the setback requirements from the various codes/regulations. Required setbacks are as follows or as determined by a qualified geotechnical engineer:

- Minimum spacing between trenches shall be 4 feet measured from the edge of trench.
- Stormwater infiltration facilities shall be set back at least 100 feet from drinking water wells and springs used for public drinking water supplies. Stormwater infiltration facilities shall be set back at least 10 feet from septic tanks and septic drainfields. Additional setbacks from DOH publication 333-117 On-Site Sewage Systems, Chapter 246-272A WAC may apply. Infiltration facilities upgradient of drinking water supplies and within 1, 5, and 10-year time of travel zones must comply with Health Department requirements (Washington Wellhead Protection Program, DOH, Publication # 331-018).
- All infiltration systems shall be at least 10 feet from any structure. If necessary, setbacks shall be increased from the minimum 10 feet in order to maintain a 1H:1V side slope for future excavation and maintenance.
- All infiltration systems shall be placed at least 5 feet from any property line. If necessary, setbacks shall be increased from the minimum 5 feet in order to maintain a 1H:1V side slope for future excavation and maintenance.
- Infiltration systems shall be setback from sensitive areas, steep slopes, landslide hazard areas, and erosion hazard areas as governed by Auburn City Code. Runoff discharged near landslide hazard areas must be evaluated by a geotechnical engineer or qualified geologist licensed in Washington State. The discharge point shall not be placed on or above slopes greater than 20% (5H:1V) or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and City approval. Infiltration trenches should not be built on slopes steeper than 20%.
- For sites with septic systems, infiltration systems shall be downgradient of the drainfield unless the site topography clearly prohibits surface flows from intersecting the drainfield.

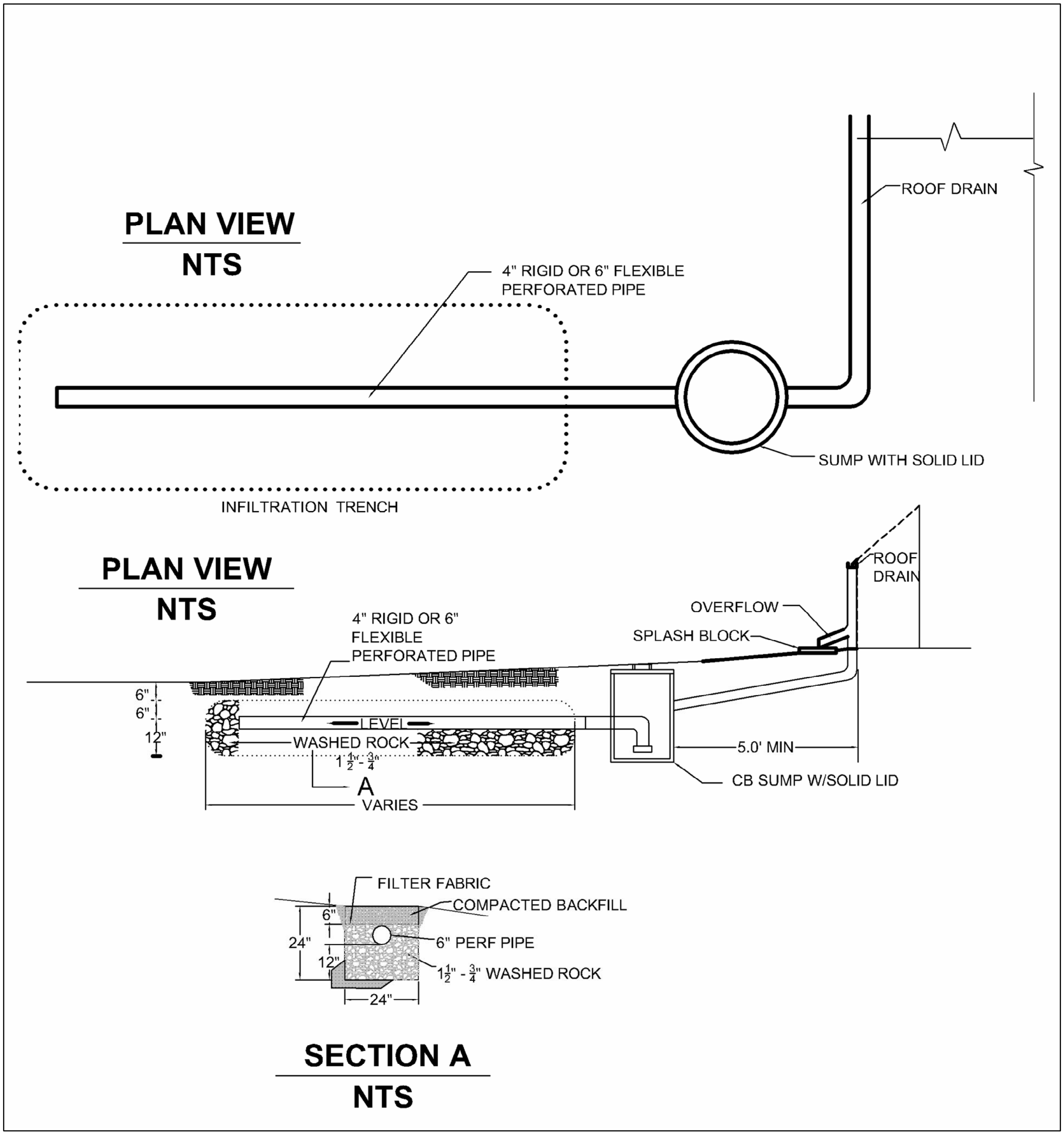


Figure III-2-1. Typical Downspout Infiltration Trench

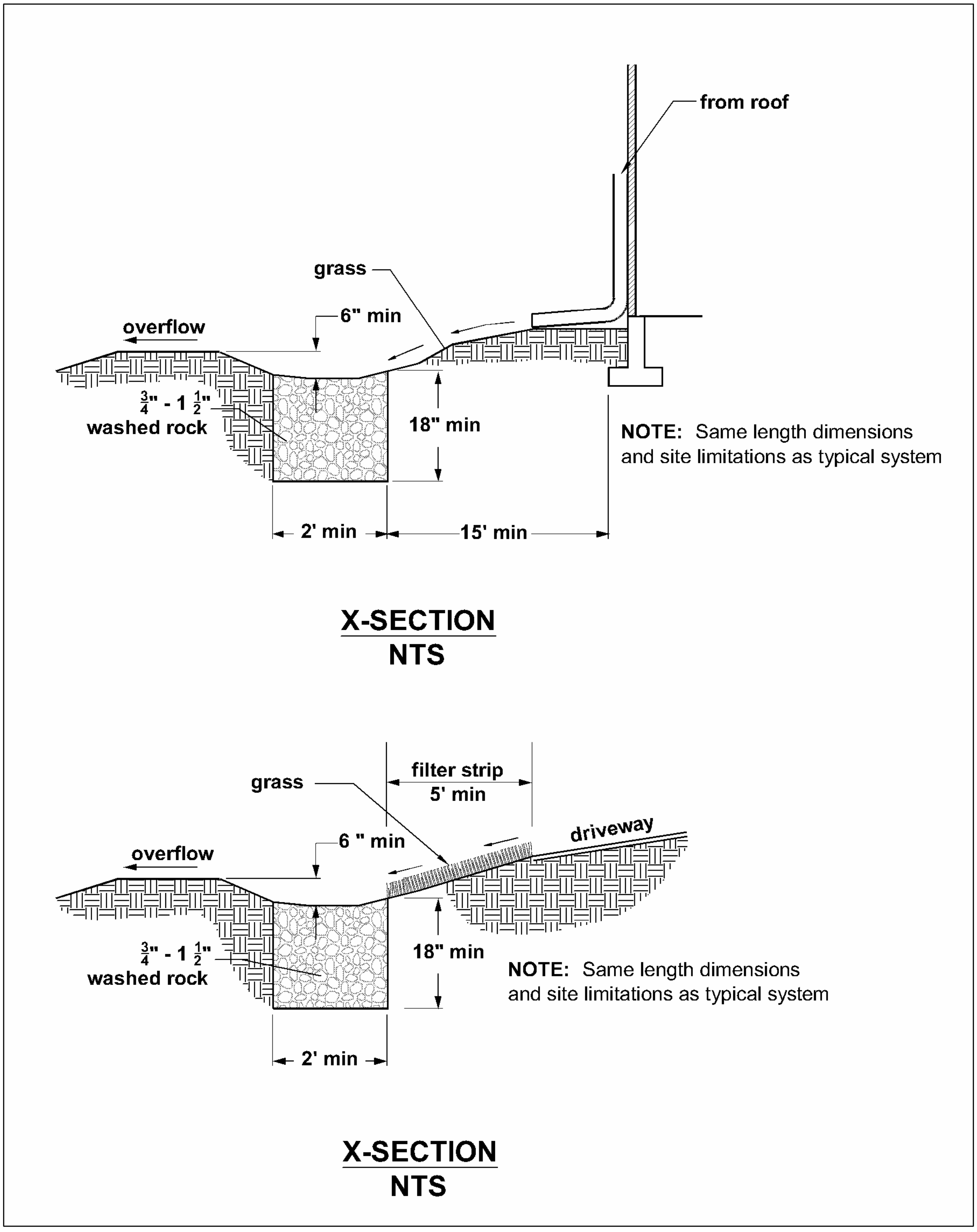


Figure III-2-2. Alternative Downspout Infiltration Trench System for Coarse Sand and Gravel

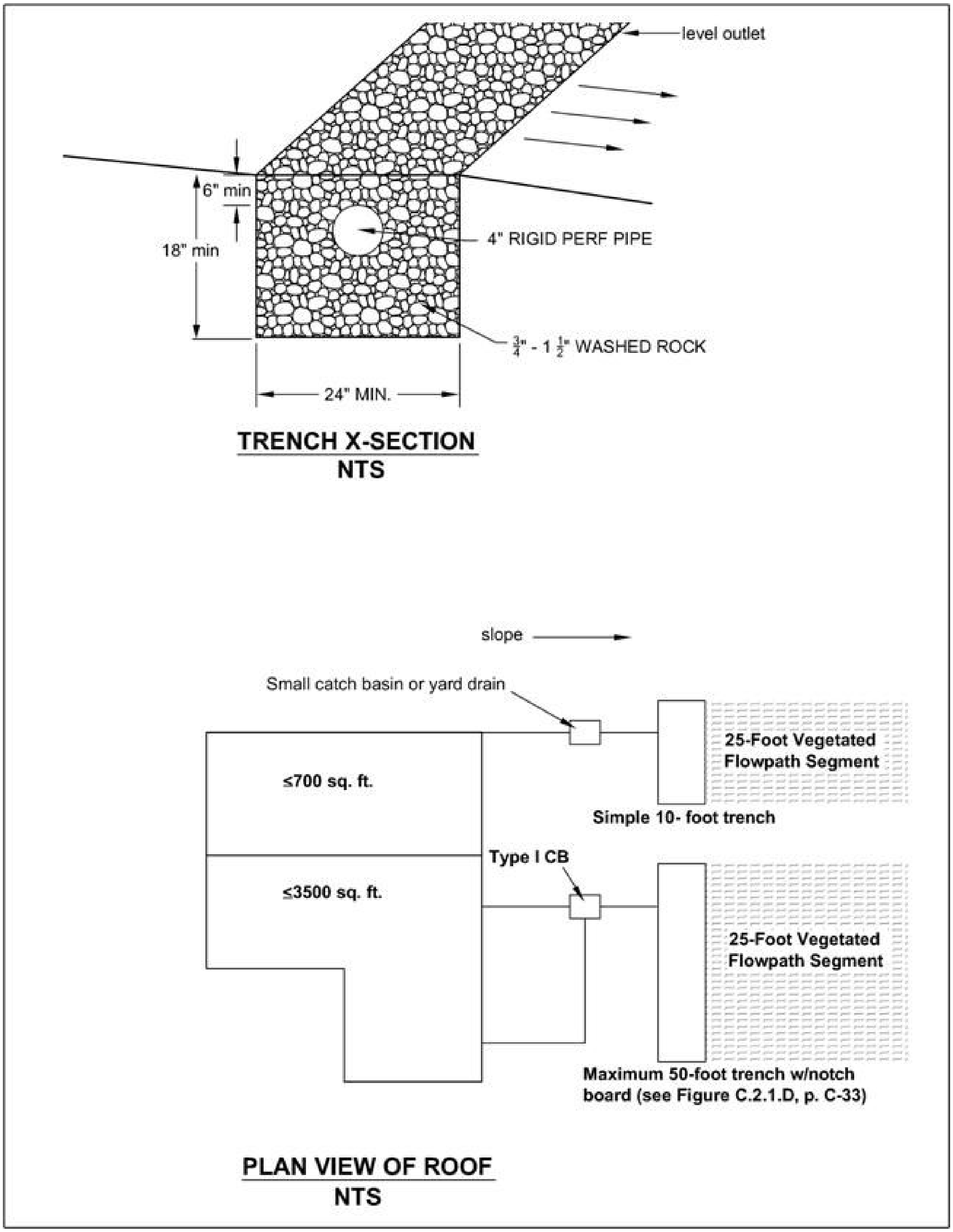


Figure III-2-3. Typical Downspout Dispersion Trench

2.1.3 Downspout Dispersion Systems

Downspout dispersion systems are splash blocks or dispersion facilities that spread roof runoff over vegetated pervious areas. Dispersion attenuates peak flows by slowing entry of the runoff into the conveyance system, allowing for some infiltration, and providing some water quality benefits. Also refer to BMP L610, Downspout Dispersion, in Volume VI.

2.1.3.1 Application

Downspout dispersion may be used on all sites that cannot infiltrate roof runoff and that meet the feasibility and setback requirements.

2.1.3.2 Flow Credit for Roof Downspout Dispersion

If roof runoff is dispersed according to the requirements of this section, and the *vegetative flow*[1] path of the roof runoff is 50 feet or greater through undisturbed native landscape or lawn/landscape area that meets BMP L613, the roof area may be modeled as a grassed surface for both threshold determination and modeling.

2.1.3.3 General Design Criteria

- Downspout dispersion trenches designed as shown in Figure III-2-3 should be used for all downspout dispersion applications except where splash blocks are allowed.
- Perforated stub-out connections shall not be used.
- For sites with septic systems, the discharge point of all dispersion systems must be downgradient of the drainfield. This requirement may be waived if site topography clearly prohibits flows from intersecting the drainfield.
- For sites with septic systems, the discharge point must be downslope of the primary and reserve drainfield areas. This requirement may be waived if site topography clearly prohibits flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc) indicate that this is unnecessary.
- Place all dispersion systems at least 5 feet from any property line. If necessary, setbacks shall be increased from the minimum 5 feet in order to maintain a 1:1 side slope for future excavation and maintenance.
- Setback dispersion systems from sensitive areas, steep slopes, landslide hazard areas, and erosion hazard areas as governed by Auburn City Code.
- All dispersions systems shall be at least 10 feet from any structure. If necessary, setbacks shall be increased from the minimum 10 feet in order to maintain a 1H:1V side slope for future excavation and maintenance.
- No erosion or flooding of downstream properties shall result.

---

[1] *Vegetative flow* path is measured from the downspout or dispersion system discharge point perpendicular to the topographic contours to the downstream property line, stream, wetland, or other impervious surface.

- Runoff discharged towards landslide hazard areas must be evaluated by a geotechnical engineer or a licensed geologist, hydrogeologist, or engineering geologist. The discharge point shall not be placed on or above slopes greater than 20% (5H:1V) or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and City approval.

Design Criteria for Dispersion Trenches

- A vegetated flowpath of at least 25 feet in length must be maintained between the outlet of the trench and any property line, structure, stream, wetland, or impervious surface. A vegetated flowpath of at least 50 feet in length must be maintained between the outlet of the trench and any slope, 20% or greater. Sensitive area buffers may count towards flowpath lengths if approved by the City of Auburn.
- Trenches serving up to 700 square feet of roof area may be simple 10-foot-long by 2-foot-wide gravel filled trenches as shown in Figure III-2-3. For roof areas larger than 700 square feet, a dispersion trench with notched grade board may be used as approved by the City. The total length of this design must not exceed 50 feet and must provide at least 10 feet of trench per 700 square feet of roof area.
- Dispersion systems shall be setback from sensitive areas, steep slopes, landslide hazard areas, and erosion hazard areas as governed by Auburn City Code.

Design Criteria for Splashblocks

A typical downspout splashblock is shown in Volume VI section 2.2.1.1 BMP L610 Downspout Dispersion. In general, if the ground is sloped away from the foundation and there is adequate vegetation and area for effective dispersion, splashblocks will adequately disperse storm runoff. If the ground is fairly level, if the structure includes a basement, or if foundation drains are proposed, splashblocks with downspout extensions may be a better choice because the discharge point is moved away from the foundation. Downspout extensions can include piping to a splashblock/discharge point a considerable distance from the downspout, as long as the runoff can travel through a well-vegetated area as described below.

- A vegetated flow path of at least 50 feet shall be maintained between the discharge point and any property line, structure, steep slope, stream, wetland, lake, or other impervious surface. Sensitive area buffers may count toward flow path lengths. The minimum spacing between splash blocks shall be 10 feet on a contour line.
- Flows shall not be directed onto sidewalks.
- A maximum of 700 square feet of roof area may drain to each splashblock.
- A splashblock or a pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) shall be placed at each downspout discharge point.
- No erosion or flooding of downstream properties may result.
- Runoff discharged towards landslide hazard areas must be evaluated by a professional engineer with geotechnical expertise or a licensed geologist, hydrogeologist, or engineering geologist. Splash blocks may not be placed on or above slopes greater than 20% (5H:1V) or above erosion hazard areas without

evaluation by a professional engineer with geotechnical expertise or qualified geologist and City approval.

2.1.4 Bioinfiltration "Rain Gardens"

Purpose and Definition

Bioretention areas are shallow stormwater retention systems designed to mimic forested systems by controlling stormwater through detention, infiltration, and evapotranspiration. Bioretention areas provide water quality treatment through sedimentation, filtration, adsorption, and phytoremediation. Bioretention facilities are integrated into the landscape to better mimic natural hydrologic conditions. Bioretention facilities may be used as a water quality facility or a water quality and flow control (retention) facility.

Use "Low Impact Development: Technical Guidance Manual for Puget Sound" and Washington State University "Rain Garden Handbook for Western Washington Homeowners", June 2007 as additional guidance resources.

Applicability and Limitations

- Rain gardens can be used as on-lot retention facilities.
- Rain gardens may be used to receive roof runoff in areas where traditional infiltration is not feasible.
- Three feet of clearance is necessary between the lowest elevation of the bioretention soil or any underlying gravel layer and the seasonal high groundwater elevation or other impermeable layer if the area tributary to the facility meets or exceeds any of the following:
    - 5000 square feet of pollution-generating impervious surface
    - 10,000 square feet of impervious area
    - ¾ acre of lawn and landscape
- For bioretention systems with a contributing area less than the above thresholds, a minimum of 18 inches of clearance is required from the seasonal high groundwater or other impermeable layer.

Setback and Site Constraints

- Assure that water movement through the surface soils and interflow will remain unobstructed and soils will remain uncompacted.
- Locate bioretention facilities at least 10 feet from any structure or property line unless approved in writing by the City.
- Locate bioretention facilities at least 50 feet back from slopes with a grade of 20% or greater. A geotechnical analysis must be prepared addressing the potential impact of the facility on the slope if closer than 50 feet or greater than 20%.

Design Criteria

Flow Entrance/Presetting

- Flow velocity entering the facility should be less than 1 ft/sec.
- Use one of the four types of flow entrances:
  - Dispersed, low velocity flow across a grade or landscape area.
  - Pipe flow entrance. Include rock or other erosion protection material at the facility entrance to dissipate energy and/or provide flow dispersion.
- Do not place woody plants directly in the entrance flow path as they can restrict or concentrate flows.
- A minimum 1-inch grade change between the edge of a contributing impervious surface and the vegetated flow entrance is required.
- Install flow diversion and erosion control measures to protect the bioretention area from sedimentation until the upstream area is stabilized.
- If the catchment area exceeds 2,000 square feet, a presettling facility may be required.

Cell Ponding Area

- The ponding area provides for surface storage and particulate settling,
- Ponding depth and drawdown rate provide variable conditions that allow for a range of appropriate plant species. Soil must be allowed to dry out periodically in order to:
  - Restore hydraulic capacity of system.
  - Maintain infiltration rates.
  - Maintain adequate soil oxygen levels for healthy soil biota and vegetation.
  - Provide proper soil conditions for biodegradation and retention of pollutants.
  - Prevent conditions supportive of mosquito breeding.
- The ponding depth shall be a maximum of 12 inches.
- The surface pool drawdown time shall be 24 hours.
- The minimum freeboard measured from the invert of the overflow pipe or earthen channel to facility overtopping elevation shall be 2” for drainage areas less than 1,000 square feet and 6” for drainage areas 1,000 square feet or greater.
- If berming is used to achieve the minimum top elevation, maximum slope on berm shall be 4H:1V, and minimum top width of design berm shall be 1 foot. Soil for berming shall be imported bioretention soil or amended native soil compacted to a minimum of 90% dry density.

Overflow

- Unless designed for full infiltration of the entire runoff volume, bioretention systems must include an overflow.
- A drain pipe installed at the designed maximum ponding elevation and connected to a downstream BMP or an approved discharge point can be used as the overflow.
- Overflow shall be designed to convey the 100-year recurrence interval flow.

Soils

- For bioretention systems to meet the requirements for basic and enhanced treatment the following requirements must be met:
- The bioretention soil mix (BSM) shall meet the following requirements:
  - Have an infiltration rate between 1 and 2.4 inches per hour.
  - The CEC (cation exchange capacity) must be at least 5 meq/100 grams of dry soil.
  - The soil mix should be about 40% by volume compost and about 60% by volume aggregate component. The aggregate component shall meet the specifications in Table III-2-3.
  - The compost component shall be stable, mature, and derived from organic waste materials including yard debris, wood wastes or other organic matter. Compost must meet the Washington State compost regulations in WAC 173-350-220, which is available at http://www.ecy.wa.gov/programs/swfa/compost

Table III-2-3. Bioretention Soil Mix Aggregate Component

Sieve Size	Percent Passing
3/8”	100
#4	95-100
#10	75-90
#40	25-40
#100	4-10
#200	2-5

  - Minimum depth of treatment soil must be 18 inches.
  - Soil depths of 24” and greater should be considered to provide improved removal of nutrients as needed, including phosphorus.

- Provide a soils report, prepared by a soils professional, that addresses the following for each bioretention area:
    - A minimum of one soil log or test pit is required at each facility.
    - The soil log shall extend a minimum of 4 feet below the bottom of the subgrade (the lowest point of excavation).
    - The soil log must describe the USDA textural class of the soil horizon through the depth of the log and note any evidence of high groundwater level, such as mottling.

Underdrain

Only install underdrains in bioretention areas if:

- Infiltration is not permitted and/or a liner is used, or
- Where infiltration rates are not adequate to meet the maximum pool drawdown time.
- Where the facility is not utilized for infiltration.

Underdrain pipe diameter will depend on hydraulic capacity required, 6-inch minimum.

Use a geotextile fabric between the soil layer and underdrain.

Planting

- Plants must be tolerant of summer drought, ponding fluctuations, and saturated soil conditions.
- Consider rooting depth when choosing plants. Roots must not damage underground infrastructure.
- Locate slotted and perforated pipe at least 5 feet from tree roots and side sewer pipes.
- Consider adjacent plant communities and potential invasive species.
- Consider aesthetics, rain gardens should blend into surrounding landscapes.
- “Low Impact Development: Technical Guidance Manual for Puget Sound” is a good tool for selecting proper bioretention vegetation.

Mulch Layer

- Bioretention areas should be designed with a mulch layer. Properly selected mulch material reduces weed establishment, regulates soil temperatures and moisture, and adds organic matter to soil. Mulch should be:
    - Compost in the bottom of the facilities,
    - Wood chip mulch composed of shredded or chipped hardwood or softwood on cell slopes,

  - Free of weed seeds, soil, roots, and other material that is not trunk or branch wood and bark,
  - A maximum of 3 inches thick for compost or 4 inches thick for wood chips.
- Mulch shall not include grass clippings, mineral aggregate or pure bark.
- A dense groundcover can be used as an alternative to mulch though mulch most be used until the dense groundcover is established.

Modeling and Sizing

For sites with contributing area less than 2,000 square feet:

Table III-2-4 gives the square footage of the bottom of the rain garden per 1000 square feet of roof area.

Table III-2-4. Sizing Table for Rain Gardens

Soil Type	Raingarden bottom (square feet)
Coarse sands and cobbles	25
Medium sands	60
Fine sands, loamy sands	130
Sandy loam	160
Loam	225

For sites with contributing areas 2,000 square feet or more:

Use WWHM and model the facility as an infiltration facility with appropriate stage-storage and overflow/outflow rates. Bioretention cells may be modeled as a layer of soil with infiltration to underlying soil, ponding and overflow. The tributary area, cell bottom area, and ponding depth should be iteratively sized until the duration curves and/or peak volumes meet the flow control requirements.

NOTE: WWHM Pro has the ability to model bioretention areas with or without underdrains so facility will be sized differently than described above. Contact the Washington State Department of Ecology for more information. Use the assumptions in Table III-2-5 when sizing the facilities.

Table III-2-5. Modeling Assumptions for Rain Garden Sizing

Variable	Assumption
Computational Time Step	15 minutes
Inflows to Facility	Surface flow and interflow from drainage area routed to facility
Precipitation and Evaporation Applied to Facility	Yes
Bioretention Soil Infiltration Rate	For imported soils, for sites that have a contributing area of less than 5,000 square feet of pollution generating surfaces, less than 10,000 square feet of impervious area, and less than ¾ acre of landscaped area, reduce the infiltration rate of the BSM by a factor of 2. For sites above these thresholds, a reductions factor of 4 shall be applied. For compost amended native soil, rate is equal to native soil design infiltration rate.
Bioretention Soil Porosity	40%
Bioretention Soil Depth	Minimum of 18 inches.
Native Soil Infiltration Rate	Measured infiltration rate with applicable safety factors. See Volume III for more information on infiltration rate determination.
Infiltration Across Wetted Surface Area	Only if sides slopes are 3:1 or flatter
Overflow	Overflow elevation set at maximum ponding elevation (excluding freeboard). May be modeled as weir flow over rider edge or riser notch.

Flow Credit

If roof runoff is infiltrated according to the requirements of this section, the roof area may be discounted from the project area used for determining project thresholds and sizing stormwater facilities.

2.1.5 Collect and Convey

Where it can be demonstrated that infiltration and dispersion are not feasible for roof downspout controls, it may be allowable to collect and convey to the City stormwater system. This may be either the curb, if present, or the actual pipe and structure conveyance system.

Conveyance to the curb will only be allowed if a catch basin is located within 350 feet downstream of the discharge point. If a catch basin is not located within 350 feet of the discharge location, a storm main extension shall be required.

Minimum pipe size for conveyance to the curb shall be 4 inches in diameter for single family homes and a minimum of 6 inches in diameter for non-single family. Where capacity greater than a 6 inch diameter pipe is required, the City shall review the proposal and may require a storm main extension.

For total roof areas 2,000 to 5,000 sf, roof runoff may be allowed to be collected and conveyed to either the curb or directly connected to a structure. The runoff shall not be conveyed over driveways, sidewalks or other areas reserved for pedestrian traffic. A detail for the discharge shall be submitted to the City for review and approval.

For roof areas between 5,001 sf and 9,999 sf, roof runoff may be allowed to be collected and conveyed to the curb or stormwater structure. Capacity analysis of the road gutter, conveyance piping and catch basin leads will be required to ensure that adequate capacity exists. The City may require more than one through curb outlet for discharge to the curb.

For roof areas 10,000 sf and greater, please refer to Minimum Requirement #7.

No flow credits will be allowed for the collect and convey option.

2.2 Infiltration Facilities for Stormwater Flow Control

2.2.1 Purpose

To provide infiltration capacity for stormwater runoff quantity and flow control. Infiltration facilities may also be used for water quality treatment when designed appropriately.

2.2.2 Description

An infiltration BMP is typically an open basin (pond), trench, or buried perforated pipe used for distributing the stormwater runoff into the underlying soil (See Figure III-2-4). (See Underground Injection Control Program, Chapter 173-218 WAC).

The City prefers retention (infiltration) for storm drainage quantity control when soil conditions are satisfactory for such application and water quality treatment can be provided.

Coarser more permeable soils can be used for quantity control provided that the stormwater discharge does not cause a violation of groundwater quality criteria. Typically, treatment for removal of TSS, oil, and/or soluble pollutants is necessary prior to conveyance to an infiltration BMP.

Use of the soil for treatment purposes is also an option as long as it is preceded by a pre-settling basin or a basic treatment BMP. This section highlights design criteria that are applicable to infiltration facilities serving a flow control function. See Volume V, Chapter 5 for design criteria for treatment.

2.2.3 Application

Infiltration facilities for flow control are used to convey stormwater runoff from new development or redevelopment to the ground and groundwater after appropriate treatment. Infiltration facilities for treatment purposes rely on the soil profile to provide treatment. In either case, runoff in excess of the infiltration capacity of the facilities must be managed to comply with the flow control requirement in Volume I, if flow control applies to the project.

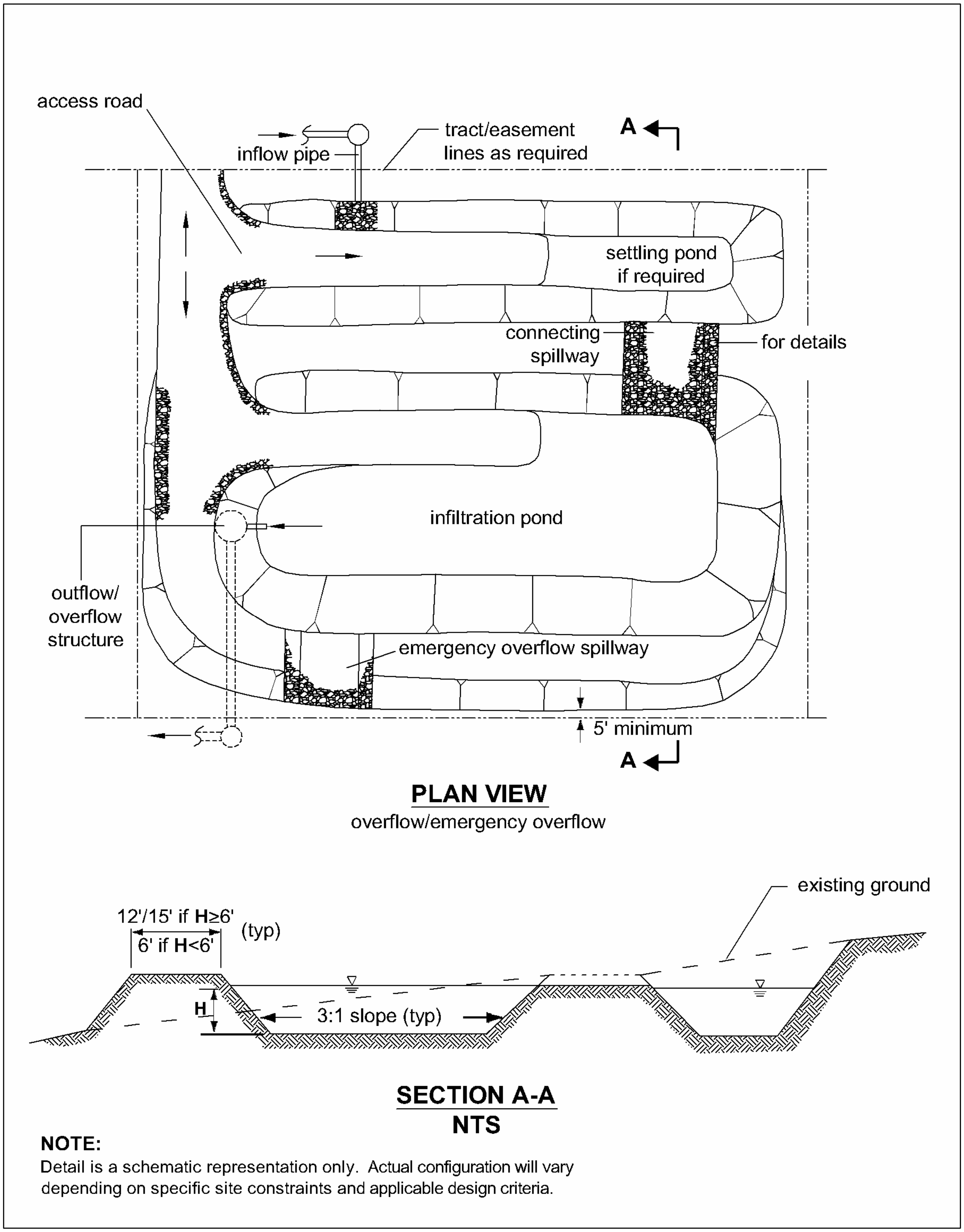


Figure III-2-4. Typical Infiltration Pond/Basin

Infiltration trenches can be considered for residential lots, commercial areas, parking lots, and open space areas. Infiltration facilities can help accomplish the following:

- Groundwater recharge
- Discharge of uncontaminated or properly treated stormwater in compliance with Ecology's UIC regulations (Chapter 173-218 WAC)
- Retrofits in limited land areas:
- Flood control
- Streambank erosion control

2.2.4 Design Methodology

Two methodologies outlining the steps for designing infiltration systems are presented in this manual. The simplified approach is outlined in Section 2.2.5 and the detailed approach is outlined in Section 2.2.6.

2.2.5 Simplified Approach

The simplified approach was derived from high groundwater and shallow pond sites in western Washington, and in general will produce `conservative' designs. The simplified approach can be used when determining the trial geometry of the infiltration facility, for small or low impact facilities, or for facilities where a more conservative design is acceptable. The simplified approach is applicable to ponds and trenches and includes the following steps:

Step 1. Select a location:

This will be based on the ability to convey flow to the location and the expected soil conditions of the location. Conduct a preliminary surface and sub-surface characterization study (Section 2.2.7). Do a preliminary check of Site Suitability Criteria (Section 2.2.10) to estimate feasibility.

Step 2. Estimate volume of stormwater, V_{design}:

Use WWHM to estimate the design. The runoff volume developed for the project site serves as input to the infiltration basin.

For infiltration basins sized simply to meet treatment requirements, the basin must successfully infiltrate 91% of the influent runoff volume. The remaining 9% of the influent volume can bypass the infiltration facility. However, if the bypass discharges to a surface water that is not exempt from flow control, the bypass must meet the flow control standard.

For infiltration basins sized to meet the flow control standard, the basin must infiltrate either all of the influent volume, or a sufficient amount of the influent volume such that any overflow/bypass meets the flow duration standard.

Step 3. Develop trial infiltration facility geometry:

To accomplish this, an infiltration rate will need to be assumed based on previously available data, or a default infiltration rate of 0.5 inches/hour can be used. This trial facility geometry should be used to help locate the facility and for planning purposes in developing the geotechnical subsurface investigation plan.

Step 4. Complete more detailed site characterization study and consider site suitability criteria:

Information gathered during initial geotechnical and surface investigations are necessary to know whether infiltration is feasible. The geotechnical investigation evaluates the suitability of the site for infiltration, establishes the infiltration rate for design, and evaluates slope stability, foundation capacity, and other geotechnical design information needed to design and assess constructability of the facility.

See Sections 2.2.7 and 2.2.10.

Step 5. Determine the infiltration rate as follows:

Three possible methods for estimating the long-term infiltration rate are provided in Section 2.2.9.

Step 6. Size the facility:

Ensure that the maximum pond depth stays below the minimum required freeboard. If sizing a treatment facility, document that the 91st percentile, 24-hour runoff volume (indicated by an approved continuous simulation model) can infiltrate through the infiltration basin surface within 48 hours. This can be calculated by multiplying a horizontal projection of the infiltration basin mid-depth dimensions by the estimated long-term infiltration rate; and multiplying the result by 48 hours.

Step 7. Construct the facility:

Maintain and monitor the facility for performance.

2.2.6 Detailed Approach

This detailed approach was obtained from Massmann (2003). Procedures for the detailed approach are as follows:

Step 1: Select a location:

This will be based on the ability to convey flow to the location and the expected soil conditions. The minimum setback distances must also be met. See Section 2.2.10 Site Suitability Criteria and setback distances.

Step 2: Estimate volume of stormwater, V_{design}:

Use WWHM to estimate V_{design}.

Step 3: Develop a trial infiltration facility geometry based on length, width, and depth:

To accomplish this, either assume an infiltration rate based on previously available data, or use a default infiltration rate of 0.5 inches/hour. This trial geometry should be used to help locate the facility, and for planning purposes in developing the geotechnical subsurface investigation plan.

Step 4: Conduct a geotechnical investigation and consider site suitability criteria:

See Sections 2.2.7 and 2.2.10.

Step 5: Determine the saturated hydraulic conductivity as follows:

For each defined layer below the pond to a depth below the pond bottom of 2.5 times the maximum depth of water in the pond, but not less than 6 feet, estimate the saturated hydraulic conductivity in cm/sec using the following relationship (see Massmann 2003, and Massmann et al., 2003)

$$\log_{10}(K_{sat}) = -1.57 + 1.90D_{10} + 0.015D_{60} - 0.013D_{90} - 2.08F_{\text{fines}} \qquad \text{(equation 1)}$$

Where, D_{10}, D_{60} and D_{90} are the grain sizes in mm for which 10 percent, 60 percent and 90 percent of the sample is more fine and f_{fines} is the fraction of the soil (by weight) that passes the #200 sieve (K_{sat} is in cm/s).

If the licensed professional conducting the investigation determines that deeper layers will influence the rate of infiltration for the facility, soil layers at greater depths must be considered when assessing the site's hydraulic conductivity characteristics. Massmann (2003) indicates that where the water table is deep, soil or rock strata up to 100 feet below an infiltration facility can influence the rate of infiltration. Note that only the layers near and above the water table or low permeability zone (e.g., a clay, dense glacial till, or rock layer) need to be considered, as the layers below the groundwater table or low permeability zone do not significantly influence the rate of infiltration. Also note that this equation for estimating hydraulic conductivity assumes minimal compaction consistent with the use of tracked (i.e., low to moderate ground pressure) excavation equipment. If the soil layer being characterized has been exposed to heavy compaction, or is heavily consolidated due to its geologic history (e.g., overridden by continental glaciers), the hydraulic conductivity for the layer could be approximately an order of magnitude less than what would be estimated based on grain size characteristics alone (Pitt, 2003). In such cases, compaction effects must be taken into account when estimating hydraulic conductivity. For clean, uniformly graded sands and gravels, the reduction in K_{sat} due to compaction will be much less than an order of magnitude. For well-graded sands and gravels with moderate to high silt content, the reduction in K_{sat} will be close to an order of magnitude. For soils that contain clay, the reduction in K_{sat} could be greater than an order of magnitude.

For critical designs, the in-situ saturated conductivity of a specific layer can be obtained through field tests such as the packer permeability test (above or below the water table), the piezocone (below the water table), an air conductivity test (above the water table), or through the use of a pilot infiltration test (PIT) as described in Volume III, Appendix B. Note that these field tests generally provide a hydraulic conductivity combined with a hydraulic gradient (i.e., Equation 5). In some of these tests, the hydraulic gradient may be close to 1.0; therefore, in effect, the magnitude of the test result is the same as the hydraulic conductivity. In other cases, the hydraulic gradient may be close to the gradient that is likely to occur in the full-scale infiltration facility. This issue will need to be evaluated on a case-by-case basis when interpreting the results of field tests. It is important to recognize that the gradient in the test may not be the same as the gradient likely to occur in the full-scale infiltration facility in the long-term (i.e., when groundwater mounding is fully developed).

Once the saturated hydraulic conductivity for each layer has been identified, determine the effective average saturated hydraulic conductivity below the pond. Hydraulic conductivity estimates from different layers can be combined using the harmonic mean:

$$K_{equiv} = \frac{d}{\sum \frac{d_i}{K_i}} \qquad \text{(equation 2)}$$

Where, d is the total depth of the soil column, d_i is the thickness of layer "i" in the soil column, and K_i is the saturated hydraulic conductivity of layer "i" in the soil column. The depth of the soil column, d, typically would include all layers between the pond bottom and the water table. However, for sites with very deep water tables (>100 feet) where groundwater mounding to the base of the pond is not likely to occur, it is recommended that the total depth of the soil column in Equation 2 be limited to approximately 20 times the depth of pond. This is to ensure that the most important and relevant layers are included in the hydraulic conductivity calculations. Deep layers that are not likely to affect the infiltration rate near the pond bottom should not be included in Equation 2. Equation 2 may over-estimate the effective hydraulic conductivity value at sites with low conductivity layers immediately beneath the infiltration pond. For sites where the lowest conductivity layer is within five feet of the base of the pond, it is suggested that this lowest hydraulic conductivity value be used as the equivalent hydraulic conductivity rather than the value from Equation 2. The harmonic mean given by Equation 2 is the appropriate effective hydraulic conductivity for flow that is perpendicular to stratigraphic layers, and will produce conservative results when flow has a significant horizontal component such as could occur due to groundwater mounding.

Step 6: Calculate the hydraulic gradient as follows:

The steady state hydraulic gradient is calculated as follows:

$$\text{gradient} = i \approx \frac{D_{wt} + D_{pond}}{138.62(K^{0.1})} CF_{size} \qquad \text{(equation 3)}$$

Where, D_{wt} is the depth from the base of the infiltration facility to the water table in feet, K is the saturated hydraulic conductivity in feet/day, D_{pond} is the depth of water in the facility in feet (see Massmann et al., 2003, for the development of this equation), and CF_{size}, is the correction for pond size. The correction factor was developed for ponds with bottom areas between 0.6 and 6 acres in size. For small ponds (ponds with area equal to 2/3 acre), the correction factor is equal to 1.0. For large ponds (ponds with area equal to 6 acres), the correction factor is 0.2, as shown in Equation 4.

$$CF_{size} = 0.73(A_{pond})^{-0.76} \qquad \text{(equation 4)}$$

Where, A_{pond} is the area of pond bottom in acres. This equation generally will result in a calculated gradient of less than 1.0 for moderate to shallow groundwater depths (or to a low permeability layer) below the facility, and conservatively accounts for the development of a groundwater mound. A more detailed groundwater mounding analysis using a program such as MODFLOW will usually result in a gradient that is equal to or greater than the gradient calculated using Equation 3. If the calculated gradient is greater than 1.0, the water table is considered to be deep, and a maximum gradient of 1.0 must be used. Typically, a depth to groundwater of 100 feet or more is required to obtain a gradient of 1.0 or more using this equation. Since the gradient is a function of depth of water in the facility, the gradient will vary as the pond fills during the season. The gradient could be calculated as part of the stage-discharge calculation used in the continuous runoff models. As of the date of this update, neither the WWHM or MGSFlood have that capability. However, updates to those models may soon incorporate the capability. Until that time, use a steady-state hydraulic gradient that corresponds with a ponded depth of ¼ of the maximum ponded depth – as measured from the basin floor to the overflow.

Step 7: Calculate the infiltration rate using Darcy's law as follows:

$$f = K\left(\frac{dh}{dz}\right) = Ki$$ (equation 5)

Where, f is the specific discharge or infiltration rate of water through a unit cross-section of the infiltration facility (L/t), K is the hydraulic conductivity (L/t), dh/dz is the hydraulic gradient (L/L), and "i" is the gradient.

Step 8: Adjust infiltration rate or infiltration stage-discharge relationship obtained in Steps 6 and 7:

This is done to account for reductions in the rate resulting from long-term siltation and biofouling, taking into consideration the degree of long-term maintenance and performance monitoring anticipated, the degree of influent control (e.g., pre-settling ponds biofiltration swales, etc.), and the potential for siltation, litterfall, moss buildup, etc. based on the surrounding environment. It should be assumed that an average to high degree of maintenance will be performed on these facilities. A low degree of maintenance should be considered only when there is no other option (e.g., access problems). The infiltration rate estimated in Step 8 and 9 is multiplied by the reduction factors summarized in Table III-2-6.

Table III-2-6. Infiltration Rate Reduction Factors to Account for Biofouling and Siltation Effects for Ponds

Potential for Biofouling	Degree of Long-Term Maintenance/Performance Monitoring	Infiltration Rate Reduction Factor ($CF_{silt/bio}$)
Low	Average to High	0.9
Low	Low	0.6
High	Average to High	0.5
High	Low	0.2

(Massman, 2003)

The values in this table assume that final excavation of the facility to the finished grade is deferred until all disturbed areas in the upgradient drainage area have been stabilized or protected (e.g., construction runoff is not allowed into the facility after final excavation of the facility). Ponds located in shady areas where moss and litterfall from adjacent vegetation can build up on the pond bottom and sides, the upgradient drainage area will remain in a disturbed condition long-term, and no pretreatment (e.g., pre-settling ponds, biofiltration swales, etc.) is provided, are one example of a situation with a high potential for biofouling. A low degree of long-term maintenance includes, for example, situations where access to the facility for maintenance is very difficult or limited, or where there is minimal control of the party responsible for enforcing the required maintenance. A low degree of maintenance should be considered only when there is no other option.

Also adjust this infiltration rate for the effect of pond aspect ratio by multiplying the infiltration rate determined in Step 7 (Equation 5) by the aspect ratio correction factor Faspect as shown in the following equation:

$$CF_{aspect} = 0.02A_r + 0.98 \qquad \text{(equation 6)}$$

Where, Ar is the aspect ratio for the pond (length/width). In no case shall CFaspect be greater than 1.4.

The final infiltration rate will therefore be as follows:

$$f = Ki \times CF_{aspect} \times CF_{silt/bio} \qquad \text{(equation 7)}$$

The rates calculated based on Equations 5 and 7 are long-term design rates. No additional reduction factor or factor of safety is needed.

Step 9: Size the facility:

Size the facility to ensure that the desirable pond depth is three feet, with one-foot minimum required freeboard. The maximum allowable pond depth is six feet.

Where the infiltration facility is being used to meet treatment requirements, check that the 91st percentile, 24-hour runoff volume (indicated by WWHM or MGS Flood) can infiltrate through the infiltration basin surface within 48 hours. This can be calculated by multiplying a horizontal projection of the infiltration basin mid-depth dimensions by the estimated long-term infiltration rate; and multiplying the result by 48 hours. Finally, check to make sure that the basin can drain its maximum ponded water depth within 24 hours.

Step 10: Construct the facility:

Maintain and monitor the facility for performance in accordance with Section 2.2.11.

2.2.7 Site Characterization Criteria

One of the first steps in siting and designing infiltration facilities is to conduct a characterization study. Information gathered during initial geotechnical investigations can be used for the site characterization.

2.2.7.1 Surface Features Characterization

- Topography within 500 feet of the proposed facility.
- Anticipated site use (street/highway, residential, commercial, high-use site).
- Location of water supply wells within 500 feet of proposed facility.
- Location of groundwater protection areas and/or 1, 5 and 10 year time of travel zones for municipal well protection areas.
- A description of local site geology, including soil or rock units likely to be encountered, the groundwater regime, and geologic history of the site.

2.2.7.2 Subsurface Characterization

- Conduct pit/hole explorations during the wet season (December 1st through April 30th) to provide accurate groundwater saturation and groundwater information.
- Subsurface explorations (test holes or test pits) to a depth below the base of the infiltration facility of at least 5 times the maximum design depth of ponded water proposed for the infiltration facility,
- Continuous sampling (representative samples from each soil type and/or unit within the infiltration receptor) to a depth below the base of the infiltration facility of 2.5 times the maximum design ponded water depth, but not less than 6 feet.
- For basins, at least one test pit or test hole per 5,000 ft^2 of basin infiltrating surface (in no case less than two per basin).
- For trenches, at least one test pit or test hole per 50 feet of trench length (in no case less than two per trench).

The depth and number of test holes or test pits, and samples should be increased, if in the judgment of a licensed engineer with geotechnical expertise (P.E.), a licensed geologist, engineering geologist, hydrogeologist, or other licensed professional acceptable to the City, the conditions are highly variable and such increases are necessary to accurately estimate the performance of the infiltration system. The exploration program may also be decreased if, in the opinion of the licensed engineer or other professional, the conditions are relatively uniform and the borings/test pits omitted will not influence the design or successful operation of the facility. In high water table sites, the subsurface exploration sampling need not be conducted lower than two (2) feet below the groundwater table.

Prepare detailed logs for each test pit or test hole and a map showing the location of the test pits or test holes. Logs must include at a minimum, depth of pit or hole, soil descriptions, depth to water, presence of stratification (Logs must substantiate whether stratification does or does not exist. The licensed professional may consider additional methods of analysis to substantiate the presence of stratification that will significantly impact the design of the infiltration facility).

2.2.7.3 Infiltration Rate Determination

Determine the representative infiltration rate of the unsaturated vadose zone based on infiltration tests and/or grain-size distribution/texture (see next section). Determine site infiltration rates using the Pilot Infiltration Test (PIT) described in Volume III, Appendix B, if practicable. Such site testing should be considered to verify infiltration rate estimates based on soil size distribution and textural analysis. Infiltration rates may also be estimated based on soil grain-size distributions from test pits or test hole samples (particularly where a sufficient source of water does not exist to conduct a pilot infiltration test). As a minimum, one soil grain-size analysis per soil stratum in each test hole shall be performed within 2.5 times the maximum design water depth, but not less than 6 feet.

2.2.7.4 Soil Testing

Soil characterization for each soil unit (soils of the same texture, color, density, compaction, consolidation and permeability) encountered should include:

- Grain-size distribution (ASTM D422 or equivalent AASHTO specification)
- Textural class (USDA) (See Figure III-2-5).
- Percent clay content (include type of clay, if known)
- Color/mottling
- Variations and nature of stratification

If the infiltration facility will be used to provide treatment as well as flow control, the soil characterization should also include cation exchange capacity (CEC) and organic matter content for each soil type and strata. Where distinct changes in soil properties occur, perform analysis to a depth below the base of the facility of at least 2.5 times the maximum design water depth, but not less than 6 feet. Consider if soils are already contaminated, thus diminishing pollutant sorptive capacity.

For soils with low CEC and organic content, deeper characterization of soils may be warranted (refer to Section 2.2.10 Site Suitability Criteria)

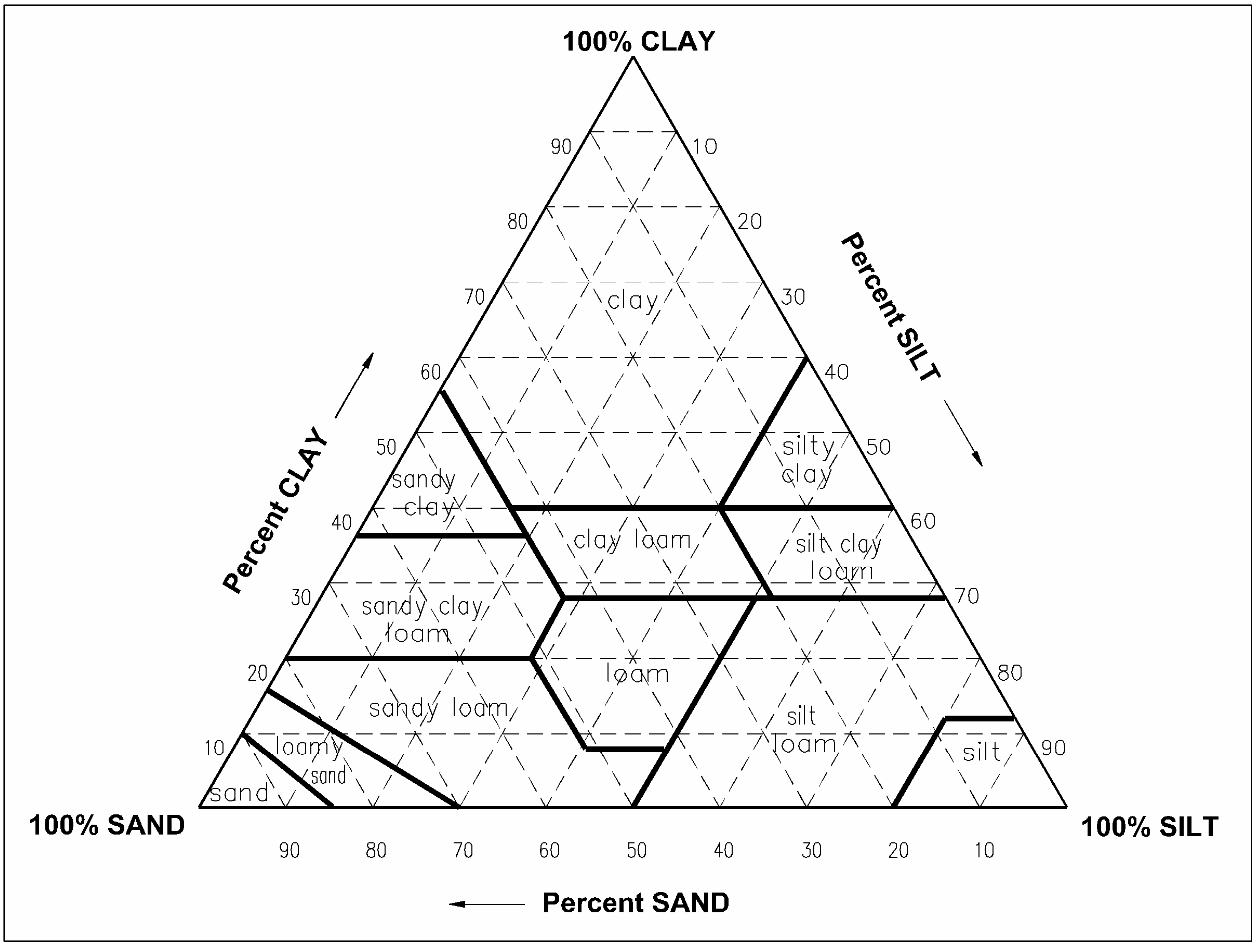


Figure III-2-5. USDA Textural Triangle[2]

2.2.7.5 Infiltration Receptor

The requirements of this section will be applied as directed by the City. Infiltration receptor (unsaturated and saturated soil receiving the stormwater) characterization should include:

- Installation of groundwater monitoring wells (at least three per infiltration facility, or three hydraulically connected surface and groundwater features that will establish a three-dimensional relationship for the groundwater table, unless the highest groundwater level is known to be at least 50 feet below the proposed infiltration facility) to:
  - Monitor the seasonal groundwater levels at the site during at least one wet season, and,

[2] Shaded area is applicable for design of infiltration BMPs. Source, U.S. Department of Agriculture

  - Consider the potential for both unconfined and confined aquifers, or confining units, at the site that may influence the proposed infiltration facility as well as the groundwater gradient. Other approaches to determine groundwater levels at the proposed site could be considered if pre-approved by the City, and
  - Determine the ambient groundwater quality, if that is a concern.
- An estimate of the volumetric water holding capacity of the infiltration receptor soil. This is the soil layer below the infiltration facility and above the seasonal high-water mark, bedrock, hardpan, or other low permeability layer. This analysis should be conducted at a conservatively high infiltration rate based on vadose zone porosity, and the water quality runoff volume to be infiltrated. This, along with an analysis of groundwater movement, will be useful in determining if there are volumetric limitations that would adversely affect drawdown.
- Determination of:
  - Depth to groundwater table and to bedrock/impermeable layers
  - Seasonal variation of groundwater table based on well water levels and observed mottling
  - Existing groundwater flow direction and gradient
  - Lateral extent of infiltration receptor
  - Horizontal hydraulic conductivity of the saturated zone to assess the aquifer's ability to laterally transport the infiltrated water.
- Impact of the infiltration rate and volume at the project site on groundwater mounding, flow direction, and water table; and the discharge point or area of the infiltrating water. A groundwater mounding analysis should be conducted at all sites where the depth to seasonal groundwater table or low permeability stratum is less than 15 feet and the runoff to the infiltration facility is from more than one acre. (The site professional may consider conducting an aquifer test, or slug test to aid in determining the type of groundwater mounding analysis necessary at the site)

  A detailed soils and hydrogeologic investigation should be conducted if potential pollutant impacts to groundwater are a concern, or if the applicant is proposing to infiltrate in areas underlain by till or other impermeable layers. (Suggested references: "Implementation Guidance for the Groundwater Quality Standards", Department of Ecology, publication 96-2, 2005).

2.2.8 Design Infiltration Rate Determination – Guidelines and Criteria

Infiltration rates can be determined using either a correlation to grain size distribution from soil samples, textural analysis, or by in-situ field measurements. Short-term infiltration rates up to 2.4 in/hr represent soils that typically have sufficient treatment properties. Long-term infiltration rates are used for sizing the infiltration pond based on maximum pond level and drawdown time. Long-term infiltration rates up to 2.0 inches per hour can also be considered for treatment if SSC-4 and SSC-6 are met, as defined in Section 2.2.10.

Historically, infiltration rates have been estimated from soil grain size distribution (gradation) data using the United States Department of Agriculture (USDA) textural analysis approach. To use the USDA textural analysis approach, the grain size distribution test must be conducted in accordance with the USDA test procedure (SOIL SURVEY MANUAL, U.S. Department of Agriculture, October 1993, page 136). This manual only considers soil passing the #10 sieve (2 mm) (U.S. Standard) to determine percentages of sand, silt, and clay for use in Figure III-2-5 (USDA Textural Triangle). However, many soil test laboratories use the ASTM soil size distribution test procedure (ASTM D422), which considers the full range of soil particle sizes, to develop soil size distribution curves. The ASTM soil gradation procedure must not be used with Figure III-2-5 to perform USDA soil textural analyses.

2.2.9 Three Methods for Determining Long-term Infiltration Rates for Sizing Infiltration Facilities

For designing the infiltration facility the site professional must select one of the three methods described below that will best represent the long-term infiltration rate at the site. The long-term infiltration rate should be used for routing and sizing the basin/trench for the maximum drawdown time of 48 hours. If the pilot infiltration test (Table III-2-9) or ASTM gradation approach (Table III-2-8) is selected corroboration with a textural based infiltration rate (Table III-2-7) is also desirable. Appropriate correction factors must be applied as specified. Verification testing of the completed facility is strongly encouraged and may be required by the City. (See Section 2.2.10.8 - Verification Testing)

1. USDA Soil Textural Classification

Table III-2-7 provides the correlation between USDA soil texture and infiltration rates for estimating infiltration rates for homogeneous soils based on gradations from soil samples and textural analysis. The USDA soil texture – infiltration rate correlation in Table III-2-7 is based on the correlation developed by Rawls, et al (1982), but with minor changes in the infiltration rates based on WEF/ASCE (1998). The infiltration rates provided through this correlation represent short-term conservative rates for homogeneous soils. These rates do not account for the effects of site variability, long-term clogging due to siltation and biomass buildup in the infiltration facility, or other processes that can decrease infiltration rates. Correction factors must be applied to these rates.

Table III-2-7. Recommended Infiltration Rates based on USDA Soil Textural Classification

	Short-Term Infiltration Rate (in/hr)[1]	**Correction Factor (CF)**	**Estimated Long-Term (Design) Infiltration Rate (in/hr)**
Clean, sandy gravels and gravelly sands (i.e., 90% of the total soil sample is retained in the #10 sieve)	20	2	10[2]
Sand	8	4	2[3]
Loamy sand	2	4	0.5
Sandy loam	1	4	0.25
Loam	0.5	4	0.13

[1] From WEF/ASCE, 1998
[2] Not recommended for treatment
[3] Refer to SSC-4 and SSC-6 for treatment acceptability criteria

Based on experience with long-term full-scale infiltration pond performance, Ecology's Technical Advisory Committee (TAC) recommends that the short-term infiltration rates be reduced as shown in Table III-2-7, dividing by a correction factor of 2 to 4, depending on the soil textural classification. The correction factors provided in Table III-2-7 represent an average degree of long-term facility maintenance, TSS reduction through pretreatment, and site variability in the subsurface conditions. These conditions might include deposits of ancient landslide debris, buried stream channels, lateral grain size variability, and other factors that affect homogeneity).

These correction factors could be reduced, subject to the approval of the local jurisdiction, under the following conditions:

For sites with little soil variability,

- Where there will be a high degree of long-term facility maintenance,
- Where specific, reliable pretreatment is employed to reduce TSS entering the infiltration facility

In no case shall a correction factor less than 2.0 be used.

Correction factors higher than those provided in Table III-2-7 should be considered for situations where long-term maintenance will be difficult to implement, where little or no pretreatment is anticipated, or where site conditions are highly variable or uncertain. These situations require the use of best professional judgment by the site engineer and the approval of the local jurisdiction. An Operation and Maintenance plan and a financial bonding plan may be required by the local jurisdiction.

2. ASTM Gradation Testing at Full Scale Infiltration Facilities

As an alternative to Table III-2-7, recent studies by Massmann and Butchart (2000) were used to develop the correlation provided in Table III-2-8. These studies compare infiltration measurements from full-scale infiltration facilities to soil gradation data developed using the ASTM procedure (ASTM D422). The primary source of the data used by Massmann and Butchart was from Wiltsie (1998), who included limited infiltration studies only on Thurston County sites. However, Massmann and Butchart also included limited data from King and Clark County sites in their analysis. This table provides recommended long-term infiltration rates that have been correlated to soil gradation parameters using the ASTM soil gradation procedure.

Table III-2-8 can be used to estimate long-term design infiltration rates directly from soil gradation data. The City may require additional correction factors be applied to the values shown in Table III-2-8 depending on the site conditions. As is true of Table III-2-7, the long-term rates provided in Table III-2-8 represent average conditions regarding site variability, the degree of long-term maintenance and pretreatment for TSS control, and represent a moderate depth to groundwater below the pond. The long-term infiltration rates in Table III-2-8 may need to be decreased if the site is highly variable, the groundwater table is shallow, there is fine layering present that would not be captured by the soil gradation testing, or if maintenance and influent characteristics are not well controlled. The data that forms the basis for Table III-2-8 was from soils that would be classified as sands or sandy gravels. No data was available for finer soils at the time the table was developed. Therefore, Table III-2-8 should not be used for soils with a D_{10} size (10% passing the size listed) less than 0.05 mm (U.S. Standard Sieve).

Table III-2-8. Alternative Recommended Infiltration Rates Based on ASTM Gradation Testing

D_{10} Size from ASTM D422 Soil Gradation Test (mm)	Estimated Long-Term (Design) Infiltration Rate (in/hr)
> 0.4	9[1]
0.3	6.5[1]
0.2	3.5[1]
0.1	2.0[2]
0.05	0.8

[1] Not recommended for treatment
[2] Refer to SSC-4 and SSC-6 for treatment acceptability criteria

The infiltration rates provided in Table III-2-7 and Table III-2-8 represent rates for homogeneous soil conditions. If more than one soil unit is encountered within 6 feet of the base of the facility or 2.5 times the proposed maximum water design depth, use the lowest infiltration rate determined from each of the soil units as the representative site infiltration rate.

If soil mottling, fine silt or clay layers, which cannot be fully represented in the soil gradation tests, are present below the bottom of the infiltration pond, the infiltration rates provided in the tables will be too high and should be reduced. Based on limited full-scale infiltration data (Massmann and Butchart, 2000; Wiltsie, 1998), it appears that the presence of mottling indicates soil conditions that reduce the infiltration rate for homogeneous conditions by a factor of 3 to 4.

3. In-situ Infiltration Measurements

Where feasible, Ecology encourages in-situ infiltration measurements, using a procedure such as the Pilot Infiltration Test (PIT) described in Volume III, Appendix B. Small-scale infiltration tests such as the EPA Falling Head or double ring infiltrometer test (ASTM D3385-88) are not recommended unless modified versions are approved in writing by The City. These small-scale infiltration tests tend to seriously overestimate infiltration rates and, based on recent Ecology experience, are considered unreliable.

The infiltration rate obtained from the PIT test shall be considered to be a short-term rate. This short-term rate must be reduced through correction factors to account for site variability and number of tests conducted, degree of long-term maintenance and influent pretreatment/control, and potential for long-term clogging due to siltation and bio-buildup.

The typical range of correction factors to account for these issues, based on Ecology experience, is summarized in Table III-2-9. The range of correction factors is for general guidance only. The specific correction factors used shall be determined based on the professional judgment of the licensed engineer or other soils professional considering all issues which may affect the long-term infiltration rate, subject to the approval of The City.

Table III-2-9. Correction Factors to be Used with In-Situ Infiltration Measurements to Estimate Long-Term Design Infiltration Rates

Issue	Partial Correction Factor
Site variability and number of locations tested	CF_y = 1.5 to 6
Degree of long-term maintenance to prevent siltation and bio-buildup	CF_m = 2 to 6
Degree of influent control to prevent siltation and bio-buildup	CF_i = 2 to 6

Total Correction Factor (CF) = $CF_y + CF_m + CF_i$

The following discussions are to provide assistance in determining the partial correction factors to apply in Table III-2-9.

Site variability and number of locations tested – The number of locations tested must be capable of producing a picture of the subsurface conditions that fully represents the conditions throughout the facility site. The partial correction factor used to compensate for site variability depends on the level of uncertainty that adverse subsurface conditions may occur. If the range of uncertainty is low - for example, conditions are known to be uniform through previous exploration and site geological factors - one pilot infiltration test may be adequate to justify a partial correction factor at the low end of the range. If the level of uncertainty is high, a partial correction factor near the high end of the range may be appropriate. This might be the case where the site conditions are highly variable due to a deposit of ancient landslide debris, or buried stream channels. In these cases, even with many explorations and several pilot infiltration tests, the level of uncertainty may still be high. A partial correction factor near the high end of the range could be assigned where conditions have a more typical variability, but few explorations and only one pilot infiltration test is conducted. That is, the number of explorations and tests conducted do not match the degree of site variability anticipated.

Degree of long-term maintenance to prevent siltation and bio-buildup – The standard of comparison here is the long-term maintenance requirements provided in Volume I, Appendix D, and any additional requirements by local jurisdictional authorities. Full compliance with these requirements would be justification to use a partial correction factor at the low end of the range. If there is a high degree of uncertainty that long-term maintenance will be carried out consistently, or if the maintenance plan is poorly defined, a partial correction factor near the high end of the range may be justified.

Degree of influent control to prevent siltation and bio-buildup – A partial correction factor near the high end of the range may be justified under the following circumstances:

- If the infiltration facility is located in a shady area where moss buildup or litter fall buildup from the surrounding vegetation is likely and cannot be easily controlled through long-term maintenance
- If there is minimal pre-treatment, and the influent is likely to contain moderately high TSS levels.
- If influent into the facility can be well controlled such that the planned long-term maintenance can easily control siltation and biomass buildup, then a partial correction factor near the low end of the range may be justified.

The determination of long-term design infiltration rates from in-situ infiltration test data involves a considerable amount of engineering judgment. Therefore, when reviewing or determining the final long-term design infiltration rate the results of both textural analyses and in-situ infiltration tests results will be considered when available and may be required by the City.

2.2.10 Site Suitability Criteria (SSC)

This section provides criteria that must be considered for siting infiltration systems. When a site investigation reveals that any of the applicable criteria cannot be met appropriate mitigation measures must be implemented so that the infiltration facility will not pose a threat to safety, health, and the environment.

For site selection and design decisions a geotechnical and hydrogeologic report should be prepared by a qualified engineer with geotechnical and hydrogeologic experience, or a licensed geologist, hydrogeologist, or engineering geologist. The design engineer may utilize a team of certified or registered professionals in soil science, hydrogeology, geology, and other related fields.

2.2.10.1 SSC-1 Setback Criteria

Setback requirements contained within this manual and other applicable setbacks include those contained within the uniform building code requirements, City of Auburn Zoning and Building Codes, County Health District requirements, Washington State Department of Health On-Site Sewage Systems Chapter 246-272A WAC, and other state regulations.

These additional setback requirements may be required as determined by the project engineer and/or the City.

- Drinking water wells, septic tanks or drainfields, and springs used for public drinking water supplies (DOH, Publication # 333-117, Chapter 246-272A WAC).
- Infiltration facilities upgradient of drinking water supplies and within 1, 5, and 10-year time of travel zones must comply with Health Dept. requirements (Washington Wellhead Protection Program, DOH, Publication #331-018).
- Additional setbacks must be considered if roadway deicers or herbicides are likely to be present in the influent to the infiltration system.
- Building foundations within 20 feet downslope and within100 feet upslope
- Native Growth Protection Easement (NGPE) within 20 feet
- From the top of slopes >20% and within 50 feet.
- Evaluate on-site and off-site structural stability due to extended subgrade saturation and/or head loading of the permeable layer, including the potential impacts to downgradient properties, especially on hills with known side-hill seeps.

2.2.10.2 SSC-2 Groundwater Protection Areas

A site is not suitable if the infiltration facility will cause a violation of Ecology's Groundwater Quality Standards (See SSC-9 for verification testing guidance).

2.2.10.3 SSC-3 High Vehicle Traffic Areas

An infiltration BMP may be considered for runoff from areas of industrial activity and the high vehicle traffic areas described below. For such applications sufficient pollutant removal (including oil removal) must be provided upstream of the infiltration facility to ensure that groundwater quality standards will not be violated and that the infiltration facility is not adversely affected.

High Vehicle Traffic Areas are:

- Commercial or industrial sites subject to an expected average daily traffic count (ADT) ≥100 vehicles/1,000 ft² gross building area (trip generation), and
- Road intersections with an ADT of ≥ 25,000 on the main roadway, or ≥ 15,000 on any intersecting roadway.

2.2.10.4 SSC-4 Drawdown Time

Infiltration facilities designed for flow control do not have a required drawdown time criteria.

2.2.10.5 SSC-5 Depth to Bedrock, Water Table, or Impermeable Layer

The base of all infiltration basins or trench systems shall be ≥ 5 feet above the seasonal high-water mark, bedrock (or hardpan) or other low permeability layer. A separation down to 3 feet may be considered if the groundwater mounding analysis, volumetric receptor capacity, and the design of the overflow and/or bypass structures are judged by the site professional and the City to be adequate to prevent overtopping and meet the site suitability criteria specified in this section.

2.2.10.6 SSC-6 Seepage Analysis and Control

Determine whether there would be any adverse effects caused by seepage zones on nearby building foundations, basements, roads, parking lots or sloping sites.

2.2.10.7 SSC-7 Cold Climate and Impact of Roadway Deicers

For cold climate design criteria (snowmelt/ice impacts) refer to D. Caraco and R. Claytor Design Supplement for Stormwater BMPs in Cold Climates, Center for Watershed Protection, 1997.

Potential impact of roadway deicers on potable water wells must be considered in the siting determination. Mitigation measures must be implemented if infiltration of roadway deicers can cause a violation of groundwater quality standards.

2.2.10.8 SSC-8 Verification Testing of the Completed Facility

Verification testing of the completed full-scale infiltration facility is recommended to confirm that the design infiltration parameters are adequate. The site professional should determine the duration and frequency of the verification testing program including the monitoring program for the potentially impacted groundwater. The groundwater monitoring wells installed during site characterization (See Section 2.2.7) may be used for this purpose. Long-term (more than two years) in-situ drawdown and confirmatory monitoring of the infiltration facility would be preferable (See King County reference). The City may require verification testing on a site-by-site basis.

2.2.11 Design Criteria for Infiltration Facilities

The design criteria for infiltration facilities shall be the same as for detention ponds described in Section 2.3.1.2 as applicable. All retention ponds shall be appropriately and aesthetically located, designed and planted. Pre-approval of the design concept, including landscaping, is required by the City for all proposed public ponds. The size of the infiltration facility can be determined by routing the influent runoff file generated by the continuous runoff model through it. The primary mode of discharge from an infiltration facility is infiltration into the ground. However, when the infiltration capacity of the facility is reached, additional runoff to the facility will cause the facility to overflow. Overflows from an infiltration facility must comply with the Minimum Requirement #7 for flow control in Volume I. Infiltration facilities used for runoff treatment must not overflow more than 9% of the influent runoff volume.

In order to determine compliance with the flow control requirements, the Western Washington Hydrology Model (WWHM) must be used.

(A) For 100% infiltration

Ensure that the pond infiltrates 100% using the pond bottom area only.

(B) For 91% infiltration (water quality treatment volume)

Ensure that the pond infiltrates 91% using the pond bottom area only.

Infiltration facilities for treatment can be located upstream or downstream of detention and can be off-line or on-line.

- ***On-line*** treatment facilities placed ***upstream or downstream*** of a detention facility must be sized to infiltrate 91% of the runoff volume directed to it.
- ***Off-line*** treatment facilities placed ***upstream*** of a detention facility must have a flow splitter designed to send all flows at or below the 15-minute water quality flow rate, as predicted by WWHM to the treatment facility. The treatment facility must be sized to infiltrate all the runoff sent to it (no overflows from the treatment facility are allowed).
- ***Off-line*** treatment facilities placed ***downstream*** of a detention facility must have a flow splitter designed to send all flows at or below the 2-year flow frequency from the detention pond, as predicted by WWHM to the treatment facility. The treatment facility must be sized to infiltrate all the runoff sent to it (no overflows from the treatment facility are allowed).

  See Volume V, Section 3.5.1 for flow splitter design details.

(C) To meet flow duration standard with infiltration ponds

This design will allow something less than 100% infiltration as long as any overflows will meet the flow duration standard. You would need a discharge structure with orifices and risers similar to a detention facility except that, in addition, you also have infiltration occurring from the pond.

Slope of the base of the infiltration facility must be $<$3 percent.

Spillways/overflow structures – A non-erodible outlet or spillway with a firmly established elevation must be constructed to discharge overflow. Ponding depth, drawdown time, and storage volume are calculated from that reference point.

For infiltration treatment facilities, side-wall seepage is not a concern if seepage occurs through the same stratum as the bottom of the facility. However, for engineered soils or for soils with very low permeability, the potential to bypass the treatment soil through the side-walls may be significant. In those cases, the side-walls must be lined, either with an impervious liner or with at least 18 inches of treatment soil, to prevent seepage of untreated flows through the side walls.

2.2.12 Construction Criteria

Initial basin excavation should be conducted to within 1-foot of the final elevation of the basin floor. Excavate infiltration trenches and basins to final grade only after all disturbed areas in the upgradient project drainage area have been permanently stabilized. The final phase of excavation should remove all accumulation of silt in the infiltration facility before putting it in service. After construction is completed, prevent sediment from entering the infiltration facility by first conveying the runoff water through an appropriate pretreatment system such as a pre-settling basin, wet pond, or sand filter.

Infiltration facilities should generally not be used as temporary sediment traps during construction. If an infiltration facility is to be used as a sediment trap, it must not be excavated to final grade until after the upgradient drainage area has been stabilized. Any accumulation of silt in the basin must be removed before putting it in service.

Traffic Control – Relatively light-tracked equipment is recommended for this operation to avoid compaction of the basin floor. The use of draglines and trackhoes should be considered for constructing infiltration basins. The infiltration area should be flagged or marked to keep heavy equipment away.

2.2.13 Maintenance Criteria

Provisions must be made for regular and perpetual maintenance of the infiltration basin/trench, including replacement and/or reconstruction of the any media that are relied upon for treatment purposes. Maintain when water remains in the basin or trench for more than 24 hours after the end of a rainfall event, or when overflows occur more frequently than planned. Off-line infiltration facilities should not overflow. Infiltration facilities designed to completely infiltrate all flows to meet flow control standards should not overflow. An Operation and Maintenance Plan, approved by the local jurisdiction, must ensure that the desired infiltration rate is maintained.

Adequate access for operation and maintenance must be included in the design of infiltration basins and trenches.

Removal of accumulated debris/sediment in the basin/trench should be conducted every 6 months or as needed to prevent clogging, or when water remains in the pond for greater than 24 hours after the end of a rainfall event.

For more detailed information on maintenance, see Volume I, Appendix D – Maintenance Standards for Drainage Facilities.

2.2.14 Verification of Performance

During the first 1-2 years of operation, verification testing (specified in SSC-9) is strongly recommended, along with a maintenance program that results in achieving expected performance levels. Operating and maintaining groundwater monitoring wells (specified in Section 2.2.10 - Site Suitability Criteria) is also strongly encouraged.

2.2.15 Infiltration Basins

This section covers design and maintenance criteria specific for infiltration basins. See schematic in Figure III-2-4.

Description

Infiltration basins are earthen impoundments used for the collection, temporary storage and infiltration of incoming stormwater runoff.

Design Criteria Specific for Basins

The finished floor elevation for buildings shall be a minimum of one foot (1') above the maximum high water elevation.

Access should be provided for vehicles to easily maintain the forebay (presettling basin) area and not disturb vegetation, or resuspend sediment any more than is absolutely necessary.

The slope of the basin bottom should not exceed 3% in any direction.

A minimum of one foot of freeboard is recommended when establishing the design ponded water depth. Freeboard is measured from the rim of the infiltration facility to the maximum ponding level or from the rim down to the overflow point if overflow or a spillway is included.

Erosion protection of inflow points to the basin must also be provided (e.g., riprap, flow spreaders, energy dissipators (See Volume III, Chapter 3). Select suitable vegetative materials for the basin floor and side slopes to be stabilized. Refer to Volume V, Chapter 7 for recommended vegetation.

Lining material – Basins can be open or covered with a 6 to 12-inch layer of filter material such as coarse sand, or a suitable filter fabric to help prevent the buildup of impervious deposits on the soil surface. A nonwoven geotextile should be selected that will function sufficiently without plugging (see geotextile specifications in Appendix C of Volume V). The filter layer can be replaced or cleaned when/if it becomes clogged.

Vegetation – The embankment, emergency spillways, spoil and borrow areas, and other disturbed areas should be stabilized and planted, preferably with grass, in accordance with Stormwater Site Plan (See Minimum Requirement #1 of Volume I). Without healthy vegetation the surface soil pores would quickly plug.

Refer to Section 2.3.1.2 for additional design criteria.

Maintenance Criteria for Basins

Maintain basin floor and side slopes to promote dense turf with extensive root growth. This enhances infiltration, prevents erosion and consequent sedimentation of the basin floor, and prevents invasive weed growth. Bare spots are to be immediately stabilized and revegetated.

Do not allow vegetation growth to exceed 18 inches in height. Mow the slopes periodically and check for clogging, and erosion. Remove all clippings.

Seed mixtures should be the same as those recommended in Table II-3-3 (Volume II, Chapter 3). The use of slow-growing, stoloniferous grasses will permit long intervals between mowing. Mowing twice a year is generally satisfactory. Fertilizers shall not be applied.

2.2.16 Infiltration Trenches

This section covers design, construction and maintenance criteria specific to infiltration trenches.

2.2.16.1 Description:

Infiltration trenches are generally at least 24 inches wide, and are backfilled with a coarse stone aggregate, allowing for temporary storage of stormwater runoff in the voids of the aggregate material. Stored runoff then gradually infiltrates into the surrounding soil. The surface of the trench can be covered with grating and/or consist of stone, gabion, sand, or a grassed covered area with a surface inlet. Perforated rigid pipe of at least 8-inch diameter can also be used to distribute the stormwater in a stone trench. Perforated pipes used in conjunction with infiltration systems shall be installed with the perforated holes facing downward toward the bottom of the trench.

2.2.16.2 Design Criteria

Due to accessibility and maintenance limitations, infiltration trenches must be carefully designed and constructed.

Infiltration systems shall be located outside of parking and driving areas, unless otherwise approved by the City.

Catch basins shall be provided on each end of the infiltration trench. Access to these catch basins is required for maintenance and operation. Infiltration trenches and galleries shall be designed such that no point in the facility is located more than fifty feet (50') from an access structure.

Backfill Material - The aggregate material for the infiltration trench shall consist of a clean aggregate with a maximum diameter of 3 inches and a minimum diameter of 1.5 inches. Void space for these aggregates shall be in the range of 30 to 40 percent.

Geotextile fabric liner - The aggregate fill material shall be completely encased in an engineering geotextile material. Geotextile should surround all of the aggregate fill material except for the top one-foot, which is placed over the geotextile. Geotextile fabric with acceptable properties must be carefully selected to avoid plugging (see Appendix C of Volume V).

The bottom sand or geotextile fabric is optional.

Refer to the Federal Highway Administration Manual "Geosynthetic Design and Construction Guidelines," Publication No. FHWA HI-95-038, May 1995 for design guidance on geotextiles in drainage applications. Refer to the NCHRP Report 367, "Long-Term Performance of Geosynthetics in Drainage Applications," 1994, for long-term performance data and background on the potential for geotextiles to clog, blind, or to allow piping to occur and how to design for these issues.

Overflow Channel - Because an infiltration trench is generally used for small drainage areas, an emergency spillway is not necessary. However, a non-erosive overflow channel leading to a stabilized watercourse should be provided.

Surface Cover - A stone filled trench can be placed under a porous or impervious surface cover to conserve space.

Observation Well - An observation well should be installed at the lower end of the infiltration trench to check water levels, drawdown time, sediment accumulation, and conduct water quality monitoring. Figure III-2-6 illustrates observation well details. It should consist of a perforated PVC pipe which is 4 to 6 inches in diameter and it should be constructed flush with the ground elevation. For larger trenches a 12-36 inch diameter well can be installed to facilitate maintenance operations such as pumping out the sediment. The top of the well should be capped to discourage vandalism and tampering.

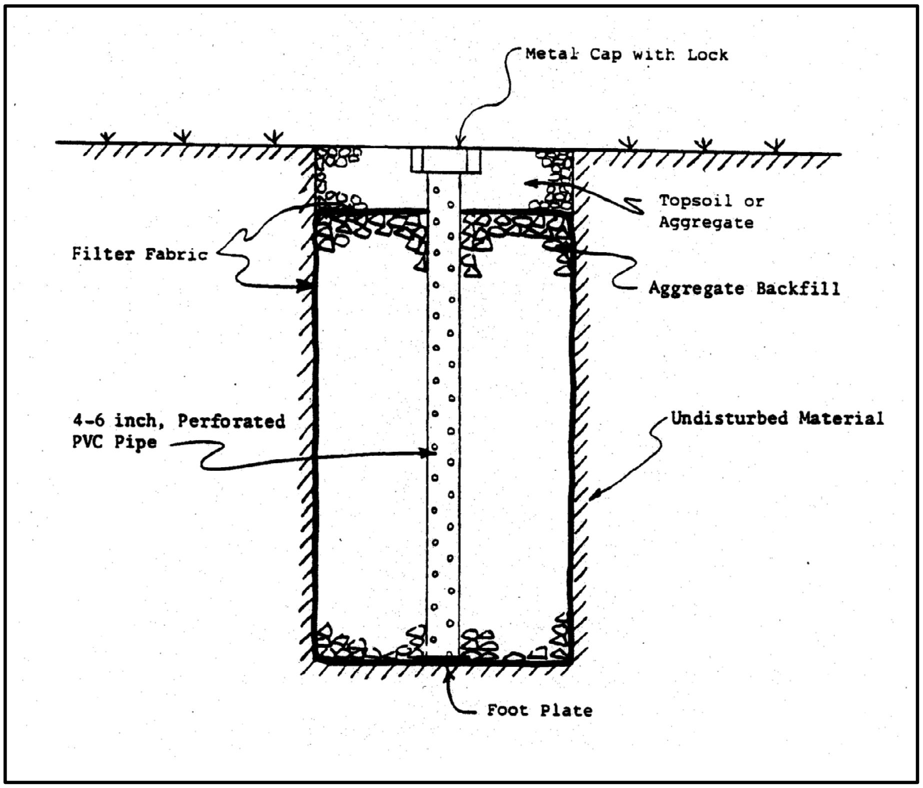


Figure III-2-6. Observation Well Details

2.2.16.3 Construction Criteria

Trench Preparation - Excavated materials must be placed away from the trench sides to enhance trench wall stability. Care should also be taken to keep this material away from slopes, neighboring property, sidewalks and streets. It is recommended that this material be covered with plastic. (see Volume II, Chapter 3, BMP C123: Plastic Covering).

Stone Aggregate Placement and Compaction - The stone aggregate should be placed in lifts and compacted using plate compactors. As a rule of thumb, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures geotextile conformity to the excavation sides, thereby reducing potential piping and geotextile clogging, and settlement problems.

Potential Contamination - Prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate shall be removed and replaced with uncontaminated stone aggregate.

Overlapping and Covering - Following the stone aggregate placement, the geotextile must be folded over the stone aggregate to form a 12 inch minimum longitudinal overlap. When overlaps are required between rolls, the upstream roll should overlap a minimum of 2 feet over the downstream roll in order to provide a shingled effect.

Voids behind Geotextile - Voids between the geotextile and excavation sides must be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Natural soils should be placed in these voids at the most convenient time during construction to ensure geotextile conformity to the excavation sides. Soil piping, geotextile clogging, and possible surface subsidence will be avoided by this remedial process.

Unstable Excavation Sites - Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft or cohesionless soils predominate. Trapezoidal, rather than rectangular, cross-sections may be needed.

2.2.16.4 Maintenance Criteria

Sediment buildup in the top foot of stone aggregate or the surface inlet should be monitored on the same schedule as the observation well.

2.3 Detention Facilities

This section presents the methods, criteria, and details for design and analysis of detention facilities. These facilities provide for the temporary storage of increased surface water runoff resulting from development pursuant to the performance standards set forth in Minimum Requirement #7 for flow control (Volume I). Storm detention systems shall be designed such that the storm drainage from public systems does not discharge into areas of private ownership or private maintenance responsibility.

There are three primary types of detention facilities described in this section: detention ponds, tanks, and vaults.

2.3.1 Detention Ponds

The design criteria in this section are for detention ponds. However, many of the criteria also apply to infiltration ponds (Volume III, Section 2.2 and Volume V), and water quality wetponds and combined detention/wetponds (Volume V). All detention ponds shall be appropriately and aesthetically located, designed and planted. Pre-approval of the design concept, including landscaping is required by the City for all proposed public ponds.

2.3.1.1 Dam Safety for Detention BMPs

Stormwater detention facilities that can impound 10 acre-feet (435,600 cubic feet; 3.26 million gallons) or more above normal, surrounding grade with the water level at the embankment crest are subject to Ecology's dam safety requirements, even if water storage is intermittent and infrequent (WAC 173-175-020). The principal safety concern is for the downstream population at risk if the dam should breach and allow an uncontrolled release of the pond contents. Peak flows from dam failures are typically much larger than the 100-year flows which these ponds are typically designed to accommodate. The Applicant shall contact Ecology's Dam Safety Engineers at Ecology Headquarters if any of these conditions are met.

2.3.1.2 Design Criteria

Standard details for detention ponds are provided in Figure III-2-7 through Figure III-2-10 and Table III-2-10. Control structure discussion and details are provided in Section 2.3.4.

General

- Ponds must be designed as flow-through systems (however, parking lot storage may utilize a back-up system; see Section 2.3.5). Developed flows must enter through a conveyance system separate from the control structure and outflow conveyance system. Maximizing distance between the inlet and outlet is encouraged to promote sedimentation.
- Pond bottoms shall be level and be located a minimum of 0.5 feet below the inlet and outlet to provide sediment storage.
- Design criteria for outflow control structures are specified in Section 2.3.4.
- A geotechnical analysis and report must be prepared for slopes 20% or greater, or if located within 200 feet of the top of a slope 20% or greater or landslide hazard area. The scope of the geotechnical report shall include the assessment of impoundment seepage on the stability of the natural slope where the facility will be located within the setback limits set forth in this section.
- Detention ponds should be designed using rounded shapes and variations in slopes to provide a more natural and aesthetically pleasing facility.
- The total maximum depth of the detention pond from the bottom to the emergency overflow water surface elevation shall be fifteen feet (15').

Side Slopes

- Interior side slopes above any wetpond surfaces, if present, shall not be steeper than 3H:1V unless an analysis is provided by a geotechnical engineer, demonstrating that steeper slopes will be stable. The analysis shall include, at a minimum, an assessment of the existing soil types, soil properties, groundwater conditions, potential for seepage, and stability of proposed slopes. The geotechnical analysis should also provide recommendations to ensure stability both during construction and in perpetuity.
- Exterior side slopes must not be steeper than 2H:1V unless analyzed for stability by a geotechnical engineer.
- A 10 foot level bench is required around the perimeter of the top of ponds to separate the pond facility from adjacent slopes.
- For maintenance and aesthetic reasons, pond designs should minimize structural elements such as retaining walls. For ponds where retaining walls are required, they should be limited to a maximum of three sides.
- Pond walls may be vertical retaining walls, provided:
  - They are constructed of minimum 3,000 psi structural reinforced concrete.
  - A fence is provided along the top of the wall.

- At least 25% of the pond perimeter shall be a vegetated soil slope not steeper than 3H:1V.
- Access for maintenance per this section shall be provided.
- The design is stamped by a licensed civil engineer with structural expertise.

Other retaining walls such as rockeries, concrete, masonry unit walls, and keystone type walls may be used if designed by a geotechnical engineer or civil engineer with structural expertise. If the entire pond perimeter is to be retaining walls, ladders shall be provided on the walls for safety reasons.

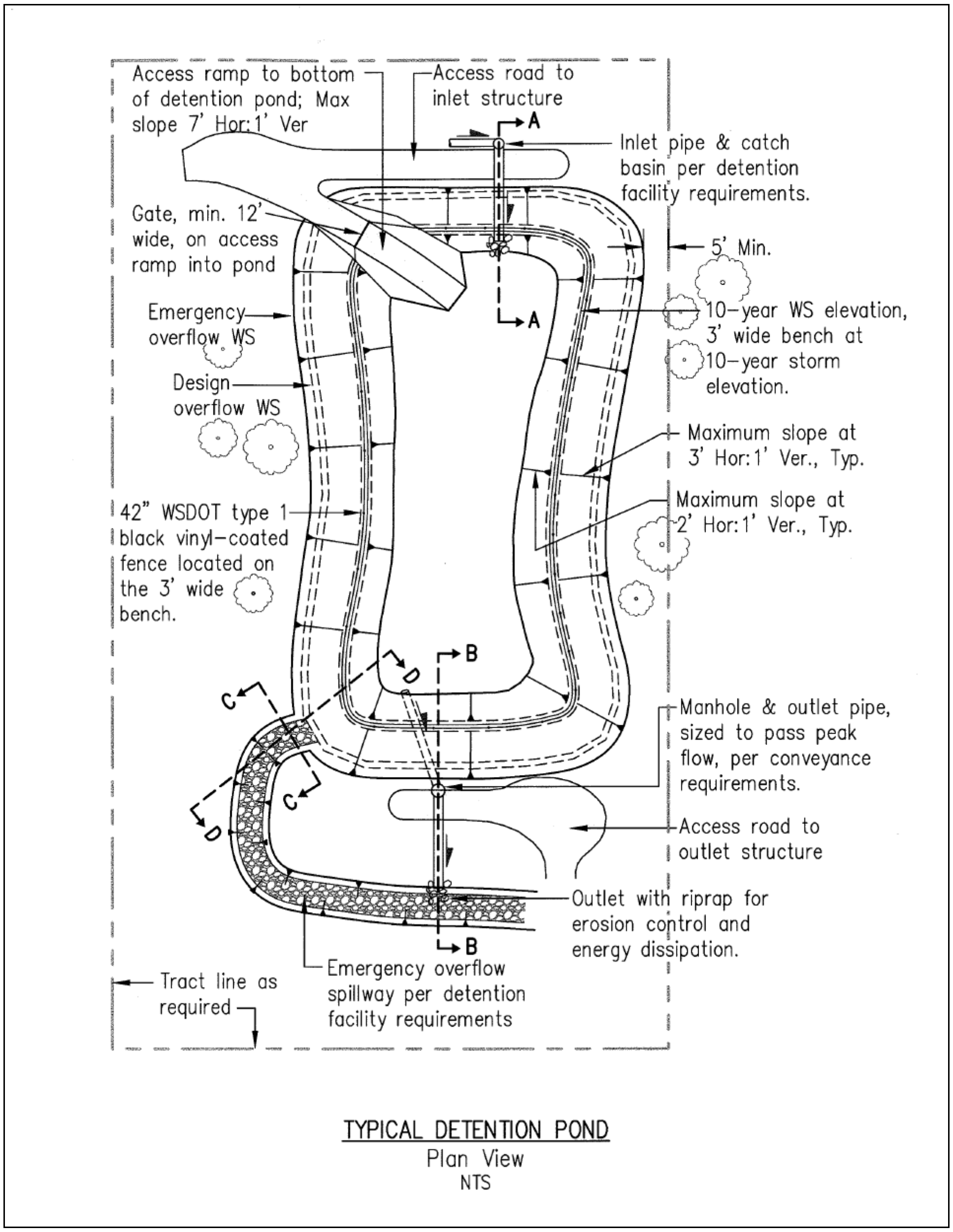


Figure III-2-7. Typical Detention Pond

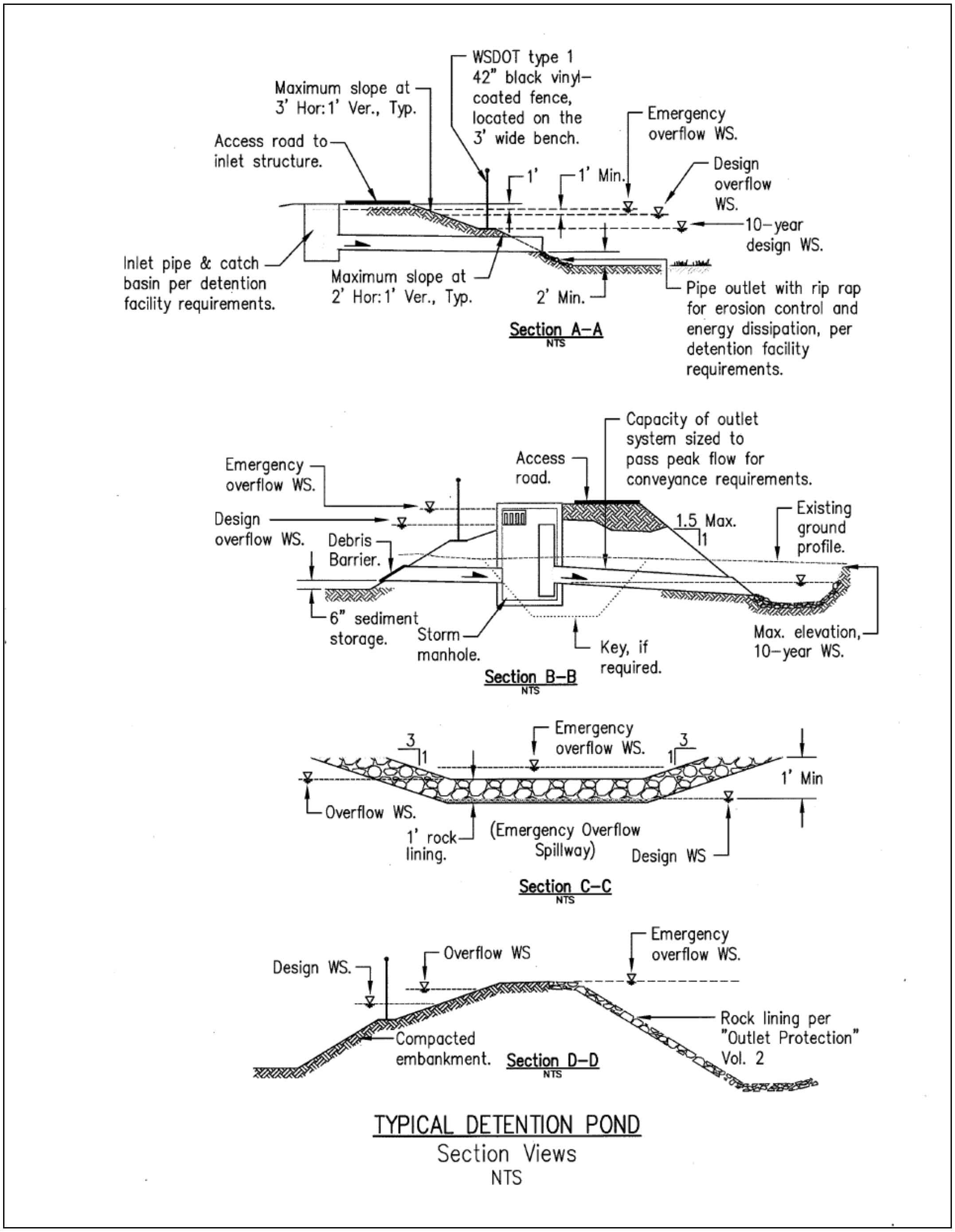
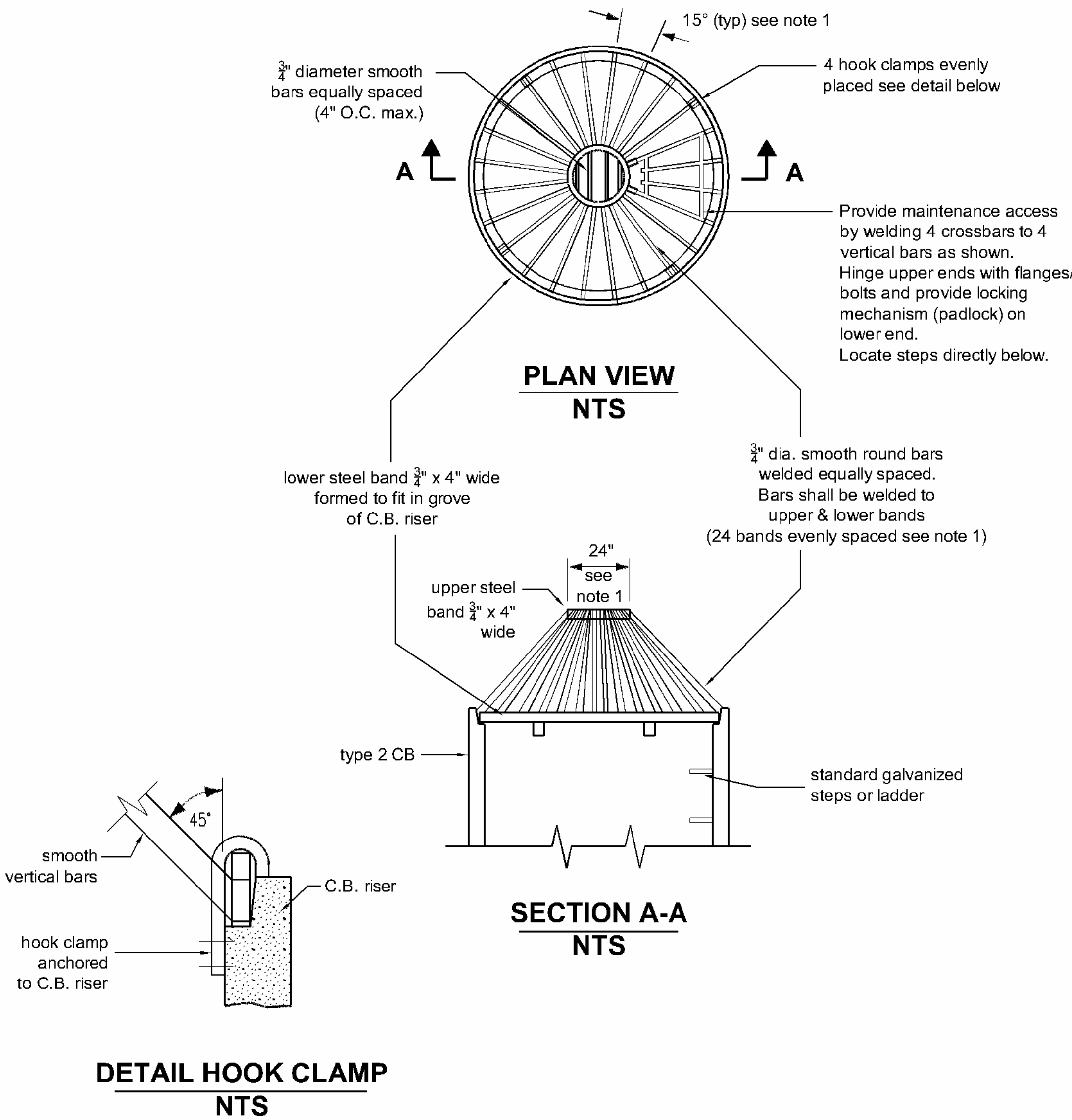


Figure III-2-8. Typical Detention Pond Sections



NOTES:

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

Figure III-2-9. Overflow Structure

Embankments

- Pond berm embankments higher than 6 feet must be designed by a professional engineer with geotechnical expertise.
- For berm embankments 6 feet or less in height, the minimum top width shall be 6 feet or as recommended by a geotechnical engineer.
- Pond berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical engineer) free of loose surface soil materials, roots, and other organic debris.
- Pond berm embankments greater than 4 feet in height must be constructed by excavating a key equal to 50 percent of the berm embankment cross-sectional height and width unless specified otherwise by a geotechnical engineer. Embankment compaction should be accomplished in such a manner as to produce a dense, low permeability engineered fill that can tolerate post-construction settlements with a minimum of cracking. The embankment fill shall be placed on a stable subgrade and compacted to a minimum of 95% of the Standard Proctor Maximum Density, ASTM Procedure D698. Placement moisture content should lie within 1% dry to 3% wet of the optimum moisture content.
- The berm embankment shall be constructed of soils with the following minimum characteristics per the United States Department of Agriculture's Textural Triangle: a minimum of 20% silt and clay, a maximum of 60% sand, a maximum of 60% silt, with nominal gravel and cobble content.
- Anti-seepage filter-drain diaphragms must be placed on outflow pipes in berm embankments impounding water with depths greater than 8 feet at the design water surface. See Dam Safety Guidelines, Part IV, Section 3.3.B. An electronic version of Dam Safety Guidelines is available in PDF format at www.ecy.wa.gov/programs/wr/dams/dss.html

Overflow

- In all ponds, tanks, and vaults, a primary overflow (usually a riser pipe within the control structure; see Section 2.3.4) shall be provided to bypass the 100-year developed peak flow over or around the restrictor system. The design must provide controlled discharge directly into the downstream conveyance system.
- A secondary inlet to the control structure shall be provided in ponds as additional protection against overtopping should the inlet pipe to the control structure become plugged. A grated opening ("jailhouse window") in the control structure manhole functions as a weir (see Figure III-2-8) when used as a secondary inlet.

  The maximum circumferential length of this opening must not exceed one-half the control structure circumference.

  The "birdcage" overflow structure as shown in Figure III-2-9 may also be used as a secondary inlet.

Emergency Overflow Spillway

- In addition to the above overflow provisions, ponds shall have an emergency overflow spillway. For impoundments of 10 acre-feet or greater, the emergency overflow spillway must meet the state's dam safety requirements (see above). For impoundments less than 10 acre-feet, ponds must have an emergency overflow spillway that is sized to pass the 100-year developed peak flow. Emergency overflow spillways shall control the location of pond overtopping such that flow is directed into the downstream conveyance system or public right of way.
- As an option for ponds with berms less than 2 feet in height and located at grades less than 5 percent, emergency overflow may be provided by an emergency overflow structure, such as a Type II manhole fitted with a birdcage as shown in Figure III-2-9. The emergency overflow structure must be designed to pass the 100-year developed peak flow, with a minimum of 6 inches of freeboard, directly to the downstream conveyance system or another acceptable discharge point.
- The emergency overflow spillway shall be armored with riprap in conformance with the "Outlet Protection" BMP in Volume II (BMP C209). The spillway must be armored full width, beginning at a point midway across the berm embankment and extending downstream to where emergency overflows re-enter the conveyance system (See Figure III-2-8).
- Emergency overflow spillway designs must be analyzed as broad-crested trapezoidal weirs as described in Methods of Analysis at the end of this section. Either one of the weir sections shown in Figure III-2-8 may be used.

Access

The following access shall be provided.

- Maintenance access road(s) shall be provided to the control structure and other drainage structures associated with the pond (e.g., inlet or bypass structures).
- An access ramp is required for pond cleaning and maintenance. The ramp must extend to the pond bottom with a maximum slope of 7H:1V (see access road criteria below).
- The internal berm of a wetpond or combined detention and wetpond may be used for access if it is designed to support a loaded 80,000 pound truck considering the berm is normally submerged and saturated.
- For combined detention and wetpond facilities, a 5 foot level bench area is required around the perimeter a minimum of 1 foot, but no more than 3 feet, above the wetpond surface elevation.
- Where a portion of the pond is constructed within a fill slope, an access road shall be provided adjacent to the detention pond along the entire length of the fill.
- Access roads/ramps must meet the following requirements:
    - o Access roads may be constructed with an asphalt or gravel surface, or modular grid pavement.

- Maximum grade shall be 7H:1V percent.
- Outside turning radius shall be a minimum of 50 feet.
- Fence gates shall be located only on straight sections of road.
- Access roads shall be 15 feet in width.
- A driveway meeting City design standards must be provided where access roads connect to paved public roadways.

- If a fence is required, access shall be limited by a double-posted gate. If a fence is not required, access shall be limited by two fixed bollards on each side of the access road and two removable bollards equally located between the fixed bollards.
- Additional easements or modification to proposed lot boundaries may be required to provide adequate access to detention facilities. Right-of-way may be needed for detention pond maintenance. Any tract not abutting public right-of-way shall have a 15-foot wide extension of the tract to an acceptable access location.

Fencing

- A fence is required when a pond interior side slope is steeper than 3H:1V, or when the wetpond depth is greater than 24 inches. Fencing is required for all vertical walls. Fencing is required if more than 10 percent of slopes are steeper 3H:1V.

  Also note that detention ponds on school sites shall comply with safety standards developed by the Department of Health (DOH) and the Superintendent for Public Instruction (SPI). These standards include what is called a 'non-climbable fence.'

- Fences shall be 42 inches in height (see WSDOT Standard Plan L-2, Type 1 chain link fence).
- Access gates shall be 16 feet in width consisting of two swinging sections 8 feet in width.
- Vertical metal balusters or 9 gauge galvanized steel fabric with bonded black vinyl coating shall be used as fence material with the following aesthetic features:
  - All posts, cross bars, and gates shall be painted or coated black.
  - Fence posts and rails shall conform to WSDOT Standard Plan L-2 for Types 1, 3, or 4 chain link fence.
- For metal baluster fences, Uniform Building Code standards apply.
- Wood fences may be used in residential areas where the fence will be maintained by homeowners associations or adjacent lot owners.
- Wood fences shall have pressure treated posts (ground contact rated) either set in 24-inch deep concrete footings or attached to footings by galvanized brackets. Rails and fence boards may be cedar, pressure-treated fir, or hemlock.

Signage

Detention ponds, infiltration ponds, wetponds, and combined ponds in residential subdivisions shall have a sign placed for maximum visibility from adjacent streets, sidewalks, and paths. An example and specifications for a permanent surface water control pond are provided in Figure III-2-10 and Table III-2-10.

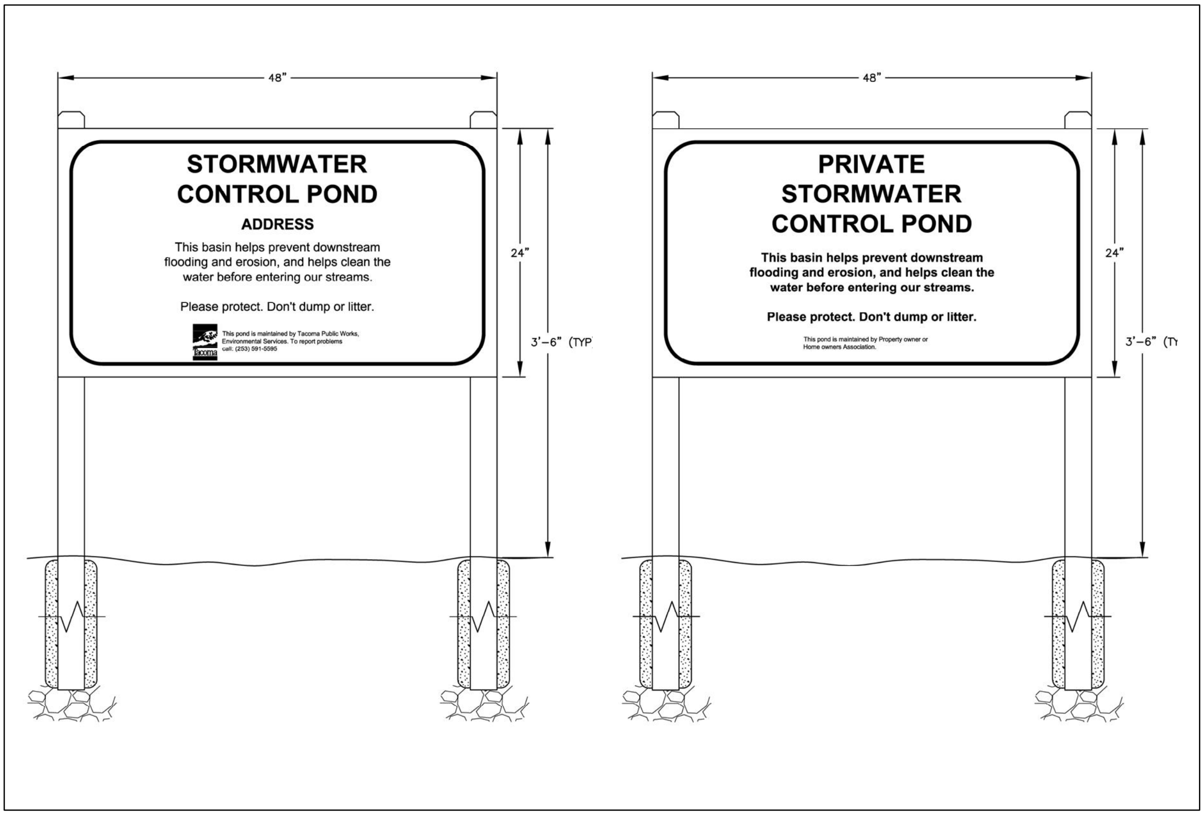


Figure III-2-10. Examples of Permanent Surface Water Control Pond Sign

Table III-2-10. Permanent Surface Water Control Pond Sign Specifications

Size	48 inches by 24 inches
Material	0.125 gauge aluminum
Face	Non-reflective vinyl or 3 coats outdoor enamel (sprayed)
Lettering	Silk-screen enamel where possible, or vinyl letters
Colors	Per City specifications where required
Type Face	Helvetica condensed. Title: 3 inch; Sub-Title: 1-1/2 inch; Text: 1 inch;
Border	Outer 1/8-inch border distance from edge: 1/4 inch All text shall be at least 1-3/4 inches from border.
Installation	Secure to chain link fence if available. Otherwise install on two posts as described below. Top of sign no higher than 42 inches from ground surface.

Posts	Pressure-treated 4" x 4"; beveled tops 1-1/2 inches higher than the top of the sign; mounted atop gravel bed, installed in 30-inch concrete-filled post holes (8-inch minimum diameter)
Placement	Face sign in direction of primary visual or physical access. Do not block any access road. Do not place within 6 feet of structural facilities (e.g. manholes, spillways, pipe inlets).
Special Notes	This facility is lined to protect groundwater (if a liner restricting infiltration of stormwater is used).

Setbacks

The City requires specific setbacks for sites with steep slopes, landslide areas, open water features, springs, wells, and septic tank drain fields. Adequate room for maintenance access and equipment shall also be considered. Project proponents should consult the Auburn City Codes to determine all applicable setback requirements. Where a conflict occurs between setbacks, the most stringent of the setback requirements applies.

Setbacks shall be as follows:

- Stormwater ponds shall be set back at least 100 feet from drinking water wells, septic tanks or drainfields, and springs used for public drinking water supplies.
- Infiltration facilities upgradient of drinking water supplies and within 1, 5, and 10-year time of travel zones must comply with Health Dept. requirements (Washington Wellhead Protection Program, DOH Publication # 331-018). Additional setbacks for infiltration facilities may be required per DOH publication #333-117, On-Site Sewage Systems Chapter 246-272A WAC.
- The 100-year water surface elevation shall be at least 10 feet from any structure or property line. If necessary, setbacks shall be increased from the minimum 10 feet in order to maintain a 1H:1V side slope for future excavation and maintenance. Vertical pond walls may necessitate an increase in setbacks.
- All pond systems shall be setback from sensitive areas, steep slopes, landslide hazard areas, and erosion hazard areas as governed by the Auburn City Code. Facilities near landslide hazard areas must be evaluated by a geotechnical engineer or qualified geologist. The discharge point shall not be placed on or above slopes 20% (5H:1V) or greater, or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and City approval.
- For sites with septic systems, ponds shall be downgradient of the drainfield unless the site topography clearly prohibits subsurface flows from intersecting the drainfield.

Seeps and Springs

Intermittent seeps along cut slopes are typically fed by a shallow groundwater source (interflow) flowing along a relatively impermeable soil stratum. These flows are storm driven. However, more continuous seeps and springs, which extend through longer dry periods, are likely from a deeper groundwater source. When continuous flows are intercepted and directed through flow control facilities, adjustments to the facility design shall be made to account for the additional base flow. Flow monitoring of intercepted flow may be required for design purposes.

Planting Requirements

Exposed earth on the pond bottom and interior side slopes shall be sodded or seeded with an appropriate seed mixture. All remaining areas of the tract shall be planted with grass or be landscaped and mulched with a 4-inch cover of hog fuel or shredded wood mulch. Shredded wood mulch is made from shredded tree trimmings, usually from trees cleared on site. The mulch should be free of garbage and weeds and should not contain excessive resin, tannin, or other material detrimental to plant growth. Multiple plantings and mulching may be required until vegetation has established itself. A bond may be required to guarantee vegetation stabilization for detention facilities.

Landscaping

Public and private storm drainage facilities should enhance natural appearances, protect significant cultural and natural resources, and be appropriate to the use of the site and the surrounding area. Landscaping shall be designed to screen the storm drainage facilities and create a natural-appearing setting while not adversely impacting the function and maintenance of the storm drainage facilities. A Landscape Plan with the Stormwater Site Plan is required for City review and approval.

Landscaping is required for all stormwater tract areas (see below for areas not to be landscaped). Landscaped stormwater tracts may, in some instances, provide a recreational space. In other instances, “naturalistic” stormwater facilities may be placed in open space tracts.

The following criteria shall be incorporated when designing landscaping for storm drainage facilities.

- Identify the type of landscaping and screening appropriate to the site taking into account zoning and proposed use. Landscaping and screening requirements are described in Auburn City Code (ACC) Title 18. The purpose of each type is to reflect the level of landscaping and screening density needed to maintain compatibility with the character of the neighborhood.
- An effort should be made to retain all significant trees on site, evergreens six inches (6”) or greater in diameter, or any deciduous tree four inches (4”) in diameter or greater as defined in ACC Title 18. Diameter measurements are taken at four feet (4’) above grade elevation. Authorization by the City is required for removal of any significant trees.
- Identify the soil type and hydrological regime or each portion of the storm drainage facility to determine appropriate site criteria for plant selection.
- Select tree and shrub species from the Plant Selection Guide contained herein. Plant choices must reflect the functional and aesthetic needs of the site. Fall planting is recommended for optimal acclimation and survivability. An irrigation system will be required for public ponds to insure plant establishment. Irrigation systems may also be needed for private ponds if plantings are done in the spring/summer or in times of limited precipitation, unless other watering provisions are established.
- Plant choices are not restricted to those listed in the Plant Selection Guide, but plant selection must be based on ease of maintenance, appropriateness to the use of the site (commercial, residential, or industrial), and survivability. Plant selection should correspond with street tree requirements and neighborhood character as appropriate. Selections are to be approved by the City during the review process. NOTE: Plants

identified in the Guide are predominately native and reflect the soil conditions and water regimes of the area.

- Develop a Landscape Plan to scale identifying the location and species of existing trees and the location and schedule of species, quantity and size of all proposed tree, shrubs, and ground covers. Drawings should be scaled at 1"=10' or 1"=20' to optimally relay information on the plant location and placement. Construction specifications should indicate appropriate soil amendments where necessary and planting specifications as recommended by the American Standards for Nursery Stock and the American National Standards Institute (ANSI).
- Excluding access points, a minimum of ten feet (10') width of Type-III landscaping in accordance with Auburn City Code 18.50 shall be provided around the exterior length of the pond. This width may be reduced to five feet (5') if the interior side slopes of the pond are landscaped.
- No tree and shrub planting is allowed with pipeline easements, traveled surfaces, or over underground utilities.
- No trees or shrubs shall be planted within 10 feet of inlet or outlet pipes or manmade drainage structures such as spillways or flow spreaders. Species with roots that seek water, such as willow or poplar, shall be avoided within 50 feet of pipes or manmade structures.
- Planting shall be restricted on berms that impound water either permanently or temporarily during storms. This restriction does not apply to cut slopes that form pond banks, only to berms.
    - Trees or shrubs may not be planted on portions of water-impounding berms taller than four feet high. Only grasses may be planted on berms taller than four feet.

      Grasses allow unobstructed visibility of berm slopes for detecting potential dam safety problems, such as animal burrows, slumping, or fractures in the berm.

    - Trees planted on portions of water-impounding berms less than 4 feet high must be small, not higher than 20 feet mature height, and must have a fibrous root system. Table III-2-11 gives some examples of trees with these characteristics developed for the Central Puget Sound.

  NOTE: The internal berm in a wetpond is not subject to this planting restriction since the failure of an internal berm would be unlikely to create a safety problem.

- All landscape material, including grass, shall be planted in topsoil. Native underlying soils may be made suitable for planting if amended with 4 inches of compost tilled into the subgrade. Compost used should meet specifications for Grade A compost quality. See http://www.ecy.wa.gov/programs/swfa/compost/
- For a naturalistic effect as well as ease of maintenance, trees of shrubs shall be planted in clumps to form "*landscape islands*" rather than planting evenly spaced.
- The landscaped islands shall be a minimum of six feet apart, and if set back from fences or other barriers, the setback distance should also be a minimum of 6 feet.

Where tree foliage extends low to the ground, the 6 feet setback should be counted from the outer drip line of the trees (estimated at maturity).

- This setback allows a 6-foot wide mower to pass around and between clumps.
- Evergreen trees and trees which produce relatively little leaf-fall (such as Oregon ash, mimosa, or locust) are preferred in areas draining to the pond.
- Trees should be set back so that branches do not extend over the pond (to prevent deposition of leaves into the pond).
- Drought tolerant species are recommended.

The following lists contain the suggested trees, plants and grasses to be used in landscaping storm drainage facilities. The trees and plants listed are native to the region and should be chosen over non-native species. The lists shown are not all-inclusive, additional trees and plants may be acceptable upon approval of the City.

Table III-2-11. Plant Selection Guide

Tree Selection Guide for Storm Drainage Detention/Retention Facilities				
Suggested Trees		Tolerates Wet to Saturated Soils	Recommend Moderately Wet to Dry Soils	Recommend Dry Soils
Botanical Name	**Common Name**			
Acer circinatum	Vine Maple			♦
Alnus rubra	Red Alder			♦
Betula papyrifera	Paper Birch	♦		
Corylus cornuta	Hazelnut			♦
Crataegus douglasii	Black Hawthorn			♦
Fraxinus latifolia	Oregon Ash	♦		
Picea sitchensis	Sitka Spruce	♦		
Pinus contorta	Shore Pine			♦
Pinus monticula	Western White Pine			♦
Populus tremuloides	Quaking Aspen	♦		
Prunus virginiana	Choke Cherry			♦
Pseudotsuga menziesii	Douglas Fir			♦
Salix lasiandra	Pacific Willow	♦		
Salix scouleriana	Scouler Willow		♦	
Salix sitchensis	Sitka Willow	♦		
Thuja pljcata	Western Red Cedar		♦	
Tsuga heterophylla	Western Hemlock			♦

Shrub Selection Guide for Storm Drainage Detention/Retention Facilities				
Suggested Shrubs		Tolerates Wet to Saturated Soils	Recommend Moderately Wet to Dry Soils	Recommend Dry Soils
Botanical Name	**Common Name**			
Amelanchier alnifolia	Serviceberry			♦
Cornus sericea	Red Osier Dogwood	♦		
Gaultheria shallon	Salal			♦
Holidiscus discolor	Ocean Spray			♦
Lonicera involucrata	Black Twinberry	♦		
Mahonia aquifolium	Tall Oregon Grape			♦
Mahonia repens	Low Oregon Grape			♦
Oemleria cerasiformis	Indian Plum			♦
Physocarpus capitatus	Pacific Ninebark	♦		
Ribes sanguineum	Red Flowering Currant			♦
Rosa nutkana	Nootka Rose		♦	
Rosa rugosa	Rugosa Rose	♦		
Rubus spectabilis	Salmonberry		♦	
Rubus spectabilis	Thimbleberry		♦	
Sambucus racemosa	Red Elderberry			♦
Symphoricarpos albus	Snowberry			♦
Vaccinium ovatum	Evergreen Huckleberry			♦
Vaccinium parviflorum	Red Huckleberry			♦

Perennial Groundcover Selection Guide for Storm Drainage Detention/Retention Facilities				
Suggested Perennial Groundcover		Tolerates Wet to Saturated Soils	Recommend Moderately Wet to Dry Soils	Recommend Dry Soils
Botanical Name	**Common Name**			
Athyrium filix-femina	Lady Fern		♦	
Dicentra formosa	Bleeding Heart			♦
Polystichum munitum	Sword Fern			♦

Aquatic/Emergent Wetland Selection Guide for Storm Drainage Detention/Retention Facilities		
Suggested Aquatics/Emergent Wetland Plants		Tolerates Open Water (3' + Depth) to Shallow Standing Water (<1' Depth)
Botanical Name	Common Name	
Potamogeton natans	Floating Pondweed	♦
Lotus conicalitatus	Birdsfoot Trefoil	♦
Nymphaea odorata	American Water Lily	♦
Lemna minor	Common Duckweed	♦
Polygonum punctatum	Dotted Smartweed	♦
Polygonum amphibium	Water Smartweed	♦
Oenanthe sarmentosa	Water Parsley	♦
Alisma plantago-aquitica	American Waterplantain	♦
Sparganium spp.	Bur-reed	♦
Sagittaria spp.	Arrowhead	♦
Scirpus acutus	Hardstem Bulrush	♦
Scirpus microcarpus	Small-fruited Bulrush	♦
Carex obnupta	Slough Sedge	♦
Carex languinosa	Wooly Sedge	♦
Eleocharis spp.	Spike Rush	♦
Carex spp.	Sedge	♦
Tolmiea menziesii	Piggy back plant	♦
Hordcum brachyantherum	Meadow Barley	♦

Grass Seed Mixes for Detention/Retention Facilities			
Moisture Condition By Weight	Species	Common Name	Percent
Very Moist	Agrosotis tenuis	Colonial Bentgrass	50
	Festuca ruba	Red Fescue	10
	Alopocuris pratensis	Meadow Foxtail	40
Moist	Festuca arundinacea	Meadow Fescue	70
	Agrosotis tenuis	Colonial Bentgrass	15
	Alopecurus pratensis	Meadow Foxtail	10
	Trifoluim hybridum	White Clover	5
Moist-Dry	Agrosotis tenuis	Colonial Bentgrass	10
	Festuca ruba	Red Fescue	40
	Lolium multiflorum	Annual Ryegrass	40
	Trifolium repens	White Clover	10

Application rates: Hydroseed @ 60 lbs/acre Handseed @ 2 lbs/1000 square feet

Maintenance

A maintenance plan shall be prepared for all surface water management facilities. See Volume I, Appendix D for specific maintenance requirements.

All private drainage systems serving multiple lots shall require a signed Stormwater Maintenance and Access agreement with the City. The agreement shall designate the systems to be maintained and the parties responsible for maintenance. Contact the City to determine the applicability of this requirement to a project.

Any standing water removed during the maintenance operation must be disposed of in a City approved manner. See the dewatering requirements in Volume II of this manual. *Pretreatment may be necessary.* Residuals must be disposed in accordance with state and local solid waste regulations (See Minimum Functional Standards for Solid Waste Handling, Chapter 173-304 WAC).

2.3.1.3 Methods of Analysis

Detention Volume and Outflow

The volume and outflow design for detention ponds must be in accordance with Minimum Requirements # 7 in Volume I and the hydrologic analysis and design methods in Chapter 1 of this Volume. Design guidelines for restrictor orifice structures are given in Section 2.3.4.

The design water surface elevation is the highest elevation which occurs in order to meet the required outflow performance for the pond.

Detention Ponds in Infiltrative Soils

Detention ponds may occasionally be sited on till soils that are sufficiently permeable for a properly functioning infiltration system (see Section 2.2). These detention ponds have a surface discharge and may also utilize infiltration as a second pond outflow. Detention ponds sized with infiltration as a second outflow must meet all the requirements of Section 2.2 for infiltration ponds, including a soils report, testing, groundwater protection, pre-settling, and construction techniques.

Emergency Overflow Spillway Capacity

For impoundments under 10-acre-feet, or ponds not subject to dam safety requirements, the emergency overflow spillway weir section must be designed to pass the 100-year runoff event for developed conditions assuming a broad-crested weir. The **broad-crested weir equation** for the spillway section in Figure III-2-11, for example, would be:

$$Q_{100} = C\,(2g)^{1/2}\left[\frac{2}{3}LH^{3/2} + \frac{8}{15}(\tan\theta)\,H^{5/2}\right] \qquad \text{(equation 1)}$$

Where Q_{100} = peak flow for the 100-year runoff event (cfs)
C = discharge coefficient (0.6)
g = gravity (32.2 ft/sec^2)
L = length of weir (ft)

H	=	height of water over weir (ft)
θ	=	angle of side slopes (degrees)

NOTE: Q100 is either the peak 10-minute flow computed from the 100-year, 24-hour storm and a Type 1A distribution, or the 100-year, 1-hour flow, indicated by an approved continuous runoff model, multiplied by a factor of 1.6

Assuming C = 0.6 and Tan θ = 3 (for 3:1 slopes), the equation becomes:

$$Q_{l00} = 3.21[LH^{3/2} + 2.4 H^{5/2}] \quad \text{(equation 2)}$$

To find width *L* for the weir section, the equation is rearranged to use the computed Q_{l00} and trial values of H (0.2 feet minimum):

$$L = [Q_{l00}/(3.21H^{3/2})] - 2.4 H \text{ or 6 feet minimum} \quad \text{(equation 3)}$$

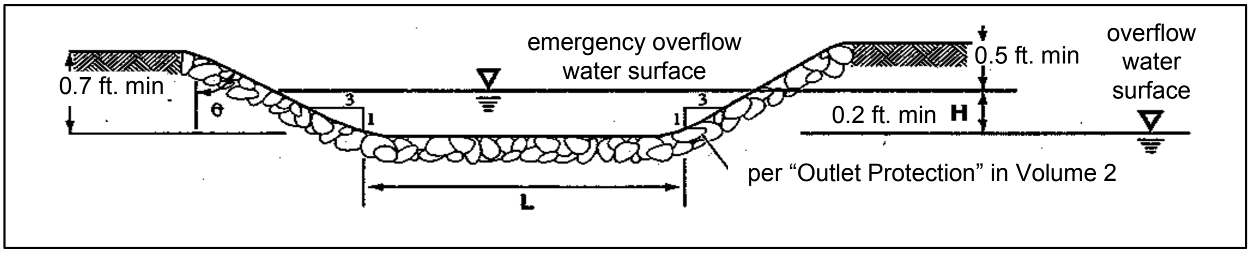


Figure III-2-11. Weir Section for Emergency Overflow Spillway

2.3.2 Detention Tanks

Detention tanks are underground storage facilities typically constructed with large diameter pipe. Standard detention tank details are shown in Figure III-2-12 and Figure III-2-13. Control structure details are shown in Section 2.3.4.

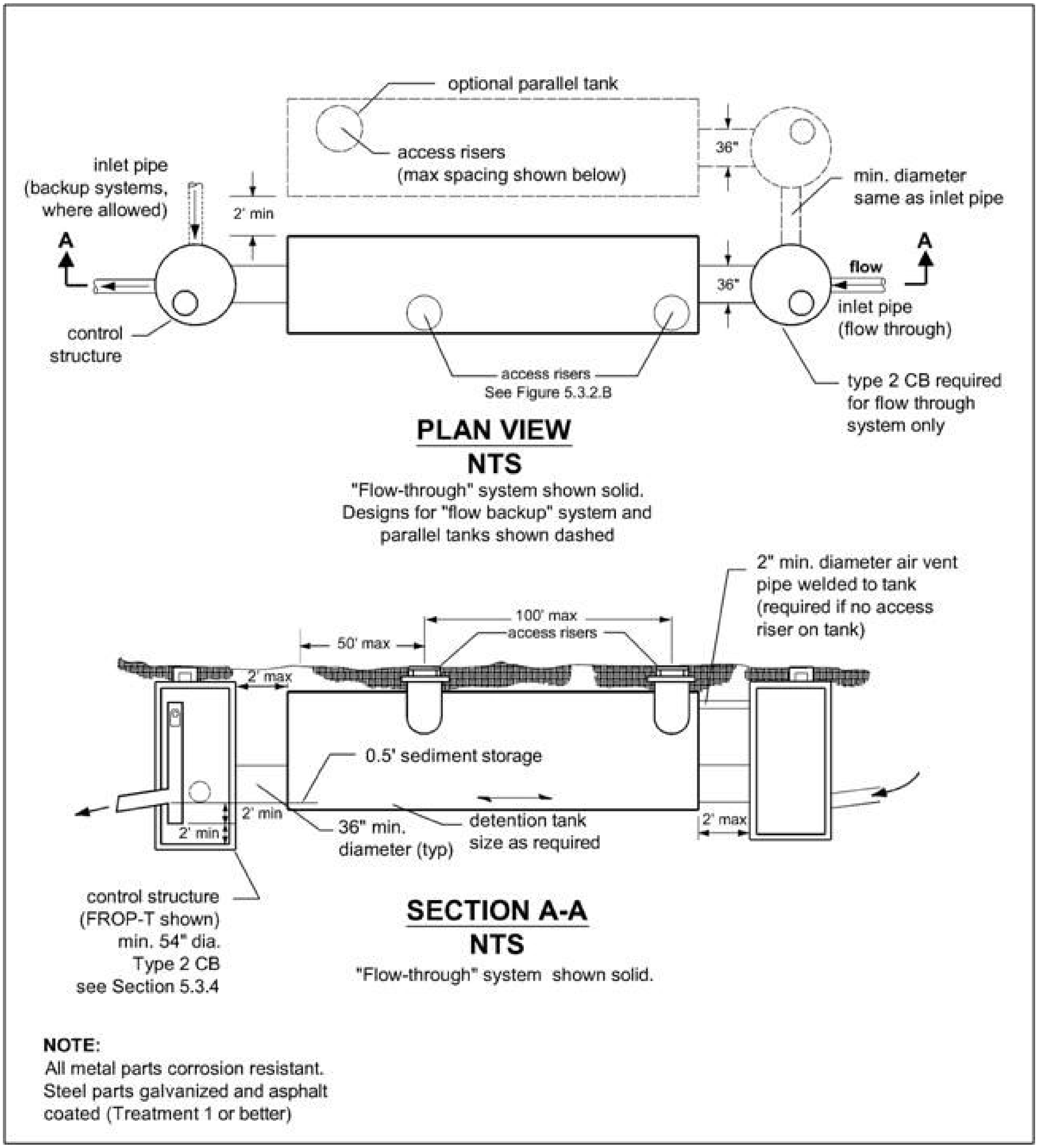
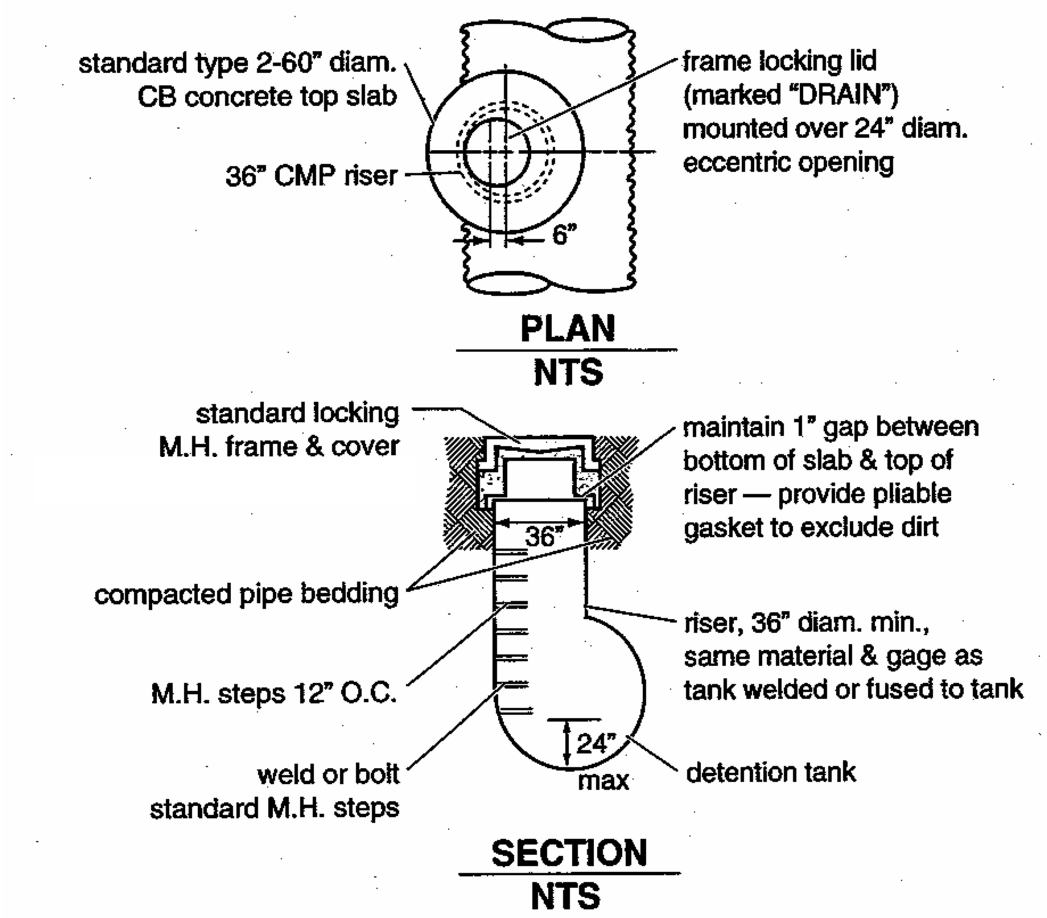


Figure III-2-12. Typical Detention Tank



Notes:

1. Use adjusting blocks as required to bring frame to grade.
2. All materials to be aluminum or galvanized and asphalt coated (Treatment 1 or better).
3. Must be located for access by maintenance vehicles.
4. May substitute WSDOT special Type IV manhole (RCP only).

Figure III-2-13. Detention Tank Access Detail

2.3.2.1 Design Criteria

General

- Tanks shall be designed as flow-through systems with manholes in line (see Figure III-2-12) to promote sediment removal and facilitate maintenance. Tanks shall also be designed to allow stormwater to back-up into the system if the tank is preceded by water quality facilities.
- The detention tank bottom shall be located 6 inches below the inlet and outlet to provide dead storage for sediment. If arch pipe is used, the minimum dead storage is 0.5 feet.
- The minimum pipe diameter for a detention tank is 36 inches.
- The minimum thickness for CMP shall be 12-gauge.
- Tanks larger than 36 inches may be connected to each adjoining structure with a short section (2-foot maximum length) of 35-inch minimum diameter pipe. These sections shall not be considered as access when determining required access points.
- Details of outflow control structures are given in Section 2.3.4.

Materials

See City of Auburn Construction Standards Section 9.05.

Structural Stability

Tanks must meet structural requirements for overburden support and traffic loading if appropriate. H-20 live loads shall be accommodated for tanks lying under parking areas and access roads. Metal tank end plates shall be designed for structural stability at maximum hydrostatic loading conditions. Tanks shall not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

Buoyancy

Buoyancy calculations shall be required where groundwater may induce flotation. Engineers are required to address this issue in project design documentation.

Access

The following requirements for access shall be met along with those stipulated in Section 2.3.1.

- The maximum depth from finished grade to tank invert shall be 20 feet.
- Access openings shall be positioned a maximum of 50 feet from any location within the tank. A minimum of one access opening per tank shall be provided.
- All tank access openings shall have round, solid locking lids (usually 1/2 to 5/8-inch diameter Allen-head cap screws).

- Thirty-six inch minimum diameter CMP riser-type manholes (see Figure III-2-13) of the same gauge as the tank material may be used for access along the length of the tank and at the upstream terminus of the tank in a backup system. The top slab is separated (1-inch minimum gap) from the top of the riser to allow for deflections from vehicle loadings without damaging the riser tank.
- All tank access openings must be readily accessible to maintenance vehicles.
- Tanks must comply with the OSHA confined space requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s) just under the access lid.

Access Roads

Access roads are needed to all detention tanks, control structures, and risers. The access roads must be designed and constructed as specified for detention ponds in Section 2.3.1.

Setbacks

For setback requirements see Section 2.3.1.

Maintenance

Provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Volume I, Appendix D for specific maintenance requirements.

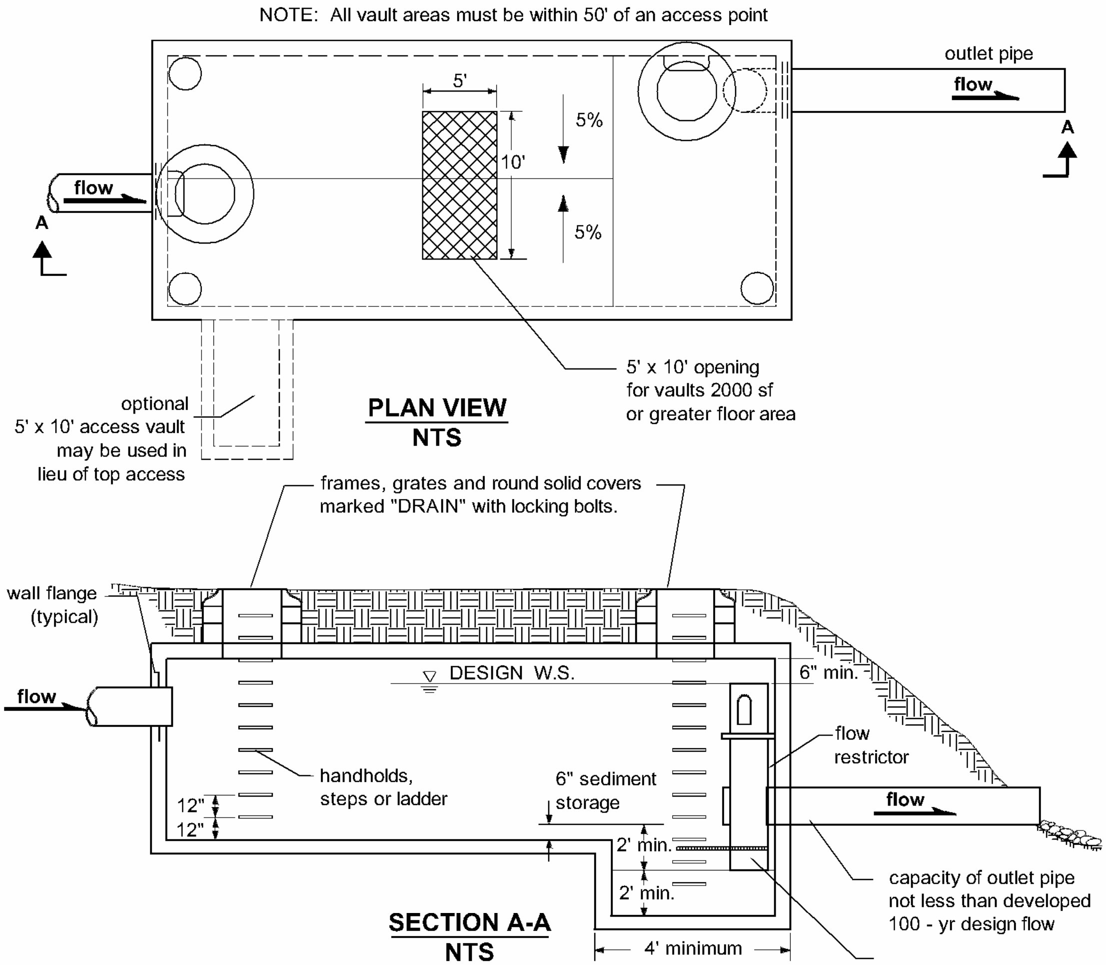
Methods of Analysis

Detention Volume and Outflow

The volume and outflow design for detention tanks must be in accordance with Minimum Requirement # 7 in Volume I and the hydrologic analysis and design methods in Volume III, Chapter 1. Restrictor and orifice design are given in Section 2.3.4.

2.3.3 Detention Vaults

Detention vaults are box-shaped underground storage facilities typically constructed with reinforced concrete. A standard detention vault detail is shown in Figure III-2-14. Control structure details are shown in Section 2.3.4. A detention vault may be used for commercial, industrial, or roadway projects when there are space limitations precluding the use of aboveground storage options. Vaults are box-shaped underground storage facilities typically constructed with reinforced concrete. The use of public vaults for residential development is discouraged. A design of a detention vault may be modified into a wetvault to provide stormwater quality (see Volume V 8.2.2)



NOTES:

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

Figure III-2-14. Typical Detention Vault

2.3.3.1 Design Criteria

General

- Detention vaults shall be designed as flow-through systems with bottoms level (longitudinally) or sloped toward the inlet to facilitate sediment removal. Distance between the inlet and outlet should be maximized (as feasible).
- The detention vault bottom shall slope at least 5 percent from each side towards the center, forming a broad “v” to facilitate sediment removal. More than one “v” may be used to minimize vault dept. The vault bottom may be flat with 0.5 – 1 foot of sediment storage if removable panels are provided over the entire vault. It is recommended that the removable panels be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.
- The invert elevation of the outlet shall be elevated above the bottom of the vault to provide an average 6 inches of sediment storage over the entire bottom. The outlet shall also be elevated a minimum of 2 feet above the orifice to retain oil within the vault.
- Details of outflow control structures are given in Section 2.3.4.

Buoyancy

A buoyancy analysis is required to demonstrate that the vault will not be impacted by ground water.

Materials

Minimum 3,000 psi structural reinforced concrete may be used for detention vaults. All construction joints must be provided with water stops.

Structural Stability

All vaults must meet structural requirements for overburden support and H-20 traffic loading (See Standard Specifications for Highway Bridges, 1998 Interim Revisions, American Association of State Highway and Transportation Officials). Vaults located under roadways must meet live load requirements of the City. Cast-in-place wall sections must be designed as retaining walls. Structural designs for cast-in-place vaults must be stamped by a licensed civil engineer with structural expertise. Vaults must be placed on stable, well-consolidated native material with suitable bedding. Vaults must not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

Access

Access must be provided over the inlet pipe and outlet structure. The following guidelines for access shall be used.

- Access openings shall be positioned a maximum of 50 feet from any location within the vault. Additional access points may be needed on large vaults.
- An access opening shall be provided directly above the lowest point of each “v” in the vault floor.

- An access opening shall be provided directly above each connection to the vault.
- For vaults with greater than 1,250 square feet of floor area, a 5' x 10' removable panel should be provided over the inlet pipe (instead of a standard frame, grate and solid cover). Alternatively, a separate access vault may be provided, as shown in Figure III-2-14.
- For vaults under roadways, the removable panel must be located outside the travel lanes. Alternatively, multiple standard locking manhole covers may be provided.
- Ladders and hand-holds shall be provided at all access openings, and as needed to meet OSHA confined space requirements.
- All access openings, except those covered by removable panels, may have round, solid locking lids, or 3-foot square, locking diamond plate covers.
- Vaults with widths 10 feet or less must have removable lids.
- The maximum depth from finished grade to the vault invert shall be 15 feet.
- Internal structural walls of large vaults should be provided with openings sufficient for maintenance access between cells. The openings should be sized and situated to allow access to the maintenance "v" in the fault floor.
- A minimum of two access openings shall be provided into each cell.
- The minimum internal height shall be 7 feet from the highest point of the vault floor (not sump), and the minimum width shall be 4 feet. However, concrete vaults may be a minimum 3 feet in height and width if used as a tank with access manholes at each end, and if the width is no larger than the height. Also the minimum internal height requirement may not be needed for any areas covered by removable panels.
- Vaults must comply with the OSHA confined space requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.
- Ventilation pipes (minimum 12-inch diameter or equivalent) shall be provided in all four corners of vaults to allow for artificial ventilation prior to entry of maintenance personnel into the vault. Alternatively, removable panels over the entire vault, or manhole access at 12-foot spacing, may be provided.

Access Roads

Access shall be designed and constructed as specified for detention ponds in Section 2.3.1.

Setbacks

For setback requirements see Section 2.3.1.

Maintenance

Provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Volume I, Appendix D for specific maintenance requirements.

2.3.3.2 Methods of Analysis

Detention Volume and Outflow

The volume and outflow design for detention vaults must be in accordance with Minimum Requirement # 7 in Volume I and the hydrologic analysis and design methods in Chapter 1. Restrictor and orifice design are given in Section 2.3.4.

2.3.4 Control Structures

Control structures are catch basins or manholes with a restrictor device for controlling outflow from a facility to meet the desired performance.

The restrictor device usually consists of two or more orifices and/or a weir section sized to meet performance requirements. Standard control structure details are shown in Figure III-2-15 through Figure III-2-17.

2.3.4.1 Design Criteria

Multiple Orifice Restrictor

In most cases, control structures need only two orifices: one at the bottom and one near the top of the riser, although additional orifices may best utilize detention storage volume. Several orifices may be located at the same elevation if necessary to meet performance requirements.

- Minimum orifice diameter is 0.5 inches. In some instances, a 0.5-inch bottom orifice will be too large to meet target release rates, even with minimal head. In these cases, do not reduce the live storage depth to less than 3 feet in an attempt to meet the performance standards. Under such circumstances, flow-throttling devices may be a feasible option. These devices will throttle flows while maintaining a plug-resistant opening.
- Orifices may be constructed on a tee section as shown in Figure III-2-15 or on a baffle as shown in Figure III-2-16.
- In some cases, performance requirements may require the top orifice/elbow to be located too high on the riser to be physically constructed (e.g. a 13-inch diameter orifice positioned 0.5 feet from the top of the riser). In these cases, a notch weir in the riser pipe may be used to meet performance requirements (see Figure III-2-17).
- Backwater effects from water surface elevations in the conveyance system shall be evaluated. High tailwater elevations may affect performance of the restrictor system and reduce live storage volumes. Backwater effects shall also be analyzed for areas that are influenced by tides.

Riser and Weir Restrictor

- Properly designed weirs may be used as flow restrictors (see Figure III-2-17 and Figure III-2-19 through Figure III-2-21). However, they must be designed to provide for primary overflow of the developed 100-year peak flow discharging to the detention facility.

- The combined orifice and riser (or weir) overflow may be used to meet performance requirements. However, the design must still provide for primary overflow of the developed 100-year peak flow assuming all orifices are plugged. Figure III-2-22 can be used to calculate the head in feet above a riser of given diameter and flow.

Access

The following guidelines for access shall be used.

- An access road to the control structure is needed for inspection and maintenance, and must be designed and constructed as specified for detention ponds in Section 2.3.1.
- Manhole and catch basin lids for control structures must be locking, and rim elevations must match proposed finish grade.
- Manholes and catch basins must meet the OSHA confined space requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser, just under the access lid.

Information Plate

A brass or stainless steel plate shall be permanently attached inside each control structure with the following information engraved on the plate:

- Name and file number of project
- Name and company of (1) developer, (2) engineer, and (3) contractor
- Date constructed
- Date of manual used for design
- Outflow performance criteria
- Release mechanism size, type, and invert elevation
- List of stage, discharge, and volume at one-foot increments
- Elevation of overflow
- Recommended frequency of maintenance.

2.3.4.2 Maintenance

Control structures require regular maintenance and cleaning. Maintenance frequency and procedures shall be addressed in the facility maintenance manual.

Volume I, Appendix D provides maintenance recommendations for control structures and catch basins.

2.3.4.3 Methods of Analysis

This section presents the methods and equations for design of **control structure restrictor devices.** Included are details for the design of orifices, rectangular sharp-crested weirs, v-notch weirs, sutro weirs, and overflow risers.

Orifices

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

$$Q = C\,A\sqrt{2gh} \qquad \text{(equation 4)}$$

where Q = flow (cfs)
C = coefficient of discharge (0.62 for plate orifice)
A = area of orifice (ft^2)
h = hydraulic head (ft)
g = gravity (32.2 ft/sec^2)

Figure III-2-18 illustrates this simplified application of the orifice equation.

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

$$d = \sqrt{\frac{36.88Q}{\sqrt{h}}} \qquad \text{(equation 5)}$$

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

Rectangular Sharp-Crested Weir

The rectangular sharp-crested weir design shown in Figure III-2-19 may be analyzed using standard weir equations for the fully contracted condition.

$$Q = C\,(L - 0.2H)H^{3/2} \qquad \text{(equation 6)}$$

where Q = flow (cfs)
C = 3.27 + 0.40 H/P (ft)
H, P = as shown in Figure III-2-19
L = length (ft) of the portion of the riser circumference as necessary not to exceed 50 percent of the circumference
D = inside riser diameter (ft)

NOTE: This equation accounts for side contractions by subtracting 0.1H from L for each side of the notch weir.

V-Notch Sharp - Crested Weir

V-notch weirs as shown in Figure III-2-20 may be analyzed using standard equations for the fully contracted condition.

Proportional or Sutro Weir

Sutro weirs are designed so that the discharge is proportional to the total head. This design may be useful in some cases to meet performance requirements.

The sutro weir consists of a rectangular section joined to a curved portion that provides proportionality for all heads above the line A-B (see Figure III-2-21). The weir may be symmetrical or non-symmetrical.

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

$$\frac{x}{b} = 1 - \frac{2}{\pi} Tan^{-1}\sqrt{\frac{Z}{a}} \qquad \text{(equation 7)}$$

Where a, b, x and Z are as shown in Figure III-2-14.

The head-discharge relationship is:

$$Q = C_d \, b \sqrt{2ga}\,(h_1 - \frac{a}{3}) \qquad \text{(equation 8)}$$

where Q = flow (cfs)
g = gravity

Values of *Cd* for both symmetrical and non-symmetrical sutro weirs are summarized in Table III-2-12.

When b > 1.50 or a > 0.30, use Cd=0.6.

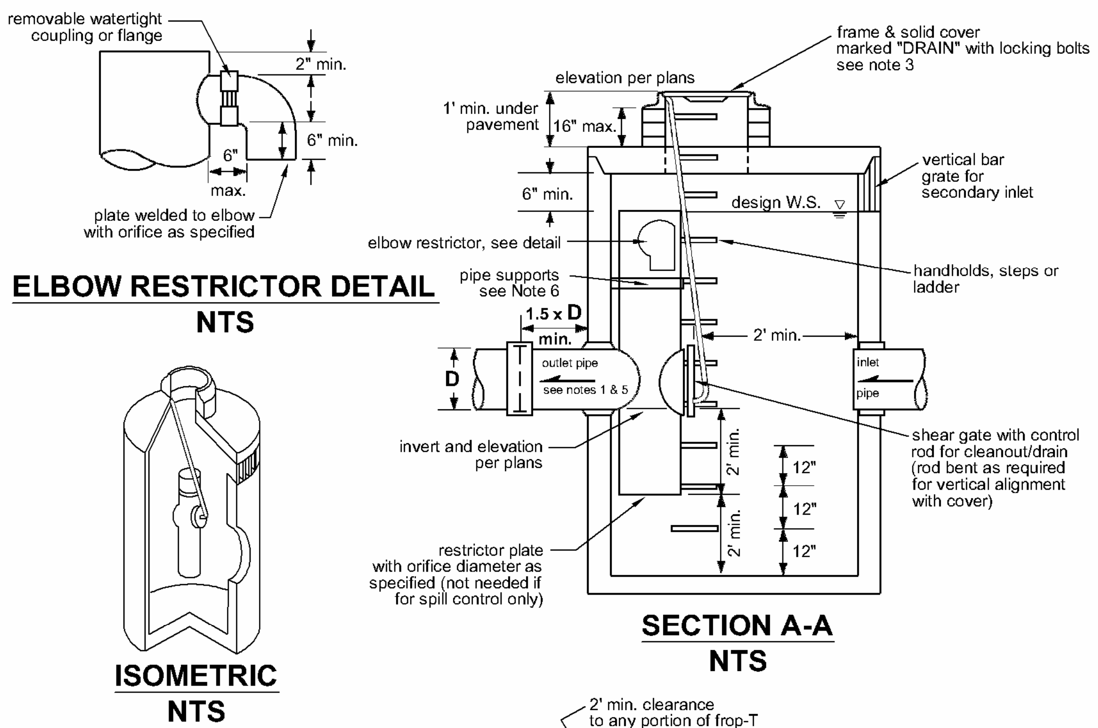
Riser Overflow

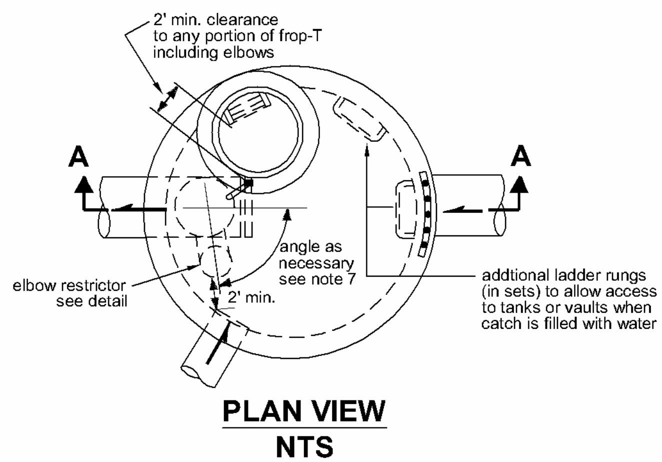
The nomograph in Figure III-2-22 can be used to determine the head (in feet) above a riser of given diameter and for a given flow (usually the 100-year peak flow for developed conditions).

NOTE: Q100 is either the peak 10-minute flow computed from the 100-year, 24-hour storm and a Type 1A distribution, or the 100-year, 1-hour flow, indicated by an approved continuous runoff model, multiplied by a factor of 1.6

Table III-2-12. Values of Cd for Sutro Weirs

C_d Values, Symmetrical					
a (ft)	**b (ft)**				
	0.50	**0.75**	**1.0**	**1.25**	**1.50**
0.02	0.608	0.613	0.617	0.6185	0.619
0.05	0.606	0.611	0.615	0.617	0.6175
0.10	0.603	0.608	0.612	0.6135	0.614
0.15	0.601	0.6055	0.610	0.6115	0.612
0.20	0.599	0.604	0.608	0.6095	0.610
0.25	0.598	0.6025	0.6065	0.608	0.6085
0.30	0.597	0.602	0.606	0.6075	0.608
C_d Values, Non-Symmetrical					
a (ft)	**b (ft)**				
	0.50	**0.75**	**1.0**	**1.25**	**1.50**
0.02	0.614	0.619	0.623	0.6245	0.625
0.05	0.612	0.617	0.621	0.623	0.6235
0.10	0.609	0.614	0.618	0.6195	0.620
0.15	0.607	0.6115	0.616	0.6175	0.618
0.20	0.605	0.610	0.614	0.6155	0.616
0.25	0.604	0.6085	0.6125	0.614	0.6145
0.30	0.603	0.608	0.612	0.6135	0.614





NOTES:

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

Figure III-2-15. Flow Restrictor (TEE)

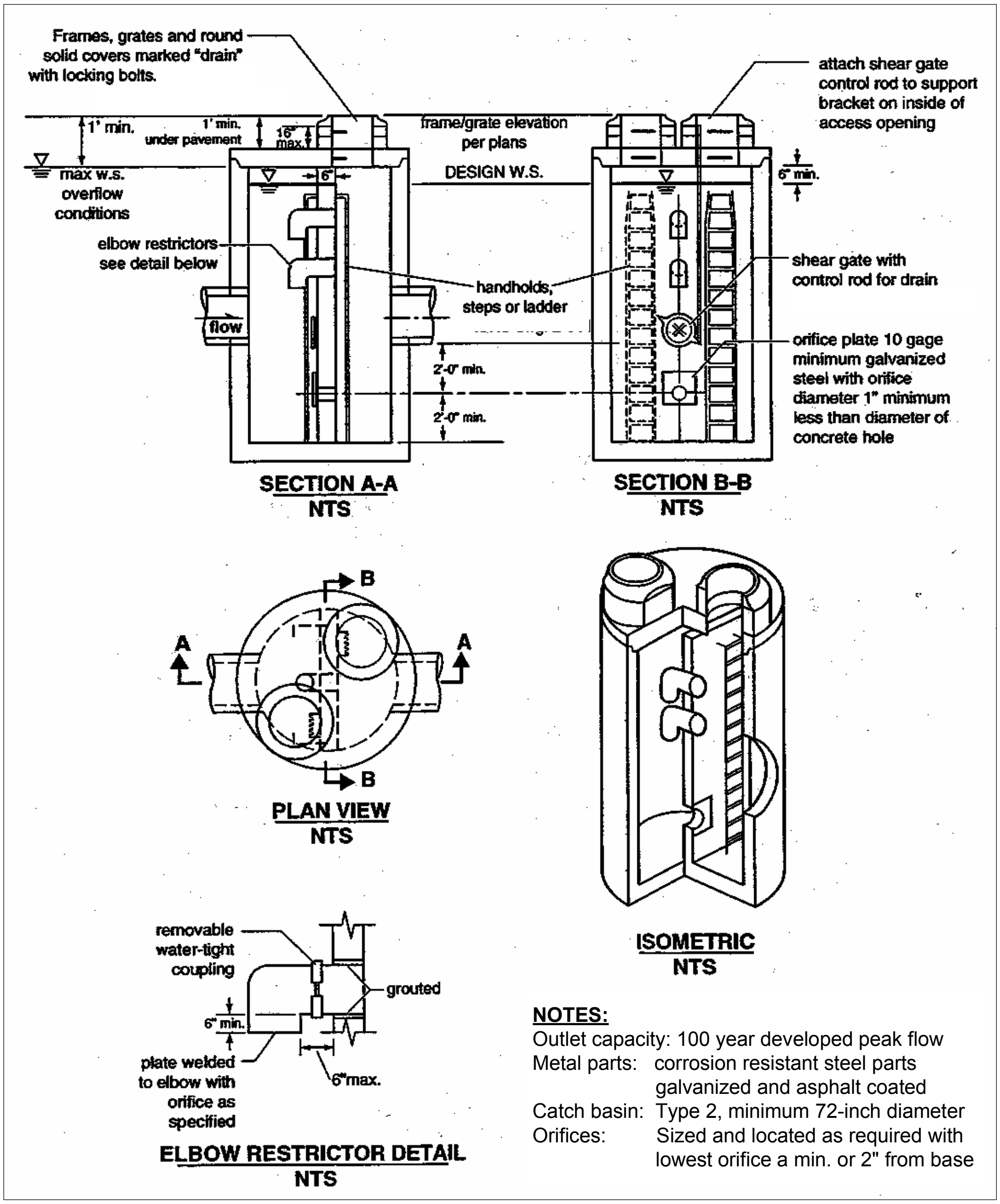
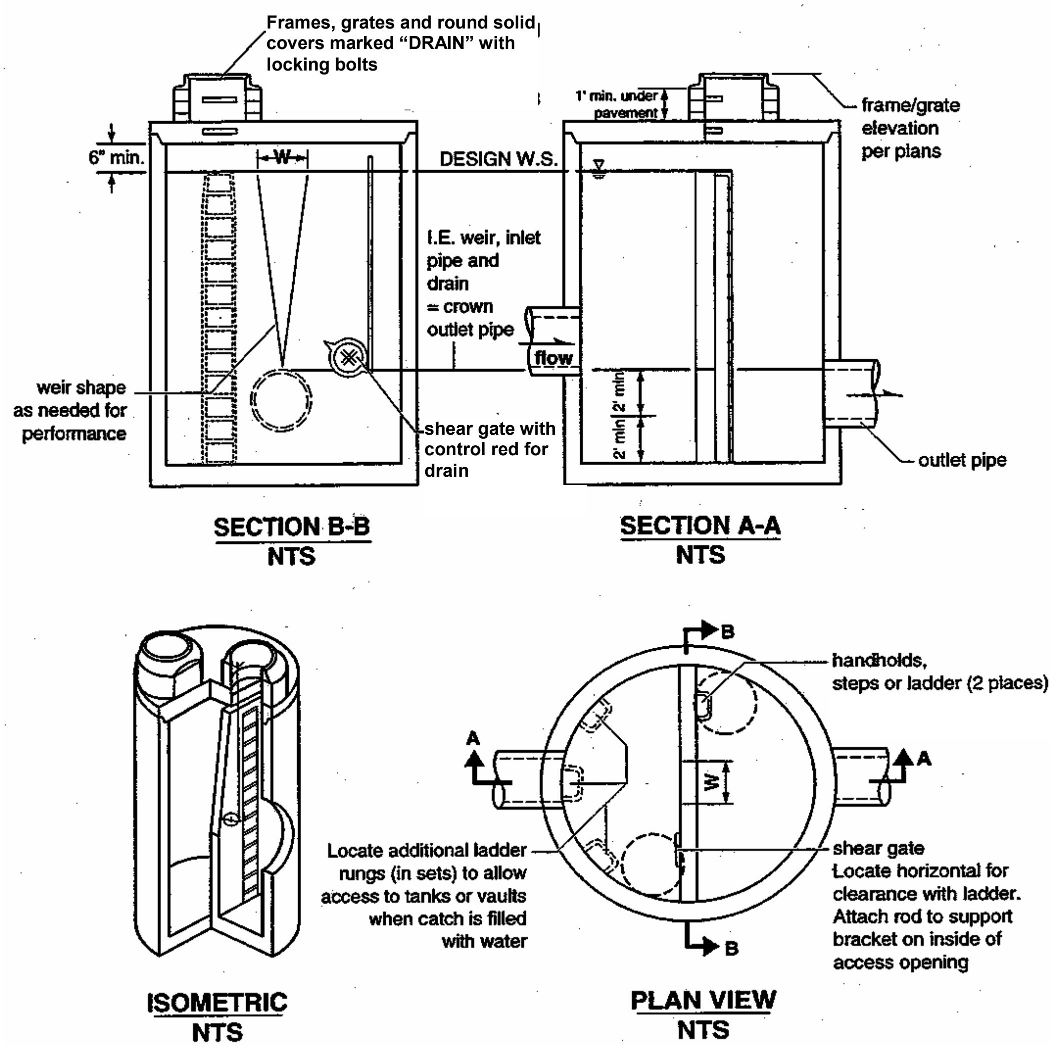


Figure III-2-16. Flow Restrictor (Baffle)



NOTES:
Outlet Capacity: 100-year developed peak flow.
Metal Parts: corrosion resistant steel parts galvanized and asphalt coated.
Catch Basin: type 2 Min. 72" diameter

Baffle Wall: to be designed with concrete reinforcing as required.
Spill containment must be provided to temporarily detain oil or floatable pollutants in runoff due to accidental spill

Figure III-2-17. Flow Restrictor (Weir)

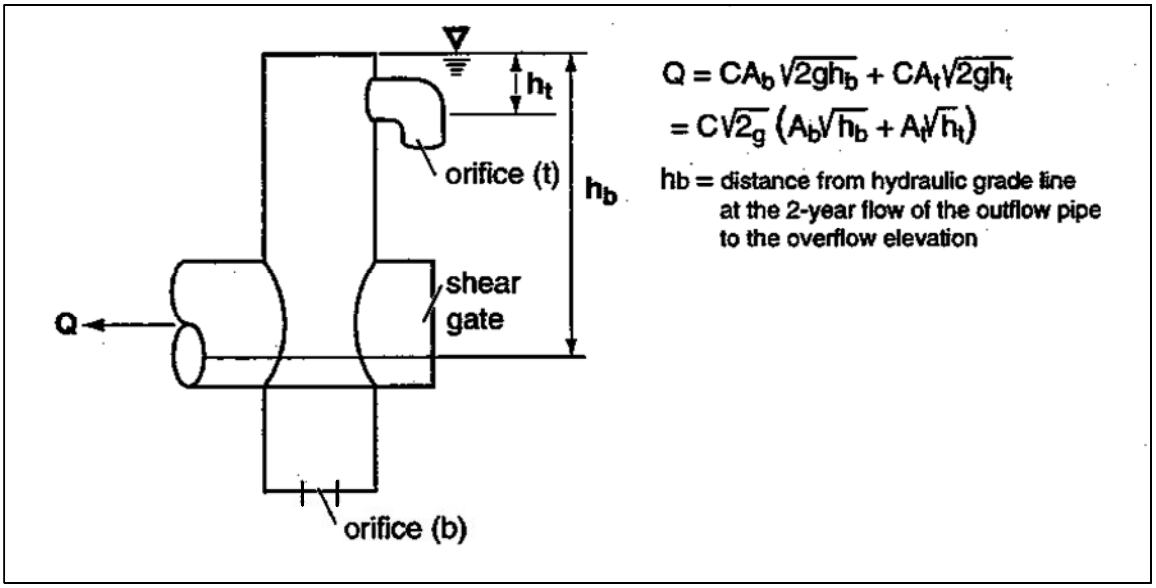


Figure III-2-18. Simple Orifice

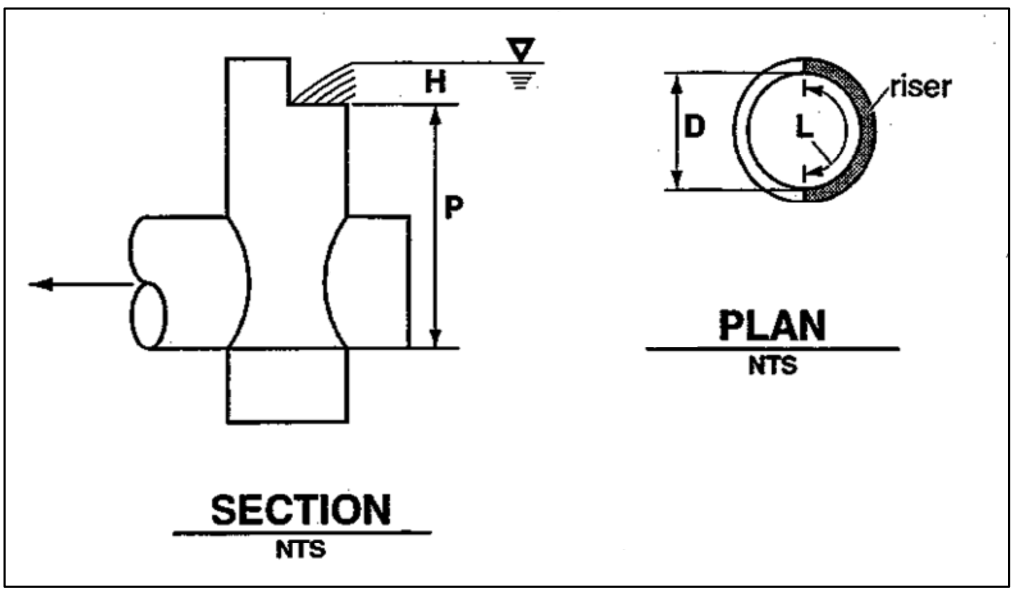
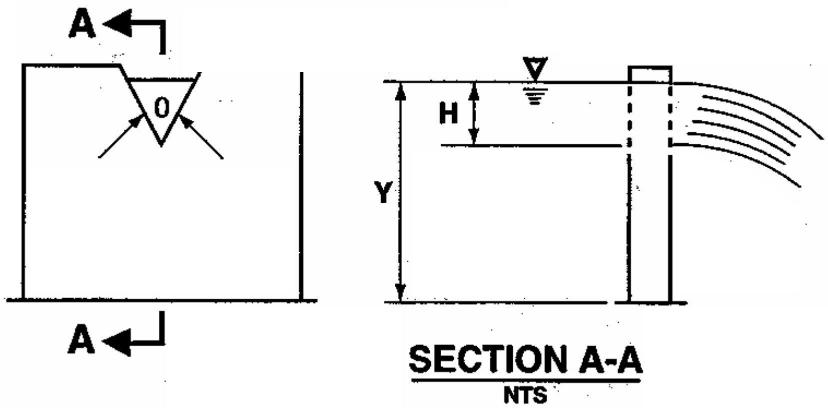


Figure III-2-19. Rectangular, Sharp-Crested Weir



$Q = C_d(\tan \theta/2)Y^{5/2}$, in cfs

Where values of C_d may be taken from the following chart:

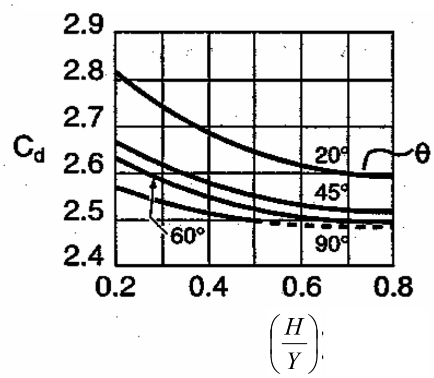


Figure III-2-20. V-Notch, Sharp-Crested Weir

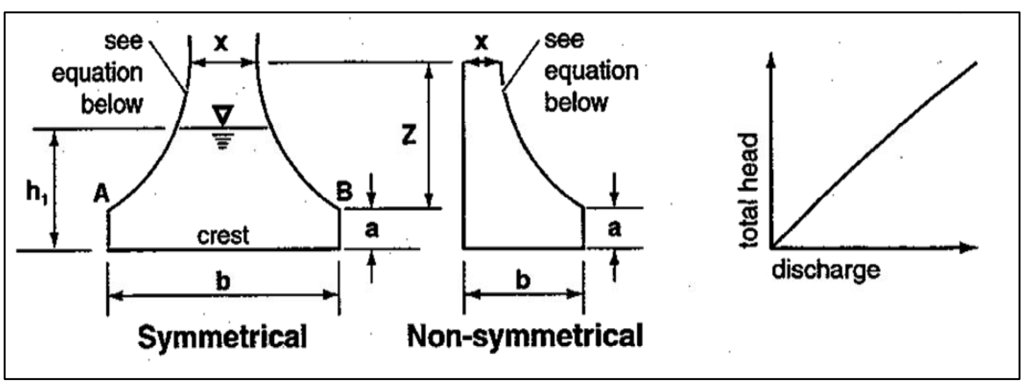


Figure III-2-21. Sutro Weir

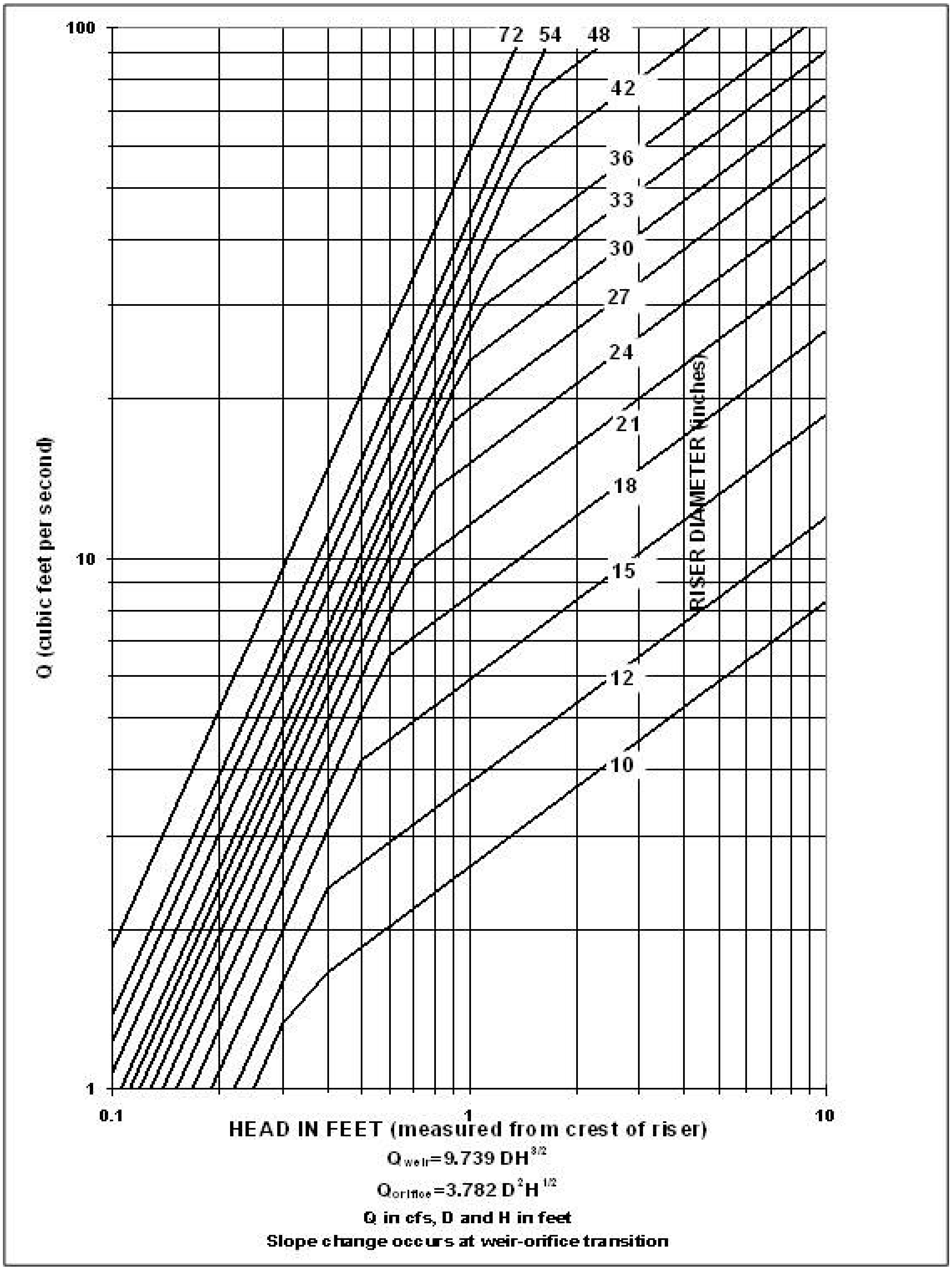


Figure III-2-22. Riser Inflow Curves

2.3.5 Other Detention Options

This section presents other design options for detaining flows to meet flow control facility requirements.

Use of Parking Lots for Additional Detention

Private parking lots may be used to provide additional detention volume for runoff events greater than the 2-year runoff event provided all of the following are met:

- The depth of water detained does not exceed 0.5 feet (6 inches) at any location in the parking lot for runoff events up to and including the 100-year event.
- The gradient of the parking lot area subject to ponding is 1 percent or greater.
- The emergency overflow path is identified and noted on the engineering plan. The overflow must not create a significant adverse impact to downhill properties or drainage system.
- Fire lanes be used for emergency equipment are free of ponding water for all runoff events up to and including the 100-year event.
- The overflow elevation shall be a minimum of one foot (1') below the finish floor elevation of adjacent building, adjacent properties, landscaping and parking stalls.
- At no time shall parking lot ponding encroach on walking paths, sidewalks, or American Disabilities Act (A.D.A) required parking stalls or adjacent A.D.A. access.

Use of Roofs for Detention

Detention ponding on roofs of structures may be used to meet flow control requirements provided all of the following are met:

- The roof support structure is analyzed by a structural engineer to address the weight of ponded water and meets the requirements of the applicable building code.
- The roof area subject to ponding is sufficiently waterproofed to achieve a minimum service life of 30 years.
- The minimum pitch of the roof area subject to ponding is 1/4-inch per foot.
- An overflow system is included in the design to safely convey the 100-year peak flow from the roof.
- A mechanism is included in the design to allow the ponding area to be drained for maintenance purposes, or in the event the restrictor device is plugged.

Chapter 3 Conveyance System Design and Hydraulic Analysis

This chapter presents acceptable methods for the analysis and design of storm and surface water conveyance systems. Conveyance systems can be separated into the following categories:

- Pipe systems
- Culverts
- Open Channels (ditches, swales)
- Outfalls

Pipe systems, culverts, and open channels are addressed in Section 3.4. Outfalls are addressed in Section 3.5.

The purpose of a conveyance system is to drain surface water, up to a specific design flow, from properties so as to provide protection to property and the environment. This chapter contains detailed design criteria, methods of analysis and standard details for all components of a conveyance system. A complete basic understanding of hydrology and hydraulics and the principles on which the methodology of hydrologic analysis is based is essential for the proper and accurate application of methods used in designing conveyance systems.

- A minimum of ten (10') shall be provided between the centerline of the conveyance and any property line or obstruction that would impede maintenance.
- Where storm drainage is directed against a curb, the curb shall be either a concrete curb and gutter or concrete vertical curb. An extruded curb or asphalt wedge section in any form will not be allowed.

3.1 Conveyance System Analysis Requirements

The project engineer shall provide calculations demonstrating the adequacy of all the project's existing and proposed surface water conveyance system components. The project engineer shall provide calculations regarding all off-site flows as required by Volume I. All relevant work/calculations shall be submitted for City review as part of a permit submittal. Small and/or isolated storm system (detention and water quality treatment) designs shall address how they will be incorporated into larger drainage systems likely to be built in the future. For example, site specific frontage and half street improvement designs shall also use a corridor analysis approach to ensure that they can be incorporated into larger future storm systems.

3.1.1 On-site Analysis

All proposed on-site surface water conveyance systems shall be sized to meet the required design event per Section 3.2.

3.1.2 Offsite Analysis (1/4 mile Downstream Analysis)

Refer to Minimum Requirement #10 (Offsite Analysis and Mitigation) in Volume I to determine whether a downstream analysis is required for a specific project. All projects shall complete a qualitative downstream analysis. A quantitative analysis shall be required as described in Minimum Requirement #10.

The engineer must field survey all existing storm drainage systems downstream from the project for a minimum of ¼ mile from the point of connection to the existing public drainage system, unless a City-identified trunk-line is encountered. The goal of the inspection and analysis is to evaluate whether the capacity of the drainage system(s) is adequate to handle the existing flows, flows generated by the proposed project, and any overflow. Adequacy will be evaluated based on conveyance capacity, flooding problems, erosion damage or potential, amount of freeboard in channels and pipes, and storage potential within the system. **All existing and proposed off-site surface water conveyance systems shall be sized to convey flows from the required design storm event per Section 3.2.**

The offsite analysis may be stopped shorter than the required ¼-mile downstream if the analysis reaches a City identified trunk line. Storm drainage pipes greater than or equal to 36 inches in diameter are generally considered trunk lines. However, where minimal grades (less than 0.5%) necessitated the use of a larger pipe to maintain flows, the City may not consider a pipe greater than or equal to 36 inches as a trunk line. Contact the City for final determination of whether a storm drainage pipe is a trunk line.

If a capacity problem or streambank erosion problem is encountered, the flow durations from the project will be restricted per Minimum Requirement #7 – Flow Control. The design shall meet the requirements of Chapter 2 of this volume. For projects that do not meet the thresholds of Minimum Requirement #7, and are therefore not required to provide flow control by the Department of Ecology, the project proponent may be allowed to correct the downstream problem instead of providing on-site flow control.

3.2 Design Event

The design events for all existing and new conveyance systems are as follows:

- All private pipe systems less than 24 inches in diameter shall be designed to convey at minimum the 10-year, 24-hour peak flow rate without surcharging (the water depth in the pipe must not exceed 90% of the pipe diameter).
- All private pipe systems greater than or equal to 24-inches in diameter and all public pipe systems shall be designed to convey the 25-year, 24-hour peak flow rate without surcharging (the water depth in the pipe must not exceed 90% of the pipe diameter).
- Culverts shall convey the 25-year, 24-hour peak flow rate without submerging the culvert inlet (i.e. $HW/D \leq 1$).
- Constructed and natural channels shall contain the 100-year, 24-hour storm event.

3.2.1 Additional Design Criteria

- For the 100-year event, overtopping of the pipe conveyance system may occur. However, the additional flow shall not extend beyond half the lane width of the outside lane of the traveled way and shall not exceed 4 inches in depth at its deepest point.
- All conveyance systems shall be designed for fully developed conditions. The fully developed conditions for the project site shall be derived from the percentages of proposed and existing impervious area. For off-site tributary areas, typical percentages of impervious area for fully developed conditions are provided in Table III-3-13.
- Conveyance systems shall be modeled as if no on-site detention is provided upstream.

Table III-3-13. Percentage Impervious for Fully Developed Conditions Offsite Tributary Areas

Land Use Description	Percentage Impervious
Commercial/Industrial	85%
Residential	65%

3.3 Methods of Analysis

Proponent site surveys shall be used as the basis for determining the capacity of existing systems. For preliminary analyses only, the proponent may use City of Auburn drainage maps and record drawings. For naturally occurring drainage systems, drainage ditches, or undeveloped drainage courses, the engineer must take into account the hydraulic capacity of the existing drainage course and environmental considerations such as erosion, siltation, and increased water velocities or water depths.

Describe capacities, design flows, and velocities in each reach. Describe required materials or specifications for the design (e.g. rock lined for channels when velocity is exceeded; high density polyethylene pipe needed for steep slope). Comprehensive maps showing the flow route and basins for both the on-site and off-site surface water (for the minimum 1/4 mile downstream distance) must be included in the storm drainage calculations.

If hydrologic modeling is required, the Project Engineer shall state methods, assumptions, model parameters, data sources, and all other relevant information to the analysis. If model parameters are used that are outside the standards of practice, or if parameters are different than those standards, justify the parameters. Copies of all calculations for capacity of channels, culverts, drains, gutters and other conveyance systems shall be included with the Stormwater Site Plan. If used, include all standardized graphs and tables and indicate how they were used. Show headwater and tailwater analysis for culverts when necessary. Provide details on references and sources of information used. Single event modeling shall be used for designing conveyance systems, WWHM is not accepted.

For a full description of the information required for preparing a Stormwater Site Plan consult Volume I, Chapter 4.

3.3.1 Rational Method

This method shall only be used for preliminary pipe sizing and capacity analysis. For flow control sizing derivations and water quality treatment sizing and flows see Chapter 2 of this volume and Chapter 3 of Volume V.

The Rational Method is a simple, conservative method for analyzing and sizing conveyance elements serving small drainage sub-basins, subject to the following specific limitations:

- Only for use in predicting peak flow rates for sizing conveyance elements **(not for use in sizing flow control or treatment facilities)**
- Drainage sub-basin area, *A*, cannot exceed 10 acres for a single peak flow calculation
- The time of concentration, T_c, must be computed using the method described below and cannot exceed 100 minutes. A minimum T_c of 6.3 minutes shall be used.
- Unlike other methods of computing times of concentration, the 6.3 minutes is not an initial collection time to be added to the total computed time of concentration.

3.3.1.1 Rational Method Equation

The following is the traditional Rational Method equation:

$$Q_R = CI_RA \qquad \text{(equation 1)}$$

Where Q_R = peak flow (cfs) for a storm of return frequency R

C = estimated runoff coefficient (ratio of rainfall that becomes runoff)

I_R = peak rainfall intensity (inches/hour) for a storm of return frequency R

A = drainage sub-basin area (acres)

When the composite runoff coefficient, C_c (see equation 2) of a drainage basin exceeds 0.60, the T_c and peak flow rate from the impervious area should be computed separately. The computed peak rate of flow for the impervious surface alone may exceed that for the entire drainage basin using the value at T_c for the total drainage basin. The higher of the two peak flow rates shall then be used to size the conveyance element.

"C" Values

The allowable runoff coefficients to be used in this method are shown in Table III-3-14 by type of land cover. These values were selected following a review of the values previously accepted by the City for use in the Rational Method and as described in several engineering handbooks. The value for single family residential areas were computed as composite values (as illustrated in the following equation) based on the estimated percentage of coverage by roads, roofs, yards, and unimproved areas for each density. For drainage basins containing several land cover types, the following formula may be used to compute a composite runoff coefficient, C_c:

$$C_c = (C_1A_1+C_2A_2+\ldots+C_nA_n)/A_t \quad \text{(equation 2)}$$

Where A_t = total area (acres)

$A_{1,2\ldots n}$ = areas of land cover types (acres)

$C_{1,2\ldots n}$ = runoff coefficients for each area land cover type

Table III-3-14. Runoff Coefficients – "C" Values for the Rational Method

GENERAL LAND COVERS			
LAND COVER	**C**	**LAND COVER**	**C**
Dense forest	0.10	Playgrounds	0.30
Light forest	0.15	Gravel areas	0.80
Pasture	0.20	Pavement and roofs	0.90
Lawns	0.25	Open water (pond, lakes, wetlands)	1.00
SINGLE FAMILY RESIDENTIAL AREAS* ***[Density is in dwelling units per gross acreage (DU/GA)]***			
LAND COVER DENSITY	**C**	**LAND COVER DENSITY**	**C**
0.20 DU/GA (1 unit per 5 ac.)	0.17	3.00 DU/GA	0.42
0.40 DU/GA (1 unit per 2.5 ac.)	0.20	3.50 DU/GA	0.45
0.80 DU/GA (1 unit per 1.25 ac.)	0.27	4.00 DU/GA	0.48
1.00 DU/GA	0.30	4.50 DU/GA	0.51
1.50 DU/GA	0.33	5.00 DU/GA	0.54
2.00 DU/GA	0.36	5.50 DU/GA	0.57
2.50 DU/GA	0.39	6.00 DU/GA	0.60

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

For combinations of land covers listed above, an area-weighted "C_c x A_t" sum should be computed based on the equation $C_c \times A_t = (C_1 \times A_1)+(C_2 \times A_2)\ldots(C_n \times A_n)$, where $A_t = (A_1+A_2\ldots A_n)$, the total drainage basin area

"I_R" Peak Rainfall Intensity

The peak rainfall intensity, I_R, for the specified design storm of return frequency *R* is determined using a unit peak rainfall intensity factor, i_R, in the following equation:

$$I_R = (P_R)(i_R) \qquad \text{(equation 3)}$$

Where P_R = the total precipitation at the project site for the 24-hour duration storm event for the given return frequency. Refer to Table III-3-15 for P_R values. Total precipitation can also be found in Chapter 1 of Volume III.

i_R = the unit peak rainfall intensity factor

The unit peak rainfall intensity factor, i_R, is determined by the following equation:

$$i_R = (a_R)(T_c)^{(-bR)} \qquad \text{(equation 4)}$$

Where T_c = time of concentration (minutes), calculated using the method described below and subject to equation limitations ($6.3 < Tc < 100$)

a_R, b_R = coefficients from Table III-3-15 used to adjust the equation for the design storm
return frequency R

Table III-3-16 includes a table of rainfall intensity as a function of time of concentration, calculated using the coefficients from Table III-3-15.

Table III-3-15. Coefficients for the Rational Method

Design Storm Frequency	***P_R (inches)***	***a_R***	***b_R***
2 years	2.0	1.58	0.58
5 years	2.5	2.33	0.63
10 years	3.0	2.44	0.64
25 years	3.5	2.66	0.65
50 years	3.5	2.75	0.65
100 years	4.0	2.61	0.63

Table III-3-16. Rainfall Intensities for the City of Auburn

	Rainfall Intensity (I_R) (inches per hour)					
	Design storm recurrence interval (probability)					
Time of Concentration (min)	**2-year (50%)**	**5-year (20%)**	**10-year (10%)**	**25-year (4%)**	**50-year (2%)**	**100-year (1%)**
6.3	1.09	1.83	2.25	2.81	2.91	3.27
7	1.02	1.71	2.11	2.63	2.72	3.06
8	0.95	1.57	1.93	2.41	2.49	2.82
9	0.88	1.46	1.79	2.23	2.31	2.62
10	0.83	1.37	1.68	2.08	2.15	2.45
11	0.79	1.29	1.58	1.96	2.03	2.30
12	0.75	1.22	1.49	1.85	1.91	2.18
13	0.71	1.16	1.42	1.76	1.82	2.07
14	0.68	1.10	1.35	1.67	1.73	1.98
15	0.66	1.06	1.29	1.60	1.66	1.90
16	0.63	1.02	1.24	1.54	1.59	1.82
17	0.61	0.98	1.19	1.48	1.53	1.75
18	0.59	0.94	1.15	1.42	1.47	1.69
19	0.57	0.91	1.11	1.37	1.42	1.63
20	0.56	0.88	1.08	1.33	1.37	1.58
25	0.49	0.77	0.93	1.15	1.19	1.37
30	0.44	0.68	0.83	1.02	1.06	1.22
35	0.40	0.62	0.75	0.92	0.95	1.11
40	0.37	0.57	0.69	0.85	0.88	1.02
45	0.35	0.53	0.64	0.78	0.81	0.95
50	0.33	0.50	0.60	0.73	0.76	0.89
55	0.31	0.47	0.56	0.69	0.71	0.84
60	0.29	0.44	0.53	0.65	0.67	0.79
70	0.27	0.40	0.48	0.59	0.61	0.72
80	0.25	0.37	0.44	0.54	0.56	0.66
90	0.23	0.34	0.41	0.50	0.52	0.61
100	0.22	0.32	0.38	0.47	0.48	0.57

"T_c" Time of Concentration

The time of concentration is defined as the time it takes runoff to travel overland (from the onset of precipitation) from the most hydraulically distant location in the drainage basin to the point of discharge.

Due to the mathematical limits of the equation coefficients, values of T_c less than 6.3 minutes or greater than 100 minutes cannot be used. Therefore, real values of T_c less than 6.3 minutes must be assumed to be equal to 6.3 minutes, and values greater than 100 minutes must be assumed to be equal to 100 minutes.

T_c is computed by summation of the travel times T_t of overland flow across separate flowpath segments. The equation for time of concentration is:

$$T_c = T_1 + T_2 + \ldots + T_n \qquad \text{(equation 5)}$$

Where $T_{1,2\ldots n}$ = travel time for consecutive flowpath segments with different categories or flowpath slope

Travel time for each segment, *t*, is computed using the following equation:

$$T_t = L/60V \qquad \text{(equation 6)}$$

where T_t = travel time (minutes)

T_t through an open water body (such as a pond) shall be assumed to be zero with this method.

T_t = Travel time for each segment (ft)

L = the distance of flow across a given segment (feet)

V = average velocity (ft/s) across the land cover = $k_R \sqrt{s_o}$

Where k_R = time of concentration velocity factor; see Table III-3-17.

s_0 = slope of flowpath (feet/feet)

Table III-3-17. "n" and "k" Values Used in Time Calculations for Hydrographs

"n_s" Sheet Flow Equation Manning's Values (for the initial 300 ft. of travel)	
Manning values for sheet flow only, from Overton and Meadows 1976[1]	**n_s**
Smooth surfaces (concrete, asphalt, gravel, or bare hand packed soil)	0.011
Fallow fields or loose soil surface (no residue)	0.05
Cultivated soil with residue cover ≤20%	0.06
Cultivated soil with residue cover >20%	0.17
Short prairie grass and lawns	0.15
Dense grasses	0.24
Bermuda grass	0.41
Range (natural)	0.13
Woods or forest with light underbrush	0.40
Woods or forest with dense underbrush	0.80
"k" Values Used in Travel Time/Time of Concentration Calculations[2]	
Sheet Flow	**k_R**
Forest with heavy ground litter and meadow	2.5
Fallow or minimum tillage cultivation	4.7
Short grass pasture and lawns	7.0
Nearly bare ground	10.1
Grasses waterway	15.0
Paved area (sheet flow) and shallow gutter flow	20.0
Shallow Concentrated Flow (After the initial 300 ft. of sheet flow, R = 0.1)	**k_s**
1. Forest with heavy ground litter and meadows (n = 0.10)	3
2. Brushy ground with some trees (n= 0.060)	5
3. Fallow or minimum tillage cultivation (n = 0.040)	8
4. High grass (n = 0.035)	9
5. Short grass, pasture and lawns (n = 0.030)	11
6. Nearly bare ground (n = 0.025)	13
7. Paved and gravel areas (n = 0.012)	27
Channel Flow (intermittent) (At the beginning of visible channels R = 0.2)	**k_c**
1. Forested swale with heavy ground litter (n = 0.10)	5
2. Forested drainage course/ravine with defined channel bed (n = 0.050)	10
3. Rock-lined waterway (n = 0.035)	15
4. Grassed waterway (n = 0.030)	17
5. Earth-lined waterway (n = 0.025)	20
6. CMP pipe, uniform flow (n = 0.024)	21
7. Concrete pipe, uniform flow (0.012)	42
8. Other waterways and pipe	0.508/n
Channel Flow (Continuous stream, R = 0.4)	**k_c**
9. Meandering stream with some pools (n = 0.040)	20
10. Rock-lined stream (n = 0.035)	23
11. Grass-lined stream (n = 0.030)	27
12. Other streams, man-made channels and pipe	0.807/n

[1] See TR-55, 1986
[2] 210-VI-TR-55, Second Ed., June 1986

3.4 Pipes, Culverts and Open Channels

This section presents the methods, criteria and details for analysis and design of pipe systems, culverts, and open channel conveyance systems.

Storm drainage conveyance for public street requirements are as follows:

- Maximum surface run without considering curve super elevation (gutter flow) between catch basins on paved roadway surfaces shall be as follows:

Pavement Slope, %	Maximum Flow Length, ft
0.5 – 1	200
1 to 6	300
6 to 12	200

- The minimum longitudinal street gutter slope shall be one/half percent (0.5%).V
- Vaned catch basin grates and through-curb inlets may be required for roadway grades in excess of six percent (6%).
- Storm manholes or catch basins shall not be designed within the vehicular wheel paths.
- The design of street drainage conveyance should seek to minimize the number of structures and redundant pipes.

3.4.1 Pipe Systems

Pipe systems are networks of storm drain pipes, catch basins, manholes, inlets, and outfalls, designed and constructed to convey surface water. The hydraulic analysis of flow in storm drainage pipes typically is limited to gravity flow; however in analyzing existing systems it may be necessary to address pressurized conditions. A properly designed pipe system will maximize hydraulic efficiency by utilizing proper material, slope, and pipe size.

3.4.1.1 Design Flows

Design flows for sizing or assessing the capacity of pipe systems shall be determined using the hydrologic analysis methods described in this chapter. Approved single event models described in Chapter 1 of this volume may also be used to determine design flows. The design event is described in Section 3.2. Pipe systems shall be designed to convey the design event without surcharging (water depth in pipe shall not exceed 90% of the pipe diameter).

3.4.1.2 Conveyance Capacity

Two methods of hydraulic analysis using Manning's Equation are required by the City of Auburn for the analysis of pipe systems. First, the **Uniform Flow Analysis** method is used for preliminary design and analysis of pipe systems. Second, the **Backwater Analysis** method is used to analyze both proposed and existing pipe systems to verify adequate capacity. See Section 3.2 for the required design events for pipe systems.

Uniform Flow Analysis

This method is typically used for preliminary sizing of new pipe systems to convey the design flow as calculated from the required design event from Section 3.2.

Assumptions:

- Flow is uniform in each pipe (i.e., depth and velocity remain constant throughout the pipe for a given flow).
- Friction head loss in the pipe barrel alone controls capacity. Other head losses (e.g., entrance, exit, junction, etc.) and any backwater effects or inlet control conditions are not specifically addressed.
- All pipes shall be designed for fully developed conditions. The fully developed conditions shall be derived from the percentages of impervious area provided in Table III-3-18.

Table III-3-18. Percentage Impervious for Modeling Fully Developed Conditions

Land Use Description[1]	% Impervious
Commercial/Industrial	85
Residential	65

[1] For the land use descriptions, roads are included in the percentage impervious.

- All pipes shall be modeled as if no on-site detention is provided up-stream.

Each pipe within the system shall be sized and sloped such that **its barrel capacity at normal full flow** is equal to or greater than the design flow calculated from the appropriate design storm as identified in Section 3.2. The nomographs in Figure III-3-23 can be used for approximate sizing of the pipes or Manning's Equation can be solved for pipe size directly:

$$V = \frac{1.49}{n} R^{2/3} S^{1/2} \quad \text{(equation 7)}$$

or use the continuity equation, $Q = A \bullet V$, such that

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \qquad \text{(equation 8)}$$

Where *Q* = discharge (cfs)

V = velocity (fps)
A = area (sf)
n = Manning's roughness coefficient; see Table III-3-19
R = hydraulic radius = area/wetted perimeter
S = slope of the energy grade line (ft/ft)

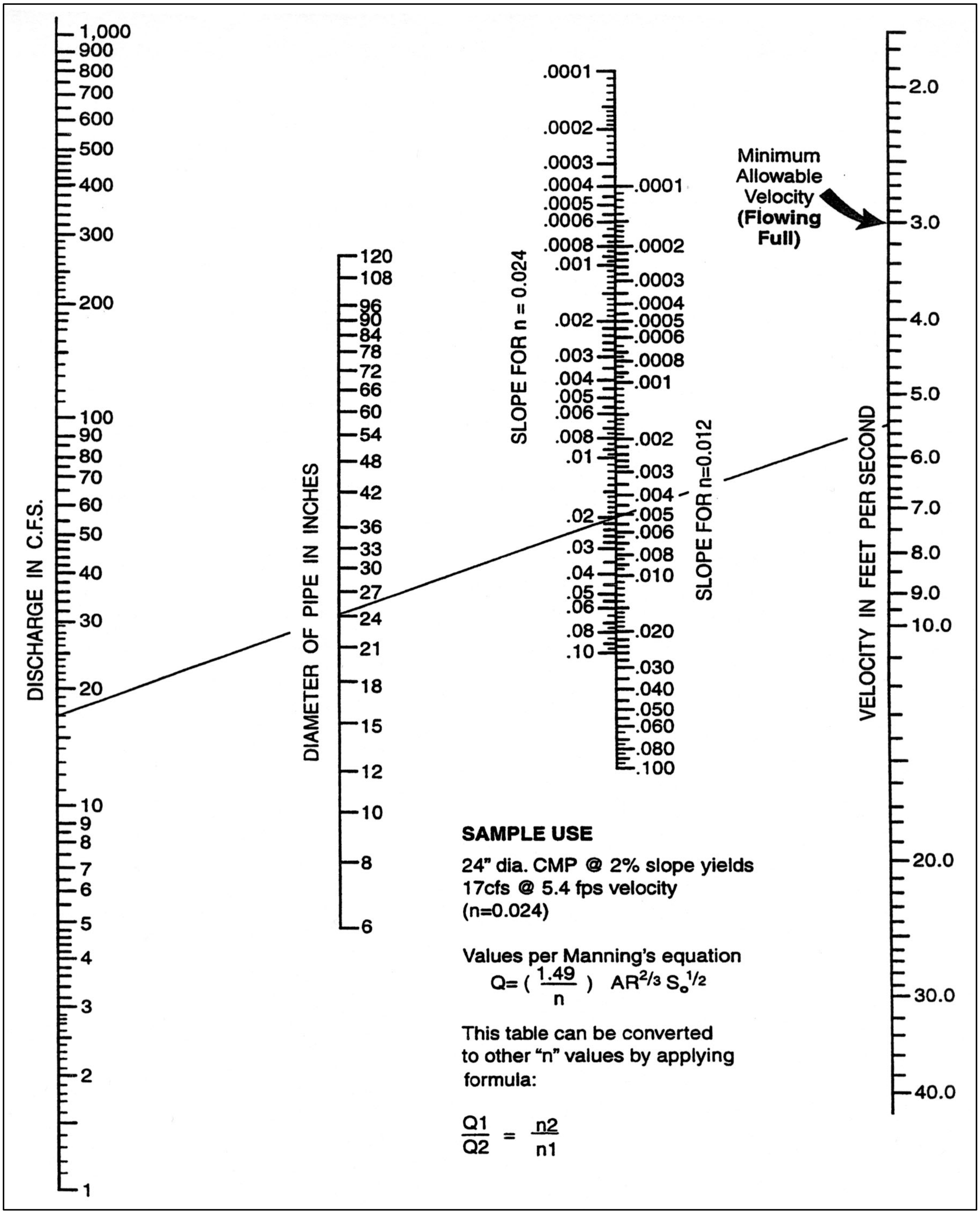


Figure III-3-23. Nomograph for Sizing Circular Drains Flowing Full

Table III-3-19. Manning's "n" Values for Pipes

Type of Pipe Material		Analysis Method	
		Backwater Flow	Manning's Equation Flow
A.	Concrete pipe and CPEP-smooth interior pipe	0.012	0.014
B.	Annular Corrugated Metal Pipe or Pipe Arch:		
	1. 2-2/3" x 1/2" corrugation (riveted)		
	a. plain or fully coated	0.024	0.028
	b. paved invert (40% of circumference paved):		
	(1) flow full depth	0.018	0.021
	(2) flow 0.8 depth	0.016	0.018
	(3) flow 0.6 depth	0.013	0.015
	c. treatment	0.013	0.015
	2. 3" x 1" corrugation	0.027	0.031
	3.6" x 2" corrugation (field bolted)	0.030	0.035
C.	Helical 2-2/3" x 1/2" corrugation and CPEP-single wall	0.024	0.028
D.	Spiral rib metal pipe and PVC pipe	0.011	0.013
E.	Ductile iron pipe cement lined	0.012	0.014
F.	High density polyethylene pipe (butt fused only)	0.009	0.009

For **pipes flowing partially full**, the actual velocity may be estimated from the hydraulic properties shown in Figure III-3-24 by calculating Q_{full} and V_{full} and using the ratio of Q_{design}/Q_{full} to find V and d (depth of flow).

Table III-3-19 provides the recommended Manning's "n" values for preliminary design for pipe systems. The "n" values for this method are 15% higher in order to account for entrance, exit, junction, and bend head losses.

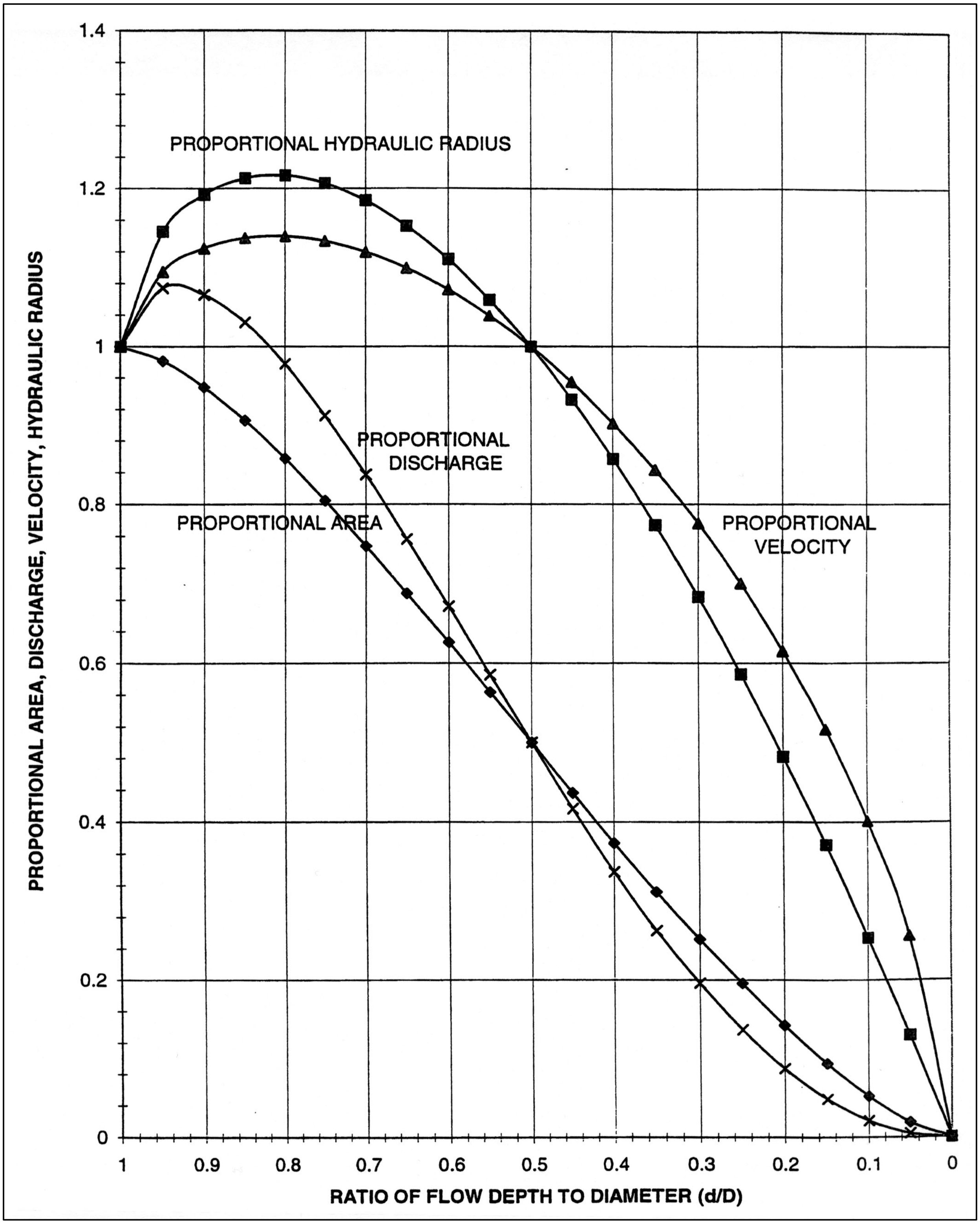


Figure III-3-24. Circular Channel Ratios

3.4.1.3 Backwater Analysis

A backwater analysis shall be required when the design depth of flow is greater than 90% of the pipe inside diameter or as directed by the City. The backwater analysis method described in this section is used to analyze the capacity of both proposed and existing pipe systems to convey the required design flow (i.e., either the 10-year or 25-year peak flow as required in Section 3.2). The backwater analysis shall verify that the pipe system meets the following conditions:

- For the 25-year event, there shall be a minimum of 0.5 feet of freeboard between the water surface and the top of any manhole or catch basin.
- For the 100-year event, overtopping of the pipe conveyance system may occur, however, the additional flow shall not extend beyond half the lane width of the outside lane of the traveled way and shall not exceed 4 inches in depth at its deepest point. Refer to the Washington State Department of Transportation (WSDOT) Hydraulics Manual for pavement drainage calculations. Off-channel storage on private property is allowed with recording of the proper easements. When this occurs, the additional flow over the ground surface is analyzed using the methods for open channels described in Sections 3.2 and 3.4.3 and added to the flow capacity of the pipe system.

This method is used to compute a simple backwater profile (hydraulic grade line) through a proposed or existing pipe system for the purposes of verifying adequate capacity. It incorporates a re-arranged form of Manning's equation expressed in terms of friction slope (slope of the energy grade line in ft/ft). The friction slope is used to determine the head loss in each pipe segment due to barrel friction, which can then be combined with other head losses to obtain water surface elevation at all structures along the pipe system.

The backwater analysis begins at the downstream end of the pipe system and is computed back through each pipe segment and structure upstream. The friction, entrance, and exit head losses computed for each pipe segment are added to that segment's tailwater elevation (the water surface elevation at the pipes' outlet) to obtain its outlet control headwater elevation. This elevation is then compared with the inlet control headwater elevation, computed assuming the pipe's inlet alone is controlling capacity using the methods for inlet control presented in Section 3.4.2. The condition that creates the highest headwater elevation determines the pipe's capacity. The approach velocity head is then subtracted from controlling headwater elevation, and the junction and bend head losses are added to compute the total headwater elevation, which is then used as the tailwater elevation for the upstream pipe segment.

The Backwater Calculation Sheet in Figure III-3-25 can be used to compile the head losses and headwater elevations for each pipe segment. The numbered columns on this sheet are described in Table III-3-20. An example calculation is performed in Figure III-3-26.

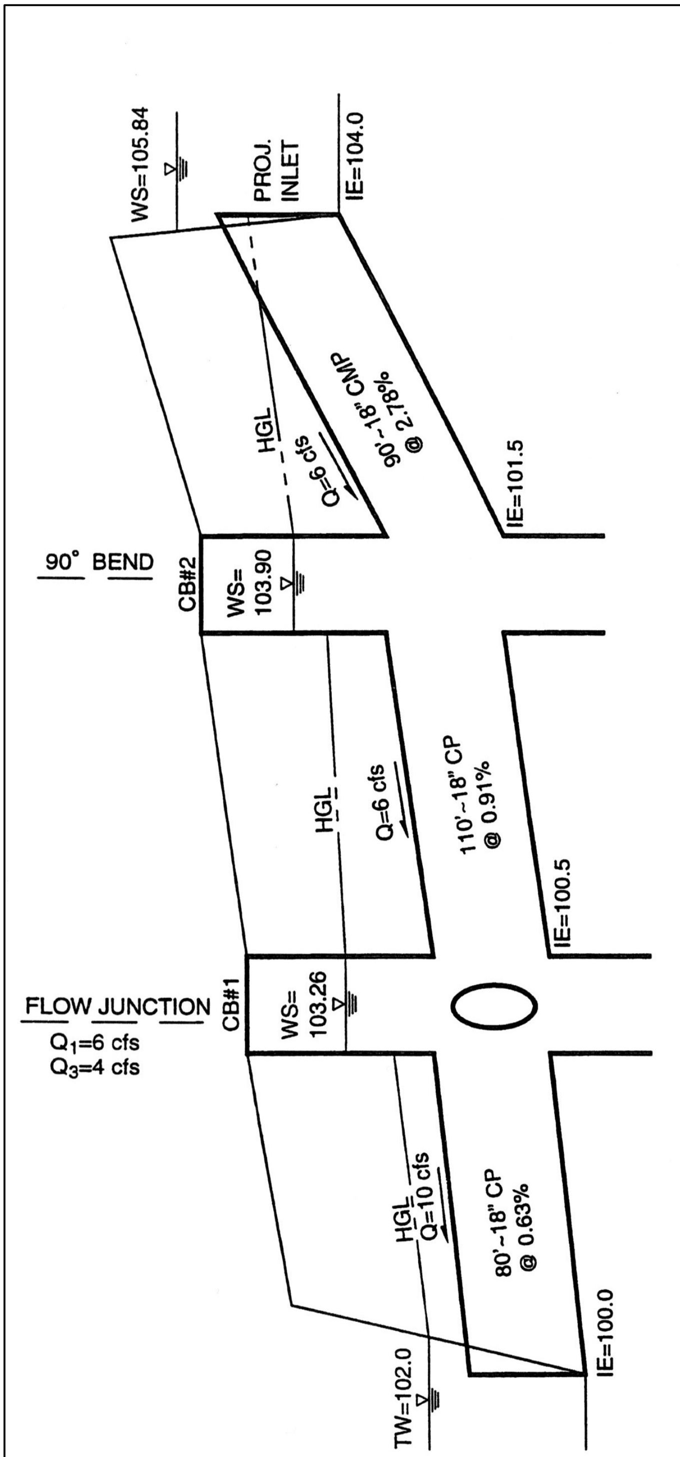
This method should not be used to compute stage/discharge curves for level pool routing purposes. See Volume III, Chapter 2 for level pool routing.

Pipe Segment CB to CB		(1) Q (cfs)	(2) Lngth (ft)	(3) Pipe Size	(4) "n" Value	(5) Outlet Elev (ft)	(6) Inlet Elev (ft)	(7) Barrel Area (sq. ft)	(8) Barrel Vel (fps)	(9) Barrel Vel Head (ft)	(10) TW Elev (ft)	(11) Fric-tion Loss (ft)	(12) Entr HGL Elev (ft)	(13) Entr Head Loss (ft)	(14) Exit Head Loss (ft)	(15) Outlt Cntrl Elev (ft)	(16) Inlet Cntrl Elev (ft)	(17) Appr Vel Head (ft)	(18) Bend Head Loss (ft)	(19) Junc Head Loss (ft)	(20) HW Elev (ft)

Figure III-3-25. Backwater Calculation Sheet

Table III-3-20. Backwater Calculation Sheet Notes

Column	Description
(1)	Design flow to be conveyed by pipe segment.
(2)	Length of pipe segment.
(3)	Pipe size: indicate pipe diameter or span % rise.
(4)	Manning's *"n"* value.
(5)	Outlet Elevation of pipe segment.
(6)	Inlet Elevation of pipe segment.
(7)	Barrel Area: this is the full cross-sectional area of the pipe.
(8)	Barrel Velocity: this is the full velocity in the pipe as determined by: $V = Q/A$ or Col. (8) = Col. (1)/Col. (7)
(9)	Barrel Velocity Head = $V^3/2g$ or $(\text{Col. }(8))^2/2g$; Where g = 32.2 ft./sec.^{2} (acceleration due to gravity)
(10)	Tailwater (*TW*) Elevation: this is the water surface elevation at the outlet of the pipe segment. If the pipe's outlet is not submerged by the TW and the TW depth is less than $D+d_c)/2$, set TW equal to $D+d_c)/2$ to keep the analysis simple and still obtain reasonable results (D=pipe barrel height and d_c=critical depth, both in feet. See Figure III-3-33 for determination of d_c.
(11)	Friction Loss = $S_f \times L$ (or S_f X Col (2)); Where S_f is the friction slope or head loss per linear foot of pipe as determined by Manning's equation expressed in the form: $S_f = (nV)^{2/}2.22R^{1.33}$
(12)	Hydraulic Grade Line (HGL) Elevation just inside the entrance of the pipe barrel; this is determined by adding the friction loss to the TW elevation: Col. (12) = Col. (11) + (Col. (10) If this elevation falls below the pipe's inlet crown, it no longer represents the true HGL when computed in this manner. The true HGL will fall somewhere between the pipe's crown and either normal flow depth or critical flow depth, whichever is greater. To keep the analysis simple and still obtain reasonable results (i.e. erring on the conservative side), set the HGL elevation equal to the crown elevation.
(13)	Entrance Head Loss = $K_e/2g$ (or K_e x Col (9)) Where K_e = Entrance Loss Coefficient from Table III-3-24. This is the head lost due to flow contractions at the pipe entrance.
(14)	Exit Head Loss = 1.0 x $V^2/2g$ or 1.0 x Col. (9); This is the velocity head lost or transferred downstream.
(15)	Outdoor Control Elevation = Col. (12) + Col. (13) + Col. (14) This is the maximum headwater elevation assuming the pipe's barrel and inlet/outlet characteristics are controlling capacity. It does not include structure losses or approach velocity considerations.
(16)	Inlet Control Elevation (see Section 3.4.2.5 for computation of inlet control on culverts); this is the maximum headwater elevation assuming the pipe's inlet is controlling capacity. It does not include structure losses or approach velocity considerations.
(17)	Approach Velocity Head: This is the amount of head/energy being supplied by the discharge from an upstream pipe or channel section, which serves to reduce the headwater elevation. If the discharge is from a pipe, the approach velocity head is equal to the barrel velocity head computed for the upstream pipe. If the upstream pipe outlet is significantly higher in elevation (as in a drop manhole) or lower in elevation such that its discharge energy would be dissipated, an approach velocity head of zero should be assumed.
(18)	Bend Head Loss = K_b x $V^2/2g$ (or K_b x Col. (17)); Where K_b = Bend Loss Coefficient (from Figure III-3-32). This is due to loss of head/energy required to change direction of flow in an access structure.
(19)	Junction Head Loss: This is the loss in head/energy which results from the turbulence created when two or more streams are merged into one within the access structure. Figure III-3-30 can be used to determine this loss, or it an be computed using the following equations derived from Figure III-3-30: Junction Head Loss = K_j x $V^2/2g$ (or K_j x Col. (17) where K_j is the Junction Loss Coefficient determined by: $K_j = (Q^3/Q^1)/(1.18 + 0.63(Q^3/Q^1))$
(20)	Headwater (HW) Elevation: This is determined by combining the energy heads in Columns 17, 18, and 19 with the highest control elevation in either Column 15 or 16, as follows: Col. (20) = Col. (15 or 16) – Col. (17) + Col. (18) + Col. (19)



BACKWATER CALCULATION SHEET

(15)/(16): Select the greater elevation

Pipe Segment CB to CB		(1) Q (cfs)	(2) Length (ft)	(3) Pipe Size	(4) "n" Value	(5) Outlet Elev (ft)	(6) Inlet Elev (ft)	(7) Barrel Area (sqft)	(8) Barrel Vel (fps)	(9) Barrel Vel Head (ft)	(10) TW Elev (ft)	(11) Friction Loss (ft)	(12) Entr HGL Elev (ft)	(13) Entr Head Loss (ft)	(14) Exit Head Loss (ft)	(15) Outlt Contr Elev (ft)	(16) Inlet Contr Elev (ft)	(17) Appr Vel Head (ft)	(18) Bend Head Loss (ft)	(19) Junc Head Loss (ft)	(20) HW Elev (ft)
Out fall	1	10	80	18"	0.012	100.00	100.50	1.77	5.65	0.50	102.00	0.62	102.62	0.25	0.50	103.37	102.75	-0.18	0.002	0.07	103.26
1	2	6	110	18"	0.012	100.50	101.50	1.77	3.39	0.18	103.26	0.31	103.57	0.09	0.18	103.84	102.95	-0.18	0.24	0.0	103.90
2	Inlet	6	90	18"	0.024	101.50	104.00	1.77	3.39	0.18	103.90	1.00	(104.9) 105.5	0.16	0.18	105.84	105.80	-0.0	0.0	0.0	105.84

Figure III-3-26. Backwater Pipe Calculation Example

3.4.1.4 Inlet Grate Capacity

The *Washington State Department of Transportation (WSDOT) Hydraulics Manual* can be used in determining the capacity of inlet grates when capacity is of concern. When verifying capacity, assume:

- Grate areas on slopes are 80 percent free of debris, and “vaned” grates are 95 percent free.
- Grate areas in sags or low spots are 50 percent free of debris, and “vaned” grates, 75 percent free.

3.4.1.5 Pipe Materials

See City of Auburn Construction Standards Division 7 for pipe specifications.

3.4.1.6 Pipe Sizes

- The following pipe sizes shall be used for pipe systems to be maintained by the City of Auburn: 12-inch, 15-inch, 18-inch, 21-inch, 24-inch, 30-inch, 36-inch and 42-inch.
- Pipes smaller than 12-inch may only be used for privately maintained systems, or to match the diameter of existing downstream mains, or as approved in writing by the City.
- Catch basin leads shall be a minimum of 12-inch.
- Single-family home site roof, foundation and driveway drains may use pipe as small as 4 inch.
- Non-single family roof, foundation and small driveway drains may use pipe as small as 6-inch. Pipes under 10-inch may require capacity analysis if requested by the City.
- For pipes larger than 30-inch increasing increments of 6-inch intervals shall be used (36-inch, 42-inch, 48-inch, etc.).

3.4.1.7 Changes in Pipe Sizes

- Pipe direction changes or size increases or decreases are only allowed at manholes and catch basins.
- Where a minimal fall is necessary between inlet and outlet pipes in a structure, pipes must be aligned vertically by one of the following in order of preference:
    a. Match pipe crowns
    b. Match 80% diameters of pipes
    c. Match pipe inverts or use City approved drop inlet connection

3.4.1.8 Pipe Alignment and Depth

- Pipes must be laid true to line and grade with no curves, bends, or deflections in any direction.

***Exception:** Vertical deflections in HDPE and ductile iron pipe with flanged restrained mechanical joint bends (not greater than 30%) on steep slopes are allowed provided the pipe adequately drains, with a minimum velocity of 2 feet per second (fps).*

- A break in grade or alignment or changes in pipe material shall occur only at catch basins or manholes.
- For the standard main alignment refer to the City's Engineering Design and Construction Standards.
- The standard depth for new mains measures six (6) feet from the center of the pipe to the main street surface.
- The project engineer shall consult with the City for the potential of a future extension of the storm system. In this case, the City may require modifications to the depth or alignment.
- Connections to the main shall be at 90°. Slight variations may be allowed.
- Pipes shall be allowed to cross under retaining walls as specifically approved in writing by the City when no other reasonable alternatives exist.

3.4.1.9 Pipe Slopes and Velocities

- The slope of the pipe shall be set so that a minimum velocity of 2 feet per second can be maintained at full flow.
- A minimum slope for all pipes shall be 0.5% (under certain circumstances, a minimum slope of 0.3% may be allowed with prior approval in writing from The City).
- Maximum slopes, velocities, and anchor spacings are shown in Table III-3-21. If velocities exceed 15 feet per second for the conveyance system design event described in Section 3.2, provide anchors and/or restrained joints at bends and junctions.

3.4.1.10 Pipes on Steep Slopes

- Slopes 20% or greater shall require all drainage to be piped from the top to the bottom in High Density Polyethylene (HDPE) pipe (butt-fused) or ductile iron pipe welded or mechanically restrained. Additional anchoring design is required for these pipes.
- Above-ground installation is required on slopes greater than 40% to minimize disturbance to steep slopes, unless otherwise approved in writing by The City.
- HDPE pipe systems longer than 100 feet must be anchored at the upstream end if the slope exceeds 20% or as required by The City.
- Above ground installations of HDPE shall address the high thermal expansion/contraction coefficient of the pipe material. An analysis shall be completed to demonstrate that the system as designed will tolerate the thermal expansion of the pipe material.

Table III-3-21. Maximum Pipe Slopes, Velocities and Anchor Requirements

Pipe Material	Pipe Slope Above Which Pipe Anchors Required and Minimum Anchor Spacing	Max. Slope Allowed	Max. Velocity @ Full Flow
Spiral Rib[1], PVC[1]	20% (1 anchor per 100 L.F. of pipe)	30%[(3)]	30 fps
Concrete[1]	10% (1 anchor per 50 L.F. of pipe)	20%[(3)]	30 fps
Ductile Iron[4]	40% (1 anchor per pipe section)	None	None
HDPE[2]	50% (1 anchor per 100 L.F. of pipe – cross slope installations may be allowed with additional anchoring and analysis)	None	None

[1] Not allowed in landslide hazard areas.

[2] Butt-fused pipe joints required. Above-ground installation is required on slopes greater than 40% to minimize disturbance to steep slopes.

[3] Maximum slope of 20% allowed for these pipe materials with no joints (one section) if structures are provided at each end and the pipes are property grouted or otherwise restrained to the structures.

[4] Restrained joints required on slopes greater than 25%. Above-ground installation is required on slopes greater than 40% to minimize disturbance to steep slopes.

3.4.1.11 Structures

For the purposes of this Manual, all catch basins and manholes shall meet WSDOT standards such as Type 1L, Type 1, and Type 2. Table III-3-22 presents the structures and pipe sizes allowed by size of structure.

Table III-3-22. Allowable Structures and Pipe Sizes

Catch Basin Type[1]	Maximum Inside Pipe Diameter	
	CMP)[(5)], Spiral Rib)[5], CPEP (single wall)[5], HDPP, Ductile Iron, PVC [2] (Inches)	Concrete, CPEP (smooth interior), (Inches)
Inlet [4]	12	12
Type 1 [3]	15	12
Type IL [3]	21	18
Type 2 - 48-inch dia.	30	24
Type 2 - 54-inch dia.	36	30
Type 2 – 60-inch dia.	42	36
Type 2 - 72-inch dia.	54	42
Type 2 - 96-inch dia.	72	60

[1] Catch basins (including manhole steps, ladder, and handholds) shall conform to the W.S.D.O.T. Standard Plans or an approved equal based upon submittal for approval.

[2] Maintain the minimum sidewall thickness per this Section.

[3] Maximum 5 vertical feet allowed between grate and invert elevation.

[4] Normally allowed only for use in privately maintained drainage systems and must discharge to a catch basin immediately downstream.

[5] Allowed for private system installations only.

The following criteria shall be used when designing a conveyance system that utilizes catch basins or manholes:

- Catch basin (or manhole) diameter shall be determined by pipe diameter and orientation at the junction structure. A plan view of the junction structure, drawn to scale, will be required when more than four pipes enter the structure on the same plane, or if angles of approach and clearance between pipes is of concern. The plan view (and sections if necessary) must insure a minimum distance (of solid concrete wall) between pipe openings of 8 inches for 48-inch and 54-inch diameter catch basins and 12 inches for 72-inch and 96-inch diameter catch basins
- Type 1 catch basins should be used when overall catch basin height does not exceed eight (8) feet or when the invert depth does not exceed five (5) feet below rim.
- Type 1L catch basins should be used for the following situations:
  - When overall catch basin height does not exceed eight (8) feet or when invert depth does not exceed five (5) feet below rim.
  - When any pipes tying into the structure exceed 21 inches connecting to the long side, or 18 inches connecting to the short side at or very near to right angles.
- Type 2 (48-inch minimum diameter) catch basins or manholes shall be used at the following locations or for the following situations:
  - When overall structure height exceed 8 feet.
  - When all pipes tying into the structure exceed the limits set for Type 1 structures. Type 2 catch basins or manholes over 4 feet in height shall have standard ladders.
  - All Type 2 catch basins shall be specifically approved by the City. Type 2 catch basins shall not be substituted for manholes unless specifically approved by The City.
- The maximum slope of ground surface for a radius of 5 feet around a catch basin grate shall be 3:1. The preferred slope is 5:1 to facilitate maintenance access.
- Catch basin (or manhole) evaluation of structural integrity for H-20 loading will be required for multiple junction catch basins and other structures that exceed the recommendations of the manufacturers. The City may require further review for determining structural integrity.
- Catch basins leads shall be no longer than 50 feet.
- Catch basins shall not be installed in graveled areas or sediment generating areas.

- Catch basins shall be located:
  - At the low point of any sag vertical curve or grade break where the grade of roadway transitions from a negative to a positive grade.
  - Prior to any intersection such that a minimal amount of water flows across the intersection, through a curb ramp, or around a street return.
  - Prior to transitions from a typical crown to a full warp through a down hill grade.
- Catch basins shall not be placed in areas of expected pedestrian traffic. The engineer shall avoid placing a catch basin in crosswalks, adjacent to curb ramps, or in the gutter of a driveway. Care shall be taken on the part of the engineer to assure that the catch basin will not be in conflict with any existing or proposed utilities.
- All catch basins, inlets, etc. shall be marked as directed by the City.
- Connections to structures and mains shall be at 90°. Slight variations may be allowed.
- The maximum surface run between structures shall not exceed 400 linear feet.
- Changes in pipe direction, or increases or decreases in size, shall only be allowed at structures.
- For pipe slope less than the required minimum, distance between structures shall be decreased to 200 linear feet.
- For Type 1and 1L, catch basin to catch basin connections shall not be allowed.
- Bubble up systems shall not be allowed.

3.4.1.12 Pipe Clearances

Horizontal

A minimum of 5 feet horizontal separation shall be maintained between the storm main and all water or sanitary sewer mains. This shall also apply to laterals.

Vertical

Where crossing an existing or proposed utility or sanitary sewer main, the alignment of the storm system shall be such that the two systems cross as close to perpendicular as possible. Where crossing a sanitary sewer main, provide a minimum 18 inches of vertical separation. For crossings of water mains refer to the City Engineering Design and Construction Standards. The minimum vertical separation for a storm main crossing any other utility shall be 6 inches. *Note: Where the vertical separation of two parallel systems exceeds the horizontal separation, additional horizontal separation may be required to provide future access to the deeper system.*

3.4.1.13 Pipe Cover

- Suitable pipe cover over storm pipes in road rights-of-way shall be calculated for H-20 loading by the Project Engineer. Pipe cover is measured from the finished grade elevation down to the top of the outside surface of the pipe. Pipe manufacturer's recommendations are acceptable if verified by the Project Engineer.
- PVC (ASTM D3034 - SDR 35) minimum cover shall be three feet in areas subject to vehicular traffic; maximum cover shall be 30 feet or per the manufacturer's recommendations and as verified with calculations from the Project Engineer.
- Cover for ductile iron pipe may be reduced to a 1-foot minimum. Use of reinforced concrete pipe or AWWA C900 PVC pipe in this situation requires the engineer to provide verifying calculations to confirm the adequacy of the selected pipe's strength for the burial condition.
- Pipe cover in areas not subject to vehicular loads, such as landscape planters and yards, may be reduced to a 1-foot minimum.
- Catch basin evaluation of structural integrity for H-20 loading will be required for multiple junction catch basins and other structures that exceed the recommendations of the manufacturers.

3.4.1.14 System Connections

Connections to a pipe system shall be made only at catch basins or manholes. No wyes or tees are allowed except on private roof/footing/yard drain systems on pipes 8 inches in diameter, or less. Where wyes and tees are utilized, clean-outs shall be required upstream of each wye and tee.

Connections to structures and mains shall be at 90°. Slight variations may be allowed.

Minimum fall through manhole structures shall be 0. 1 foot. Pipes of different diameters shall be aligned vertically in manholes by one of the following methods, listed in order of preference:

1. Match pipe crowns
2. Match 80% diameters of pipes.
3. Match pipe inverts or use City approved drop inlet connection.

Drop connections shall be considered on a case by case basis.

Private connections to the City storm system shall be at a drainage structure (i.e. catch basin or manhole) and only if sufficient capacity exists. Tee connections into the side of a pipe shall not be permitted.

Roof downspouts may be infiltrated or dispersed in accordance with the provisions of Chapter 2. Infiltration and dispersion shall be evaluated first. If infiltration and dispersion are not feasible, roof drains may be discharged through the curb per Section 2.1.5 into the roadway gutter or connected into a drainage structure. Roof downspouts may **not** be connected directly into the side of a storm drainage pipe.

3.4.1.15 Debris Barriers

Access barriers are required on all pipes 12 inches and larger exiting a closed pipe system. Debris barriers (trash racks) are required on all pipes entering a pipe system. See Figure III-3-27 for required debris barriers on pipe ends outside of roadways and for requirements on pipe ends (culverts) projecting from driveways or roadway side slopes.

NOTES:
1. CMP or LCPE pipe end-section shown; for concrete pipe beveled end section, see KCRS drawing No. 2-001.
2. All steel parts must be galvanized and asphalt coated (treatment 1 or better).

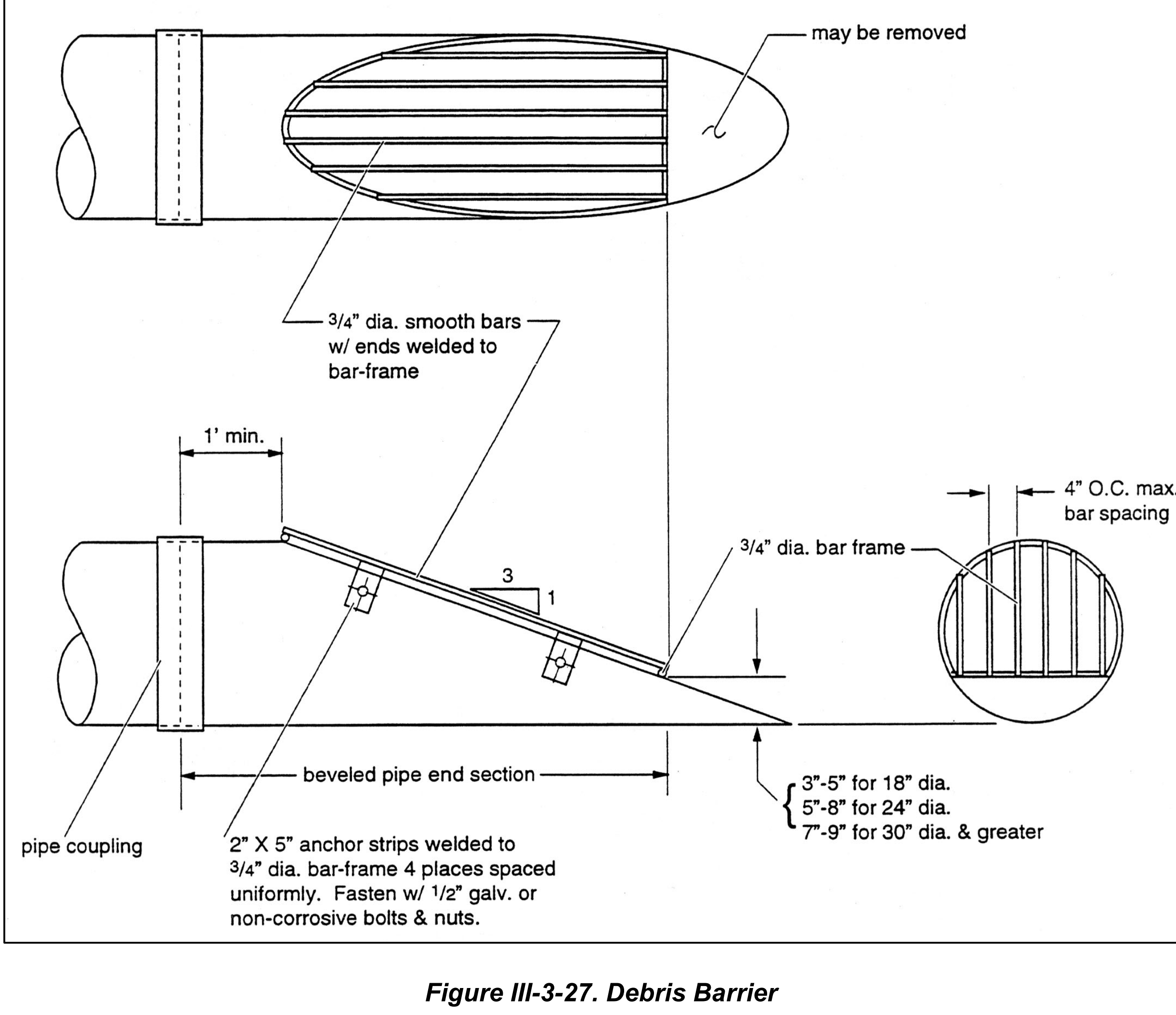


Figure III-3-27. Debris Barrier

3.4.2 Culverts

Culverts are relatively short segments of pipe of circular, elliptical, rectangular, or arch cross section and typically convey flow under road embankments or driveways. Culverts installed in streams and natural drainages shall meet the City's Critical Areas Code and *any fish passage requirements of the Washington State Department of Fish and Wildlife.*

3.4.2.1 Design Event

The design event for culverts is given in Section 3.2.

3.4.2.2 Design Flows

Design flows for sizing or assessing the capacity of culverts shall be determined using the hydrologic analysis methods described in this chapter.

Other single event models as described in Chapter 2 of this volume may be used to determine design flows. In addition, culverts shall not exceed the headwater requirements as established below:

3.4.2.3 Headwater

- For culverts 18-inch diameter or less, the maximum allowable headwater elevation for the 100-year, 24-hour design storm (measured from the inlet invert) shall not exceed 2 times the pipe diameter or arch-culvert-rise.
- For culverts larger than 18-inch diameter, the maximum allowable headwater elevation for the 100-year, 24-hour design storm (measured from the inlet invert) shall not exceed 1.5 times the pipe diameter or arch-culvert-rise.
- The maximum headwater elevation at the 100-year, 24-hour design flow shall be below any road or parking lot subgrade.

3.4.2.4 Conveyance Capacity

Use the procedures presented in this section to analyze both inlet and outlet control conditions to determine which governs. Culvert capacity is then determined using graphical methods.

3.4.2.5 Inlet Control Analysis

Nomographs such as those provided in Figure III-3-28 and Figure III-3-29 can be used to determine the inlet control headwater depth at design flow for various types of culverts and inlet configurations. These and other nomographs can be found in the FHWA publication *Hydraulic Design of Highway Culverts, HDS No. #5 (Report No. FHWA-NHI-01-020),* September 2001; or the WSDOT *Hydraulic Manual.*

Also available in the FHWA publication are the design equations used to develop the inlet control nomographs. These equations are presented below.

For **unsubmerged** inlet conditions (defined by $Q/AD^{0.5} \leq 3.5$);

Form 1*: $HW/D = H_c/D + K(Q/AD^{0.5})^M - 0.5S$** (equation 9)

Form 2*: $HW/D = K(Q/AD^{0.5})^M$ (equation 10)

For **submerged** inlet conditions (defined by $Q/AD^{0.5} \geq 4.0$);

$HW/D = c(Q/AD^{0.5})^2 + Y - 0.5S$** (equation 11)

Where HW = headwater depth above inlet invert (ft)

D = interior height of culvert barrel (ft)

H_c = specific head (ft) at critical depth ($d_c + V_c^2/2g$)

Q = flow (cfs)

A = full cross-sectional area of culvert barrel (sf)

S = culvert barrel slope (ft/ft)

K,M,c,Y = constants from Table III-3-23

The specified head H_c is determined by the following equation:

$H_c = d_c + V_c^2/2g$ (equation 12)

where d_c = critical depth (ft); see Figure III-3-33

V_c = flow velocity at critical depth (fps)

g = acceleration due to gravity (32.2 ft/sec2)

* The appropriate equation form for various inlet types is specified in Table III-3-23

** For mitered inlets, use +0.7S instead of –0.5S.

NOTE: Between the unsubmerged and submerged conditions, there is a transition zone ($3.5 < Q/AD^{0.5} < 4.0$) for which there is only limited hydraulic study information. The transition zone is defined empirically by drawing a curve between and tangent to the curves defined by the unsubmerged and submerged equations. In most cases, the transition zone is short and the curve is easily constructed.

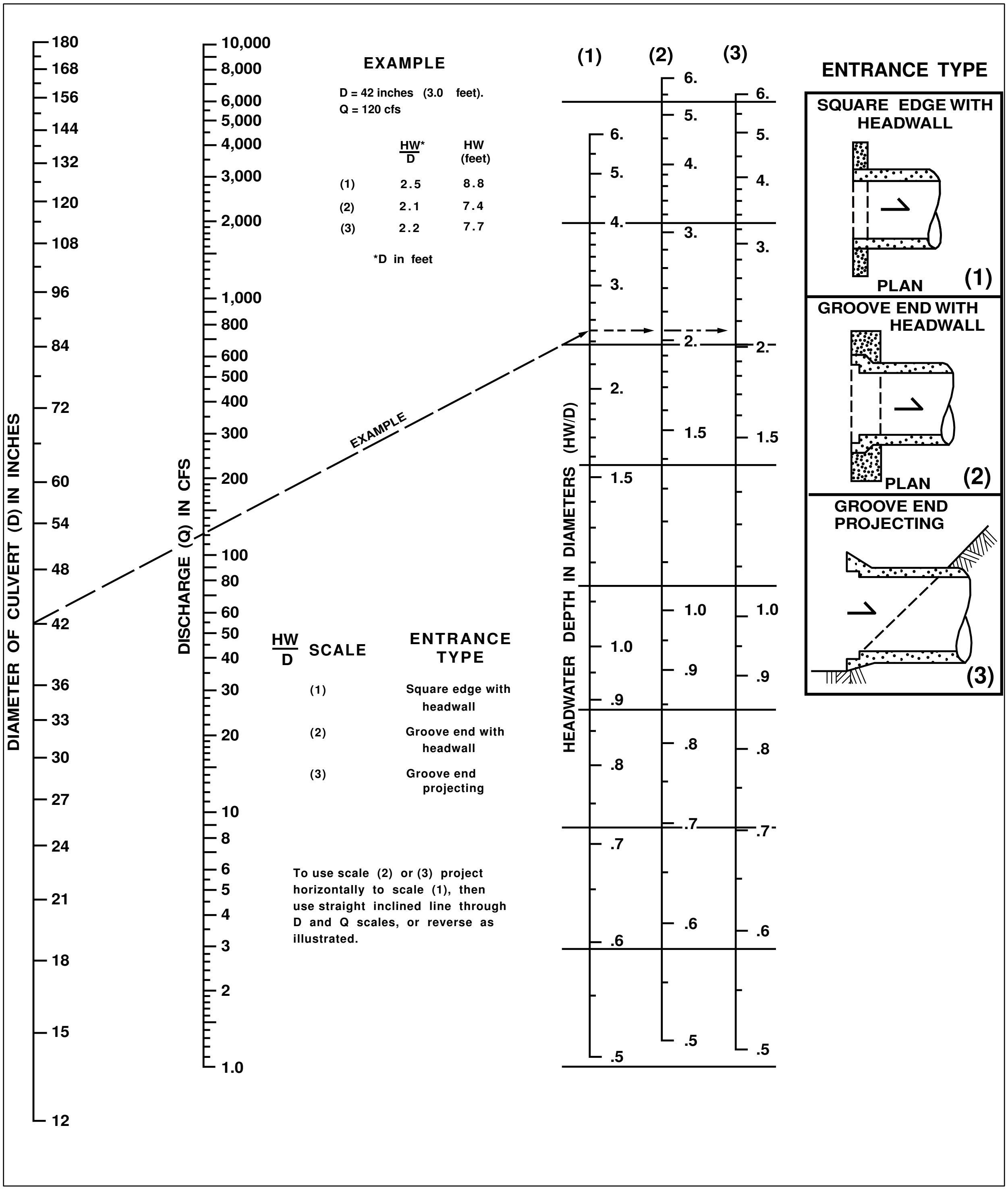


Figure III-3-28. Headwater Depth for Smooth Interior Pipe Culverts with Inlet Control

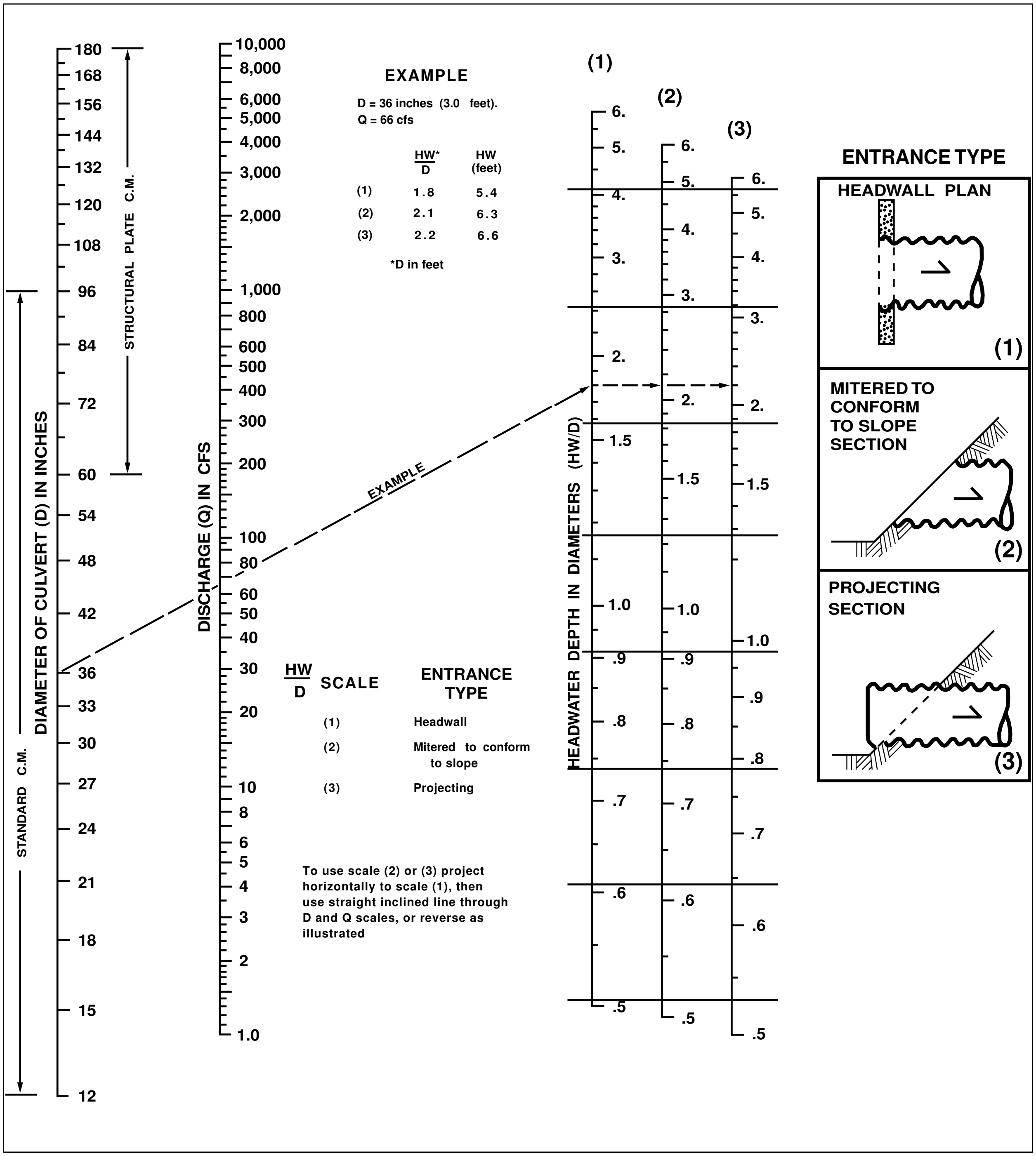


Figure III-3-29. Headwater Depth for Corrugated Pipe Culverts with Inlet Control

Table III-3-23. Constants for Inlet Control Equations*

Shape and Material	Inlet Edge Description	Unsubmerged			Submerged	
		Equation Form	*K*	*M*	*c*	*Y*
Circular Concrete	Square edge with headwall Groove end with headwall Groove end projecting	1	0.0098 0.0078 0.0045	2.0 2.0 2.0	0.0398 0.0292 0.0317	0.67 0.74 0.69
Circular CMP	Headwall Mitered to slope Projecting	1	0.0078 0.0210 0.0340	2.0 1.33 1.50	0.0379 0.0463 0.0553	0.69 0.75 0.54
Rectangular Box	30^o to 75^o wingwall flares 90^o and 15^o wingwall flares 0^o wingwall flares	1	0.026 0.061 0.061	1.0 0.75 0.75	0.0385 0.0400 0.0423	0.81 0.80 0.82
CM Boxes	90^o headwall Thick wall projecting Thin wall projecting	1	0.0083 0.0145 0.0340	2.0 1.75 1.5	0.0379 0.0419 0.0496	0.69 0.64 0.57
Arch CMP	90^o headwall Mitered to slope Projecting	1	0.0083 0.0300 0.0340	2.0 1.0 1.5	0.0496 0.0463 0.0496	0.57 0.75 0.53
Bottomless Arch CMP	90^o headwall Mitered to slope Thin wall projecting	1	0.0083 0.0300 0.0340	2.0 2.0 1.5	0.0379 0.0463 0.0496	0.69 0.75 0.57

*Source: FHWA HDS No. 5

3.4.2.6 Outlet Control Analysis

Nomographs such as those provided in Figure III-3-31 and Figure III-3-32 can be used to determine the **outlet control headwater depth** at design flow for various types of culverts and inlets. Outlet control nomographs other than those provided can be found in *FHWA HDS No. 5* or the *WSDOT Hydraulic Manual.*

The outlet control headwater depth can also be determined using the simple Backwater Analysis method presented in Section 3.4 for analyzing pipe system capacity. This procedure is summarized as follows for culverts:

$$HW = H + TW – LS \qquad \text{(equation 13)}$$

where H = $H_f + H_e + H_{ex}$

H_f = friction loss (ft) = $(V^2n^2L)/(2.22R^{1.33})$

NOTE: If $(H_f\text{+TW-LS}) < D$, adjust H_f such that $(H_f\text{+TW-LS}) = D$. This will keep the analysis simple and still yield reasonable results (erring on the conservative side).

H_e = entrance head loss (ft) = $K_e(V^2/2g)$

H_{ex} = exit head loss (ft) = $V^{2/}2g$

TW = tailwater depth above invert of culvert outlet (ft)

NOTE: If $TW < (D+d_c)/2$, set $TW = (D+d_c)/2$. This will keep the analysis simple and still yield reasonable results.

L = length of culvert (ft)
S = slope of culvert barrel (ft/ft)
D = interior height of culvert barrel (ft)
V = barrel velocity (fps)
n = Manning's roughness coefficient from Table III-3-19
R = hydraulic radius (ft)
K_e = entrance loss coefficient (from Table III-3-24)
G = acceleration due to gravity (32.2 ft/sec^2)
d_c = critical depth (ft); see Figure III-3-33

NOTE: The above procedure should not be used to develop stage/discharge curves for level pool routing purposes because its results are not precise for flow conditions where the hydraulic grade line falls significantly below the culvert crown (i.e., less than full flow conditions).

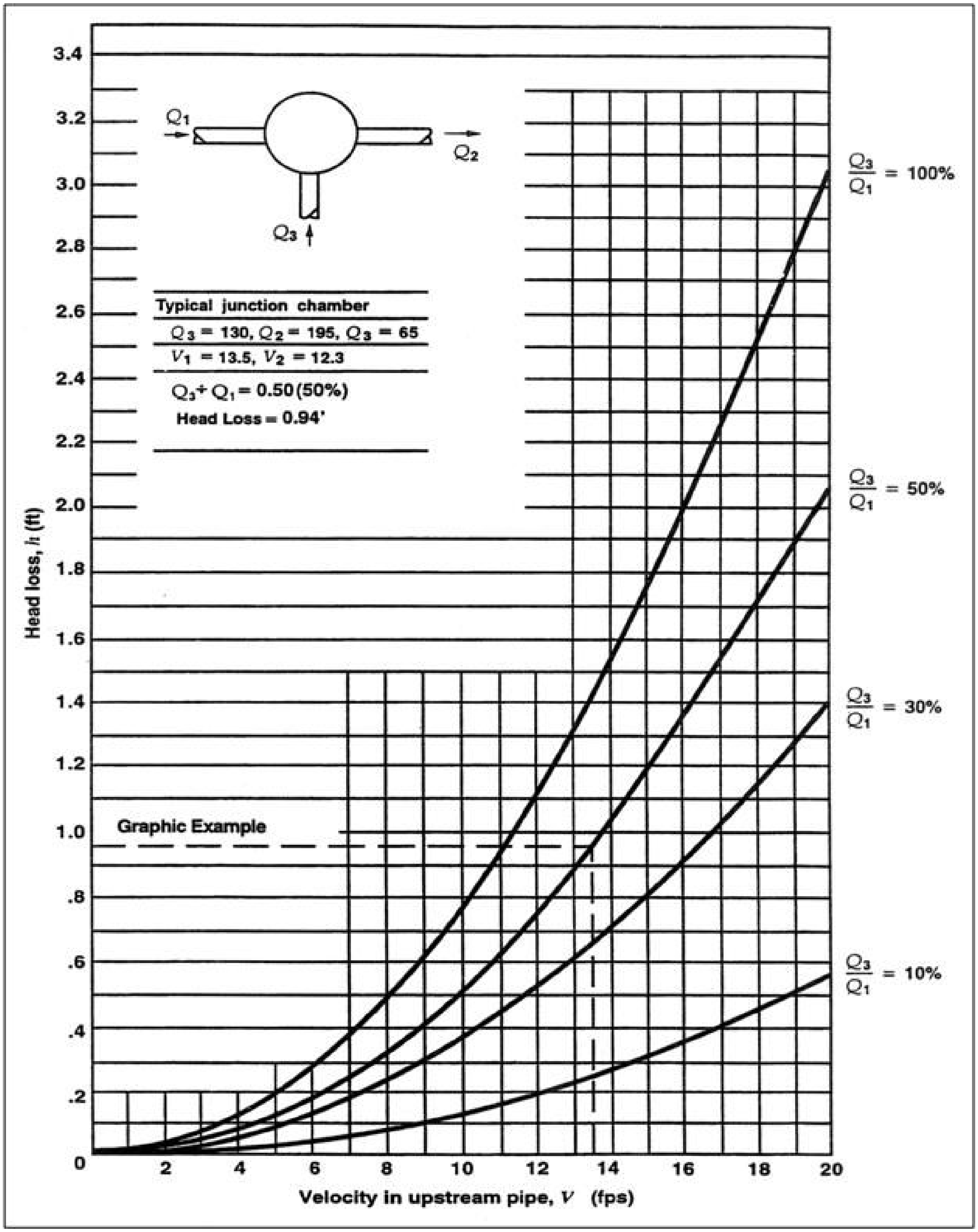


Figure III-3-30. Junction Head Loss in Structures

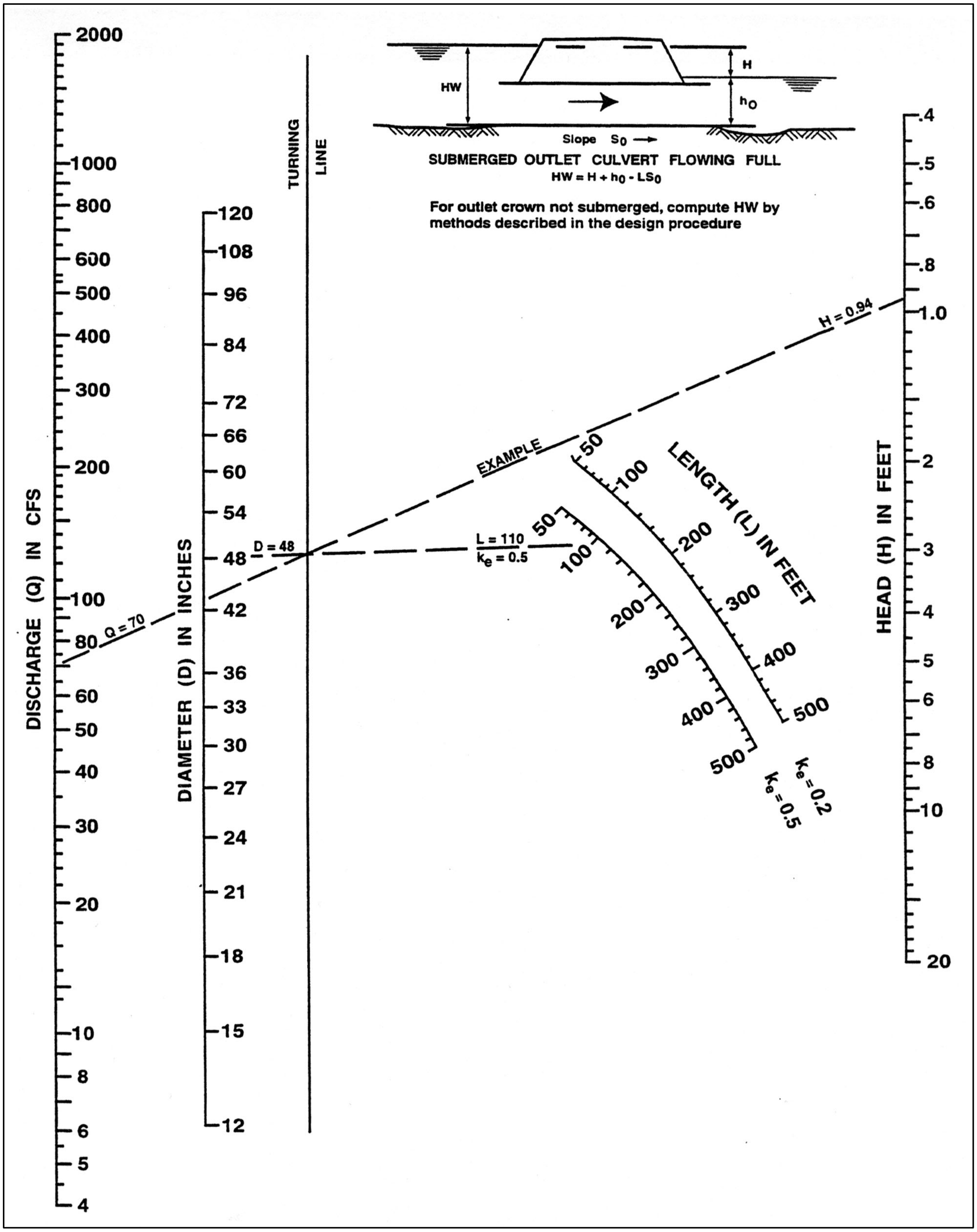


Figure III-3-31. Head for Culverts (Pipe W/"N"=0.012) Flowing Full with Outlet Control

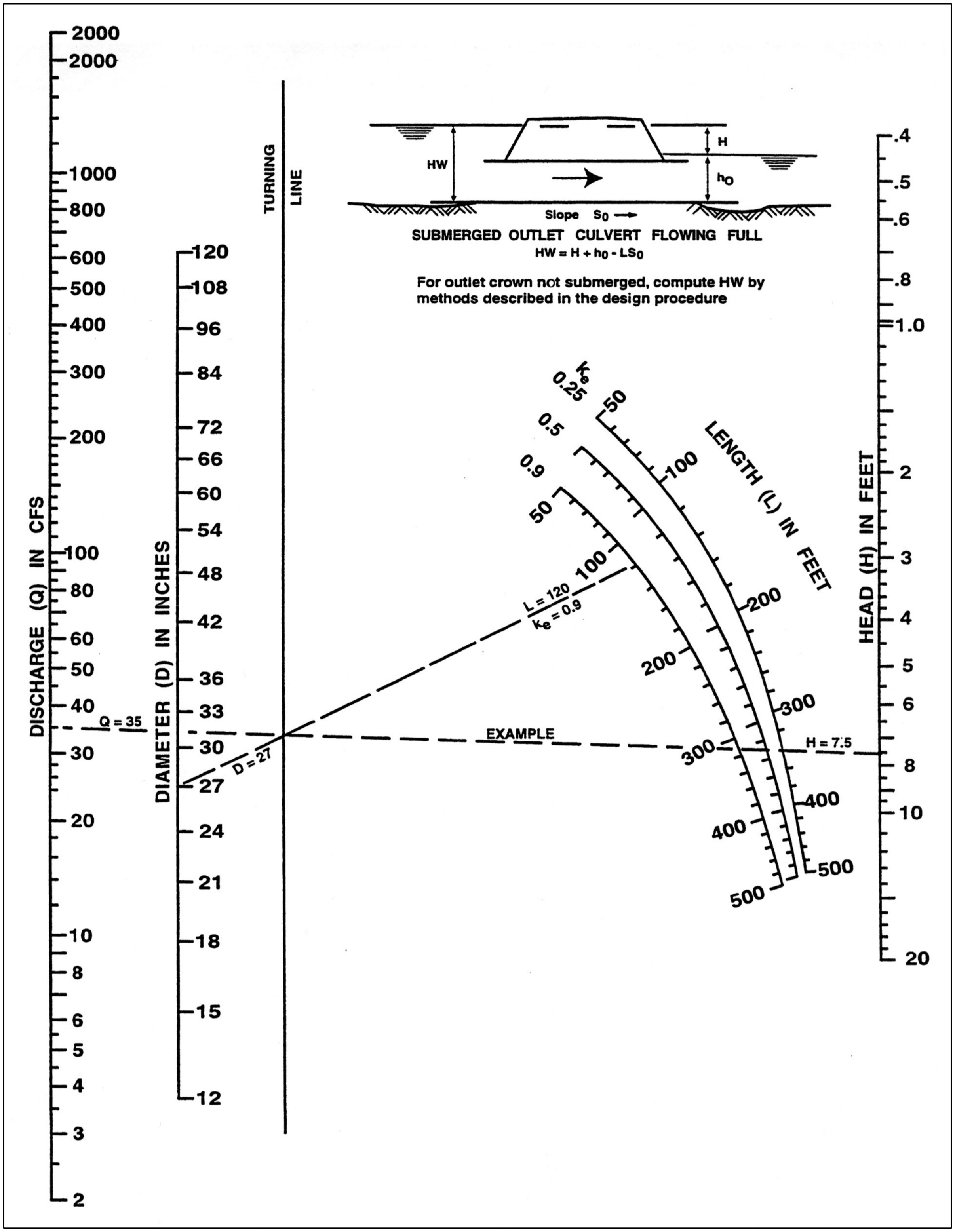


Figure III-3-32. Head for Culverts (Pipe W/"N"=0.024) Flowing Full with Outlet Control

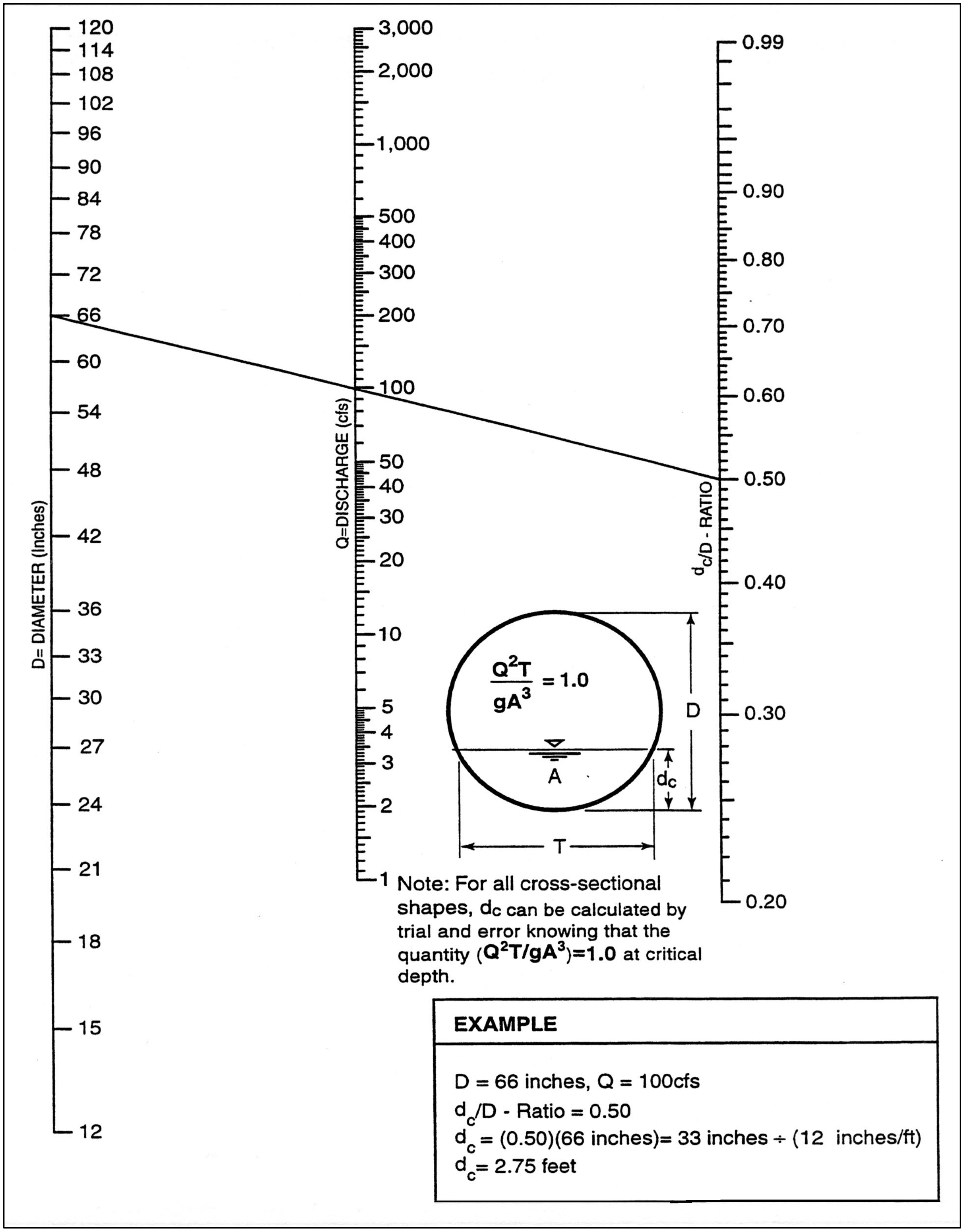


Figure III-3-33. Critical Depth of Flow for Circular Culverts

Table III-3-24. Entrance Loss Coefficients

Type of Structure and Design Entrance	Coefficient, K_e
<u>Pipe, Concrete, PVC, Spiral Rib, DI, and LCPE</u>	
Projecting from fill, socket (bell) end	0.2
Projecting from fill, square cut end	0.5
Headwall, headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded (radius = 1/12D)	0.2
Mitered to conform to fill slope	0.7
End section conforming to fill slope*	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
<u>Pipe, Pipe-Arch, Corrugated Metal and Other Non-Concrete or D.I.</u>	
Projecting from fill (no headwall)	0.9
Headwall, or headwall and wingwalls (square-edge)	0.5
Mitered to conform to fill slope (paved or unpaved slope)	0.7
End section conforming to fill slope*	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
<u>Box, Reinforced Concrete</u>	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrel dimension or beveled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel	
Square-edged at crown	0.4
Crown edge rounded to radius of 1/12 barrel dimension or beveled top edge	0.2
Wingwall at 10° to 25° to barrel	
Square-edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7
Side- or slope-tapered inlet	0.2

NOTE: "End section conforming to fill slope" are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both **inlet and outlet control**. Some end sections incorporating a **closed taper** in their design have a superior hydraulic performance.

3.4.2.7 Inlets and Outlets

All inlets and outlets in or near roadway embankments must be flush with and conforming to the slope of the embankments.

- For culverts 18-inch diameter and larger, the embankment around the culvert inlet shall be protected from erosion by **rock lining or riprap** as specified in Table III-3-27, except the length shall extend at least 5 feet upstream of the culvert, and the height shall be at or above the design headwater elevation.
- **Inlet structures**, such as concrete headwalls, may provide a more economical design by allowing the use of smaller entrance coefficients and, hence, smaller diameter culverts. When properly designed, they will also protect the embankment from erosion and eliminate the need for rock lining.
- In order to maintain the stability of roadway embankments, concrete headwalls, wingwalls, or tapered inlets and outlets may be required if **right-of-way or easement constraints** prohibit the culvert from extending to the toe of the embankment slopes. All inlet structures or headwalls installed in or near roadway embankments must be flush with and conforming to the slope of the embankment.
- **Debris barriers (trash racks)** are required on the inlets of all culverts that are over 60 feet in length and are 12 to 36 inches in diameter. This requirement also applies to the inlets of pipe systems. See Figure III-3-27 for a debris barrier detail. Exceptions are culverts on Type 1 or 2 streams.
- For culverts 18-inch diameter and larger, the receiving channel of the outlet shall be protected from erosion by **rock lining** specified in Table III-3-27, except the height shall be one foot above maximum tailwater elevation or one foot above the crown per Figure III-3-41, whichever is higher.

3.4.3 Open Channels

This section presents the methods, criteria, and details for hydraulic analysis and design of open channels.

3.4.3.1 Natural Channels

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

3.4.3.2 Constructed Channels

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

- **Vegetation-lined channels** are the most desirable of the constructed channels when properly designed and constructed. The vegetation stabilizes the slopes of the channel, controls erosion of the channel surface, and removes pollutants. The channel storage, low velocities, water quality benefits, and greenbelt multiple-use benefits create significant advantages over other constructed channels. The presence of vegetation in channels creates turbulence, which results in loss of energy and increased flow retardation; therefore, the design engineer must consider sediment deposition and scour, as well as flow capacity, when designing the channel.
- **Rock-lined channels** are necessary where a vegetative lining will not provide adequate protection from erosive velocities they may be constructed with riprap, gabions, or slope mattress linings. The rock lining increases the turbulence, resulting in a loss of energy and increased flow retardation. Rock lining also permits a higher design velocity and therefore a steeper design slope than in grass-lined channels. Rock linings are also used for erosion control at culvert and storm drain outlets, sharp channel bends, channel confluences, and locally steepened channel sections.
- **Bioengineered vegetation lining** is a desirable alternative to the conventional methods of rock armoring. *Soil bioengineering* is a highly specialized science that uses living plants and plant parts to stabilize eroded or damaged land. Properly bioengineering systems are capable of providing a measure of immediate soil protection and mechanical reinforcement. As the plants grow they produce vegetative protective cover and a root reinforcing matrix in the soil mantle. This root reinforcement serves several purposes:

  a. The developed anchor roots provide both shear and tensile strength to the soil, thereby providing protection from the frictional shear and tensile velocity components to the soil mantle during the time when flows are receding and pore pressure is high in the saturated bank.

  b. The root mat provides a living filter in the soil mantle that allows for the natural release of water after the high flows have receded.

  c. The combined root system exhibits active friction transfer along the length of the living roots. This consolidates soil particles in the bank and serves to protect the soil structure from collapsing and the stabilization measures from failing.

3.4.3.3 Design Flows

Design flows for sizing or assessing the capacity of open channels shall be determined using the hydrologic analysis methods described in this chapter. Single event models as described in Chapter 2 of this volume may be used to determine design flows. In addition, open channel shall meet the following:

- **Open channels** shall be designed to provide required conveyance capacity while minimizing erosion and allowing for aesthetics, habitat preservation, and enhancement.
- **An access easement for maintenance** is required along all constructed channels located on private property. Required easement widths and building setback lines vary with channel top width.
- **The maximum distance** from the edge of the adjacent access to the farthest point shall be eighteen feet (18').
- **Channel cross-section geometry** shall be trapezoidal, triangular, parabolic, or segmental as shown in Figure III-3-34 through Figure III-3-36. Side slopes shall be no steeper than 3:1 for vegetation-lined channels and 2:1 for rock-lined channels.
- **Vegetation-lined channels** shall have bottom slope gradients of 6% or less and a maximum velocity at design flow of 5 fps (see Table III-3-26).
- **Rock-lined channels or bank stabilization of natural channels** shall be used when design flow velocities exceed 5 feet per second. Rock stabilization shall be in accordance with Table III-3-26 or stabilized with bioengineering methods as described above in "Constructed Channels."

PROPERTIES OF DITCHES

	DIMENSIONS				HYDRAULICS			
NO.	Side Slopes	B	H	W	A	WP	R	$R^{(2/3)}$
D-1	--	--	6.5"	5'-0"	1.84	5.16	0.356	0.502
D-1C	--	--	6"	25'-0"	6.25	25.50	0.245	0.392
D-2A	1.5:1	2'-0"	1'-0"	5'-0"	3.50	5.61	0.624	0.731
B	2:1	2'-0"	1'-0"	6'-0"	4.00	6.47	0.618	0.726
C	3:1	2'-0"	1'-0"	8'-0"	5.00	8.32	0.601	0.712
D-3A	1.5:1	3'-0"	1'-6"	7'-6"	7.88	8.41	0.937	0.957
B	2:1	3'-0"	1'-6"	9'-0"	9.00	9.71	0.927	0.951
C	3:1	3'-0"	1'-6"	12'-0"	11.25	12.49	0.901	0.933
D-4A	1.5:1	3'-0"	2'-0"	9'-0"	12.00	10.21	1.175	1.114
B	2:1	3'-0"	2'-0"	11'-0"	14.00	11.94	1.172	1.112
C	3:1	3'-0"	2'-0"	15'-0"	18.00	15.65	1.150	1.098
D-5A	1.5:1	4'-0"	3'-0"	13'-0"	25.50	13.82	1.846	1.505
B	2:1	4'-0"	3'-0"	16'-0"	30.00	16.42	1.827	1.495
C	3:1	4'-0"	3'-0"	22'-0"	39.00	21.97	1.775	1.466
D-6A	2:1	--	1'-0"	4'-0"	2.00	4.47	0.447	0.585
B	3:1	--	1'-0"	6'-0"	3.00	6.32	0.474	0.608
D-7A	2:1	--	2'-0"	8'-0"	8.00	8.94	0.894	0.928
B	3:1	--	2'-0"	12'-0"	12.00	12.65	0.949	0.965
D-8A	2:1	--	3'-0"	12'-0"	18.00	13.42	1.342	1.216
B	3:1	--	3'-0"	18'-0"	27.00	18.97	1.423	1.265
D-9	7:1	--	1'-0"	14'-0"	7.00	14.14	0.495	0.626
D-10	7:1	--	2'-0"	28'-0"	28.00	28.28	0.990	0.993
D-11	7:1	--	3'-0"	42'-0"	63.00	42.43	1.485	1.302

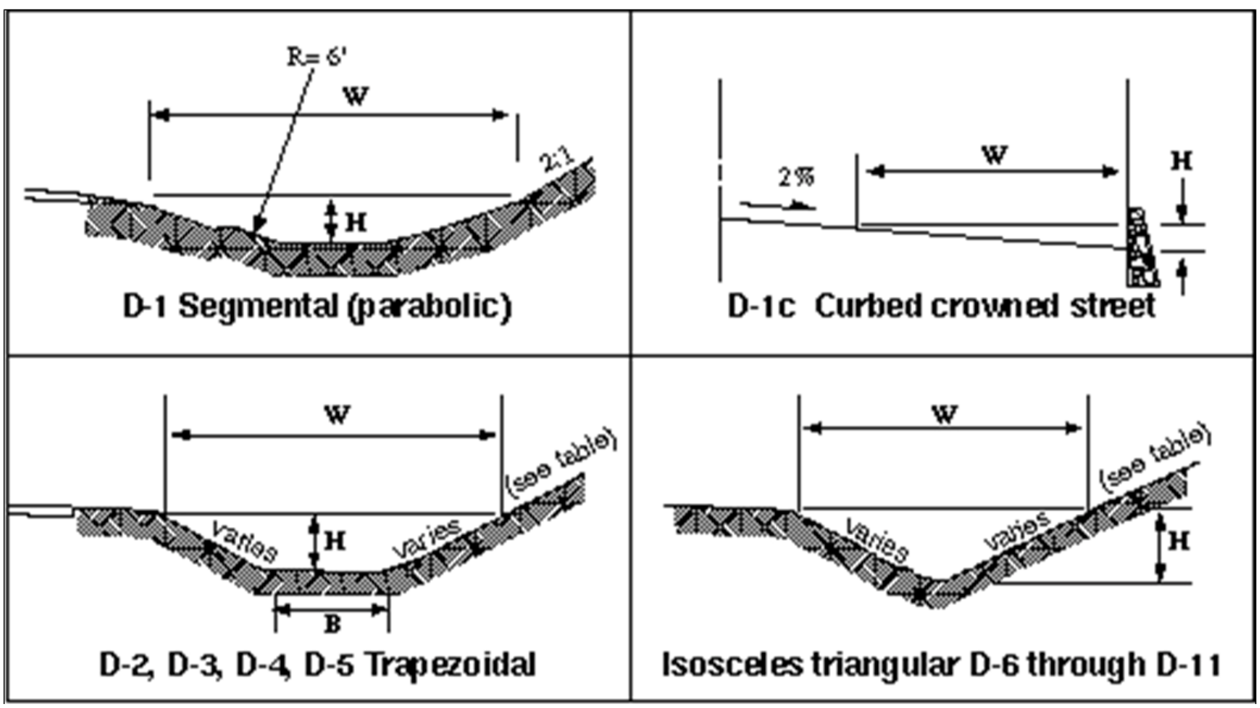


Figure III-3-34. Ditches – Common Section

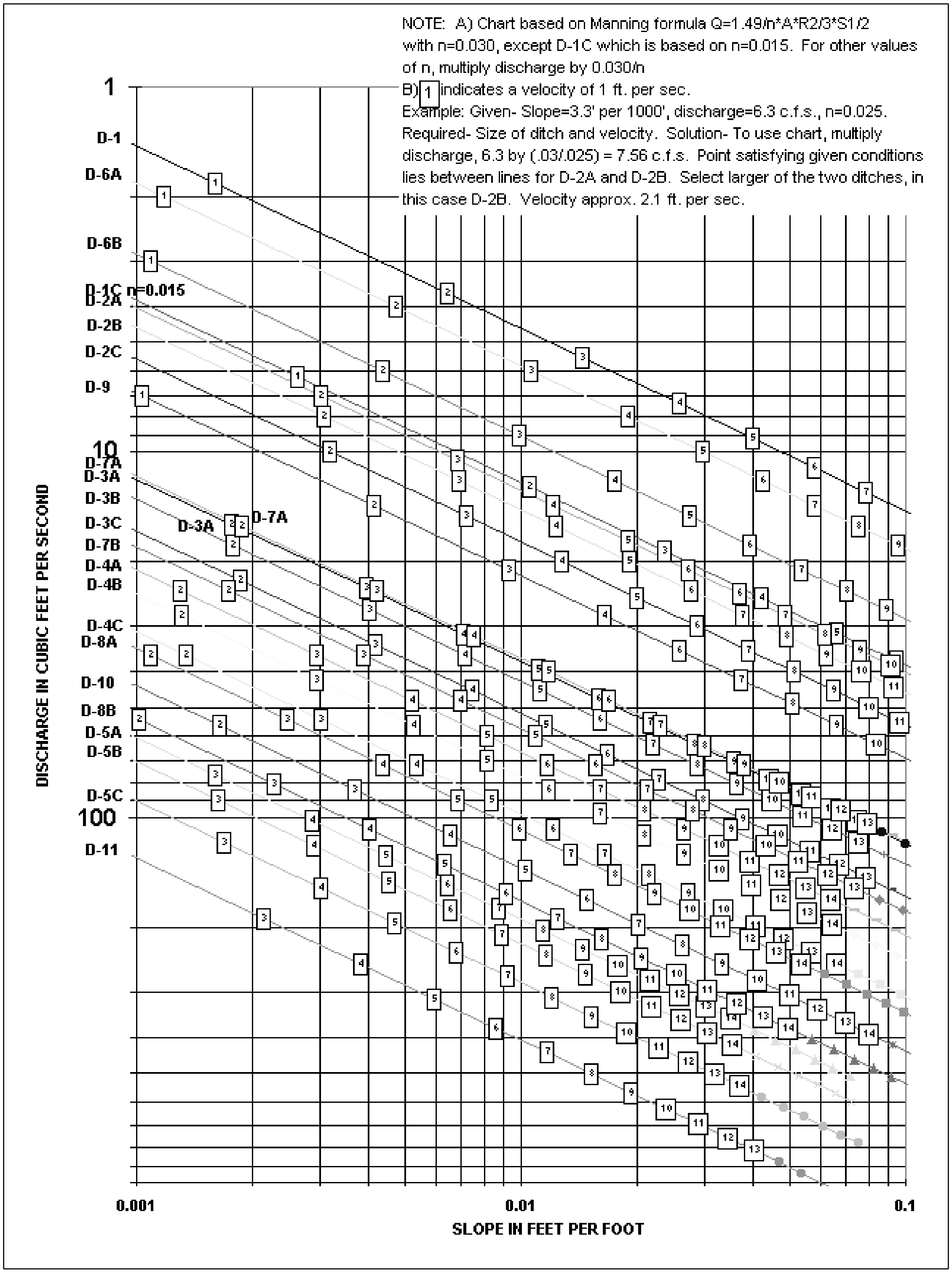
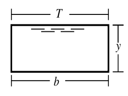
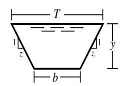
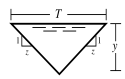
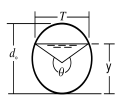
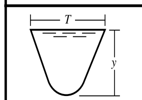
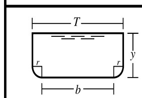
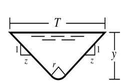


Figure III-3-35. Drainage Ditches – Common Sections

Section	Area A	Wetted perimeter P	Hydraulic radius R	Top width W	Hydraulic depth D	Section factor Z
 Rectangle	by	$b + 2y$	$\frac{by}{b + 2y}$	b	y	$by^{1.5}$
 Trapezoid	$(b + zy)y$	$b + 2y\sqrt{1 + z^2}$	$\frac{(b + zy)y}{b + 2y\sqrt{1 + z^2}}$	$b + 2zy$	$\frac{(b + zy)y}{b + 2zy}$	$\frac{[(b + zy)y]^{1.5}}{\sqrt{b + 2zy}}$
 Triangle	zy^2	$2y\sqrt{1 + z^2}$	$\frac{zy}{2\sqrt{1 + z^2}}$	$2zy$	$^1/_2 y$	$\frac{\sqrt{2}}{2} zy^{2.5}$
 Circle	$^1/_8(\theta - \sin\theta)d_\circ^2$	$^1/_2 \theta d_\circ$	$^1/_4 (1 - \frac{\sin\theta}{\theta}) d_\circ$	$(\sin(^1/_2\theta)d_\circ)$ *or* $2\sqrt{y(d_\circ - y)}$	$^1/_8 \left(\frac{\theta - \sin\theta}{\sin {^1/_2}\theta}\right) d_\circ$	$\frac{\sqrt{2}}{32} \frac{(\theta - \sin\theta)^{1.5}}{(\sin {^1/_2}\theta)^{0.5}} d_\circ^{2.5}$
 Parabola	$^2/_3 Ty$	$T + \frac{8y^2}{3T}$ *	$\frac{2T^2 y}{3T^2 + 8y^2}$ *	$\frac{3A}{2y}$	$^2/_3 y$	$^2/_9 \sqrt{6} Ty^{1.5}$
 Round-cornered Rectangle ($y>r$)	$(\frac{\pi}{2} - 2)r^2 + (b + 2r)y$	$(\pi - 2)r + b + 2y$	$\frac{(\frac{\pi}{2} - 2)r^2 + (b + 2r)y}{(\pi - 2)r + b + 2y}$	$b + 2r$	$\frac{(\frac{\pi}{2} - 2)r^2}{(b + 2r)} + y$	$\frac{[(\frac{\pi}{2} - 2)r^2 + (b + 2r)y]^{1.5}}{\sqrt{b + 2y}}$
 Round-bottomed Triangle	$\frac{T^2}{4z} - \frac{r^2}{z}(1 - z\cot^{-1} z)$	$\frac{T}{z}\sqrt{1 + z^2} - \frac{2r}{z}(1 - z\cot^{-1} z)$	$\frac{A}{P}$	$2[z(y - r) + r\sqrt{1 + z^2}]$	$\frac{A}{T}$	$A\sqrt{\frac{A}{T}}$

*Satisfactory approximation for the interval 0<x≤1, where x=4y/T. When x>1, use the exact expression $P = (^T/_2)\left[\sqrt{1 + x^2} + {^1/_x} \ln\left(x + \sqrt{1 + x^2}\right)\right]$

Figure III-3-36. Geometric Elements of Common Sections

Table III-3-25. Values of the Roughness Coefficient "n"

Type of Channel and Description	Manning's "*n*"* (Normal)
I. Constructed Channels	
a. Earth, straight and uniform	
1. Clean, recently completed	0.018
2. Gravel, uniform section, clean	0.025
3. With short grass, few weeds	0.027
b. Earth, winding and sluggish	
1. No vegetation	0.025
2. Grass, some weeds	0.030
3. Dense weeds or aquatic plants in deep channels	0.035
4. Earth bottom and rubble sides	0.030
5. Stony bottom and weedy banks	0.035
6. Cobble bottom and clean sides	0.040
c. Rock lined	
1. Smooth and uniform	0.035
2. Jagged and irregular	0.040
d. Channels not maintained, weeds and brush uncut	
1. Dense weeds, high as flow depth	0.080
2. Clean bottom, brush on sides	0.050
3. Same as #2, highest stage of flow	0.070
4. Dense brush, high stage	0.100

Type of Channel and Description	Manning's "*n*"* (Normal)
II. Natural Streams	
II-1 Minor Streams (top width at flood stage <100 ft)	
a. Streams on plain	
1. Clean, straight, full stage no rifts or deep pools	0.030
2. Same as #1, but more stones and weeds	0.035
3. Clean, winding, some pools and shoals	0.040
4. Same as #3, but some weeds	0.040
5. Same as #4, but more stones	0.070
6. Sluggish reaches, weedy deep pools	0.100
7. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.050
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages	
1. Bottom: gravel, cobbles, and few boulders	0.040
2. Bottom: cobbles with large boulders	0.050
II-2 Floodplains	
a. Pasture, no brush	
1. Short grass	0.030
2. High grass	0.035
b. Cultivated areas	
1. No crop	0.030
2. Mature row crops	0.035
3. Mature field crops	0.040
c. Brush	
1. Scattered brush, heavy weeds	0.050
2. Light brush and trees	0.060
3. Medium to dense brush	0.070
4. Heavy, dense brush	0.100
d. Trees	
1. Dense willows, straight	0.150
2. Cleared land with tree stumps, no sprouts	0.040
3. Same as #2, but with heavy growth of sprouts	0.060
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.100
5. Same as #4, but with flood stage reaching branches	0.120

****Note:** These "n" values are "normal" values for use in analysis of channels. For conservative design for channel capacity, the maximum values listed in other references should be considered. For channel bank stability, the minimum values should be considered.*

Table III-3-26. Channel Protection

Velocity at Design Flow (fps)		**REQUIRED PROTECTION**		
Greater than	**Less than or equal to**	**Type of Protection**	**Thickness**	**Minimum Height Above Design Water Surface**
0	5	Grass lining or bioengineered lining	N/A	0.5 foot
5	8	Rock lining[1] or bioengineered lining	1 foot	1 foot
8	12	Riprap[2]	2 feet	2 feet
12	20	Slope mattress gabion, etc.	Varies	2 feet

(1) Rock Lining shall be reasonable well graded as follows:
Maximum stone size: 12 inches
Median stone size: 8 inches
Minimum stone size: 2 inches

(2) Riprap shall be reasonably well graded as follows:
Maximum stone size: 24 inches
Median stone size: 16 inches
Minimum stone size: 4 inches

Note: *Riprap sizing is governed by side slopes on channel, assumed to be approximately 3:1.*

3.4.3.4 Conveyance Capacity

There are three acceptable methods of analysis for sizing and analyzing the capacity of open channels:

- Manning's equation for preliminary sizing
- Direct Step backwater method
- Standard Step backwater method

3.4.3.5 Manning's Equation for Preliminary Sizing

Manning's equation is used for preliminary sizing of open channel reaches of uniform cross section and slope (i.e., prismatic channels) and uniform roughness. This method assumes the flow depth (or normal depth) and flow velocity remain constant throughout the channel reach for a given flow.

The charts in Figure III-3-34 and Figure III-3-35 can be used to obtain graphic solutions of Manning's equation for common ditch sections. For conditions outside the range of these charts or for more precise results, Manning's equation can be solved directly from its classic forms shown in Equations 7 and 8 Section 3.4.1.2.

Table III-3-25 provides a reference for selecting the appropriate "*n*" values for open channels. A number of engineering reference books, such as *Open-Channel Hydraulics* by V.T. Chow, may also be used as guides to select "*n*" values. Figure III-3-36 contains the geometric elements of common channel sections useful in determining area A, wetted perimeter WP, and hydraulic radius (R=A/WP).

If flow restrictions raise the water level above normal depth within a given channel reach, a *backwater condition* (or non-uniform flow) is said to exist. This condition can result from flow restrictions created by a downstream culvert, bridge, dam, pond, lake, etc., and even a downstream channel reach having a higher normal flow depth. If backwater conditions are found to exist for the design flow, a backwater profile must be computed to verify that the channel's capacity is still adequate as designed. The Direct Step or Standard Step backwater methods presented in this section can be used for this purpose.

3.4.3.6 Direct Step Backwater Method

The Direct Step Backwater Method can be used to compute backwater profiles on prismatic channel reaches (i.e. reaches having uniform cross section and slope) where a backwater condition or restriction to normal flow is known to exist. The method can be applied to a series of prismatic channel reaches in succession beginning at the downstream end of the channel and computing the profile upstream.

Calculating the coordinates of the water surface profile using the method is an iterative process achieved by choosing a range of flow depths, beginning at the downstream end, and proceeding incrementally up to the point of interest or to the point of normal flow depth. This is best accomplished by the use of a table (see Figure III-3-38) or computer programs.

$Q =$ ________ $n =$ ________ $S_o =$ ________ $\alpha =$ ________ $Y_n' =$ ________

y (1)	A (2)	R (3)	$R^{4/3}$ (4)	V (5)	$\alpha V^2/2g$ (6)	E (7)	ΔE (8)	S_f (9)	$\bar{S}_f$ (10)	$S_o - \bar{S}_f$ (11)	Δx (12)	x (13)

Figure III-3-37. Open Channel Flow Profile Computation

y (1)	A (2)	R (3)	$R^{4/3}$ (4)	V (5)	$\alpha V^2/2g$ (6)	E (7)	ΔE (8)	S_f (9)	$\bar{S}_f$ (10)	$S_o - \bar{S}_f$ (11)	Δx (12)	x (13)
6.0	72.0	2.68	3.72	0.42	0.0031	6.0031	-	0.00002	-	-	-	-
5.5	60.5	2.46	3.31	0.50	0.0040	5.5040	0.4990	0.00003	0.000025	0.00698	71.50	71.5
5.0	50.0	2.24	2.92	0.60	0.0064	5.0064	0.4976	0.00005	0.000040	0.00696	71.49	142.99
4.5	40.5	2.01	2.54	0.74	0.0098	4.5098	0.4966	0.00009	0.000070	0.00693	71.64	214.63
4.0	32.0	1.79	2.17	0.94	0.0157	4.0157	0.4941	0.00016	0.000127	0.00687	71.89	286.52
3.5	24.5	1.57	1.82	1.22	0.0268	3.5268	0.4889	0.00033	0.000246	0.00675	72.38	358.90
3.0	18.0	1.34	1.48	1.67	0.0496	3.0496	0.4772	0.00076	0.000547	0.00645	73.95	432.85
2.5	12.5	1.12	1.16	2.40	0.1029	2.6029	0.4467	0.00201	0.001387	0.00561	79.58	512.43
2.0	8.0	0.89	0.86	3.75	0.2511	2.2511	0.3518	0.00663	0.004320	0.00268	131.27	643.70

The step computations are carried out as shown in the above table. The values in each column of the table are explained as follows:

Col. 1. Depth of flow (ft) assigned from 6 to 2 feet

Col. 2. Water area (ft^2) corresponding to depth y in Col. 1

Col. 3 Hydraulic radius (ft) corresponding to y in Col. 1

Col. 4. Four-thirds power of the hydraulic radius

Col. 5. Mean velocity (fps) obtained by dividing Q (30 cfs) by the water area in Col. 2

Col. 6. Velocity head (ft)

Col. 7. Specific energy (ft) obtained by adding the velocity head in Col. 6 to depth of flow in Col. 1

Col. 8. Change of specific energy (ft) equal to the difference between the E value in Col. 7 and that of the previous step.

Col. 9. Friction slope S_f, computed from V as given in Col. 5 and $R^{4/3}$ in Col. 4

Col.10. Average friction slope between the steps, equal to the arithmetic mean of the friction slope just computed in Col. 9 and that of the previous step

Col.11. Difference between the bottom slope, S_o, and the average friction slope, $\bar{S}_f$

Col.12. Length of the reach (ft) between the consecutive steps; Computed by $\Delta x = \Delta E/(S_o - \bar{S}_f)$ or by dividing the value in Col. 8 by the value in Col. 11

Col.13. Distance from the beginning point to the section under consideration. This is equal to the cumulative sum of the values in Col. 12 computed for previous steps.

There are a number of commercial software programs for use on personal computers that use variations of the Standard Step backwater method for determining water surface profiles. The most common and widely accepted program is called HEC-2, published and supported by the United States Army Corps of Engineers Hydraulic Engineering Center. It is the model required by FEMA for use in performing flood hazard studies for preparing flood insurance maps. Other programs include WSP-2, published by the SCS, and WSPRO or E-431, published by USGS.

Figure III-3-38. Direct Step Backwater Method – Example

Equating the total head at cross section 1 and 2, the following equation may be written:

$$S_0 \Delta x + y_1 + \alpha_1 \frac{V_1^2}{2g} = y_2 + \alpha_2 \frac{V_2^2}{2g} + S_f \Delta x \qquad \text{(equation 14)}$$

where, Δx = distance between cross sections (ft)

y_1, y_2 = depth of flow (ft at cross sections 1 and 2

V_1, V_2 = velocity (fps) at cross sections 1 and 2

α_1, α_2 = energy coefficient at cross sections 1 and 2

S_0 = bottom slope (ft/ft)

S_f = friction slope = $(n_2V_2)/2.21R^{1.33})$

g = acceleration due to gravity, (32.2 ft/sec^2)

If the specific energy E at any one cross-section is defined as follows:

$$E = y + \alpha \frac{V^2}{2g} \qquad \text{(equation 15)}$$

Assuming $\alpha = \alpha_1 = \alpha_2$ where α is the energy coefficient which corrects for the non-uniform distribution of velocity over the channel cross section, equations 14 and 15 can be combined and rearranged to solve for Δx as follows:

$$\Delta x = \frac{(E_2 - E_1)}{(S_0 - S_f)} = \frac{\Delta E}{(S_0 - S_f)} \qquad \text{(equation 16)}$$

Typically values of the energy coefficient α are as follows:

Channels, regular section	1.15
Natural streams	1.3
Shallow vegetated flood fringes (includes channel)	1.75

For a given flow, channel slope, Manning's "*n*," and energy coefficient α, together with a beginning water surface elevation y_2, the values of Δx may be calculated for arbitrarily chosen values of y_1. The coordinates defining the water surface profile are obtained from the cumulative sum of Δx and corresponding values of y.

The **normal flow depth** $\boldsymbol{y_n}$ should first be calculated from Manning's equation to establish the upper limit of the backwater effect.

3.4.3.7 Standard Step Backwater Method

The Standard Step Backwater Method is a variation of the Direct Step Backwater Method and can be used to compute backwater profiles on both prismatic and non-prismatic channels. In this method, stations are established along the channel where cross section data is known or has been determined through field survey. The computation is carried out in steps from station to station rather than throughout a given channel reach as is done in the Direct Step method. As a result, the analysis involves significantly more trial-and-error calculation in order to determine the flow depth at each station.

3.4.3.8 Computer Applications

There are several different computer programs capable of the iterative calculations involved for these analyses. The project engineer is responsible for providing information describing how the program was used, assumptions the program makes and descriptions of all variables, columns, rows, summary tables, and graphs. The most current version of any software program shall be used for analysis. Auburn may find specific programs not acceptable for use in design. Please check with Public Works, to confirm the applicability of a particular program prior to starting design.

3.4.3.9 Riprap Design[3]

Proper riprap design requires the determination of the median size of stone, the thickness of the riprap layer, the gradation of stone sizes, and the selection of angular stones, which will interlock when placed. Research by the U.S. Army Corps of Engineers has provided criteria for selecting the **median stone weight, W_{50}** (Figure III-3-39). If the riprap is to be used in a highly turbulent zone (such as at a culvert outfall, downstream of a stilling basin, at sharp changes in channel geometry, etc.), the median stone W_{50} should be increased from 200% to 600% depending on the severity of the locally high turbulence. The thickness of the riprap layer should generally be twice the **median stone diameter (D_{50})** or at least equivalent to the diameter of the maximum stone. The riprap should have a reasonably well-graded assortment of stone sizes within the following gradation:

$$1.25 \leq D_{max}/D_{50} \leq 1.50$$

$$D_{15}/D_{50} = 0.50$$

$$D_{min}/D_{50} = 0.25$$

Riprap Filter Design

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

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

---

[3] From a paper prepared by M. Schaefer, Dam Safety Section, Washington State Department of Ecology.

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

Example:

What embedded riprap design should be used to protect a streambank at a level culvert outfall where the outfall velocities in the vicinity of the downstream toe are expected to be about 8 fps.

From Figure III-3-39, W_{50} = 6.5 lbs, but since the downstream area below the outfall will be subjected to severe turbulence, increase W_{50} by 400% so that:

W_{50} = 26 lbs, D_{50} = 8.0 inches

The gradation of the riprap is shown in Figure III-3-40, and the minimum thickness would be 1 foot (from Table III-3-26); however, 16 inches to 24 inches of riprap thickness would provide some additional insurance that the riprap will function properly in this highly turbulent area.

Figure III-3-40 shows that the gradation curve for ASTM C33, size number 57 coarse aggregate (used in concrete mixes), would meet the filter criteria. Applying the filter criteria to the coarse aggregate demonstrates that any underlying material whose gradation was coarser than that of concrete sand would be protected.

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

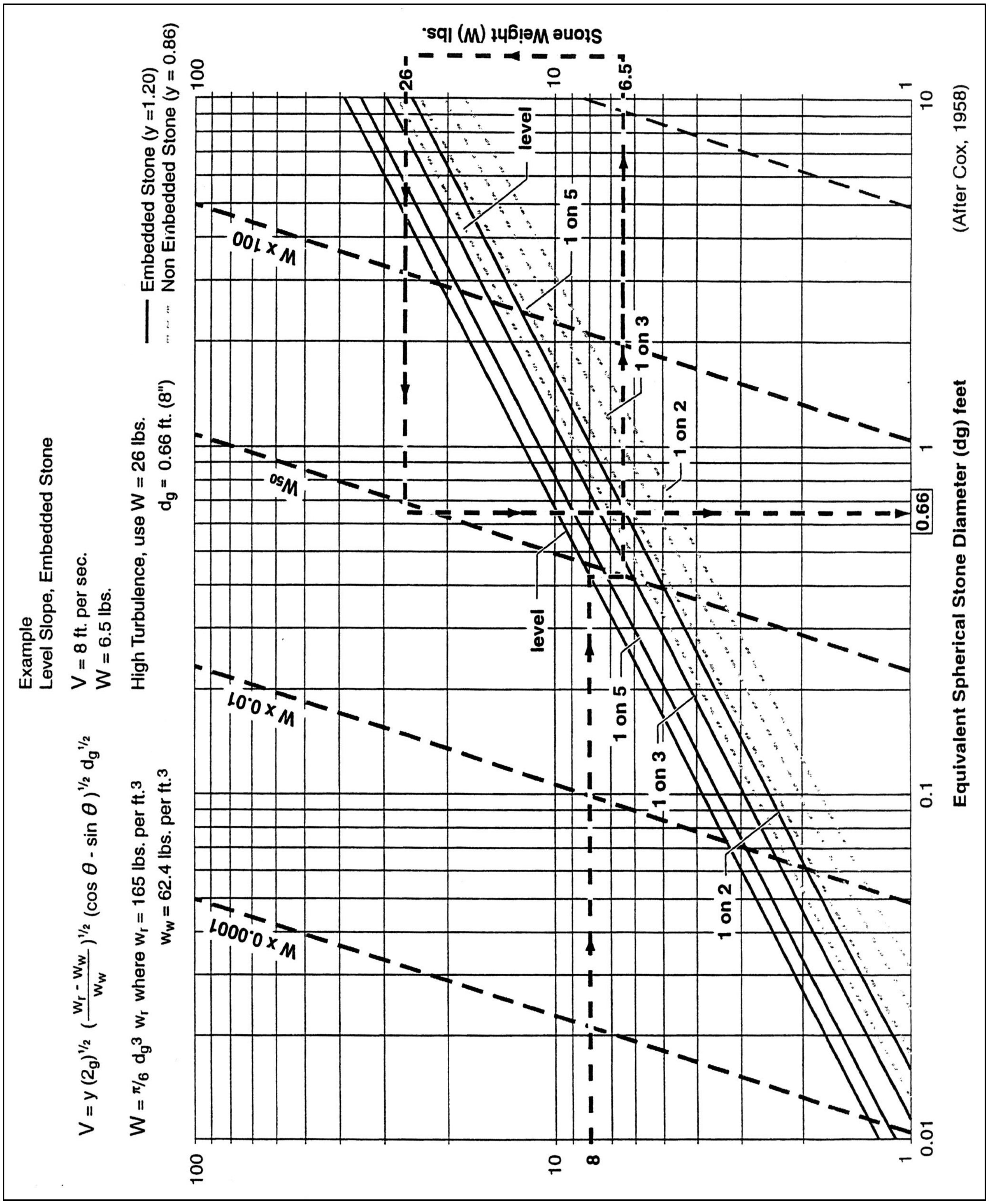


Figure III-3-39. Mean Channel Velocity vs Medium Stone Weight (W50) and Equivalent Stone Diameter

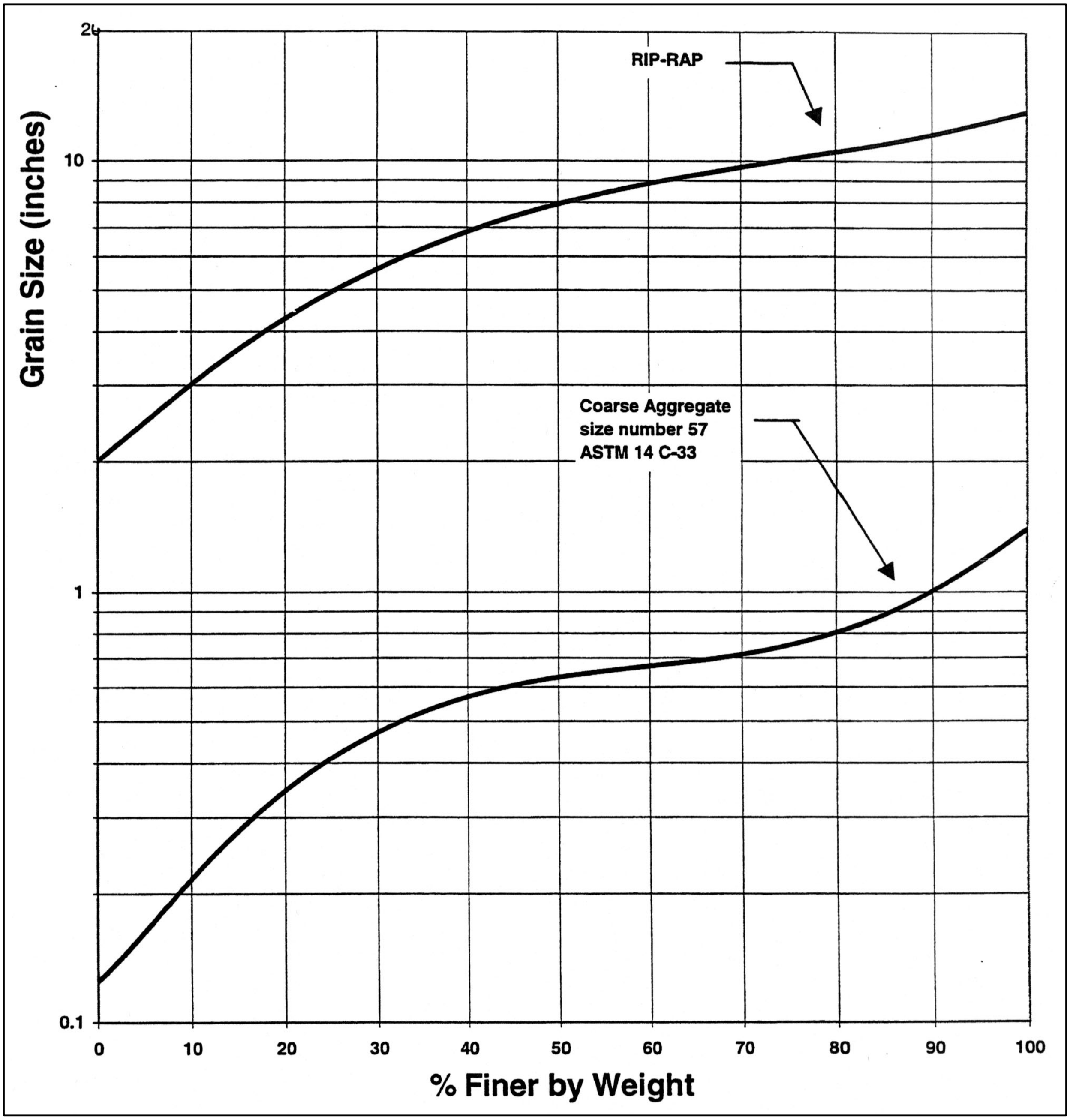


Figure III-3-40. Riprap Gradation Curve

3.5 Outfalls Systems

This section presents the methods, criteria and details for analysis and design of outfall systems. Properly designed outfalls are critical to reducing the chance of adverse impacts as the result of concentrated discharges from pipe systems and culverts, both onsite and downstream. Outfall systems include rock splash pads, flow dispersal trenches, gabion or other energy dissipaters, and tightline systems. A tightline system is typically a continuous length of pipe used to convey flows down a steep or sensitive slope with appropriate energy dissipation at the discharge end.

3.5.1 Outfall Design Criteria

All outfalls must be provided with an appropriate outlet / energy dissipation structure such as a dispersal trench, gabion outfall, or rock splash pad (see Figure III-3-41) as specified below and in Table III-3-27.

No erosion or flooding of downstream properties shall result from discharge from an outfall.

Table III-3-27. Rock Protection at Outfalls

Discharge Velocity at Design Flow in feet per second (fps)	**Required Protection**				
	Minimum Dimensions				
	Type	**Thickness**	**Width**	**Length**	**Height**
0 – 5	Rock lining[1]	1 foot	Diameter + 6 feet	8 feet *or* 4 x diameter, whichever is greater	Crown + 1 foot
>5 - 10	Riprap[2]	2 feet	Diameter + 6 feet *or* 3 x diameter, whichever is greater	12 feet *or* 4 x diameter, whichever is greater	Crown + 1 foot
>10 - 20	Gabion outfall	As required	As required	As required	Crown + 1 foot
>20	Engineered energy dissipater required				

1 **Rock lining** shall be quarry spalls with gradation as follows:

Passing 8-inch square sieve:	100%
Passing 3-inch square sieve:	40 to 60% maximum
Passing ¾-inch square sieve:	0 to 10% maximum

2 **Riprap** shall be reasonably well graded with gradation as follows:

Maximum stone size:	24 inches (nominal diameter)
Median stone size:	16 inches
Minimum stone size:	4 inches

Riprap sizing is based on outlet channel side slopes of approximately 3:1.

3.5.1.1 Energy dissipation

- For freshwater outfalls with a design velocity greater than 10 fps, a gabion dissipater or engineered energy dissipater may be required. The gabion outfall detail shown in Figure III-3-44 is illustrative only. A design engineered to specific site conditions must be developed.
- Engineered energy dissipaters, including stilling basins, drop pools, hydraulic jump basins, baffled aprons, and bucket aprons, are required for outfalls with design velocity greater than 20 fps. These should be designed using published or commonly known techniques found in such references as Hydraulic Design of Energy Dissipaters for Culverts and Channels, published by the Federal Highway Administration of the United States Department of Transportation; Open Channel Flow, by V.T. Chow; Hydraulic Design of Stilling Basins and Energy Dissipaters, EM 25, Bureau of Reclamation (1978); and other publications, such as those prepared by the Soil Conservation Service (now Natural Resource Conservation Service).
- Alternate mechanisms may be allowed with written approval of The City. Alternate mechanisms shall be designed using sound hydraulic principles with consideration of ease of construction and maintenance.
- Mechanisms that reduce velocity prior to discharge from an outfall are encouraged. Some of these are drop manholes and rapid expansion into pipes of much larger size. Other discharge end features may be used to dissipate the discharge energy. An example of an end feature is the use of a Diffuser Tee with holes in the front half, as shown in Figure III-3-45.

The in-stream sample gabion mattress energy dissipater may not be acceptable within the ordinary high water mark of fish-bearing waters or where gabions will be subject to abrasion from upstream channel sediments. A gabion basket located outside the ordinary high water mark should be considered for these applications.

3.5.1.2 Flow dispersion

- The flow dispersal trenches shown in Figure III-3-42 and Figure III-3-43 shall not be used unless both criteria below are met:
  - An outfall is necessary to disperse concentrated flows across uplands where no conveyance system exists and the natural (existing) discharge is unconcentrated; and
  - The 100-year peak discharge rate is less than or equal to 0.5 cfs.
- Flow dispersion may be allowed for discharges greater than 0.5 cfs, providing that adequate design details and calculations for the dispersal trench to demonstrate that discharge will be sheet flow are submitted and approved by The City.

- For the dispersion trenches shown in Figure III-3-42 and Figure III-3-43, a vegetated flowpath of at least 25 feet in length must be maintained between the outlet of the trench and any property line, structure, stream, wetland, or impervious surface. A vegetated flowpath of at least 50 feet in length must be maintained between the outlet of the trench and any steep slope. Sensitive area buffers may count towards flowpath lengths. For dispersion trenches discharging more than 0.5 cfs, additional vegetated flow path may be required.
- All dispersions systems shall be at least 10 feet from any structure or property line. If necessary, setbacks shall be increased from the minimum 10 feet in order to maintain a 1H:1V side slope for future excavation and maintenance.
- Dispersion systems shall be setback from sensitive areas, steep slopes, slopes 20% or greater, landslide hazard areas, and erosion hazard areas as governed by the Auburn City Code or as outlined in this manual, whichever is more restrictive.
- For sites with multiple dispersion trenches, a minimum separation of 10 feet is required between flowpaths. The City may require a larger separation based upon site conditions such as slope, soil type and total contributing area.
- Runoff discharged towards landslide hazard areas must be evaluated by a geotechnical engineer or a licensed geologist, hydrogeologist, or engineering geologist. The discharge point shall not be placed on or above slopes 20% (5H:1V) or greater or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and City approval.

Please refer to the Auburn City Code for additional requirements. ACC 16.10 Critical Areas may contain additional requirements depending upon the project proposal. A Hydraulic Project Approval (Chapter 77.55 RCW) and an Army Corps of Engineers permit may be required for any work within the ordinary high water mark.

Other provisions of that RCW or the Hydraulics Code - Chapter 220-110 WAC may also apply.

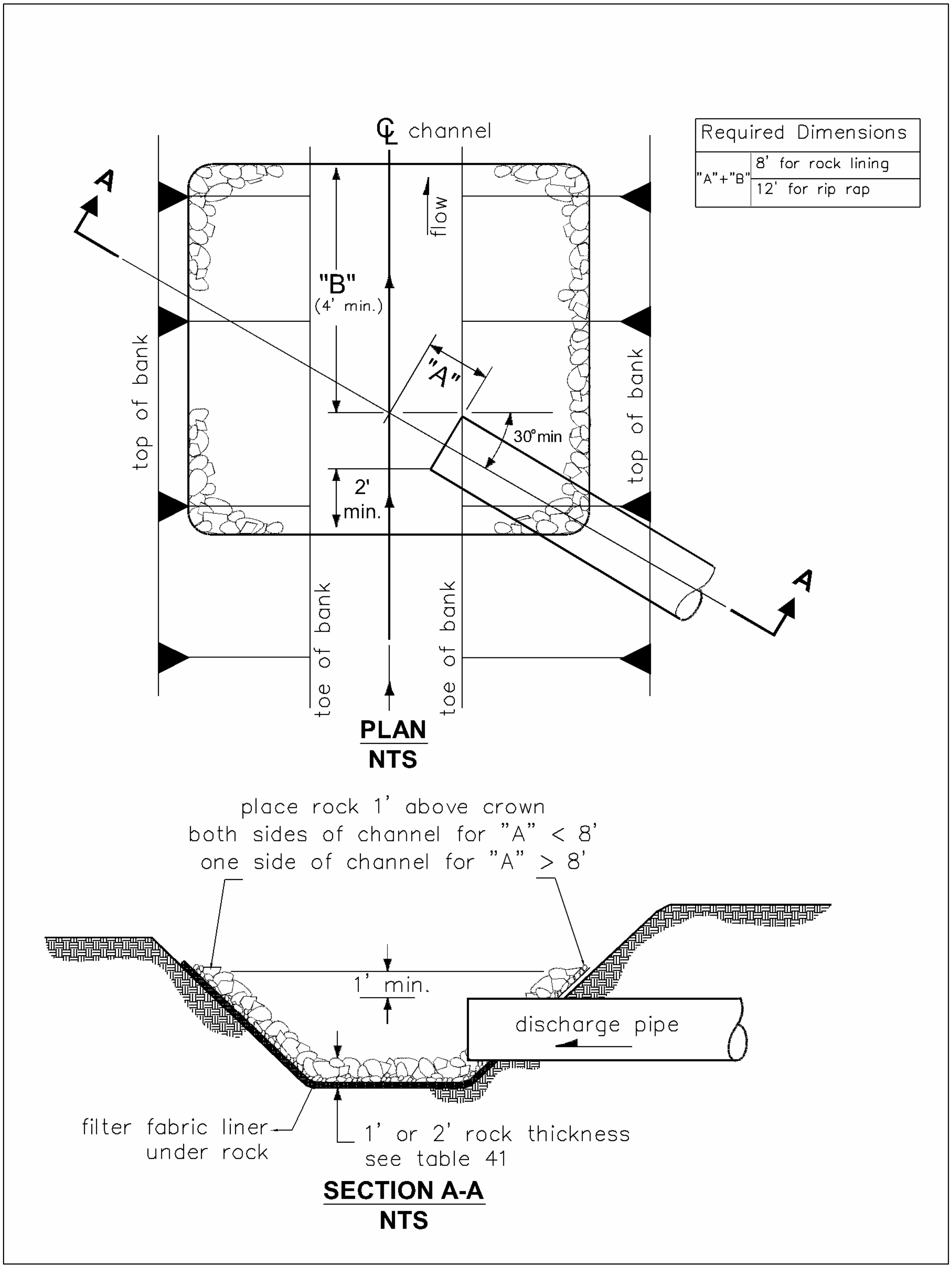


Figure III-3-41. Pipe/Culvert Outfall Discharge Protection

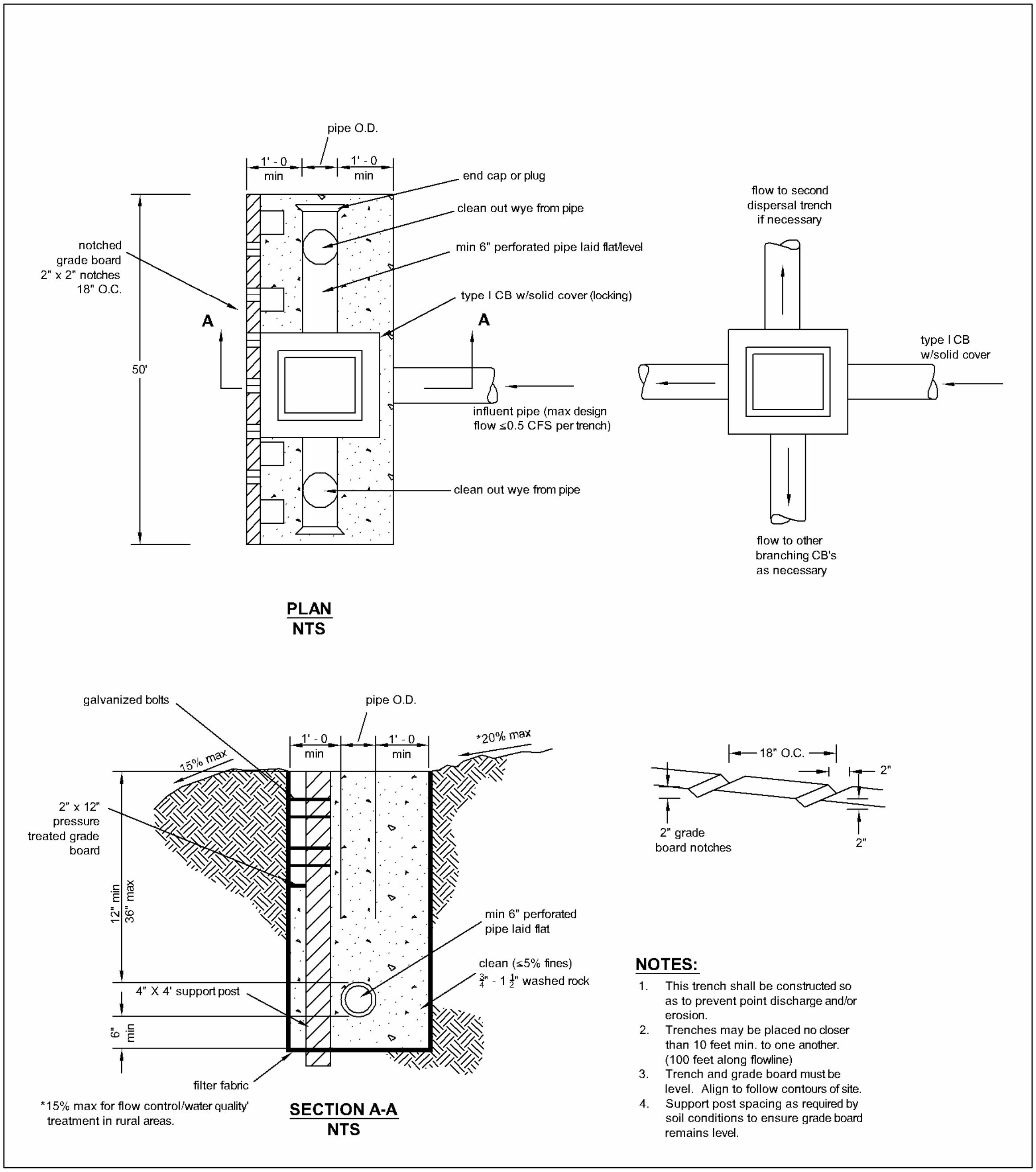
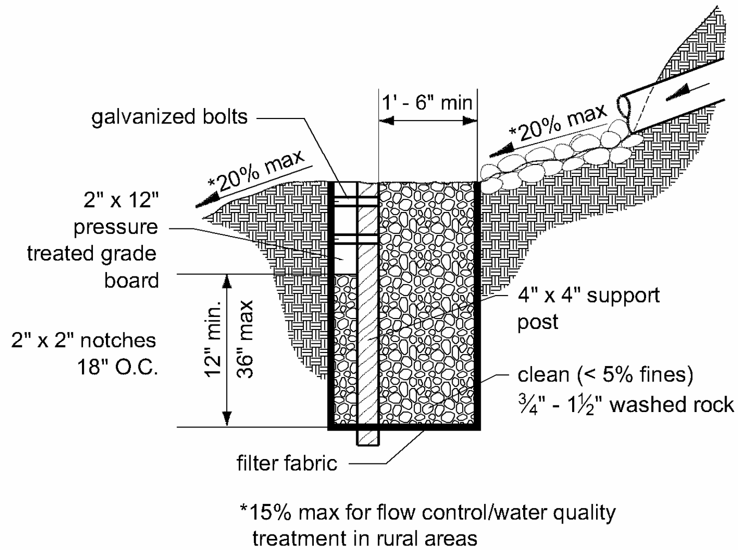


Figure III-3-42. Flow Dispersal Trench



SECTION A-A
NTS

NOTES:

1. This trench shall be constructed so as to prevent point discharge and /or erosion.
2. Trenches may be placed no closer than 10 feet min. to one another. (100 feet along flowline)
3. Trench and grade board must be level. Align to follow contours of site.
4. Support post spacing as required by soil conditions to ensure grade board remains level.

Figure III-3-43. Alternative Flow Dispersal Trench

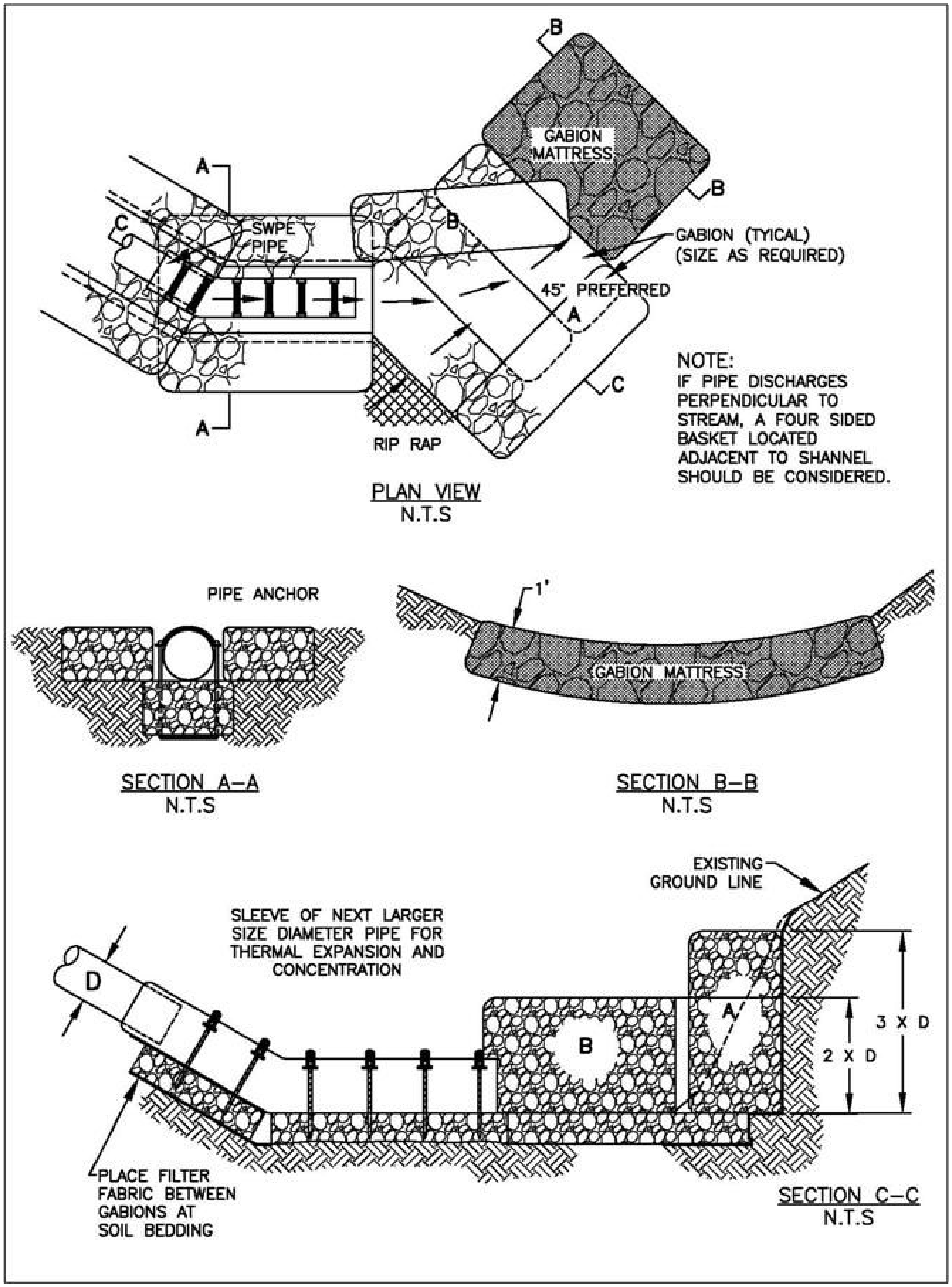


Figure III-3-44. Gabion Outfall Detail

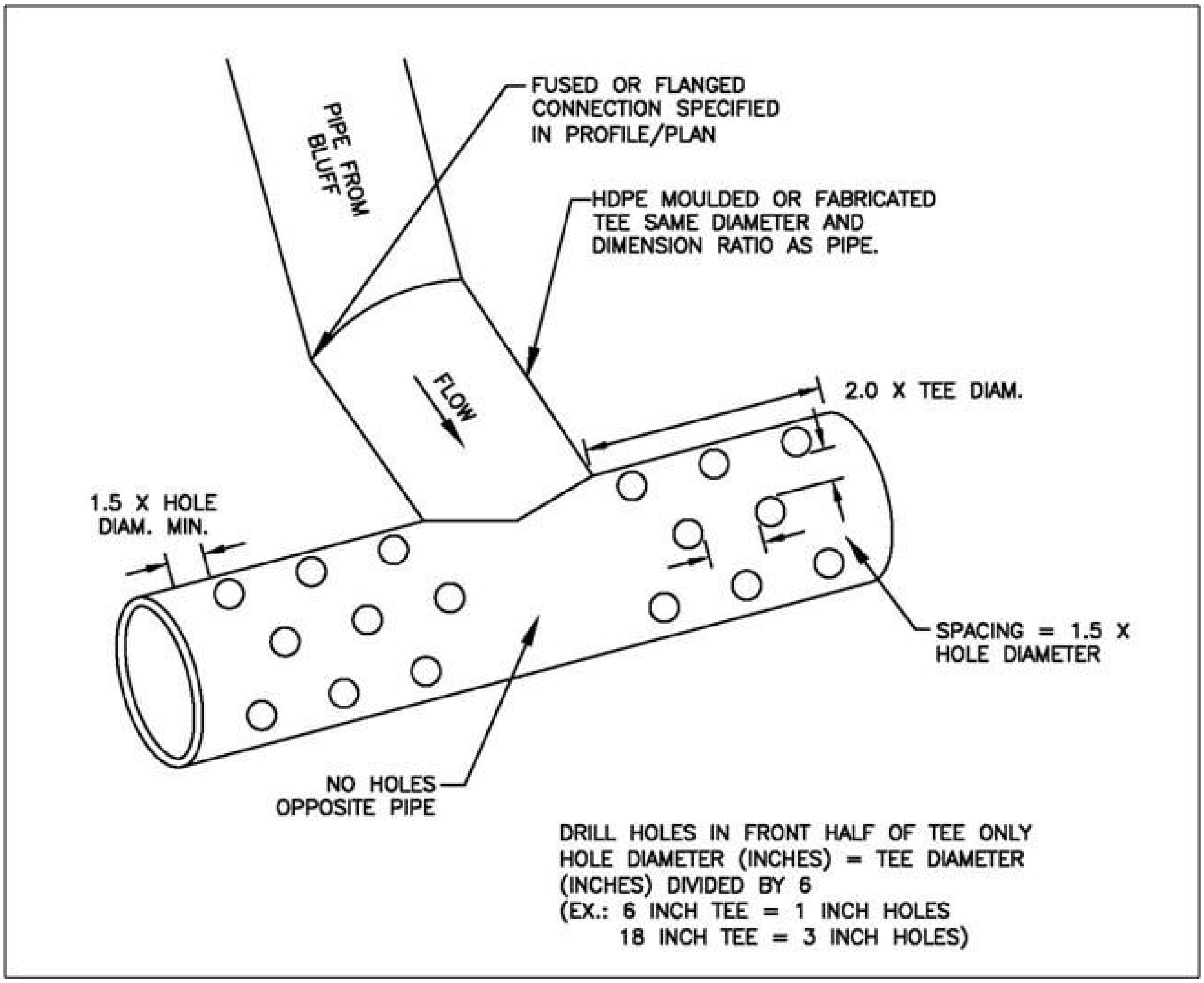


Figure III-3-45. Diffuser TEE (an example of energy dissipating end feature)

3.5.2 Tightline Systems

- Outfall tightlines may be installed in trenches with standard bedding on slopes up to 20%. In order to minimize disturbance to slopes greater than 20%, it is recommended that tightlines be placed at grade with proper pipe anchorage and support.
- High density polyethylene pipe (HDPP) tightlines must be designed to address the material limitations, particularly thermal expansion and contraction and pressure design, as specified by the manufacturer.
- Due to the ability of HDPP tightlines to transmit flows of very high energy, special consideration for energy dissipation must be made. Details of a sample gabion mattress energy dissipater have been provided as Figure III-3-44. Flows of very high energy will require a specifically engineered energy dissipater structure.
- Tightline systems may be needed to prevent aggravation or creation of a downstream erosion problem.
- Tightline systems shall have appropriate anchoring designed, both along the slope and to provide anchoring for the entire system.

3.5.3 Habitat Considerations

- New pipe outfalls can provide an opportunity for low-cost fish habitat improvements. For example, an alcove of low-velocity water can be created by constructing the pipe outfall and associated energy dissipater back from the stream edge and digging a channel, over widened to the upstream side, from the outfall to the stream. Overwintering juvenile and migrating adult salmonids may use the alcove as shelter during high flows. Potential habitat improvements should be discussed with the Washington Department of Fish and Wildlife biologist prior to inclusion in design.
- Bank stabilization, bioengineering and habitat features may be required for disturbed areas.
- Outfall structures should be located where they minimize impacts to fish, shellfish, and their habitats.
- The City’s Critical Area Code may regulate activities in these areas.

3.6 Pump Systems

Pump systems are only allowed if applied for through the City’s Exceptions process (see Volume I, Section 3.5). Feasibility of all other methods of gravity conveyance, infiltration and dispersion shall first be investigated and demonstrated to be infeasible in the following order of preference:

1. Infiltration of surface water on-site.
2. Dispersion of surface water on site.
3. Gravity connection to the City storm drainage system.
4. Pumping to a gravity system.

3.6.1 Design Criteria

If approved by the City Exceptions process (see Volume I, Section 3.5), the pump system must convey, at a minimum, the peak design flow for the 25-year 24-hour rainfall event. Pump capacity plus system storage or overflow, must convey or store the 100-year, 24-hour storm event.

3.6.2 Pump Requirements

If approved by the City Exemptions/Variance process, proposed pump systems must meet the following minimum requirements:

- The pump system shall be used to convey water from one location or elevation to another within the project site.
- The gravity-flow components of the drainage system to and from the pump system must be designed so that pump failure does not result in flooding of a building or emergency access or overflow to a location other than the natural discharge point for the project site.
- The pump system must have a dual pump (alternating) equipped with emergency back-up power OR a single pump may be provided without back-up power if the design provides the 100-year 24-hour storage volume.
- Pumps, wiring, and control systems shall be intrinsically safe per IBC requirements.
- All pump systems must be equipped with an external pump failure and high water alarm system.
- The pump system will serve only one lot or business owner.
- The pump system must be privately owned and maintained.
- The pump system shall not be used to circumvent any other City drainage requirements. Construction and operation of the pump system shall not violate any City requirements.

3.6.3 Additional Requirements

Private pumped stormwater systems will require the following additional items:

- Operations and Maintenance Manual describing the system itself and all required maintenance and operating instructions, including procedures to follow in the event of a power outage. All the requirements of Volume I, Section 4.1 shall be included in the O&M manual.
- Notice to Title on the property outlining that a private stormwater system is constructed on the site and that the maintenance of that system is the responsibility of the property owner. Wording of the Notice to Title shall be approved by the City prior to placing the Notice.
- Operations and Maintenance Agreement signed by the property owner and the City. After signature by the city, the agreement shall be recorded with the appropriate County and listed in the Notice of Title with the recording number.

All fees associated with preparing and recording documents and placing the Notice to Title shall be the responsibility of the applicant.

3.6.4 Sump Pumps

The above pump requirements do not apply to internal sump pumps. However, internal sump pumps **do require** a permit prior to connection to the City storm drainage system.

- Sump pumps shall be sized to properly remove water from basements and crawl spaces.
- Sump pumps shall NOT be connected to the sanitary sewer system.
- Consult the pump manufacturer or an engineer for appropriate sizing of a sump pump.

3.7 Easements and Access

All publicly owned, manmade drainage facilities and conveyances and all natural channels on the project site used for conveyance of altered flows due to development (including swales, ditches, stream channels, lake shores, wetlands, potholes, estuaries, gullies, ravines, etc.) shall be located within easements as required by the City.

3.7.1 Public Easements

A stormwater easement is required for the placement, operation and maintenance of facilities upon private property.

Public stormwater easements shall meet the following requirements:

- Public stormwater easements shall extend a minimum of seven and one-half feet (7 ½') to each side of the centerline of the storm pipe and seven and one-half (7 ½') beyond the outside extremity of a storm facility. Additional width may be required depending upon the depth and site topography.
- Public stormwater easements shall be provided on the City's standard easement form. Legal description of the easement and the property that the easement encumbers, along with a sketch showing both, shall be sealed by a licensed Land Surveyor and incorporated into the easement form as exhibits. The legal descriptions and sketch shall be on plain bond paper with margins acceptable to the County recording.
- Public stormwater easements shall be reviewed by the City and then recorded in the appropriate County prior to acceptance of the public storm system.

All pipes and channels must be located within the easement so that each pipe face or top edge of channel is no closer than 5 feet from its adjacent easement boundary. Pipes greater than 5 feet in diameter and channels with top widths greater than 5 feet shall be placed in easements adjusted accordingly, so as to meet the required dimensions from the easement boundaries.

The depth or proximity of steep slopes to the public system may necessitate a larger easement requirement for future excavation and maintenance purposes. See Table III-3-28 for appropriate widths based on depth of pipe.

Table III-3-28. Additional Storm Drain Easement Widths

INVERT DEPTH	WIDTH
< 10’	20’
10’ - 15’	25’
15’ - 20’	30’
> 20’	40’

Notes:

1. Greater width may be required for large diameter pipe or unfavorable site conditions.
2. Pipe shall be installed in center of easement.
3. If two pipes are to be installed in an easement, add 10 feet to the easement widths listed above. Use the deeper of the two pipes in selecting the easement width from this table. Install pipes with 10 feet of horizontal clearance between them.

3.7.2 Private Easements

Privately owned facilities shall be located in separate easements outside of dedicated public road right-of-way areas. **Private systems serving multiple lots require prior City approval.**

- A separate storm drainage detention or retention system is required for each commercial or industrial lot unless a combined storm drainage system is used for more than one lot. In such cases, a private cross drainage easement and maintenance agreement is required for each lot, unless cross drainage requirements are set up as a condition of the recorded final plat. Copies of the recorded easements or plat condition, including the stormwater pollution prevention plan must be provided to the City prior to civil plan approval.

- All projects shall execute with the City a standard Stormwater Easement and Maintenance Agreement for the site’s private storm drainage facilities. The easement shall be approved by the City and executed by the owner prior to issuance of occupancy permits for the development.

3.7.3 Maintenance Access

A minimum 15-foot wide access easement shall be provided to drainage facilities from a public street or right-of-way. Access easements shall be surfaced with a minimum 12-foot width of crushed rock, or other approved surface to allow year-round equipment access to the facility.

Maintenance access must be provided for all manholes, catch basins, vaults, or other underground drainage facilities operated by the City. Maintenance shall be through a public easement.

Maintenance access to privately maintained facilities may also be required.

THIS PAGE INTENTIONALLY LEFT BLANK.

Appendix A Auburn Design Storm

Table III-A-29. Design Storm Precipitation Values

Return Frequency 24-Hour Storm Event (Years)	Precipitation (Inches)
0.5	1.44
2	2.0
5	2.5
10	3.0
25	3.5
50	3.5
100	4.0

The depth of a 7-day, 100-year storm can be determined in one of three ways:

Use 12 inches for the lowland areas between sea level and 650 MSL.
Use the U.S. Department of Commerce Technical Paper No. 49, "Two- to Ten-Day Precipitation for Return Periods of 2 to 100 Years in the Contiguous United States."
Use the U.S. Department of Commerce NOAA Atlas 2, "Precipitation Frequency Atlas of the Western United States," Volume IX – Washington, 24-hour, 100-year Isopluvials and add 6.0 inches to the appropriate isopluvial for the project area.

Appendix B Procedure for Conducting a Pilot Infiltration Test

The Pilot Infiltration Test (PIT) consists of a relatively large-scale infiltration test to better approximate infiltration rates for design of stormwater infiltration facilities. The PIT reduces some of the scale errors associated with relatively small-scale double ring infiltrometer or "stove-pipe" infiltration tests. It is not a standard test but rather a practical field procedure recommended by Ecology's Technical Advisory Committee.

Infiltration Test

- Excavate the test pit to the depth of the bottom of the proposed infiltration facility. Lay back the slopes sufficiently to avoid caving and erosion during the test.
- The horizontal surface area of the bottom of the test pit should be approximately 100 square feet. For small drainages and where water availability is a problem smaller areas may be considered as determined by the site professional.
- Accurately document the size and geometry of the test pit.
- Install a vertical measuring rod (minimum 5-ft. long) marked in half-inch increments in the center of the pit bottom.
- Use a rigid 6-inch diameter pipe with a splash plate on the bottom to convey water to the pit and reduce side-wall erosion or excessive disturbance of the pond bottom. Excessive erosion and bottom disturbance will result in clogging of the infiltration receptor and yield lower than actual infiltration rates.
- Add water to the pit at a rate that will maintain a water level between 3 and 4 feet above the bottom of the pit. A rotometer can be used to measure the flow rate into the pit.

A water level of 3 to 4 feet provides for easier measurement and flow stabilization control. However, the depth should not exceed the proposed maximum depth of water expected in the completed facility.

Every 15 – 30 min, record the cumulative volume and instantaneous flow rate in gallons per minute necessary to maintain the water level at the same point (between 3 and 4 feet) on the measuring rod.

Add water to the pit until one hour after the flow rate into the pit has stabilized (constant flow rate) while maintaining the same pond water level (usually 17 hours).

After the flow rate has stabilized, turn off the water and record the rate of infiltration in inches per hour from the measuring rod data, until the pit is empty.

Data Analysis

Calculate and record the infiltration rate in inches per hour in 30 minutes or one-hour increments until one hour after the flow has stabilized.

Use statistical/trend analysis to obtain the hourly flow rate when the flow stabilizes. This would be the lowest hourly flow rate.

Apply appropriate correction factors for site heterogeneity, anticipated level of maintenance and treatment to determine the site-specific design infiltration rate (see Table III-2-9).

Example

The area of the bottom of the test pit is 8.5-ft. by 11.5-ft.

Water flow rate was measured and recorded at intervals ranging from 15 to 30 minutes throughout the test. Between 400 minutes and 1,000 minutes the flow rate stabilized between 10 and 12.5 gallons per minute or 600 to 750 gallons per hour, or an average of (9.8 + 12.3) / 2 = 11.1 inches per hour.

Applying a correction factor of 5.5 for gravelly sand in Table III-2-9 the design long-term infiltration rate becomes 2 inches per hour, anticipating adequate maintenance and pre-treatment.

THIS PAGE INTENTIONALLY LEFT BLANK.