Multi-Agency Post-Construction Stormwater Standards Manual

June 2015

A collaboration by:

City of Lathrop, California — Incorporated 1989

City of Lodi, California

City of Manteca, California — Manteca — the family city — Incorporated May 28, 1918

City of Patterson — Incorporated 1919

San Joaquin County, California

Tracy — Think Inside the Triangle™

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Table of Contents

List of Figures

List of Tables

List of Appendices

SECTION 1. INTRODUCTION

1.1. Purpose and Goals

The Cities of Lathrop, Lodi, Manteca, Patterson, and Tracy, and portions of the County of San Joaquin (collectively Agencies) are each classified as Phase II Municipal Separate Storm Sewer System (MS4) communities. In 2013, the California State Water Resources Control Board (State Water Board) adopted a National Pollutant Discharge Elimination System (NPDES) general permit, henceforth referred to in this document as the Phase II Permit, for Phase II MS4 communities to regulate stormwater and non-stormwater discharges from MS4s to waters of the United States. As part of the Phase II Permit, the Agencies are required to develop/update post-construction standards to address stormwater quality for regulated new development and redevelopment projects (Provision E.12).

The Agencies have collaborated to prepare this 2015 Multi-Agency Post-Construction Stormwater Standards Manual (Manual) to assist the development community in complying with the requirements of Provision E.12 of the Phase II Permit and local ordinances. This Manual is not intended to conflict or contradict any local ordinances or standards. Any conflicts or issues should be discussed with the appropriate jurisdictional Agency.

The jurisdictional areas where this Manual is applicable are identified in Appendix B.

This Manual provides guidance for planning, implementing, and maintaining effective control measures with the intention of improving water quality and mitigating potential water quality impacts, including hydromodification, from stormwater and non-stormwater discharges. This Manual provides tools to address the following objectives:

- Establish the methodology to consider the effects of stormwater runoff from a new development or redevelopment project during the project planning phase;
- Minimize contiguously-connected impervious surfaces in areas of new development and redevelopment, and where feasible, to maximize on-site infiltration of stormwater runoff;
- Implement site design measures to preserve, create, or restore areas that provide important water quality benefits such as riparian corridors, wetlands, stream and buffers, and maintain, protect, and improve underlying soil quality;
- Provide source control measures to minimize the transport of and/or eliminate potential sources of pollution to stormwater runoff or run-on into the MS4 and receiving waters;
- Implement Low Impact Development (LID) control measures to reduce and/or eliminate the volume of stormwater runoff and pollutants leaving the project site;

- Control post-construction peak stormwater runoff discharge volumes and velocities (hydromodification) to mitigate impacts from downstream erosion and to protect downstream habitat; and
- Develop tools for effectively operating, managing, and maintaining stormwater control measures.

1.2. Environmental Background

Historically, stormwater management consisted of a network of impervious surfaces that directly convey stormwater runoff to curb and gutter systems, the storm drain system, and downstream receiving waters as quickly as possible to manage flood risks. In a natural setting, the following hydrologic functions occur:

- Rainfall interception: In a vegetated watershed, the surfaces of trees, shrubs, and grasses capture initial light precipitation before it reaches the ground. The interception of precipitation can delay the start and reduce the volume of stormwater runoff.
- Shallow surface storage: Shallow pockets present in natural terrain store precipitation and stormwater runoff, filter it, and allow it to infiltrate. Shallow surface storage can delay the start and reduce the volume of stormwater runoff.
- Evaporation and transpiration: Evaporation occurs when water changes from a liquid to a gas and moves into the air. Transpiration occurs when vegetation releases water vapor into the atmosphere. Both processes, collectively termed evapotranspiration, reduce the volume of stormwater runoff, locally return moisture into the atmosphere, and provide local cooling effects.
- Infiltration: Infiltration is the movement of surface water down through the soil into groundwater. Such movement filters and reduces the volume of stormwater runoff and replenishes groundwater supplies.
- Runoff: Runoff is the flow of water across the land surface that occurs after rainfall interception, surface storage, and infiltration reach capacity.

In natural settings, the majority of precipitation is either infiltrated into the soil or lost to evapotranspiration. Through urbanization and development, pervious surfaces (e.g., wooded areas, meadows, agricultural fields) are converted into impervious areas (e.g., building footprints, roads, parking lots), and the percentage of precipitation that becomes stormwater runoff increases. The impacts of such conversion may include:

- Increased concentrations of solids, nutrients, toxic pollutants, bacteria, and other nuisance organisms in storm drain system and receiving waters (e.g., creeks, rivers, streams);
- Higher stormwater runoff volumes and peak flow rates produced by storms;
- Decreased wet season groundwater recharge due to a reduced infiltration area;
- Increased dry weather urban runoff due to outdoor irrigation;

- Introduction of base flows in ephemeral streams resulting from increased dry weather urban runoff;
- Increased stream and channel instability and erosion due to increased stormwater runoff volumes, flow durations, and higher stream velocities (i.e., hydromodification impacts); and
- Increased stream temperature, which decreases dissolved oxygen levels and adversely impacts temperature-sensitive aquatic life, due to loss of riparian vegetation as well as stormwater runoff warmed by impervious surfaces.

1.3. Regulatory Background

In 1972, the Federal Water Pollution Control Act (Clean Water Act [CWA]) was amended to require NPDES permits for discharge of pollutants to waters of the United States from any point source. In 1987, the CWA was amended to add section 402(p), which required that municipal, industrial, and construction stormwater discharges be regulated under the NPDES permit program. In 1990, the United States Environmental Protection Agency (USEPA) promulgated rules that established the Phase I NPDES program to regulate stormwater from medium and large MS4s, which were defined as those serving populations of 100,000 or greater. In 1999, USEPA promulgated rules that established the Phase II NPDES program to regulate stormwater from small MS4s.

Phase II General Permit

On April 30, 2003, the State Water Board adopted the first general NPDES permit (CAS000004) under Order No. 2003-0005-DWQ for small MS4s, including non-traditional small MS4s (e.g., military bases), that required compliance with section 402(p) of the CWA and defined the minimum acceptable elements of stormwater management programs for small MS4s. On February 5, 2013, the State Water Board adopted Order No. 2013-0001-DWQ, which replaced Order No. 2003-0005-DWQ and required that the Agencies regulate post-construction development (Provision E.12) through the following program elements:

- Site design measures (Provision E.12.b)
- Regulated projects (Provision E.12.c)
- Source control measures (Provision E.12.d)
- Low impact development design standards (Provision E.12.e)
- Hydromodification measures (Provision E.12.f)
- Enforceable mechanisms (Provision E.12.g)
- Operation and maintenance of stormwater control measures (Provision E.12.h)
- Post-construction Best Management Practice condition assessment (Provision E.12.i)
- Planning and development review process (Provision E.12.j)

- Post-construction stormwater management requirements based on assessment and maintenance of watershed processes (Provision E.12.k); and
- Alternative post-construction stormwater management program (Provision E.12.l).

The underlined topics, above, are discussed in this Manual. The other topics are administrative aspects of the stormwater management program and are not pertinent to project planning, design, implementation, maintenance, and operation.

In addition to the Provision E.12 requirements for post-construction stormwater management, other elements of the Phase II Permit focus on managing other aspects of the stormwater program such as providing public education and outreach, detecting and eliminating illicit discharges, controlling pollutants from construction sites and municipal operations, and a variety of reporting, assessment, and monitoring elements.

Other State of California Regulations

In addition to the Phase II Permit requirements, proposed projects may be subject to the State Water Board's *Waste Discharge Requirements for Discharges of Storm Water Associated with Industrial Activities Excluding Construction Activities* (Industrial General Permit, Order No. 2014-0057-DWQ) and/or the *General Permit for Storm Water Discharges Associated with Construction and Land Disturbance Activities* (Construction General Permit, Order No. 2012-0006-DWQ).

If dewatering is necessary at the project site, proposed projects may be subject to the Central Valley Regional Water Quality Control Board's (Central Valley Regional Water Board) *Waste Discharge Requirements for Dewatering and Other Low Threat Discharges to Surface Waters* (Order No. R5-2013-0074).

Agency Regulations and Policies

Implementation of stormwater standards are required in each Agency's municipal codes and/or ordinances. A summary of the applicable stormwater requirements for each Agency is presented in **Table 1-1**.

Table 1-1. Summary of Agency Municipal Codes and Ordinances Regulating Stormwater

Agency	Municipal Code/Ordinance Reference
City of Lathrop	Municipal Code Chapter 13.28
City of Lodi	Municipal Code Chapter 13.14
City of Manteca	Municipal Code Section 13.28
City of Patterson	Municipal Code Chapter 13.32
City of Tracy	Municipal Code Chapter 11.32
County of San Joaquin	Code of Ordinances Division 10

1.4. Effective Date of the 2015 Post-Construction Stormwater Standards Manual

The Phase II Permit requires that these post-construction stormwater standards become effective July 1, 2015. Projects submitted for development approvals on or after July 1, 2015 must incorporate these post-construction stormwater standards into project designs. The effective dates for implementation of these post-construction stormwater standards for private and public projects are discussed further in the sections below.

Effective Date for Private Projects

Project applicants who have submitted development applications for discretionary permits that have been deemed complete for processing by or received approval of a Vesting Tentative Map from the jurisdictional Agency before July 1, 2015 are not subject to the requirements of this Manual. However, these projects must comply with the post-construction and drainage standards in effect at the time the development applications for discretionary permits were deemed complete for processing or received approval of a Vesting Tentative Map and any conditions of approval required by the jurisdictional Agency. Project applicants who submit development applications beginning July 1, 2015, or who have not had their applications deemed complete for processing by or received approval for a Vesting Tentative Map from the jurisdictional Agency before July 1, 2015 must comply with the post-construction stormwater standards outlined in this Manual.

Broad planning documents (e.g., land use master plans, conceptual master plans, or broad-based California Environmental Quality Act [CEQA] or National Environmental Policy Act [NEPA]) approved or adopted by an Agency prior to July 1, 2015 does not exempt a project applicant from the requirements of this Manual unless the development application for the project has been deemed complete or there is an approved Vesting Tentative Map.

For projects that are not subject to the planning review process (i.e., projects that do not need Vesting Tentative Maps, Tentative Maps, or Parcel Maps), project applicants must comply with this Manual unless the development application was deemed complete by the jurisdictional Agency before July 1, 2015.

Effective Date for Public Projects

For public projects, the effective date of the project is the date on which the Agency approves initiation of project design. If approval occurs prior to July 1, 2015, then the requirements of this Manual do not apply. If approval occurs on or after July 1, 2015, then the requirements of this Manual apply.

1.5. Applicability of the 2015 Post-Construction Stormwater Standards Manual

The Phase II Permit specifies three types of projects (both public and private new development and redevelopment) that must implement post-construction stormwater standards, to varying degrees, as discussed below:

- Small Projects (Provision E.12.b(i)) – These are projects that create and/or replace at least 2,500, but less than 5,000 square feet of impervious surface; or detached single-family homes that create and/or replace a minimum of 2,500 square feet of impervious surface and are not part of a larger plan of development. Small Projects exclude linear underground/overhead utility projects (LUPs).
- Regulated Projects – These are projects that create and/or replace greater than or equal to 5,000 square feet of impervious surface and LUPs that create 5,000 square feet or more of newly constructed contiguous impervious surfaces.
- Hydromodification Management Projects – These are a subset of Regulated Projects that create and/or replace one acre or more of impervious surface. A project that does not increase the impervious surface area over the pre-project condition is not considered a Hydromodification Management Project.

The Phase II Permit also establishes exceptions for specific types of projects, which would otherwise be considered Regulated Projects. These exceptions and examples are discussed as follows:

- Detached Single-Family Homes that are not part of a common plan of development regardless of the amount of impervious area created or replaced are considered Small Projects. See Appendix A for a definition of the term common plan of development.
- Routine Maintenance and Repair Projects that maintain the original line and grade, hydraulic capacity, and original purpose of the facility. Such projects include:
    - Exterior wall surface replacement;
    - Pavement resurfacing[1] within an existing footprint;
    - Routine replacement of damaged pavement[2], such as pothole repair, or short non-contiguous sections of roadway;

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[1] Pavement resurfacing (also known as an overlay, asphalt overlay, or pavement overlay) is the process of installing a new layer of pavement over the existing pavement.

  - Re-roofing regardless of whether it is a full roof replacement or an overlay;
- Interior remodels that do not modify the existing footprint;
- Excavation, trenching, and resurfacing associated with LUPs;
- Pavement grinding and resurfacing of existing roadways and parking lots;
- Construction of new sidewalks, pedestrian ramps, or bicycle lanes on existing roadways;
- Sidewalks and bicycle lanes built as part of new streets or roads when they are graded to runoff to adjacent vegetated areas;
- Impervious trails when they are graded to runoff to adjacent vegetated areas or other non-erodible areas; and
- Sidewalks, bicycle lanes, and trails when constructed with permeable surfaces.

The applicability of this Manual is presented in a flow chart in **Figure 1-1**. A summary of the post-construction stormwater standards that are applicable to a project are presented in **Table 1-2**.

Table 1-2. Applicable Post-Construction Stormwater Standards

Post-Construction Stormwater Standard	Small Project	Regulated Project	Hydromodification Management Project
Site Assessment (Section 3)	(1)	X	X
Site Design (Section 3)	X	X	X
Source Control Measures (Section 4)		X	X
Treatment Control Measures (Section 6)		X	X
Baseline Hydromodification (Section 7)		X	X
Full Hydromodification (Section 7) (2)			X
Operations & Maintenance (Section 8)		X	X

(1) It is recommended that Small Projects implement the applicable activities of site assessment process to maximize consideration for post-construction stormwater runoff.

(2) Hydromodification management is required by June 30, 2016.

[2] Pavement replacement (also known as reconstruction) is the process of removing existing pavement down to the subbase and replacing it with new base course and new pavement. If the native soil is exposed, this is considered a redevelopment project.

Redevelopment Projects

Redevelopment is defined as any land-disturbing activity that results in the creation, addition, or replacement of exterior impervious surface area at a site on which some past development has occurred.

The following thresholds are used to determine the level of post-construction stormwater standards that must be implemented for a redevelopment project:

- If a redevelopment project results in an increase of 50 percent or more of the impervious surface area of the existing development, then the stormwater runoff from the entire project, consisting of all existing, new, and/or replaced impervious surfaces, for the stormwater design volume or flow must be managed under these standards.
- If a redevelopment project results in an increase of less than 50 percent of the impervious surface of the existing development, then only the stormwater runoff from the new and/or replaced impervious surfaces must be managed under these standards.

Depending on the size of the redevelopment project, it may be considered a Small, Regulated, or Hydromodification Management Project.

Road Projects and Linear Underground/Overhead Utility Projects

The following road projects and LUPs that create 5,000 square feet or more of newly constructed contiguous impervious surface, which are classified as Regulated Projects, must comply with the post-construction stormwater standards in this Manual:

- Construction of new streets or roads, including sidewalks and bicycle lanes built as part of the new streets or roads; or
- Widening of existing streets or roads with additional traffic lanes:
    - If the addition of traffic lanes results in an alteration of 50 percent or more of the impervious surface of the existing street or road, then the stormwater runoff from the entire project, consisting of all existing, new, and/or replaced impervious surfaces, must be managed; or
    - If the addition of traffic lanes results in an alteration of less than 50 percent (but 5,000 square feet or more) of the impervious surface of the existing street or road, then only the stormwater runoff from the new and/or replaced impervious surfaces must be managed; or
- Construction of LUPs.

For road and LUP projects when the stormwater runoff from the design storm event cannot be infiltrated on-site, excess stormwater runoff must be managed through the use of practices identified in USEPA's *Managing Wet Weather with Green Infrastructure*

Municipal Handbook Green Streets (EPA 833-F-08-009, December 2008) (see Appendix J).

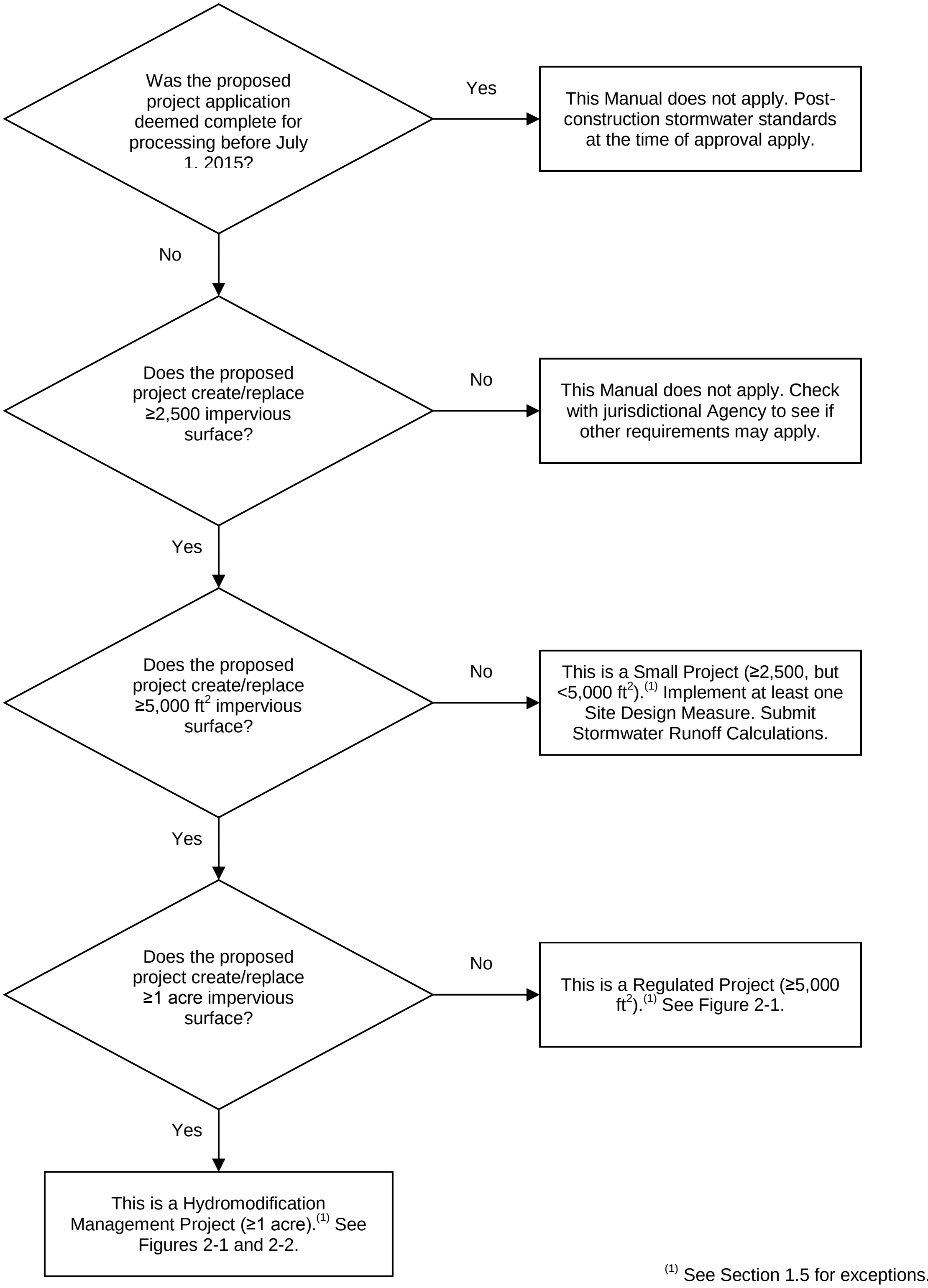

Figure 1-1. Applicability of 2015 Post-Construction Stormwater Standards Manual

1.6. Organization of the 2015 Post-Construction Stormwater Standards Manual

This Manual is organized as follows:

Section 1	Introduction to the Manual and presentation of the environmental basis for stormwater management, applicable regulations, and applicability of the Manual.
Section 2	Development of Project Stormwater Plan.
Section 3	Information on site assessment, site planning, and site design measures.
Section 4	Information on source control measures.
Section 5	Methodology for calculating the stormwater design volume or flow that must be mitigated for a project site.
Section 6	Information on stormwater treatment control measures.
Section 7	Information on the applicability of hydromodification requirements.
Section 8	Operation and maintenance requirements for stormwater control measures.

SECTION 2. PROJECT STORMWATER PLAN

2.1. Introduction

The project applicant must submit a Project Stormwater Plan to the appropriate jurisdictional Agency (i.e., City of Lathrop, City of Lodi, City of Manteca, City of Patterson, City of Tracy, or County of San Joaquin) for review as part of its development application. The Project Stormwater Plan must provide a sufficient level of information depending on the type of project and be prepared and stamped by a licensed professional engineer or landscape architect. The Project Stormwater Plan for Small Projects does not require a licensed professional engineer or landscape architect. Worksheets, which are included in Appendix D, must be submitted as part of the Project Stormwater Plan.

The Project Stormwater Plan for Small Projects must include the following information:

- Basic project information;
- Proposed site design measures (Section 3.5); and
- Results from the Post-Construction Stormwater Runoff Calculator showing the change in pre-project and post-project stormwater runoff (Section 5.5).

Project applicants for Regulated and Hydromodification Management Projects must submit a comprehensive, technical discussion describing compliance with the requirements of this Manual. These Project Stormwater Plans must include the following information:

- Basic project information;
- Identification of whether the proposed project is a Regulated or Hydromodification Management Project (Section 1.5);
- Findings from a site assessment (Section 3) that, at a minimum, must include:
    - A Site Conditions Report, if required by the Agency, summarizing relevant findings from geotechnical investigations;
    - Identification of each drainage management area (DMA);
    - Identification of pollutants of concern;
- Proposed site design measures to be implemented (Section 3.5);
- Proposed source control measures to be implemented (Section 4);
- Calculation of the Stormwater Design Volume and/or Stormwater Design Flow and results from the Post-Construction Stormwater Runoff Calculator (Section 5);
- Proposed stormwater treatment control measures, if necessary (Section 6);
- Proposed hydromodification control measures and hydromodification modeling results, if required (Section 7); and

- Proposed Operations and Maintenance Plan (Section 8).

The Project Stormwater Plan must also include a site plan that, at a minimum, illustrate:

- Existing natural hydrologic features (e.g., depressions, watercourses, wetlands, riparian corridors, undisturbed areas) and significant natural resources;
- Proposed locations and footprints of improvements creating new, or replaced impervious surfaces;
- Existing and proposed site drainage system and connections to off-site drainage;
- All DMAs with unique identifiers;
- Proposed locations and footprints of stormwater control measures (e.g., site design measures, source control measures, stormwater treatment control measures) implemented to manage stormwater runoff; and
- Maintenance areas.

Flow charts of the design process for managing stormwater runoff for proposed Regulated and Hydromodification Management Projects are presented in **Figure 2-1** and **Figure 2-2**, respectively.

Upon meeting the requirements of this Manual and other applicable requirements, the Project Stormwater Plan will be approved and signed off by the legally responsible person, or their approved designee, of the jurisdictional Agency. Note that other overall project plan approvals are necessary before construction of the proposed project may begin. The current Project Stormwater Plan review processes, which may be subject to revision, for each Agency are presented in Appendix C. A general schematic of the plan review and approval process is presented in **Figure 2-3**.

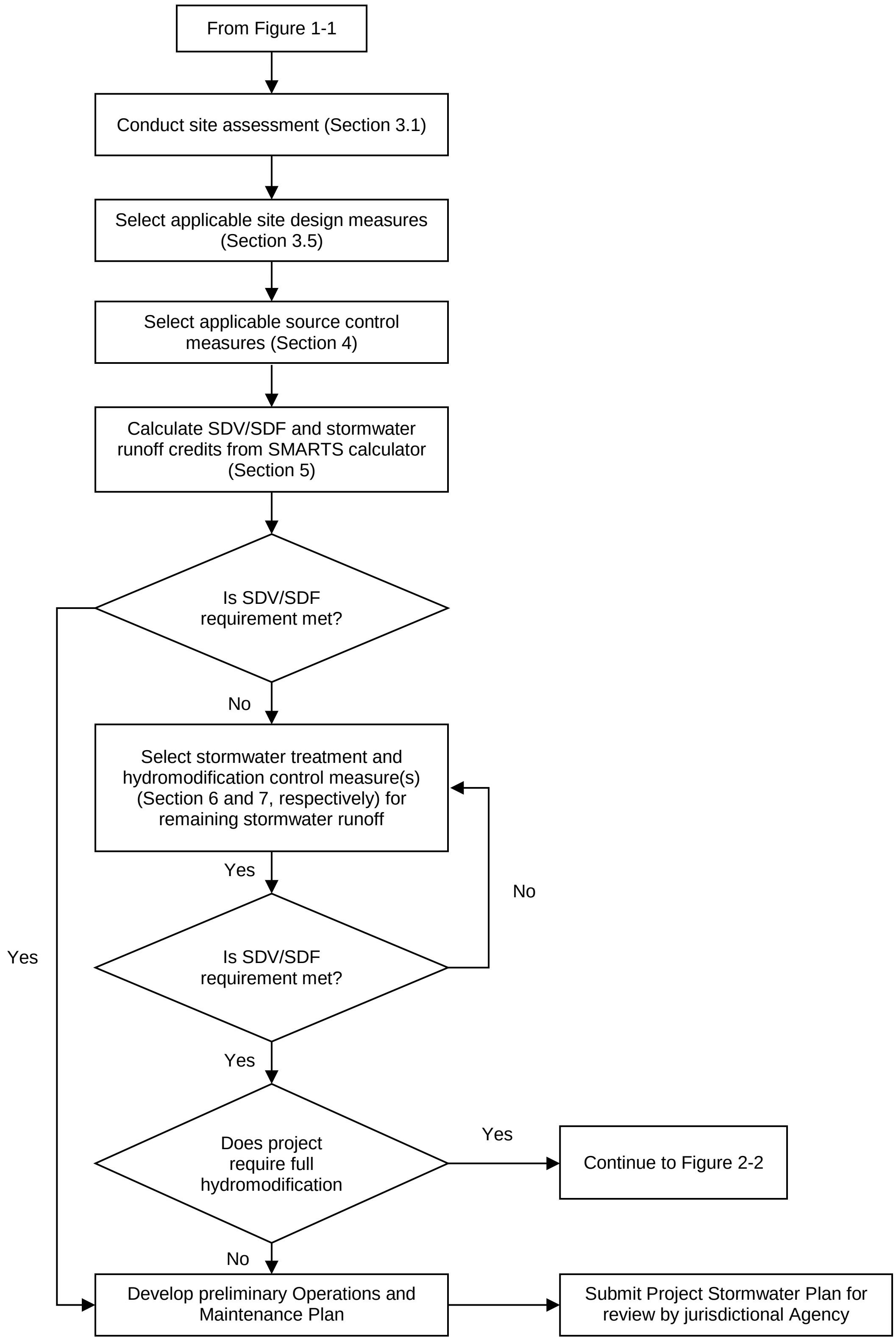

Figure 2-1. Design Process for Meeting Stormwater Requirements for Regulated and Hydromodification Management Projects

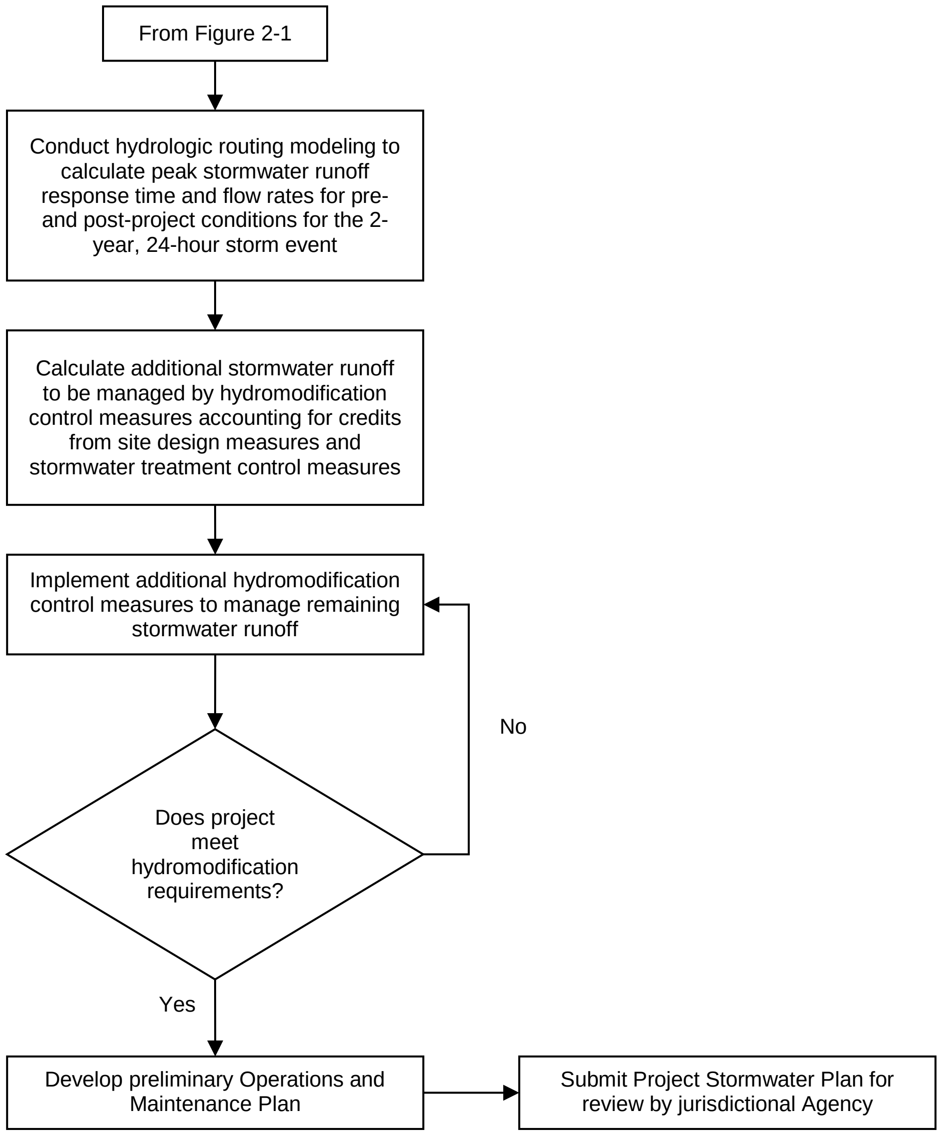

Figure 2-2. Design Process for Meeting Stormwater Requirements for Hydromodification Management Projects

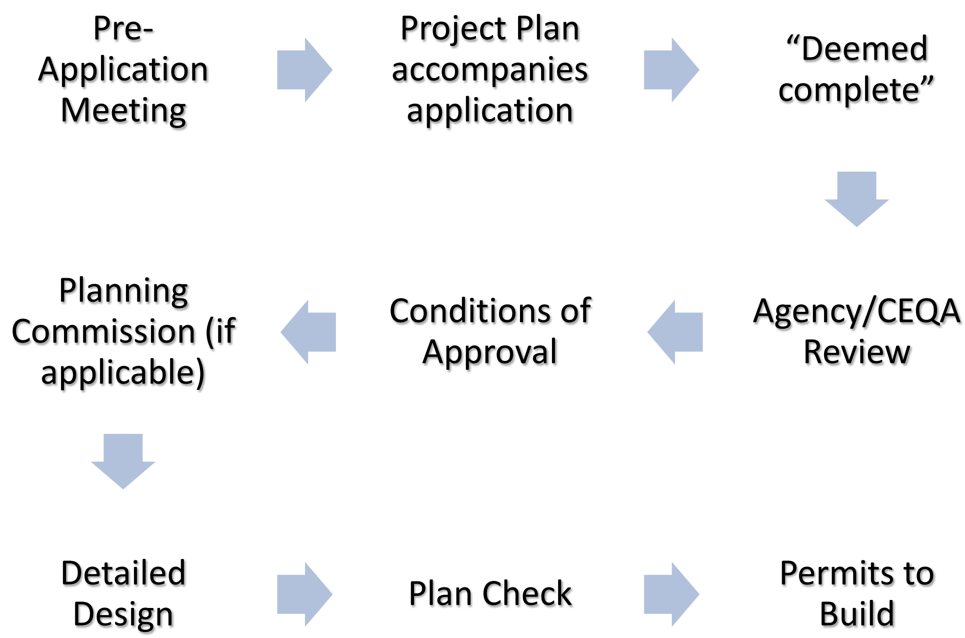

Figure 2-3. General Project Plan Review and Approval Process

SECTION 3. SITE ASSESSMENT AND SITE DESIGN MEASURES

This section outlines the steps for assessing project site conditions, implementing site planning principles, and identifying applicable site design measures during the planning phase of a project to determine applicable stormwater control measures for the project. This step in the planning and design process is important for identifying project site constraints that may limit or reduce the ability of a project site to mitigate stormwater runoff associated with the stormwater design volume or flow. Conducting this step early in the planning process reduces the possibility of having to re-design the project site if the proposed stormwater control measures cannot meet the applicable requirements.

The project applicant must conduct a site assessment, integrate site planning principles, and identify applicable site design measures for Regulated and Hydromodification Management Projects. For Small Projects, the project applicant must implement at least one site design measure. While not required by the Phase II Permit, it is recommended that Small Projects identify and implement applicable site planning principles to maximize management of post-construction stormwater runoff.

3.1. Assessing Site Conditions and Other Constraints

Assessing the applicable stormwater control measures to implement at a project site requires the review of existing information and collection of site-specific data. In assessing the project site, the project applicant must identify the following:

- Project location and description;
- Project area size (acreage), including pre-and post-construction impervious surface area;
- Delineated drainage management areas (DMAs) (see Section 3.2);
- Location of point(s) of stormwater runoff discharge from the project site (e.g., storm drain system, receiving water);
- Land use types;
- Activities expected on-site;
- Geotechnical conditions; and
- Other site considerations and constraints.

The project area size, DMAs, and point(s) of discharge of stormwater runoff are important factors for sizing and determining the placement of stormwater runoff conveyance and/or stormwater control measures. Information on the land use type(s) and activities expected to be conducted on-site before, during, and after construction is used to identify potential pollutants of concern that may be present in stormwater runoff from the project site. Determining geotechnical conditions and other potential site conditions and constraints is critical in identifying potential impacts to site layout and feasibility, selection, sizing, and placement of stormwater control measures.

Geotechnical Conditions

An investigation, which must be conducted by or under the supervision of a competent, licensed professional (e.g., civil engineer, geotechnical engineer, engineering geologist, landscape architect, land surveyor), of geotechnical conditions at the project site must be conducted and, at a minimum, considers the following conditions, which are discussed in further detail below:

- Topography;
- Soil type and geology;
- Groundwater;
- Other geotechnical issues; and
- Setbacks.

The geotechnical investigation must be conducted in accordance with the requirements or standards, including, but not limited to, approved investigation, evaluation, and testing methodologies, of the jurisdictional Agency. Available geologic or geotechnical reports on local geology may be used to aid and supplement the investigation of the geotechnical conditions at the project site. These available reports may identify relevant features such as depth to bedrock, rock type, lithology, faults, hydrostratigraphic or confining units, historic groundwater levels, areas of shallow groundwater, and past soil and groundwater issues (e.g., contamination).

If required by the Agency, a Site Conditions Report, which addresses and discusses relevant findings, must be prepared by or under the supervision of a competent, licensed professional and submitted as part of the Project Stormwater Plan. If a geotechnical report is required for the project, the Site Conditions Report may be included as part of the geotechnical report.

Topography

The project site topography must be evaluated for surface drainage patterns, topographic high and low points, and slopes. Each of these site characteristics impacts the type(s) of stormwater control measure(s) that will be most effective for the project site. For example, infiltration-based stormwater treatment control measures are more effective on level/or gently-sloped (i.e., slopes less than 10 percent) sites and may not be feasible on steeply-sloped sites (i.e., slopes greater than 10 percent). As part of this investigation, existing topographic mapping information and data or site-specific land surveying may be necessary to obtain the required information. The Site Conditions Report must discuss potential changes in the topography of the project site that may result from the project.

Soil Type and Geology

The soil type and geologic conditions of the project site must be investigated to evaluate the potential for infiltration and identify suitable and unsuitable locations at the project site for infiltration-based stormwater treatment control measures. Resources such as the National Resources Conservation Service may be used to identify soil types and information. For this Manual, soil types are classified and defined according to **Table 3-1**.

Table 3-1. Typical Soil Types and Infiltration Rates

Type	Description	Typical Infiltration Rate (in/hr) (1)
A	Sands, gravels	>1.0
B	Sandy loams with moderately fine to moderately coarse textures	0.5-1.0
C	Silty-loams or soils with moderately fine to fine texture	0.17-0.27
D	Clays	0.02-0.10

(1) Infiltrate rates presented are adapted from multiple sources (National Resource Conservation Service, American Society of Civil Engineers, etc.).

Site-specific testing of the infiltration rate(s) of the underlying soil is required, and the infiltration rate(s) must be determined using the Double-Ring Infiltrometer standard (American Society for Testing and Materials [ASTM] D3385). Underlying soils with in-situ infiltration rates of 0.5 inches per hour (in/hr) and up to 5.0 in/hr are may be considered feasible for infiltration-based stormwater treatment control measures. For underlying soils with an in-situ infiltration rate greater than 5.0 in/hr, modifications to the design of stormwater treatment control measures may be necessary. For underlying soils with an in-situ infiltration rate less than 0.5 in/hr, the soils may need to be amended to increase the infiltration rate or infiltration-based stormwater treatment control measures may not be feasible for the project site, and alternative stormwater treatment control measures must be implemented.

Groundwater

Groundwater conditions at the project site must be evaluated prior to selecting, siting, sizing, and design stormwater control measures. The seasonal high depth to groundwater beneath the project site may preclude infiltration if less than ten (10) feet of separation is maintained between the lowest flow line or invert elevation of an infiltration structure. In all cases and if approved by the jurisdictional Agency, at least five (5) feet of separation must be maintained between the flow line or invert of an infiltration structure and the seasonal high groundwater or mounded groundwater levels.

Regional groundwater information and data[3] may be used in lieu of site-specific groundwater information if it shows that at least ten (10) feet of separation can be maintained between the lowest flow line or invert elevation of an infiltration structure. For project sites that have less than ten (10) feet of separation between the seasonal high groundwater depth and the lowest flow line or invert of an infiltration structure, site-specific groundwater information and data are required as part of the Site Conditions Report. In the Site Conditions Report, the project applicant must demonstrate that the minimum groundwater separation will be maintained and that the implementation of infiltration-based stormwater treatment control measures will not cause mounding. The Site Conditions Report must also discuss potential changes in the groundwater conditions that may be result from the proposed project.

Areas with known groundwater impacts include sites listed by the Central Valley Regional Water Board's Leaking Underground Fuel Tank (LUFT) Program and Spills, Leaks, Investigations, and Cleanups (SLIC) Program. The State Water Board also maintains a database of registered contaminated sites through its Geotracker Program. For projects located in areas with known groundwater pollution, modifications to the design of stormwater treatment control measures may be necessary to prevent the potential mobilization of the groundwater contamination.

For project sites where there may be high groundwater levels or if there are known groundwater or soil impacts, alternative stormwater treatment control measures may need to be implemented (see Section 6.2, Allowed Variations for Special Site Conditions).

Note that groundwater conditions do not preclude the project applicant from implementing applicable stormwater control measures for a project site.

Other Geotechnical Issues

Infiltration of stormwater runoff can also cause geotechnical issues, including, but not limited to, settlement through collapsible soil, expansive soil movement, slope instability, and increased liquefaction hazard, due to a temporary increase in groundwater levels near infiltration-based stormwater treatment control measures. Increased water pressure in soil pores reduces soil strength, which can make foundations more susceptible to settlement and slopes more susceptible to failure.

[3] Supplemental groundwater information and data may be available from the Eastern San Joaquin County Groundwater Basin Authority (gbawater.org/home, last accessed June 30, 2015), California Department of Water Resources Groundwater (water.ca.gov/groundwater, last accessed June 30, 2015), California Department of Water Resources Water Data Library (water.ca.gov/waterdatalibrary, last accessed June 30, 2015), and/or State Water Resources Control Board Geotracker (geotracker.waterboards.ca.gov, last accessed June 30, 2015).

The geotechnical investigation must identify potential geotechnical issues and geological hazards that may result from implementing stormwater treatment control measures. Recommendations from the geotechnical engineer may be based on soils boring data, drainage patterns, and proposed plan for stormwater management (e.g., if infiltration is used, the anticipated stormwater design volume). These recommendations are essential to preventing damage from increased subsurface water pressure on surrounding properties, public infrastructure, sloped banks, and even mudslides. Relevant findings from these investigations must be presented and discussed in the Site Conditions Report.

Setbacks

The site assessment must also identify any required setbacks between stormwater control measures and property lines, public right-of-way, building foundations, slopes, drinking water wells, waterbodies, etc. The project applicant must confer with the jurisdictional Agency to identify all applicable setback requirements.

Other Site Considerations and Constraints

Managing Off-Site Drainage

Concentrated flows from off-site drainage may cause erosion if it is not properly conveyed through or around the project site or otherwise managed. The locations and sources of off-site run-on onto the project site must be identified and considered when identifying appropriate stormwater control measures so that the run-on can be properly managed. By identifying the locations and sources of off-site drainage, the volume of stormwater run-on may be estimated and factored into the siting and sizing of stormwater control measures at the project site.

Existing Utilities

Existing utilities located at a project site may limit the possible locations of stormwater control measures. For example, infiltration-based stormwater treatment control measures cannot be located near utility lines where an increased volume of water could damage utilities. The proximity of water supply wells, septic systems (and its expansion area), and underground storage tanks must also be identified for the project site. Stormwater runoff must be directed away from existing underground utilities, and project designs that require relocation of existing utilities should be avoided, if possible.

Environmentally-Sensitive Areas (ESAs)

The presence of ESAs at or near the project site may limit the siting of certain stormwater control measures, such as facilities that do not provide sufficient treatment of pollutants of concern. ESAs are typically delineated by, and fall under the regulatory oversight of state and federal agencies (e.g., United States Army Corps of Engineers, California Department of Fish and Wildlife or United States Fish and Wildlife Service, California Environmental Protection Agency). Stormwater control measures must be selected and appropriately sited to avoid adversely affecting ESAs.

3.2. Drainage Management Areas

The Phase II Permit requires that the project applicant delineate discrete DMAs, which are sub-watersheds within the project site that consist of one type of surface (i.e., pervious, impervious), and manage stormwater runoff from each DMA. The four types of DMAs are:

- Self-treating areas: These are landscaped or turf areas or natural conserved areas (i.e., pervious surfaces) where precipitation that falls onto these areas infiltrates directly into the soil. Stormwater runoff from these areas is treated by the vegetation and its volume is minimized through evapotranspiration and infiltration. Self-treating areas do not receive stormwater runoff from impervious surfaces. These areas are not required to drain to a bioretention facility. There should be minimal slope in these areas to ensure that stormwater runoff will effectively infiltrate into the vegetation and soil.
- Self-retaining areas: These are landscaped or turf areas (i.e., pervious surfaces) where the site layout or topography allows or encourages ponding. Self-retaining areas can be created on flat, heavily landscaped sites by using berms or a depressed grade to create a concaved area that can be used to retain stormwater runoff. Stormwater runoff from impervious surfaces may be directed to self-retaining areas, provided the self-retaining area has been designed to retain the stormwater runoff volume.
- Areas draining to self-retaining areas: Stormwater runoff from impervious surfaces can be managed by routing and dispersing it into self-retaining areas. The ratio of the impervious to pervious surface areas is dependent on the permeability of the soil in the self-retaining area. A high ratio may result in extended ponding of the self-retaining area and should be avoided to prevent vector issues.
- Areas draining to facilities designed to infiltrate, evapotranspire, or bioretain: The areas that drain to a facility that is designed to infiltrate, evapotranspire, or bioretain are used to size the facility (Section 6). More than one DMA can drain to the same facility, but a DMA can drain to only one facility. Ideally, all impervious surfaces should be directed to a facility that is designed to infiltrate, evapotranspire, and bioretain.

The Project Stormwater Plan must include a map/diagram identifying each DMA for the project site.

3.3. Pollutants of Concern

Urbanization can result in an increased discharge of pollutants to receiving waters. Pollutants of concern for a project site depend on the following factors:

- Project location;
- Land use and activities that have occurred on the project site in the past;

- Land use and activities that are likely to occur in the future; and
- Receiving water impairments.

As land use activities and stormwater management practices evolve, particularly with increased incorporation of stormwater control measures, characteristic stormwater runoff concentrations and pollutants of concern from various land use types are also likely to change. Common post-construction pollutants of concern based on typical land use activities are presented in **Table 3-2**.

As part of the Project Stormwater Plan, the project applicant must identify potential pollutants of concern that may be present at the project site prior to, during, and following construction. If necessary, the project applicant may be required to implement appropriate source control measures and/or stormwater treatment control measures to mitigate and/or eliminate the pollutants of concern in stormwater runoff.

Table 3-2. Typical Pollutants of Concern and Sources for Post-Construction Areas

Pollutant	Potential Sources
Sediment (total suspended solids and turbidity)	Streets, landscaped areas, driveways, roads, construction activities, atmospheric deposition, soil erosion (channels and slopes)
Pesticides and herbicides	Residential lawns and gardens, roadsides, utility right-of-ways, commercial and industrial landscaped areas, soil wash-off, past agricultural activities
Organic materials/oxygen demanding substances	Residential laws and gardens, commercial landscaping, animal waste
Metals	Automobiles, bridges, atmospheric deposition, industrial areas, soil erosion, metal surfaces, combustion processes
Oil and grease, organics associated with petroleum	Roads, driveways, parking lots, vehicle maintenance areas, gas stations, illicit dumping to storm drains, automobile emissions, and fats, oils, and grease from restaurants
Bacteria and viruses	Lawns, roads, leaking sanitary sewer lines, sanitary sewer cross-connections, animal waste (domestic and wild), septic systems, homeless encampments, sediments/biofilms in storm drain system
Nutrients	Landscape fertilizers, atmospheric deposition, automobile exhaust, soil erosion, animal waste, detergents
Trash and debris (gross solids and floatables)	Trash management areas, including dumpsters, trash enclosures, and trash cans, typically from commercial, industrial, and high-density residential developments

Source: Adapted from Preliminary Data Summary of Urban Storm Water BMPs (USEPA, 1999); and Final Staff Report Amendments to the Water Quality Control Plan for the Ocean Waters of California to Control Trash and Part 1 Trash Provisions of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California (State Water Board, 2015).

3.4. Site Planning Principles

Project applicants must implement a holistic approach to site design in order to develop a more hydraulically-functional site, help to maximize the effectiveness of LID, and integrate stormwater management throughout the project site. The use of multi-disciplinary approach that includes planners, engineers, landscape architects, and architects for site planning can facilitate and ensure that applicable requirements are met. The Phase II Permit (Provision E.12.e.(ii)(a)) identifies the following site planning principles that must be considered, and implemented if feasible, to increase the effectiveness of managing post-construction stormwater runoff at the project site:

- Define the development envelope and protected areas and identify areas that are most suitable for development and areas to be left undisturbed.
- Concentrate development on portions of the site with less permeable soils and preserve areas that can promote infiltration.
- Limit overall impervious coverage of the site with paving and roofs.
- Set back development from creeks, wetlands, and riparian habitats.
- Preserve significant trees.
- Conform the site layout along natural landforms.
- Avoid excess grading and disturbance of vegetation and soils.
- Replicate the site's natural drainage patterns.
- Detain and retain stormwater runoff throughout the site.

Other site planning principles that may be considered, and implemented if feasible, include the following:

- Use vegetated swales to convey stormwater runoff instead of paved gutters.
- Use alternative building materials instead of conventional materials for the project. Studies have indicated that metal used as roofing material, flashing, gutters, siding, and/or fences can leach metals into the environment.
- Identify flood control requirements early in the design stages. Stormwater treatment control measures designed in compliance with this Manual are not designed to manage stormwater runoff in excess design storm event (Section 5). Additional measures will need to be implemented to manage flood-related flow rates in accordance with Agency and state standards.

3.5. Site Design Measures

Site design measures can protect sensitive environmental features such as riparian areas, wetlands, and steep slopes. The intention of site design principles is to reduce pollution, stormwater runoff peak flows and volumes, and other impacts associated with development. All projects subject to this Manual (see Section 1.4) must apply site design measures to reduce stormwater runoff from the project site. For Small Projects, a project applicant is required to implement at least one site design measure. For Regulated and Hydromodification Management Projects, a project applicant must implement site design measures to the extent technically feasible to help meet the numeric sizing criteria for stormwater retention and treatment under Provision E.12.e(ii)(c) of the Phase II Permit.

The Phase II Permit identifies the following site design measures[4] that must be considered for each project:

- Stream setbacks and buffers;
- Soil quality improvement and maintenance;
- Tree planting and preservation;
- Rooftop and impervious area disconnection;
- Porous pavement;
- Vegetated swales; and
- Rain barrels and cisterns.

The following sections present information for implementing these site design measures.

Stream Setbacks and Buffers

Setbacks for development projects are required to prevent discharge directly into receiving waters. Stream setbacks and buffers are areas at a project site that are left undeveloped and pervious in order to prevent stormwater runoff from flowing directly from impervious surfaces into a stream or other waterbody. These buffer areas can reduce the volume of stormwater runoff, reduce peak stormwater runoff flow rates, and provide some treatment and removal of pollutants in stormwater runoff. If stream setbacks and buffers are implemented, the volume of stormwater runoff that may need to be managed by stormwater treatment control measures may be reduced, which also reduces sizing requirements for the stormwater treatment control measures. See Section 5.5 for calculation of stormwater volume or flow credits.

Soil Quality Improvement and Maintenance

Soil characteristics (e.g., soil type, porosity) can determine the methods that can be used at a project site to manage stormwater. These soil characteristics as well as soil

[4] The Phase II Permit also lists green roofs. This practice has been omitted from this Manual as a practice that may not be suitable due to the climate of the region and water conservation requirements. Project applicants may propose green roofs as a site design measure, but must demonstrate the water efficiency of the system.

compaction determine the feasibility of implementing stormwater treatment control measures. Soil amendments, such as compost and aeration, can improve soils and provide an environment that promotes healthy vegetation, increase storage and provide treatment of stormwater runoff as it infiltrates into the subsurface, recharge groundwater levels, reduce the needs for chemical supplements (e.g., fertilizers), and minimize erosion and sedimentation.

Because soil amendments can reduce the volume of stormwater runoff that may need to be managed by stormwater treatment control measures may be reduced, credits for may be applied for reducing the sizing requirements for the stormwater treatment control measures. See Section 5.5 for calculation of stormwater volume or flow credits.

Tree Planting and Preservation

Trees are essential to the hydrologic cycle and provide multiple benefits for stormwater management. Tree canopies provide significant precipitation interception (10-40 percent) depending on the type of tree and climate and result in a reduction in potential stormwater runoff volumes and flow rates, which can help meet hydromodification requirements. Precipitation that infiltrates near trees will be absorbed by roots and transpired. Trees also provide some pollutant removal through root uptake. Finally, trees enhance site aesthetics, increase property values, provide shading and cooling, provide erosion control, and improve air quality.

In general, consider, and implement if feasible, the following:

- Concentrate or cluster development on less sensitive areas of a project site.
- Limit clearing and grading of trees and vegetation at the project site.
- Provide adequate setbacks from structures and other infrastructure to prevent root intrusion and potential damage.
- Coordinate any necessary irrigation requirements with the site irrigation system.

When site planning, the project applicant should preserve existing trees and other vegetation at the project site. Preserving healthy existing site trees and vegetation is more effective for managing stormwater runoff than completely removing existing trees and vegetation and planting new trees and vegetation. Because trees provide a reduction in the volume and flow rate of stormwater runoff, stormwater runoff that may need to be managed by stormwater treatment control measures, including sizing requirements may be reduced.

The project applicant can also complement existing trees and vegetation with new climate-appropriate trees and vegetation as part of the project to provide additional stormwater management benefits. To receive these credits for stormwater management, the trees that are planted must meet the following requirements:

- Be planted within 25 feet of the DMA for which the credit is applied;
- Have a minimum 25-foot diameter at tree maturity;

- Spaced so that crowns do not overlap at 15 years of growth;

See Section 5.5 for calculation of stormwater volume or flow credits for preserving and planting trees at the project site. Note that other Agency-specific standards for tree requirements may apply.

Rooftop and Impervious Area Disconnection

Rooftop and impervious area disconnection can reduce stormwater runoff volumes and flows that enter the storm drain system. Rooftop drains can be disconnected from the storm drain system by directing stormwater runoff from rooftops across vegetation (e.g., rain garden) or other pervious surface. Rooftop drains can also be disconnected from the storm drain system by directing stormwater runoff from rooftops to systems (e.g., rain barrels, cisterns) that collect, store, and allow the use of stormwater runoff. Disconnected impervious areas are any impervious areas that drain stormwater runoff over an adjoining vegetated area or other pervious surface. When these areas are disconnected from the storm drain system, stormwater runoff that moves through the vegetated area or other pervious surface will have decreased flow rate and reduced volumes due to infiltration and evaporation.

If the vegetated area to which stormwater runoff will flow is designed, climate-appropriate vegetation that will withstand periods of inundation must be used. See Appendix H for examples of suitable vegetation. The vegetated area or pervious surface receiving the stormwater runoff must also properly drain to prevent vector breeding.

If rooftop and impervious area disconnected from the storm drain system, the volume of stormwater runoff that may need to be managed by stormwater treatment control measures may be reduced, which also reduces sizing requirements for the stormwater treatment control measures. See Section 5.5 for calculation of stormwater volume or flow credits.

Porous Pavement

Porous pavement (e.g., permeable interlocking concrete pavers, pervious concrete, or porous asphalt pavement) can be used to manage stormwater runoff by storing stormwater runoff in porous pavement and its sublayers of sand and gravel and infiltrating it into the underlying soil. Potential applications of porous pavement include, but are not limited to, sidewalks, patios, walkways, residential driveways, and parking lots. However, porous pavement may not be appropriate in heavily used areas, industrial or other locations where activities may introduce pollutants of concern, or areas where there are contaminated soils or groundwater. A geotechnical investigation, which is conducted in the Site Assessment (Section 3.1), must verify that porous pavement is technically feasible for the site. Because porous pavement relies on infiltration to mitigate stormwater runoff, regular maintenance to prevent occlusion is required to maintain the effectiveness of the porous pavement.

When implementing porous pavement:

- Establish protective perimeters around the porous pavement to prevent inadvertent compaction by construction activities. If the underlying soils are compacted, ripping or loosening the top two inches of the underlying soils prior to construction may be needed to improve infiltration.
- Protect the area designated for porous pavement from construction-related sediment loads. If possible, divert all flows around the areas intended for porous pavement. Implement sediment controls to prevent sediment from entering the porous pavement area.
- Follow all manufacturers' specifications for constructing and maintaining porous pavement.
- Stabilize the entire tributary area before allowing stormwater runoff into the porous pavement.

Use of porous pavement may reduce stormwater runoff volumes and flow rates. See Section 5.5 for calculation of credits for implementing porous pavement for a project.

Vegetated Swales

See Appendix F (Fact Sheet T-4) for more information on vegetated swales and its applications. Use of vegetated swales may reduce stormwater runoff volumes and flow rates. See Section 5.5 for calculation of stormwater volume or flow credits for implementing vegetated swales at the project site.

Rain Barrels and Cisterns

Rain barrels and cisterns are containers that collect and store precipitation from rooftop drainage systems that would otherwise be lost to stormwater runoff and diverted to the storm drain system or receiving water. Collection of this precipitation reduces the volume of stormwater runoff and reduces the potential for mobilization of pollutants. Other benefits include providing water conservation benefits and using a small footprint on a project site. Rain barrels are placed above ground beneath a shortened downspout next to a home or building and typically range in size from 50 to 180 gallons. Cisterns are larger storage tanks that may be located above or below ground.

Stored precipitation is typically used for landscape irrigation, but may also be used for washing. Water stored in rain barrels or cisterns must be emptied between storm events to prevent overflow or within 96 hours following a storm event to prevent vector breeding, but must not be discharged to the storm drain system. Rain barrels and cisterns must be properly maintained according to manufacturers' specifications to ensure continued effectiveness.

Because rain barrels and cisterns provide a reduction in the volume and flow rate of stormwater runoff, stormwater runoff that may need to be managed by stormwater treatment control measures may be reduced, including sizing requirements. See Section 5.5 for calculation of stormwater volume or flow credits for implementing rain barrels and/or cisterns at the project site.

SECTION 4. SOURCE CONTROL MEASURES

Source control measures are designed to prevent pollutants from contacting stormwater runoff or prevent discharge of contaminated stormwater runoff to the storm drain system and/or receiving water. This section describes source control measures to be considered for implementation in conjunction with appropriate non-structural source control measures, such as good housekeeping and employee training, to optimize pollution prevention. The Agencies may require additional source control measures not included in this Manual for specific pollutants, activities, or land uses for a project.

At a minimum, all projects that include landscape irrigation must implement water efficient landscape irrigation design, in accordance with all applicable landscape irrigation codes and ordinances, including, but not limited to the applicable Water Efficient Landscape Ordinance (WELO) requirements, which may change over time, as a source control measure.

Irrigation systems must be designed to conserve water and prevent water leaving the area of application. The design of irrigation system shall prevent excessive irrigation runoff by:

- Detecting and correcting leaks from the irrigation within 72 hours of discovering the leak. A pressure sensor can be incorporated to shut off the irrigation system if there is a sudden pressure drop, which may indicate a broken sprinkler head or water line;
- Properly designing and aiming sprinkler heads to only irrigate the planned application area;
- Not irrigating during precipitation events. Precipitation sensors can be installed to shut off irrigation system during and after storm events; and
- Designing and managing holding ponds for recycled water such that no discharge occurs unless it is the result of a minimum 25-year, 24-hour storm event. Any releases from holding ponds must be reported to the Central Valley Regional Water Board and the jurisdictional Agency within 24 hours of discharge.

Source control measures presented in this Manual apply to both stormwater and non-stormwater discharges. Non-stormwater discharges are discharges of any substance (e.g., excess irrigation, leaks and drainage from trash dumpsters, cooling water, and process wastewater) that is not comprised entirely of stormwater runoff. Any stormwater runoff that is mixed or comingled with non-stormwater flows is considered non-stormwater. Stormwater and non-stormwater discharges to the storm drain system or receiving water may be subject to local, state, or federal permitting prior to commencing discharge. The jurisdictional Agency must be contacted prior to any discharge.

The following source control measures must be implemented to the extent technically feasible to mitigate pollutant mobilization in stormwater and non-stormwater runoff from the project site:

- Parking/storage areas and maintenance;
- Landscape/outdoor pesticide use;
- Building and grounds maintenance;
- Refuse areas;
- Outdoor storage of equipment or materials;
- Vehicle and equipment cleaning;
- Vehicle and equipment repair and maintenance;
- Fuel dispensing areas;
- Pools, spas, ponds, decorative fountains, and other water features;
- Indoor and structural pest control;
- Accidental spills and leaks;
- Restaurants, grocery stores, and other food service operations;
- Interior floor drains;
- Industrial processes;
- Loading docks;
- Fire sprinkler test water;
- Drain or wash water from boiler drain lines, condensate drain lines, rooftop equipment, drainage sumps, and other sources; and
- Unauthorized non-stormwater discharges.

Fact sheets for each source control measure are presented in Appendix E. These fact sheets include pollution prevention activities, Best Management Practices, design considerations, and maintenance requirements to ensure effective implementation of the source control measure.

SECTION 5. STORMWATER DESIGN VOLUME/FLOW CALCULATION

5.1. Introduction

The requirements of the Phase II Permit are based on managing a specific volume or flow of stormwater runoff from the project site (stormwater design volume [SDV] or stormwater design flow [SDF]). By treating the SDV/SDF, it is expected that pollutant loads, which are typically higher at the beginning of storm events, will be prevented from or reduced in the discharge into the receiving waters. Additionally, treating the SDV/SDF will also reduce peak flow rates, which can reduce downstream impacts to the receiving water. This section presents information on how to calculate the SDV and/or SDF for a project site that is used in designing stormwater treatment control measures. The design standards for stormwater management outlined in this section do not meet applicable flood control requirements.

5.2. Stormwater Design Volume

All stormwater treatment control measures, based on the SDV, must mitigate (infiltrate or treat) the volume of stormwater runoff produced by the 85th percentile, 24-hour storm event based on historic rainfall records, determined as the maximized capture stormwater volume for the tributary area, from the formulae recommended in *Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87* (1998). This approach uses the following two regression equations to calculate the unit stormwater volume, which is multiplied by the area of the DMA to calculate the SDV for sizing volume-based stormwater treatment control measures:

$$C = 0.858 \times i^3 - 0.78 \times i^2 + 0.774 \times i + 0.04$$

Where:

C = stormwater runoff coefficient [unitless]; and
i = DMA imperviousness ratio [expressed as a decimal].

$$P_0 = (a \times C) \times P_6$$

Where:

P_0 = unit stormwater volume [in];
a = regression constant (1.963 for 48-hr drawdown); and
P_6 = mean annual runoff-producing rainfall depth [in] (see **Table 5-1**).

For the Agencies, except the County of San Joaquin, the mean annual runoff-producing rainfall depth, based on historic records and the NetSTORM model[5], to be used for calculating the unit stormwater volume in the region are presented in **Table 5-1**. For projects located in the jurisdiction of the County of San Joaquin, the mean annual runoff-producing rainfall depth presented in **Table 5-1** may be used if the project is near the project locations. For projects located in the jurisdiction of the County of San Joaquin that are not located in the areas identified in **Table 5-1**, the project applicant must determine the mean annual runoff-producing rainfall depth, based on historic records, for the project location. The mean annual runoff-producing rainfall depth was determined by assuming a minimum 0.1-inch storm event with a 24-hour inter-storm event period was required to produce stormwater runoff.

Table 5-1. Mean Annual Runoff-Producing Rainfall Depth

Project Location	Mean Annual Runoff-Producing Rainfall Depth	Rain Gage
Lathrop	0.36	Global Historic Climatology Data Network Station USW00023237
Lodi	0.33	Global Historic Climatology Data Network Station US1CASJ0005
Manteca	0.37	California Irrigation Management System Station #70
Patterson	0.32	Global Historic Climatology Data Network Station USC00046168
Stockton	0.36	Global Historic Climatology Data Network Station USW00023237
Tracy	0.33	California Irrigation Management System Station #167

The SDV for each DMA is calculated using the following equation:

$$SDV = A \times \frac{P_0}{12}$$

Where:

SDV = stormwater design volume [ft^3];
A = total area of DMA [ft^2]; and
P_0 = unit stormwater volume [in].

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[5] The NetSTORM computer program, which was developed by CDM Smith, was used to conduct precipitation intensity, duration, and frequency analysis. This program was also used in the development of the California Association of Stormwater Agencies (CASQA) Stormwater Best Management Practices (BMP) Handbooks.

If necessary, the project applicant must also consider run-on from areas surrounding the project site as part of the determination of the SDV.

5.3. Stormwater Runoff Coefficient

Projects typically comprise of a variety of site elements that have variable associated stormwater runoff coefficients. The stormwater runoff coefficient is a function of roughness and permeability across the surface which stormwater runoff drains. Stormwater runoff coefficients based on soil type for typical site elements that will be used to calculate the SDF are presented in **Table 5-2**.

Table 5-2. Stormwater Runoff Coefficients for Typical Site Elements

Site Element	Stormwater Runoff Coefficient (C_r) (1)	
	Type A and B Soils	Type C and D Soils
Agricultural	0.25 (2)	0.45 (2)
Asphalt/concrete pavement	0.95	0.95
Disturbed soil	0.18	0.25
Forest/undisturbed open space	0.03	0.05
Gravel pavement	0.35	0.35
Managed turf	0.18	0.25
Permeable pavement	(3)	(3)
Roofs	0.95	0.95

(1) Source: Adapted from the Center for Watershed Protection, Ellicott City, Maryland.

(2) Source: Adapted from *The Erosion and Sediment Control Handbook* (Stephen Goldman, et al., 1986).

(3) Varies with product type. Consult manufacturer for appropriate design values.

5.4. Stormwater Design Flow

Stormwater treatment control measures, based on the SDF, must mitigate (infiltrate or treat) the flow rate of stormwater runoff produced by a rain event equal to at least 0.2 in/hr intensity. The Rational Method is used to calculate the SDF according to the following equation:

$$SDF = 1.008 \times i \times A \times C_r$$

Where:

SDF = stormwater design flow [ft^3/s];
1.008 = unit conversion factor;
i = design rainfall intensity [0.2 in/hr];
A = total area of DMA [acre]; and
C_r = stormwater runoff coefficient for DMA (see **Table 5-2**).

5.5. Post-Construction Stormwater Runoff Reduction Calculators

The State Water Board developed a Post-Construction Calculator[6] to quantify the stormwater runoff reduction resulting from implementation of site design measures. Instructions for using the Post-Construction Calculator are available in the calculator spreadsheet. The Post-Construction Calculator is located on the State Water Board website at:
http://www.swrcb.ca.gov/water_issues/programs/stormwater/phase_ii_municipal.shtml.

For Small Projects, the project applicant must use the Post-Construction Calculator to quantify the stormwater runoff reduction from implementing site design measures. The results of these calculations must be submitted with the Project Stormwater Plan.

For Regulated and/or Hydromodification Management Projects, the project applicant can use the Post-Construction Calculator to quantify the stormwater runoff volume or flow reduction resulting from implementing site design measures. The stormwater runoff reduction resulting from implementing site design measures, to the extent technical feasible, is a credit that reduces the amount of stormwater runoff volume or flow that must be further treated by stormwater treatment control measures (i.e., bioretention, alternative stormwater treatment control measures) for the DMA. By reducing the amount of stormwater runoff that requires additional treatment, the size of the stormwater treatment control measure will also be reduced. It may be possible to completely manage stormwater runoff from the project site using site design measures, thereby potentially eliminating the need to include stormwater treatment control measures at the project site.

The output of the Post-Construction Calculator for each DMA must be submitted with the Project Stormwater Plan.

[6] Although the Post-Construction Calculator states that it is for Small Projects, it is the same calculator that is used for Regulated and Hydromodification Management Projects.

SECTION 6. STORMWATER TREATMENT CONTROL MEASURES

6.1. Introduction

Stormwater treatment control measures are required for Regulated and Hydromodification Management Projects to augment site design and source control measures to treat and reduce stormwater runoff and pollution loads that are potentially discharged to the receiving water to the extent technically feasible. Stormwater treatment control measures are designed to handle the frequent, smaller storm events, or the first flush stormwater runoff from larger storm events. The first flush of larger storm events is the initial period of the storm where stormwater runoff typically carries the highest concentration and loads of pollutants. Small, frequent storm events represent most of the total annual average precipitation in the Agencies' service area.

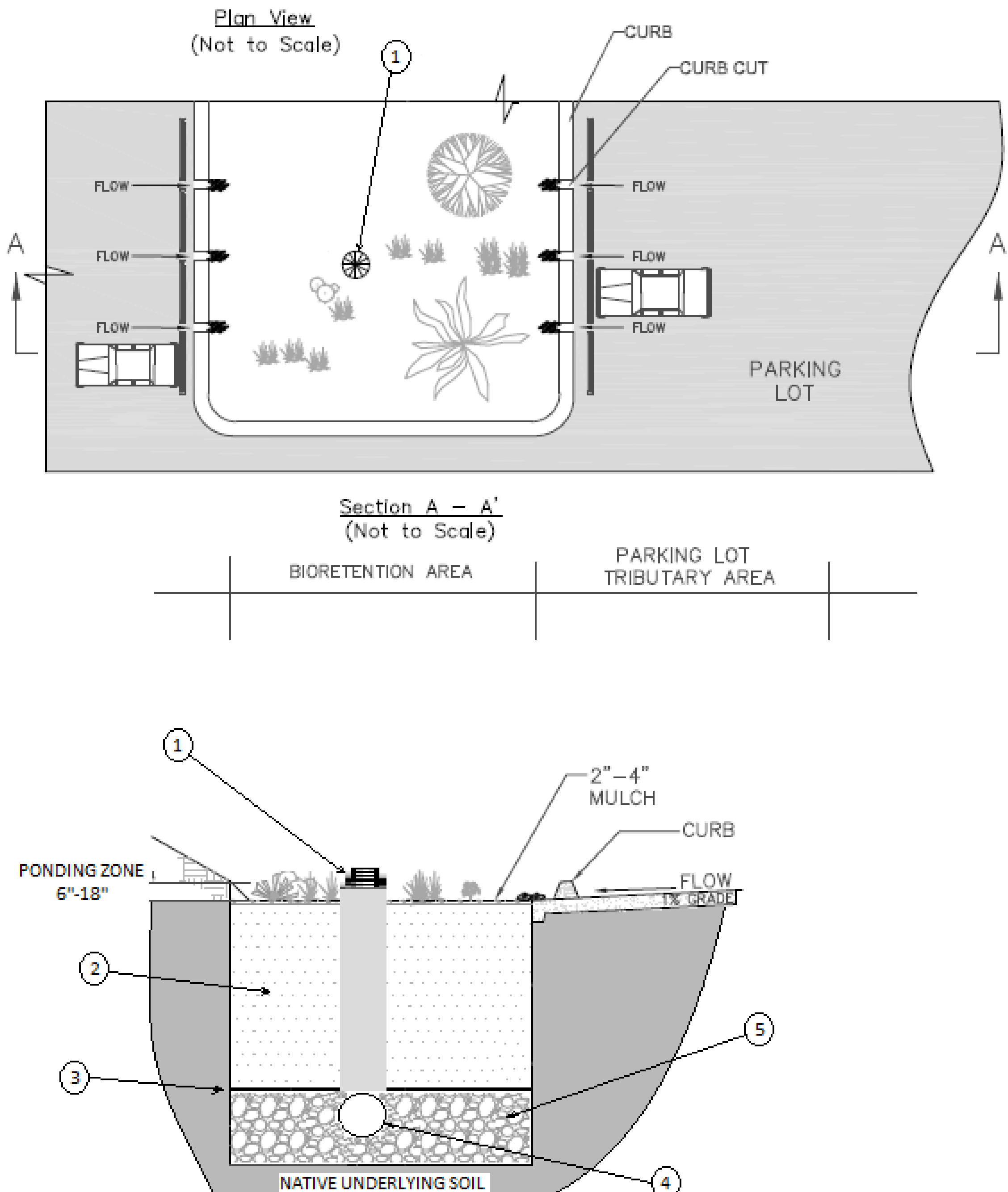
The Phase II Permit requires that all Regulated and Hydromodification Management Projects use stormwater treatment control measures to manage the portion of the SDV or SDF that is not reduced by site design measures. If a project site is able to manage the entire SDV or SDF using site design measures, stormwater treatment control measures may not be necessary.

The Phase II Permit (Provision E.12.e.(f)) identifies bioretention as the standard stormwater treatment control measure unless (1) an alternative treatment control measure that is equivalent to bioretention is proposed and demonstrated (Provision E.12.e.(g)), or (2) a specific exception applies (Provision E.12.e.(i)). The following section describes how to implement bioretention at a project site.

6.2. Bioretention

A bioretention facility, which is an LID stormwater control measure, is a vegetated shallow depression that is designed to receive, retain, and infiltrate stormwater runoff from downspouts, piped inlets, or sheet flow from adjoining impervious areas. A shallow ponding zone above the vegetated surface provides temporary storage of stormwater runoff. During storm events, stormwater runoff accumulates in the ponding zone and gradually infiltrates and filters through the engineered planting media before infiltrating into the underlying soil. Vegetation also holds water in the root zone that can be returned to the atmosphere by transpiration. Bioretention facilities are typically planted with climate-appropriate vegetation that do not require fertilization and can withstand periodic wet soils.

An example schematic of a typical bioretention area is presented in **Figure 6-1**.



NOTES

1. OVERFLOW DEVICE: VERTICAL RISER OR EQUIVALENT
2. 1.5' PLANTING MEDIA; 3' PREFERRED. PLANTING MEDIA SPECIFICATIONS PER BIORETENTION TECHNICAL SPECIFICATIONS
3. 2-4" CALTRANS CLASS 2 PERMEABLE MATERIAL (PLANTING MEDIA/GRAVEL LAYER SEPARATION ZONE)
4. PERFORATED 6" MIN PVC SDR 26 OR C900
5. 1' MIN 1"-2.5" DIAMETER STONE

Figure 6-1. Example Bioretention Facility Schematic

Design Criteria

The following sections describe the minimum design criteria for bioretention facilities.

Geotechnical

Due to the potential to contaminate groundwater and/or soils, cause slope instability, impact surrounding structures, and potential for insufficient infiltration capacity, a geotechnical investigation must be conducted during the site assessment process to verify the site suitability for bioretention. It is critical to understand how stormwater runoff will move through the soil (horizontally and vertically) and if there are any geological conditions that may inhibit the movement of water. Soil infiltration rates and the depth to the groundwater table must be evaluated to ensure that conditions are satisfactory for proper operation of a bioretention system. Bioretention facilities cannot be located on sites with a slope greater than 10 percent. A Site Conditions Report summarizing the relevant findings from the geotechnical investigation must be submitted with the Project Stormwater Plan.

Setbacks

Applicable setbacks must be implemented when siting a bioretention facility.

Pretreatment

Pretreatment, which refers to design features that provide settling of large particles before stormwater runoff enters a stormwater treatment control measure, is important to ensure proper operation of a bioretention facility and reduce the long-term maintenance burden. Pretreatment (e.g., vegetated swales, proprietary devices) must be provided to reduce the sediment load entering a bioretention facility in order to prevent the engineered planting media and/or underlying soil from being occluded prematurely and maintain the infiltration rate of the bioretention facility. Additionally for sites with high infiltration rates, pretreatment is required to protect groundwater quality.

Flow Entrance and Energy Dissipation

The DMA(s) tributary to a bioretention facility must be graded to minimize erosion as stormwater runoff enters the facility by creating sheet flow conditions rather than a concentrated stream condition or by providing energy dissipation devices at the inlet. Typically, a minimum slope of 1 percent for pervious surfaces and 0.5 percent for impervious surfaces to the inlet of the bioretention facility should be maintained. The following types of flow entrances can be used for bioretention facilities:

- Level spreaders (e.g., slotted curbs) can be used to facilitate sheet flow.
- Dispersed low velocity flow across a landscaped area. Dispersed flow may not be possible given space limitations or if the bioretention facility controls roadway or parking lot flows where curbs are mandatory.

- Dispersed flow across pavement or gravel and past wheel stops for parking areas.
- Flow spreading trench around perimeter of the bioretention facility that may be filled with pea gravel or vegetated with 3:1 side slopes.
- Curb cuts for roadside or parking lot areas. Curb cuts must include rock or other erosion controls in the channel entrance to dissipate energy. The flow entrance should drop two to three inches from curb line and provide an area for settling and periodic removal of sediment and coarse material before flow disperses to the remainder of the bioretention facility.
- Piped entrances, such as roof downspouts, must include rock, splash blocks, or other erosion controls at the entrance to dissipate energy and disperse flows.

Drainage

Bioretention facilities provide stormwater runoff storage in the ponding zone and in the voids of the planting media and gravel layers and must completely drain into the underlying soils within 48 hours. The planting media and gravel layers and underlying soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive stormwater runoff from subsequent storm events, maintain infiltration rates, maintain adequate soil oxygen levels for healthy soil biota and vegetation, and provide proper soil conditions for biodegradation and retention of pollutants.

Sizing

<u>Step 1: Determine the Adjusted SDV (SDV_{adj})</u>

Bioretention facilities are designed to capture and retain the SDV_{adj}, which is the difference between the SDV (Section 5.2) and the volume of stormwater runoff managed through site design measures (Section 5.5), for the tributary DMA(s).

<u>Step 2: Determine the design infiltration rate</u>

Determine the in-situ infiltration rate of the underlying soil using the Double-Ring Infiltrometer standard (ASTM D3385). Apply a safety factor to the in-situ infiltration rate to determine the design infiltration rate. A typical safety factor of 4 can be used (i.e., multiply in-situ infiltration rate by 0.25). The design infiltration rate (f_{design}) must be between 0.5 and 5.0 in/hr. Amending the underlying soil may improve the flow of stormwater runoff into the underlying soil if the design infiltration rate is less than 0.5 in/hr. If the infiltration rate of the underlying soil is greater than 5.0 in/hr, an underdrain may not be necessary. The infiltration rate will decline between maintenance cycles as the surface of the bioretention facility becomes occluded and particulates accumulate in the infiltrative layer.

<u>Step 3: Determine size of bioretention facility design layers</u>

Bioretention facilities consist of multiple layers that are designed to retain stormwater runoff. The design depths, which are used to size the bioretention facility, are presented in **Table 6-1**. Other design parameters for these layers are discussed in further detail in the following sections.

Table 6-1. Design Depths of Bioretention Facility Layers

Bioretention Facility Layer	Design depth
Ponding zone	0.5-1.5 ft
Planting media (excluding the mulch layer, if provided)	1.5-3.0 ft
Planting media/gravel layer separation zone (1)	2-4 in
Gravel	1 ft (min)

(1) In calculating the required bottom surface area of the bioretention facility, the planting media/ gravel layer separation zone is not considered because it is designed primarily to separate the planting media and gravel layer and not to retain stormwater runoff.

Step 4: Calculate the bottom surface area of the bioretention facility

Determine the bottom surface area (surface area at the base of side slopes, not at the top of side slopes) of the bioretention facility using the following equation:

$$A = \frac{SDV_{adj}}{d_{pz} + (\eta_{pm} \times d_{pm}) + (\eta_{gl} \times d_{gl})}$$

Where:

A = bottom surface area of bioretention facility [ft^2];
SDV_{adj} = adjusted stormwater design volume [ft^3];
d_{pz} = depth of ponding zone (0.5-1.5 ft) [ft];
η_{pm} = porosity of planting media [unitless];
d_{pm} = depth of planting media (min 1.5 ft) [ft];
η_{gl} = porosity of gravel layer [unitless]; and
d_{gl} = depth of gravel layer (min 1 ft) [ft].

The total depth of the bioretention facility must meet the following condition to ensure that the stormwater runoff will be infiltrated within the maximum drawdown time:

$$d_{pz} + (\eta_{pm} \times d_{pm}) + (\eta_{gl} \times d_{gl}) \leq \frac{f_{design}}{12} \times t_{max}$$

Where:

d_{pz} = depth of ponding zone (0.5-1.5 ft) [ft];
η_{pm} = porosity of planting media [unitless];
d_{pm} = depth of planting media (min 1.5 ft) [ft];
η_{gl} = porosity of gravel layer [unitless];

d_{gl} = depth of gravel layer (min 1 ft) [ft]
f_{design} = design infiltration rate [in/hr]; and
t_{max} = drawdown time (max 48 hrs) [hr].

For the site layout and planning purposes, the top surface area, which can be calculated from the bottom surface area and slopes of the bioretention facility, will need to be determined.

Planting Media Layer

The Phase II Permit requires that the planting media layer:

- Have a minimum depth of 1.5 feet, excluding the mulch layer, if provided;
- Achieve a long-term, in-place minimum infiltration rate of at least 5 in/hr to support maximum stormwater runoff retention and pollutant removal; and
- Consist of 60 to 70 percent sand meeting the specifications of the ASTM C33 and 30 to 40 percent compost.

Compost must be a well-decomposed, stable, weed-free organic matter source derived from waste materials including yard debris, wood wastes, or other organic material and not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product must be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program).

Mulch is recommended for the purpose of retaining moisture, preventing erosion, and minimizing weed growth. Projects subject to the California Model Water Efficiency Landscaping Ordinance (or comparable local ordinance) will be required to provide at least two inches of mulch. Aged mulch, also called compost mulch, reduces the ability of weeds to establish, keeps soil moist, and replenishes soil nutrients. If mulch is used for a bioretention facility, two to four inches (average three inches) of mulch should be used at the initiation of the facility. Annual placement (preferably in June after weeding) of one to two inches of mulch beneath plants will maintain the mulch layer.

Planting Media/Gravel Layer Separation Zone

The planting media and gravel layer must be separated by a permeable 2-4 inch layer of sand and stone that meets the grading requirements in **Table 6-2** to prevent migration of the planting media into the gravel layer.

Table 6-2. Planting Media/Gravel Layer Separation Layer Grading Requirements

Sieve Size	Percent Passing
1”	100
3/4”	90-100
3/8”	40-100
No. 4	25-100
No. 8	18-33
No. 30	5-15
No. 50	0-7
No. 200	0-3

Source: Caltrans Standard Specifications (2010) Class 2 Permeable Material

Gravel Layer

The gravel layer must consist of washed 1- to 2.5-inch diameter stone with a minimum 1-foot depth.

Underdrain

If necessary, an underdrain may be included in the design of a bioretention facility to convey treated stormwater runoff for further treatment, to the storm drain system, or to the receiving water. The underdrain must have a discharge elevation at the top of the gravel layer and a mainline diameter of six inches using slotted PVC SDR 26 or C900. The slotted PVC allows for pressure cleaning and root cutting, if necessary. The slotted pipe should have two to four rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots should be 0.04 to 1 inches wide with a length of 1 to 1.25 inches. Slots should be longitudinally-spaced such that the pipe has a minimum of one square inch opening per lineal foot and should face down. Underdrains should be sloped at a minimum of 0.5 percent in order to drain freely to an approved location.

The Phase II Permit (Provision E.12.e.(h)) identifies the following two allowed variations for special site conditions, which must be demonstrated by the project applicant, for underdrain placement:

- Bioretention facilities located in areas with documented high concentrations of pollutants in the underlying soil or groundwater, where infiltration may contribute to a geotechnical hazard, or on elevated plazas or other structures may locate the underdrain at the bottom of the subsurface drainage/storage layer.
- If the bioretention facility is located in areas with high groundwater, highly infiltrative soils (in-situ infiltration rate greater than 5.0 in/hr), or where connection of the underdrain to a surface drain or to a subsurface storm drain is infeasible, the underdrain may be omitted.

Observation Well

A rigid non-perforated observation pipe with a diameter equal to the underdrain diameter must be connected to the underdrain to provide a clean-out port as well as an observation well to monitor infiltration rates. If the underdrain is located at the top of the gravel layer, the observation well may also extend to the bottom of the gravel layer to monitor drainage of the gravel layer. The wells/clean-out port must be connected to the slotted underdrain with the appropriate manufactured connections. The wells/clean-outs must extend at least six inches above the top elevation of the bioretention facility mulch and be capped with a lockable screw cap. The ends of the underdrain pipes not terminating in an observation well/clean-out port must also be capped.

Vegetation

It is recommended that a minimum of three climate-appropriate types of tree, shrub, and/or herbaceous groundcover species be incorporated in a bioretention facility to protect against failure due to disease and/or insect infestations of a single species. Trees may be planted on the slopes or above the slopes of the bioretention facility (i.e., not planted in the planting media layer). All vegetation selected must be climate appropriate. Select vegetation that:

- Can tolerate summer drought, ponding fluctuations, and saturated soil conditions for 48 hours;
- Will be dense and strong enough to stay upright, even in flowing water;
- Does not require fertilizers;
- Is not prone to pests and is consistent with Integrated Pest Management (IPM) practices; and
- Is consistent with local water conservation ordinance requirements.

A sample list of suitable vegetation species is included in Appendix H. The vegetation species presented in Appendix H may not be suitable for all Agencies. The jurisdictional Agency may restrict the species list as deemed appropriate for the local environment and operational needs and conditions. Prior to installation, a landscape architect with experience in bioretention facility design must certify that all proposed vegetation is appropriate for the project site. Stormwater runoff must be diverted around the bioretention facility during the period of vegetation establishment.

Irrigation System

Provide an irrigation system to maintain viability of vegetation, if necessary. If possible, the general landscape irrigation system should incorporate the bioretention facility. The irrigation system must be designed to current local code or ordinance specifications and must comply with the requirements in Section 4. Supplemental irrigation may be required for the establishment period even if it is not needed later.

Overflow Device

An overflow device is required at the ponding depth near the inlet to the bioretention facility to divert stormwater runoff in excess of the design capacity of the bioretention facility. The following, or equivalent, should be provided:

- A vertical PVC pipe (SDR 26) to act as an overflow riser.
- The overflow riser(s) should be sized with a diameter equal to the underdrain diameter so it can be cleaned without damage to the pipe.
- The inlet to the riser must be at the ponding depth and capped with a spider cap to exclude floating mulch and debris. Spider caps must be screwed on or glued (i.e., not removable). The overflow device must convey stormwater runoff in excess of the design capacity of the bioretention facility to an approved discharge location (e.g., another stormwater treatment control measure, storm drain system, receiving water).

Hydraulic Restriction Layer (Special Site Condition only)

The Phase II Permit (Provision E.12.e.(h)) identifies an allowed variation for special site conditions, which must be demonstrated by the project applicant, for bioretention facilities located in areas with documented high concentrations of pollutants in the underlying soil or groundwater, where infiltration may contribute to a geotechnical hazard, or on elevated plazas or other structures. In these situations, a hydraulic restriction layer may be incorporated at the bottom of the gravel layer to prevent infiltration of stormwater runoff into the underlying soil. The hydraulic restriction layer should be installed generously with overlapping seams below the gravel layer of the bioretention facility prior to placing the gravel layer, planting media and gravel layer separation zone, and planting media layer. The specifications of the hydraulic restriction layer are presented in **Table 6-3**.

Table 6-3. Hydraulic Restriction Layer Specifications

Parameter	Test Method	Specifications
Material		Nonwoven geomembrane liner
Unit weight		8 oz/yd^3 (minimum)
Filtration rate		0.08 in/sec (minimum)
Puncture strength	ASTM D-751 (Modified)	125 lbs (minimum)
Mullen burst strength	ASTM D-751	400 lb/in^2 (minimum)
Tensile strength	AST D-1682	300 lbs (minimum)
Equiv. opening size	US Standard Sieve	No. 80 (minimum)

Construction Considerations

As part of the site planning process, the areas designated for bioretention must be identified. Compaction of underlying soils near and at the bioretention area at the project site must be avoided. Establish protective perimeters to prevent inadvertent compaction by construction activities.

The area identified for bioretention must be protected from construction-related sediment loads. During construction activities if possible, divert all flows around the areas intended for bioretention. Sediment control measures should also be implemented to prevent sediment from impacting the areas identified for bioretention. If the underlying soils are compacted or the area identified for a bioretention facility is occluded, ripping or loosening the top two inches of the underlying soils prior to construction of the bioretention facility may be needed to improve infiltration. After construction is completed, the entire tributary area to the bioretention facility must be stabilized before allowing stormwater runoff to enter it.

Maintenance Requirements

Regular maintenance and inspection are important for proper function of bioretention facilities. Bioretention facilities require annual plant, soil, and mulch layer maintenance to ensure optimal infiltration, storage, and pollutant removal. Bioretention facility maintenance requirements, which consist primarily of landscape care, include:

- Irrigate vegetation as needed during prolonged dry periods. In general, climate-appropriate vegetation should be selected and not require irrigation after full establishment (two to three years). Regularly inspect the irrigation system, if provided, for clogs or broken pipes and repair as necessary.
- Inspect flow entrances, ponding area, and surface overflow areas, at a minimum annually, and replace soil, vegetation, and/or mulch layer in areas if erosion has occurred. Properly-designed facilities with appropriate flow velocities should not cause erosion except possibly during extreme events. If erosion occurs, the flow velocities and gradients within the bioretention facility and energy dissipation and erosion protection strategies in the pretreatment area and flow entrance should be reassessed. If sediment is deposited in the bioretention facility, identify the source of the sediment within the tributary area, stabilize the source, and remove excess surface deposits.
- Inspect the bioretention facility after major storms to ensure that water infiltrates into the subsurface completely within the maximum drawdown time. If water is present in the bioretention facility more than 48 hours after a storm, the bioretention facility may be clogged. Maintenance activities triggered by a clogged facility include:
  - Check for debris/sediment accumulation, remove sediment (if any), and evaluate potential sources of sediment and vegetative or other debris. If suspected upstream sources are outside of the Agency’s jurisdiction, additional pretreatment may be necessary.

  - Determine if it is necessary to remove and replace the planting media and/or gravel layer to restore functionality of the bioretention facility.

- Prune and remove dead vegetation as needed. Replace all dead vegetation, and if specific vegetation has high mortality rates, assess the cause and, if necessary, replace with more appropriate species.
- Remove weeds and other invasive, poisonous, nuisance, or noxious vegetation as needed until the vegetation is established. Weed removal should become less frequent if the appropriate species are used and planting density is attained.
- Remove and properly dispose of trash and other litter.
- Select the proper soil mix and plants for optimal fertility, vegetation establishment, and growth to preclude the use of nutrient and pesticide supplements. Addition of nutrients and pesticides may contribute pollutant loads to receiving waters.
- In areas where heavy metals deposition is likely (e.g., tributary areas to industrial, vehicle dealerships/repair, parking lots, roads), replace mulch, if provided, annually. In areas where metals deposition is less likely (e.g., residential lots), replace or add mulch as needed to maintain a two- to three-inch depth at least once every two years.
- Eliminate standing water to prevent vector breeding. If standing water is observed more than 48 hours after a storm event, it may be necessary to remove and replace the planting media and/or gravel layer to restore functionality of the bioretention facility.
- Inspect, and clean if necessary, the underdrain and observation well/clean-out port. Inspect overflow devices for obstructions or debris, which should be removed immediately. Repair or replace damaged pipes upon discovery.

The Agencies require execution of and compliance with a Maintenance Access Agreement to be recorded by the property owner for the on-going operation and maintenance of any privately-maintained stormwater control measures. An example Maintenance Access Agreement is presented in Appendix G.

Variations for Special Site Conditions

The Phase II Permit (Provision E.12.e.(h)) allows for the bioretention design criteria discussed above to be modified for the following special site conditions, which must be demonstrated by the project applicant:

- Facilities located within 10 feet of structures or other potential geotechnical hazards established by a geotechnical engineer for the project may incorporate an impervious cutoff wall between the bioretention facility and the structure or other geotechnical hazard;
- Facilities with documented high concentrations of pollutants in underlying soil or groundwater, facilities located where infiltration could contribute to a geotechnical

hazard, and facilities located on elevated plazas or other structures may incorporate an impervious liner and may locate the underdrain discharge at the bottom of the subsurface drainage/storage layer (this configuration is commonly known as a “flow-through planter”);

- Facilities located in areas of high groundwater, highly infiltrative soils or where connection of underdrain to a surface drain or to a subsurface storm drain are infeasible, may omit the underdrain; and
- Facilities serving high-risk areas such as fueling stations, truck stops, auto repairs, and heavy industrial sites may be required to provide additional treatment to address pollutants of concern unless these high-risk areas are isolated from stormwater runoff or bioretention areas with little chance of spill migration.

While variations for special site conditions may be allowed, these are not exceptions for implementing bioretention or alternative stormwater treatment control measures at the project site.

Alternative Stormwater Treatment Control Measures

The Phase II Permit (Provision E.12.e.(g)) allows the use of alternative stormwater treatment control measure(s) if the project applicant demonstrates that the proposed measure meets all of the following measures of equivalent effectiveness criteria when compared to the bioretention standards outlined in the Phase II Permit (Provision E.12.e.(f)):

- Equal or greater amount of stormwater runoff infiltrated or evapotranspired;
- Equal or lower pollutant concentrations in stormwater runoff that is discharged after biotreatment;
- Equal or greater protection against shock loadings and spills; and
- Equal or greater accessibility and ease of inspection and maintenance.

While not specifically required in the Phase II Permit, the project applicant should also considered if a proposed alternative stormwater treatment control measure provides equal or lower pollutant loads in stormwater runoff that is discharged after treatment.

Fact sheets for alternative stormwater treatment control measures that may be proposed in the Project Stormwater Plan are included in Appendix F. Infiltration basins, infiltration trenches, and dry wells, which are each designed to infiltrate stormwater runoff, are typically accepted alternatives to bioretention. Other stormwater treatment control measures are may or may not meet the equivalent effectiveness criteria listed above. The project applicant must demonstrate, in the Project Stormwater Plan, how a proposed alternative stormwater treatment control measure meets all of the equivalent effectiveness criteria.

6.3. Exceptions to Requirements for Bioretention Facilities

The Phase II Permit (Provision E.12.e.(i)) allows specific exceptions to implementing bioretention upon demonstration by the project applicant that bioretention or alternative designs equivalent to bioretention are technically infeasible for a project. Under these situations, other types of biotreatment or media filters (e.g., tree-well filters, in-vault media filters, proprietary treatment control measures) may be used. Only Regulated and/or Hydromodification Management Projects that meet the criteria below may receive an exception from the bioretention requirements:

- Projects creating or replacing one acre or less of impervious area, and located in a designated pedestrian-oriented commercial district (i.e., smart growth projects), and having at least 85 percent of the entire project site covered by permanent structures;
- Facilities receiving stormwater runoff solely from existing (pre-project) impervious areas; and
- Historic sites, structures, or landscapes that cannot alter their original configuration in order to maintain their historic integrity.

Meeting an exception listed above does not preclude the project applicant from proposing and implementing an alternative stormwater treatment control measure to manage stormwater. The project applicant must demonstrate that the exception(s) from implementing bioretention for managing stormwater runoff and propose alternative stormwater treatment control measures applicable to the project site.

SECTION 7. HYDROMODIFICATION REQUIREMENTS

Hydromodification is the modification of hydrologic pathways (precipitation, surface runoff, infiltration, groundwater flow, return flow, surface water storage, groundwater storage, evaporation, and transpiration) that results in negative impacts to watershed health and function. The Phase II Permit requires that the project applicant determine if hydromodification requirements apply and if they do apply, what hydromodification control measures will be implemented. Baseline hydromodification requirements apply to both Regulated and Hydromodification Management Projects while full hydromodification requirements apply to only Hydromodification Management Projects. The following sections describe the baseline and full hydromodification requirements.

7.1. Baseline Hydromodification Requirements

The Phase II Permit requires that Regulated and Hydromodification Management Projects implement baseline hydromodification requirements for the design storm event. If the entire SDV/SDF is retained at the project site through site design measures and/or stormwater treatment control measures, the baseline hydromodification requirement is met. If stormwater runoff is discharged to the receiving water, hydromodification control measures (e.g., detention basin) may be required to mitigate the hydromodification impacts on the receiving water from the stormwater runoff and meet the baseline hydromodification requirements. Fact sheets for designing hydromodification control measures are presented in Appendix F (HM-1 Extended Detention Basins and HM-2 Wet Ponds).

7.2. Full Hydromodification Requirements

For Hydromodification Management Projects, which create and/or replace one acre or more of impervious surface, the Phase II Permit (Provision E.12.f) requires that the post-construction stormwater runoff flow rate not exceed the estimated pre-project flow rate for the 2-year, 24-hour design storm event. A project that does not result in a net increase of impervious surface area over the pre-project condition is not considered a Hydromodification Management Project.

Hydrologic routing modeling (e.g., USEPA's Storm Water Management Model [SWMM]) must be conducted to calculate peak stormwater runoff response time and peak project stormwater runoff rate for the entire project site for the pre- and post-construction conditions. The results of the model are then used to design hydromodification control measures (e.g., detention basins, wet ponds) to mitigate and meet the hydromodification design storm event criteria. Fact sheets for hydromodification control measures are included in Appendix F. Stormwater runoff managed by site design measures and stormwater treatment control measures will reduce additional hydromodification control measures that will need to be implemented. Flood control facilities may also be used to help meet the hydromodification requirements.

The Project Stormwater Plan must include the results of the hydromodification routing modeling and demonstrate that the project meets the hydromodification requirements.

SECTION 8. STORMWATER CONTROL MEASURE OPERATION AND MAINTENANCE

Continued effectiveness of stormwater control measures presented in this Manual requires on-going inspection and maintenance. To ensure that such maintenance is provided, the jurisdictional Agency requires the submittal of an Operations and Maintenance Plan and execution of a Maintenance Access Agreement with the owner/operator of stormwater control measure(s). In situations where the stormwater control measure(s) will be publicly-owned or maintained, the Agency will require an easement for access and maintenance of the stormwater control measure(s) or that the stormwater control measure(s) be located in lots dedicated to the Agency in fee title.

The property owner or his/her designee is responsible for complying with the Maintenance Access Agreement until the responsibility is legally transferred. Failure to properly implement the Operations and Maintenance Plan and Maintenance Access Agreement may result in enforcement by the Agency.

This section presents Conditions of Approval that may be applicable to a project, requirements for the Operations and Maintenance Plan and Maintenance Access Agreement, and the Operations and Maintenance Verification Program.

8.1. Conditions of Approval

Projects subject to this Manual will include Conditions of Approval to specify the implementation of stormwater management requirements. Example Conditions of Approval are presented in **Table 8-1**. Submittal of required plans is precedent to issuance of building, grading, or construction permits. Failure by the project applicant to meet these Conditions of Approval will delay the permitting processes.

Table 8-1. Example Stormwater Management Conditions of Approval

Example Condition of Approval	Applicability
Project applicant shall incorporate appropriate site design measure(s) and submit the results of the Post-Construction Runoff Calculator pursuant to the 2015 Post-Construction Stormwater Standards Manual. [Agency] approval of the proposed measures is precedent to issuance of any building, grading, or construction permits.	Applicable to all land developments and permit applications for projects considered Small Projects.
Project applicant shall develop and submit a Project Stormwater Plan that identifies the methods to be employed to reduce or eliminate stormwater pollutant discharges through the construction, operation and maintenance of source control measures, low impact development design, site design measures, stormwater treatment control measures, and hydromodification control measures. Design and sizing requirements shall comply with the 2015 Post-Construction Stormwater Standards Manual. [Agency] approval of the Project Stormwater Plan is precedent to issuance of any building, grading, or construction permits. Two paper copies and an electronic copy of the Project Stormwater Plan shall be provided to the [Agency].	Applicable to all land developments considered Regulated Projects.
Project applicant shall develop a hydromodification management plan to ensure the post-project stormwater runoff flow rate shall not exceed estimated pre-project flow rate for the 2-year, 24-hour storm. The hydromodification management plan shall be incorporated into the Project Stormwater Plan.	Applicable to all land developments considered Hydromodification Management Projects.
Project applicant shall develop and submit an Operations and Maintenance Plan that identifies the operations, maintenance, and inspection requirements of all stormwater treatment and baseline hydromodification control measures identified in the approved Project Stormwater Plan. [Agency] approval of the preliminary Operations and Maintenance Plan is precedent to issuance of any building, grading, or construction permits. Two paper copies and an electronic copy of the Maintenance Plan shall be provided to the [Agency]. [Agency] approval of the final Operations and Maintenance Plan and recordation of the Maintenance Access Agreement is precedent to issuance of the Certificate of Occupancy and release of Performance Bonds. Two paper copies and an electronic copy of the final Operations and Maintenance Plan shall be provided to the [Agency].	Applicable to all land developments considered Regulated Projects and/or Hydromodification Management Projects.

8.2. Operation and Maintenance Plan Requirements

A draft Operations and Maintenance Plan is required as part of the Project Stormwater Plan submittal to the jurisdictional Agency. Upon completion of the project, a final Operations and Maintenance Plan will be incorporated as part of the Maintenance Access Agreement, The Operations and Maintenance Plan must address the following requirements, which are discussed in the following sections:

- Baseline information;

- Final as-built site map and details;
- Operation, inspection, and maintenance requirements and schedule;
- Spill plan;
- Training; and
- Annual Self-Certification Report.

Baseline Information

- List property owners and persons responsible for operation and maintenance of the stormwater control measure(s) including contact information (i.e., phone numbers and addresses).
- Identify the intended method of funding (e.g., Drainage Benefit Assessment Area) of on-going operation and maintenance of the stormwater control measure(s).
- List all installed stormwater control measure(s) including description of each stormwater control measure, date of installation, and design specifications.

Final As-Built Site Map and Details

A preliminary site map must be included in the Operations and Maintenance Plan as part of the Project Stormwater Plan submittal. When available, final as-built site map and details, stamped by a licensed professional engineer or landscape architect, must be included in the final Operations and Maintenance Plan.

- Provide a final as-built site map showing boundaries of the project site, acreage, drainage patterns/contour lines, and DMAs as well as any field modifications to approved designs during construction.
- Include stormwater treatment control measure ponding depth(s) and design infiltration rate(s).
- Show each discharge location from the project site and any drainage flowing onto the project site (i.e., run-on).
- Distinguish between pervious and impervious surfaces on the map.
- Identify the location of each stormwater control measure, private sanitary sewer systems, and grade breaks for purposes of pollution prevention.
- With a legend, identify locations of expected sources of pollution generation (e.g., outdoor work and storage areas, heavy traffic areas, delivery areas, trash enclosures, fueling areas, wash-racks). Identify any areas having contaminated soil or where pollutants are stored or have been stored/disposed of in the past.

Operation, Inspection, and Maintenance Requirements and Schedule

- Identify cleaning activities, including litter removal and disposal, and schedule. Identify any housekeeping procedures that may reduce maintenance requirements.
- Identify vegetation/landscape management methods and schedule. Distinguish between maintenance appropriate for the vegetation establishment period and expected long-term maintenance. These procedures must provide sufficient detail to a person unfamiliar with these maintenance methods to perform the activity or identify the specific skills or knowledge to perform and document the maintenance.
- Identify vector control practices.[7]
- Identify equipment resource requirements necessary to operate and maintain stormwater control measures.
- Identify regulatory approvals (if any) that may be needed for on-going operation and maintenance and address acquisitions of those approvals.
- Create a checklist and schedule, preferably in the form of a table or matrix, for each activity for all facility components and stormwater control measure to be inspected and/or tested.
- Create an inspection and/or maintenance log template to document inspection and/or maintenance activities, including inspector names, dates, and stormwater control measure(s) inspected and maintained. The log should note any significant maintenance requirements due to spills or unexpected discharges.

Spill Plan

- Identify person(s) responsible for monitoring and reporting spills.
- Provide emergency notification procedures (phone and agency/persons to contact).
- As appropriate for site, provide emergency containment and cleanup procedures.
- Note downstream receiving waters, wetlands, or ESAs that may be affected by spills or chronic untreated discharges.
- As appropriate, create emergency sampling procedures for spills. Emergency sampling can protect the property owner from erroneous liability for downstream receiving area cleanups.

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[7] California Department of Public Health. (2012). Best Management Practices for Mosquito Control in California. Retrieved on July 20, 2012 from http://www.westnile.ca.gov/resources.php.

Training

Provide information about training persons responsible for operating and maintaining stormwater control measure(s). This training should include:

- Good housekeeping procedures defined in the Operations and Maintenance Plan;
- Proper maintenance of all devices, including stormwater treatment control measures;
- Identification and cleanup procedures for spills and overflows;
- Large-scale spill or hazardous material response; and
- Safety concerns when maintaining devices and cleaning spills.

Self-Certification Annual Report

The owner/operator of the stormwater control measure(s) must provide to the jurisdictional Agency an annual self-certification that its stormwater control measure(s) is(are) being properly operated and maintained. For public projects, the applicable department is required to provide the annual self-certification. The final Operations and Maintenance Plan must provide details on how the owner/operator will conduct its annual self-certification.

8.3. Maintenance Access Agreement

The Maintenance Access Agreement, which includes the final Operations and Maintenance Plan, is a legally-binding contract requiring the on-going proper operation and maintenance of stormwater control measures after the Certificate of Occupancy is issued. At a minimum, the Phase II Permit (Provision E.12.h.(ii)(a)) requires that Maintenance Access Agreement include the owner's/developer's signed statement accepting responsibility for inspection and maintenance until the responsibility is legally transferred and either:

- A signed statement from the public entity assuming responsibility for stormwater control measure operation, inspection, and maintenance and certifying that it meets all design standards; or
- Written conditions in the sales or lease agreement that require the recipient to assume responsibility for inspection and maintenance activities and to conduct a maintenance inspection at least once a year; or
- Written text in project conditions, covenants, and restrictions for residential properties that assign maintenance responsibilities to the entity (e.g., Community Services District) for inspection and maintenance of stormwater control measures; or
- A legally enforceable agreement that assigns responsibility for operation, inspection, and maintenance of stormwater control measures to the

owner/operator. A Maintenance Access Agreement with jurisdictional Agency must be executed by the owner/operator before occupancy of the project is approved.

During the plan review process, the jurisdictional Agency will also assess whether easements or performance bonds are needed. Easements are required if the Agency will assume all or part of the responsibilities for operations and maintenance (O&M) of stormwater control measures. Proposed easements should identified during the Tentative Map/Parcel Map process, or where a Tentative Map or Parcel Map is not used prior to issuance of a building/grading permit, as securing easements after properties are built and occupied can be time consuming. If used, easements need to be appropriately recorded and shown on the final property plat and property title documents.

The jurisdictional Agency will require performance bonds for construction and during the initial establishment period. For vegetative-based control measures (i.e., bioretention facilities), a bond that is extended one year upon project site stabilization and acceptance by the jurisdictional Agency is required to ensure proper maintenance of the vegetation during the initial establishment period.

8.4. Operation and Maintenance Verification Program

Note: this section applies to only the Agencies. The Phase II Permit (Provision E.12.h.) requires that the Agencies implement an Operations and Maintenance Verification Program for all stormwater treatment and baseline hydromodification control measures. As part of this requirement, the Agencies are required to develop a database or equivalent table of all regulated projects (public and private) that have installed stormwater treatment and baseline hydromodification control measures. The following information must be included in the database or equivalent table:

- Name and address of the regulated project;
- Specific description of the location (or a map showing the location) of the installed stormwater treatment and/or baseline hydromodification control measure(s);
- Date(s) that the stormwater treatment and/or baseline hydromodification control measure(s) (if any) were installed;
- Description of the type and size of the stormwater treatment and/or baseline hydromodification control measure(s) (if any) installed;
- Responsible operator(s) for each stormwater treatment and/or baseline hydromodification control measure(s) (if any) installed;
- Dates and findings of inspections (routine and follow-up) of the stormwater treatment and/or baseline hydromodification control measure(s) (if any) by the Agency; and
- Any problems and/or corrective or enforcement actions taken.

APPENDIX A

Glossary and List of Acronyms

List of Acronyms

ASTM	American Society for Testing and Materials
BMP	Best Management Practice
CCR	California Code of Regulations
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
cfs	Cubic feet per second
CWA	Clean Water Act (Federal Water Pollution Control Act)
DMA	Drainage Management Area
ESA	Environmentally Sensitive Area
HUC	Hydrologic Unit Code
IPM	Integrated Pest Management
LID	Low Impact Development
LUFT	Leaking Underground Fuel Tank
LUP	Linear Underground/Overhead Utility Projects
MEP	Maximum extent practicable
MS4	Municipal Separate Storm Sewer System
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Unit
PAH	Polycyclic aromatic hydrocarbons
SDF	Stormwater Design Flow
SDV	Stormwater Design Volume
SLIC	Spills, Leaks, Investigations, and Cleanups
STA	Seal of Testing Assurance
SWMM	Stormwater Management Model
TMDL	Total maximum daily load
TSS	Total suspended solids
USCC	United States Composting Council
USEPA	United States Environmental Protection Agency
USC	United States Code
USC	Water Efficient Landscaping Ordinance

Glossary

Agency – This refers to any of the following municipalities: City of Lathrop; City of Lodi; City of Manteca; City of Patterson; City of Tracy; County of San Joaquin.

Beneficial Uses – The uses (e.g., domestic, municipal, agricultural, and industrial supply, power generation, recreation, aesthetic enjoyment, navigation and preservation of fish and wildlife, other aquatic resources or preserves) of waters of the state protected against degradation.

Berm – Earthen mound used to direct the flow of stormwater runoff around or through a structure.

Best Management Practices (BMPs) – Methods, measures, or practices designed and selected to reduce or eliminate the discharge of pollutants to surface waters from point and nonpoint source discharges including stormwater runoff. BMPs include structural and non-structure controls and operations and maintenance procedures that can be applied before, during, and/or after pollution producing activities.

Catch Basin – A catch basin, which is also known as a storm drain inlet, is an inlet to the storm drain system that typically includes a grate or curb inlet where stormwater runoff enters the catch basin and a sump to capture sediment, debris, and associated pollutants. Catch basins act as pretreatment for other treatment practices by capturing large sediments. The performance of catch basins at removing sediment and other pollutants depends on the design of the catch basin (e.g., the size of the sump), and routine maintenance to retain the storage available in the sump to capture sediment.

Clean Water Act – This is the Federal Water Pollution Control Act of 1972, as amended, Title 33 of the United States Code (USC) 1251, et. seq., which has been incorporated by reference in Chapter 5.5 of the California Water Code.

Commercial Development – Any development on private land that is not heavy industrial or residential. This category includes, but is not limited to, hospitals, laboratories and other medical facilities, educational institutions, recreational facilities, plant nurseries, car wash facilities, mini-malls, business complexes, shopping malls, hotels, office buildings, public warehouses, and light industrial complexes.

Common Plan or Development or Sale – United States Environmental Protection Agency (USEPA) regulations include the term “common plan of development or sale” to ensure that acreage within a common project does not artificially escape the permit requirements because construction activities are phased, split among smaller parcels, or completed by different owners/developers. In the absence of an exact definition of “common plan of development or sale,” the State Water Board is required to exercise its regulatory discretion in providing a common sense interpretation of the term as it applies to construction projects and permit coverage. The common plan of development is generally a contiguous area where multiple, distinct construction activities may be taking place at different times under one plan. A plan is generally defined as any piece of documentation or physical demarcation that indicates that construction activities may occur on a common plot. Such documentation could consist of a tract map, parcel map, demolition plans, grading plans, or contract documents. Any of these documents could delineate the boundaries of a common plan area. However, broad planning documents, such as land use master plans, conceptual master plans, or broad-based CEQA or NEPA documents that identify potential projects for an agency or facility are not considered common plans of development. An overbroad interpretation of the term would render meaningless the clear “one acre” federal permitting threshold and would potentially trigger permitting of almost any construction activity that occurs within an area that had previously received area-wide utility or road improvements.

Conduit – Any channel or pipe directing the flow of water.

Construction Site – Any project, including projects requiring coverage under the General Construction Permit, that involves soil disturbing activities, including, but not limited to, clearing, grading, paving, disturbances to ground such as stockpiling, and excavation.

Culvert – A covered channel or a large diameter pipe that crosses under a road, sidewalk, etc.

Deemed Complete – The Agency approves the completed application and vesting tentative map; or 2) the Agency neither approves nor requests additional information on a project application within 30 days of the submittal by the project applicant.

Detached Single Family Home Project – The building of one single new house or the addition and/or replacement of impervious surface associated with one single existing house, which is not part of a larger plan of development.

Detention – The temporary storage of stormwater runoff to allow treatment by sedimentation and metered discharge of stormwater runoff at reduced peak flow rates. The capture and subsequent release of stormwater runoff form the site at a slower rate than it is collected with the difference being held in temporary storage.

Development – Any construction, rehabilitation, redevelopment, or reconstruction of any public or private residential project (e.g., single-family, multi-family, planned unit of development); industrial, commercial, retail, and other non-residential project projects, including public agency projects; or mass grading for future construction.

Direct Discharge – A discharge that is routed directly to waters of the United States by means of a pipe, channel, or ditch, including a municipal separate storm sewer system, or through surface runoff.

Discharge of a Pollutant – The addition of any pollutant or combination of pollutants to waters of the United States from any point source, or any addition of any pollutant or combination of pollutants to waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft which is being used as a means of transportation. The term includes additions of pollutants to waters of the United States from: surface runoff which is collected or channeled by man; discharges through pipes, sewers, or other conveyances owned by a State, municipality, or other person which do not lead to a treatment works; and discharges through pipes, sewers, or other conveyances, leading into privately-owned treatment works.

Discharger – Any responsible party or site owner or operator within the Agency's jurisdiction whose site discharges stormwater runoff or a non-stormwater discharge.

Disturbed Area – Area that is altered as a result of clearing, grading, and/or excavation.

Dry Weather – This refers to the season where prolonged dry periods occur. In California's Mediterranean climate, this usually corresponds to the period between May and September.

Erosion – The physical detachment of soil due to wind or water. Often the detached fine soil fraction becomes a pollutant transported by stormwater runoff. Erosion occurs naturally, but can be accelerated by land disturbance and grading activities such as farming, development, road building, and timber harvesting.

Erosion Control Measures – Measures used to minimize soil detachment. These may include:

- Vegetation, either undisturbed or planted (e.g., grasses, wildflowers); and
- Other materials, such as
    - Straw (applied over bare soil, crimped into soil);
    - Protective erosion control blankets;
    - Fiber (applied as mulch or hydromulch); and
    - Mulch (avoid plastics if possible).

Excavation – The process of removing earth, stone, or other materials, usually by digging.

Final Stabilization – All soil disturbing activities at each individual parcel within the site that have been completed in a manner consistent with the requirements of the State Water Resources Control Board *General Permit for Storm Water Discharges Associated with Construction and Land Disturbance Activities* (Order No. 2012-0006-DWQ).

Flood Management Facilities – Facilities or structures designed for the explicit purpose of controlling flood waters safely in or around populated areas (e.g., dams, levees, bypass areas). Flood management facilities do not include traditional stormwater conveyance structures (e.g., stormwater sewerage, pump stations, catch basins).

Grading – The cutting and/or filling of the land surface to a desired slope or elevation.

Hydromodification – Modification of hydrologic pathways (i.e., precipitation, surface runoff, infiltration, groundwater flows, return flow, surface-water storage, groundwater storage, evaporation, transpiration) that results in negative impacts to watershed health and functions.

Hydrologic Unit Code (HUC) 12 Watershed – The HUC is the "address" of the watershed. The HUC is a numeric code of the United States Geological Survey (USGS) watershed classification system used to identify the watersheds, or drainage basins, at various scales. The HUC organizes watersheds by a nested size hierarchy, so large watershed boundaries for an entire region may be assigned a two-digit HUC, while small scale, local watershed boundaries (within the larger regional watershed) may be assigned a 12-digit HUC. A HUC-12 watershed averages 22 square miles in size.

Illicit Discharge – Any discharge to a storm drain system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illicit discharge includes all non-stormwater discharges not composed entirely of stormwater and discharges that are identified under the Discharge Prohibitions section of the 2013 MS4 Permit. The term illicit discharge does not include discharges that are regulated by a National Pollutant Discharge Elimination System (NPDES) permit (other than the NPDES permit for discharge from a municipal separate storm sewer system).

Impaired Waterbody – A waterbody (e.g., stream reaches, lakes, waterbody segments) with chronic or recurring monitored violations of the applicable numeric and/or narrative water quality criteria. An impaired water is a water that has been listed on the State of California 303(d) list or has not yet been listed, but otherwise meets the criteria for listing. A water is a portion of a surface water of the state, including ocean, estuary, lake, river, creek, or wetland. The water currently may not be meeting state water quality standards or may be determined to be threatened and have the potential to not meet standards in the future. The State of California's 303(d) list can be found at http://www.swrcb.ca.gov/quality.html.

Impervious Surface – A surface covering or pavement of a developed parcel of land that prevents the land's natural ability to absorb and infiltrate rainfall/stormwater. Impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots, roads, storage areas, impervious concrete and asphalt, and any other continuous watertight pavement or covering. Landscaped soil and pervious pavement, including pavers with pervious openings and seams, underlain with pervious soil or pervious storage material, such as a gravel layer sufficient to hold a specific volume of stormwater runoff are not impervious surfaces.

Industrial Development – Development or redevelopment of property to be used for industrial purposes, such as factories, manufacturing buildings, and research and development parks.

Infill Site – A site in an urbanized area where the immediate adjacent parcels are developed with one or more qualified urban uses or at least 75 percent of the perimeter of the site adjoins parcels that have previously been developed for qualified urban uses and no parcel within the site has been created within the past 10 years.

Infiltration – The downward entry of water into the surface of the soil.

Integrated Pest Management (IPM) – An ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism.

Linear Underground/Overhead Utility Projects (LUPs) – Include, but are not limited to, any conveyance, pipe, or pipeline for the transportation of any gaseous, liquid (including water and wastewater for domestic municipal services), liquiescent, or slurry substances; any cable line or wire for the transmission of electrical energy; any cable line or wire for communications (e.g., telephone, telegraph, radio, or television messages); and associated ancillary facilities. Construction activities associated with LUPs include, but are not limited to: (a) those activities necessary for the installation of underground and overhead linear facilities (e.g., conduits, substructures, pipelines, towers, poles, cables, wires, connectors, switching regulating and transforming equipment, and associated ancillary facilities); and include, but are not limited to, (b) underground utility mark-out, potholing, concrete and asphalt cutting and removal, trenching, excavation, boring and drilling, access road and pole/tower pad and cable/wire pull station, substation construction, substructure installation, construction of tower footings and/or foundations, pole and tower installations, pipeline installation, welding, concrete and/or pavement repair or replacement, and stockpile/borrow locations.

Low Impact Development (LID) – A sustainable practice that benefits water supply and contributes to water quality protection. Unlike traditional stormwater management, which collects and conveys stormwater runoff through storm drains, pipes, or other conveyances to a centralized stormwater facility, LID takes a different approach by using site design and stormwater management to maintain the site's pre-development stormwater runoff rates and volumes. The goal of LID is to mimic the sites' pre-development hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain stormwater runoff close to the source of rainfall.

Maximum Extent Practicable (MEP) – The minimum required performance standard for implementation of the municipal stormwater management programs to reduce pollutants in stormwater. Clean Water Act §402(p)(3)(B)(iii) requires that municipal permits "shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and such other provisions as the [United States Environmental Protection Agency] Administrator or the State determines appropriate for the control of such pollutants". MEP is the cumulative effect of implementing, evaluating, and making corresponding changes to a variety of technically appropriate and economically feasible BMPs, ensuring that the most appropriate controls are implemented in the most effective manner. This process of implementing, evaluating, revising, and adding new BMPs is commonly referred to as the iterative process.

Mixed-Use Development – Development or redevelopment of property to be used for two or more different uses, all intended to be harmonious and complementary. An example is a high-rise building with retail shops on the first 2 floors, office space on floors 3 through 10, apartments on the next 10 floors, and restaurant on the top floor.

Municipal Separate Storm Sewer System (MS4) – The regulatory definition of an MS4 (Title 40 of the Code of Federal Regulations [40 CFR] Part 122.26(b)(8)) is "a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains): (i) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body (created to or pursuant of state law) including special districts under state law such as a sewer district, flood control district or drainage discharge, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act that discharges into waters of the United States; (ii) designed or used for collecting or conveying stormwater; (iii) which is not a combined sewer; and (iv) which is not part of a Publicly-Owned Treatment Works (POTW) as defined at 40 CFR Part 122.2".

In practical terms, operators of MS4s can include municipalities and local sewer districts, state and federal departments of transportation, public universities, public hospitals, military bases, and correctional facilities.

National Pollutant Discharge Elimination System (NPDES) – The federal program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.

New Development – New development means land disturbing activities; structural development, including construction or installation of a building or structure, creation of impervious surfaces; and land subdivision on an area that has not been previously developed.

Nonpoint Source Pollution – Pollution that does not come from a point source. Nonpoint source pollution originates from diffuse sources that are mostly related to land use.

Non-Stormwater Discharge – A discharge that does not originate from precipitation events. They can include, but are not limited to, discharges of process water, air conditioner condensate, non-contact cooling water, vehicle wash water, sanitary wastes, concrete washout water, paint wash water, irrigation water, or pipe testing water.

Outfall – A point source as defined by 40 CFR Part 122.2 at the point where an MS4 discharges to the waters of the United States and does not include open conveyances connecting two MS4s, or pipes, tunnels, or other conveyances which connect segments of the same stream or other waters of the United States and are used to convey waters of the United States.

Parking Lot – Land area or facility for the parking or storage of motor vehicles used for business, commerce, industry, or personal use.

Pavement Replacement (also known as reconstruction) – Process of removing existing pavement down to the subbase and replacing it with new base course and new pavement.

Pavement Resurfacing (also known as overlay, asphalt overlay, pavement overlay) – Process of installing a new layer of pavement over existing pavement.

Pervious Pavement – Pavement that stores and infiltrates rainfall at a rate that exceeds conventional pavement.

Point Source – Any discernible, confined, and discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operations, landfill leachate collection systems, vessel, or other floating craft, from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural stormwater runoff.

Pollutant – Dredged spoils, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials (except those regulated under the Atomic Energy Act of 1954, as amended [42 USC 2011 et. seq.]), heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.

Pollutants of Concern – Pollutants of concern found in urban runoff include sediments, non-sediment solids, nutrients, pathogens, oxygen-demanding substances, petroleum hydrocarbons, heavy metals, floatables, polycyclic aromatic hydrocarbons (PAHs), trash, and pesticides and herbicides.

Pollution – An alteration of the quality of the waters of the state by waste to a degree which unreasonably affects the beneficial uses of the water or facilities which serve those beneficial uses.

Precipitation – Any form of rain or snow.

Project Acceptance – Completion of all construction discretionary permitting to finalize project.

Publicly-Owned Treatment Works (POTW) – A treatment works defined by Section 212 of the Clean Water Act (33 USC 1292).

Redevelopment – Land-disturbing activity that results in the creation, addition, or replacement of exterior impervious surface area on a site on which some past development has occurred. Redevelopment does not include trenching, excavation and resurfacing associated with LUPs; pavement grinding and resurfacing of existing roadways; construction of new sidewalks, pedestrian ramps, or bike lanes on existing roadways; or routine replacement of damaged pavement such as pothole repair or replacement of short, non-contiguous sections of roadway.

Regulated Project – Refers to projects subject to the new development and redevelopment standards in Section E.12 of the 2013 MS4 Permit.

Residential Housing Subdivision – Any property development of multiple single-family homes or of dwelling units intended for multiple families/households (e.g., apartments, condominiums, town homes).

Retention – The storage of stormwater runoff to prevent it from leaving the development site.

Riparian Areas – Plant communities contiguous to and affected by surface and subsurface hydrologic features of perennial or intermittent waterbodies. Riparian areas have one or both of the following characteristics: (1) distinctively different vegetative species than adjacent areas; and (2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between wetland and upland.

Routine Maintenance and Repair Projects – Projects that maintain the original line and grade, hydraulic capacity, and original purpose of the facility.

Run-on – Discharges that originate off-site and flow onto the property of a separate project site.

Rural Area – Encompasses all population, housing, and territory not included within an urban area.

Sediment – Solid particulate matter, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment Control Measures – Measures used to trap and/or retain detached soil before discharging to receiving waters. These may include:

- Fiber rolls (e.g., keyed-in straw wattles, compost rolls);
- Silt fences;
- Retention basins; and
- Active treatment systems.

Sedimentation – The process of depositing soil particles, clays, sands, or other sediments that were picked up by stormwater runoff.

Smart Growth Projects – Projects that produce multiple-benefits such as economic, social, and environmental benefits. Smart growth projects commonly include high-density development projects that result in a reduction of stormwater runoff volume per capita as a result of reduced impervious surface.

Sheet Flow – Flow of water that occurs overland in areas, where there are no defined channels, such that water spreads out over a large area at a uniform depth.

Soil Amendment – Any material that is added to the soil to change its chemical properties, engineering properties, or erosion resistance that could become mobilized by stormwater runoff.

Source Control – Land use or site planning practices, or structural or non-structural measures, that aim to prevent runoff pollution by reducing the potential for contact with stormwater runoff at the source of pollution. Source control measures minimize the contact between pollutants and urban runoff.

Surface Drainage – Any above-ground runoff (e.g., sheet, shallow concentrated, open channel) that flows into the storm drain system.

Storm Drain – Above- and below-ground structures for transporting stormwater runoff.

Storm Drain System – The basic infrastructure in an MS4 that collects and conveys stormwater runoff to a treatment facility or receiving water.

Stormwater – Stormwater runoff, snowmelt runoff, surface runoff, and drainage, excluding infiltration and irrigation tailwater. Urban runoff and snowmelt runoff consisting only of those discharges, which originate from precipitation events. Stormwater is that portion of precipitation that flows across a surface to the storm drain system or receiving water.

Stormwater Runoff – Stormwater runoff is generated when precipitation from rain and snowmelt events flows over land or impervious surfaces and does not percolate into the ground. As stormwater runoff flows over land or impervious surfaces, it accumulates debris, chemicals, sediment, or other pollutants that could adversely affect water quality if the stormwater runoff is discharged untreated.

Stormwater Treatment System – Any engineered system designed to remove pollutants from stormwater runoff by settling, filtration, biological degradation, plant uptake, media absorption/adsorption, or other physical, biological, or chemical process. This includes landscape-based systems such as vegetated swales and bioretention facilities as well as proprietary stormwater treatment measures.

Structural Controls – Any structural facility designed and constructed to mitigate the adverse impacts of stormwater and urban runoff pollution.

Time of Concentration – The time it takes the most hydraulically-remote drop of water to travel through a watershed to a specific point of interest.

Total Maximum Daily Loads (TMDLs) – The maximum amount of a pollutant that can be discharge into a waterbody from all sources (point and nonpoint) and still maintain water quality standards. Under Section 303(d) of the Clean Water Act, TMDLs must be developed for all waterbodies that do not meet water quality standards even after the application of technology-based controls, more stringent effluent limitations required by a state or local authority, and other pollution control requirements, such as BMPs.

Total Suspended Solids (TSS) – The measure of the suspended solids in a water sample includes inorganic substances (e.g., soil particles) and organic substances (e.g., algae, aquatic plant/animal waste, particles related to industrial/sewage waste). The TSS test measures the concentration of suspended solids in water by measuring the dry weight of a solid material contained in a known volume of a sub-sample of a collected water sample. Results are reported in milligrams per liter.

Trash and Debris – Trash consists of litter and particles of litter. Section 68055.1(g) of the California Code of Regulations (CCR) defines litter as all improperly discarded waste material, including, but not limited to, convenience foods, beverage, and other product packages or containers constructed of steel, aluminum, glass, paper, plastic, and other natural and synthetic materials, thrown or deposited on the lands and waters of the state, but not including the properly discarded waste of the primary processing of agriculture, mining, logging, sawmilling, or manufacturing.

Treatment – Any method, technique, or process designed to remove pollutants and/or solids from polluted stormwater runoff, wastewater, or effluent.

Turbidity – The “cloudiness” of water quantified by the degree to which light traveling through a water column is scatted by the suspended organic and inorganic particles it contains. Results are typically reported in Nephelometric Turbidity Units (NTU).

Urbanized Area – A densely settled core of census tracts and/or census blocks that have a population of at least 50,000, along with adjacent territory containing non-residential urban land uses as well as territory with low population density included to link outlying densely settled territory with the densely settled core. It is a calculation used by the Bureau of the Census to determine the geographic boundaries of the most heavily developed and dense urban areas. Data utilized in the 2013 MS4 Permit was derived from the 2010 United States Census Data. Source: Phase II final rule (Revised June 2012), http://www.epa.gov/npdes/pubs/fact2-2.pdf.

Waste – Includes sewage and any and all other waste substances liquid, solid, gaseous, or radioactive, associated with human habitation, or of human or animal origin, or from any producing, manufacturing, or processing operation, including waste placed within containers of whatever nature, prior to, and for the purposes of, disposal.

Waste Load Allocation – The portion of the receiving water’s TMDL that is allocated to one of its existing or future point sources of pollution. Waste load allocations constitute a type of water quality-based effluent limitation.

Water Efficient Landscape Ordinance (WELO) – The Model Water Efficient Landscape Ordinance (Title 23, Division 2, Chapter 2.7 of the CCR) took effect January 1, 2010 and is designed to: (1) promote the values and benefits of landscapes while recognizing the need to invest water and other resources as efficiently as possible; (2) establish a structure for planning, designing, installing, maintaining and managing water efficient landscapes in new construction and rehabilitated projects; (3) establish provisions for water management practices and water waste prevention for existing landscapes; (4) use water efficiently without waste by setting a Maximum Applied Water Allowance as an upper limit for water use and reduce water use to the lowest practical amount; (5) promote the benefits of consistent landscape ordinances in neighboring local and regional agencies; (6) encourage local agencies and water purveyors to use economic incentives that promote the efficient use of water, such as implementing a tiered-rate structure; and (7) encourage local agencies to designate the necessary authority that implements and enforces provisions of the Model Water Efficient Landscape Ordinance or its local landscape ordinance.

Water Quality Objectives – The limits or levels of water quality elements or biological characteristics established to reasonably protect the beneficial uses of water or to prevent pollution problems within a specific area. Water quality objectives may be numeric or narrative.

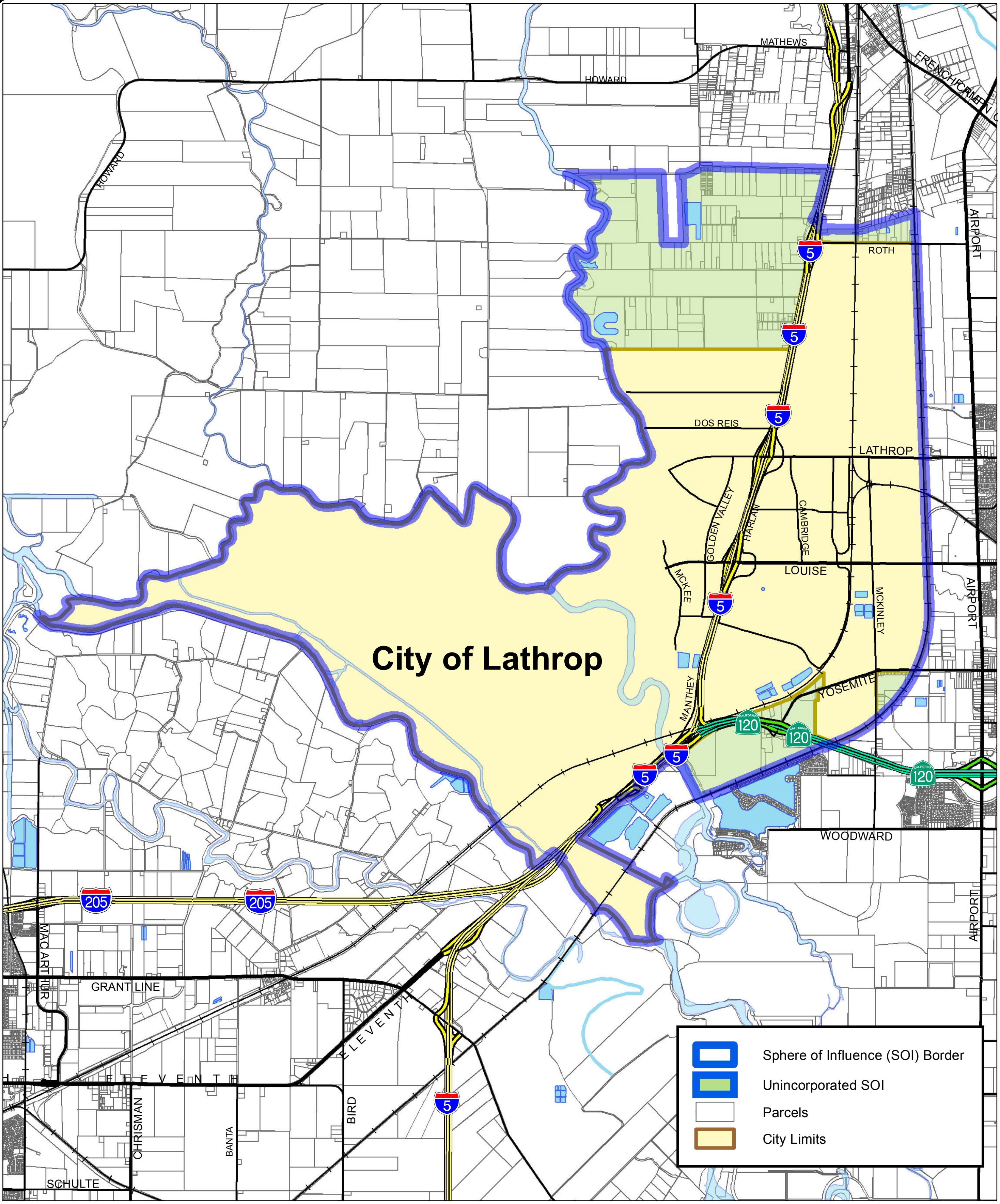
Water Quality Standards – State-adopted and USEPA-approved water quality standards for waterbodies. The standards prescribe the use of the waterbody and establish the water quality criteria that must be met to protect designated uses. Water quality standards also include the federal and state antidegradation policy.

Waters of the United States – This generally refers to surface waters, as defined by the USEPA in 40 CFR Part 122.2.

Watershed Processes – Functions that are provided by watersheds, including, but not limited to, groundwater recharge, sediment supply and delivery, streamflow, and aquatic habitat.

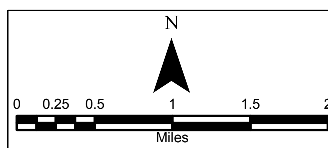
APPENDIX B

Jurisdictional Boundary Maps

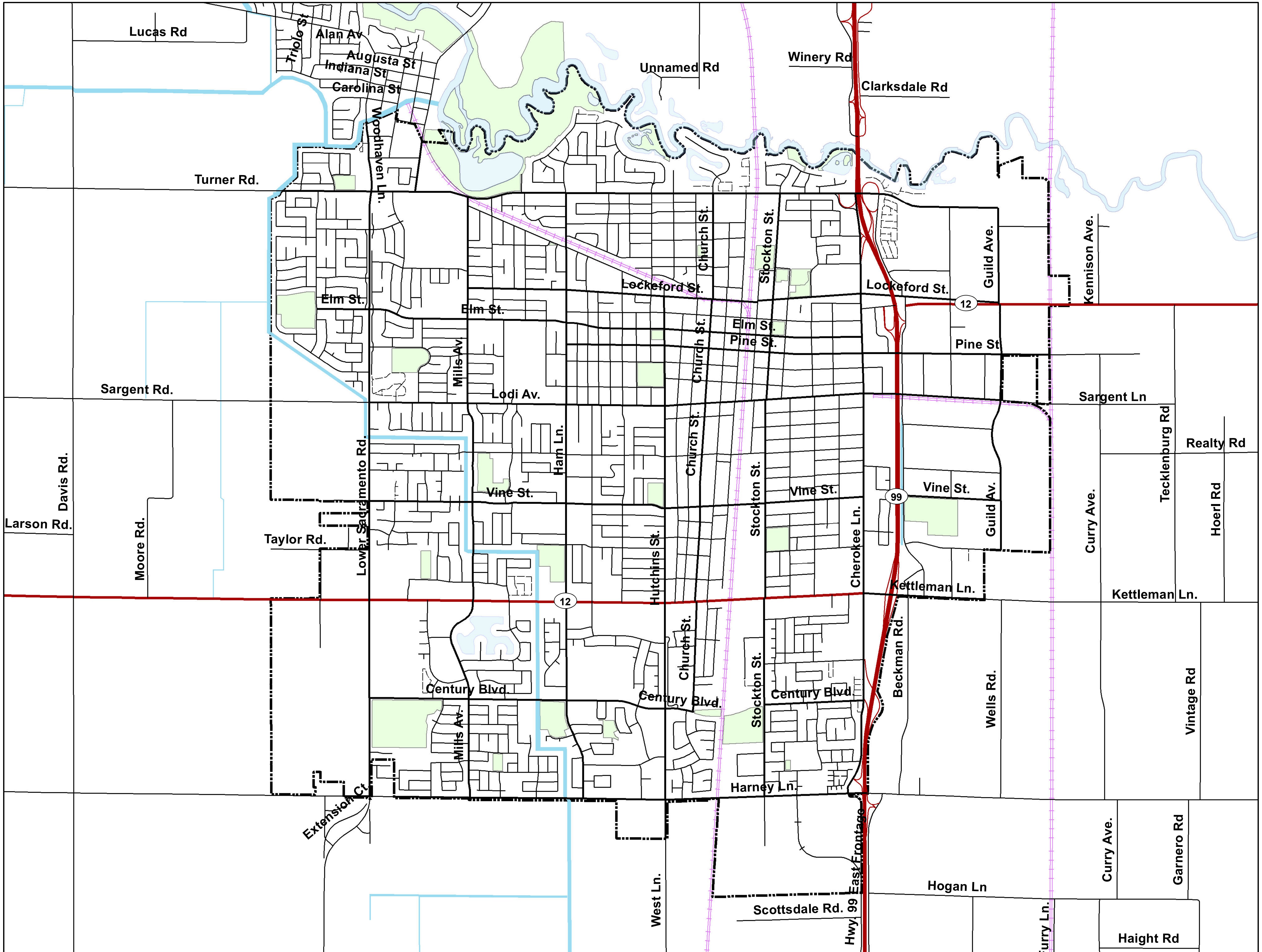


LATHROP SPHERE OF INFLUENCE

San Joaquin County Geographic Information Systems
1810 East Hazelton Avenue, Stockton, CA 95205



September 5, 2012 - GIS-rmt



City of Lodi Phase II MS4 Storm Water Permit Boundary

Legend

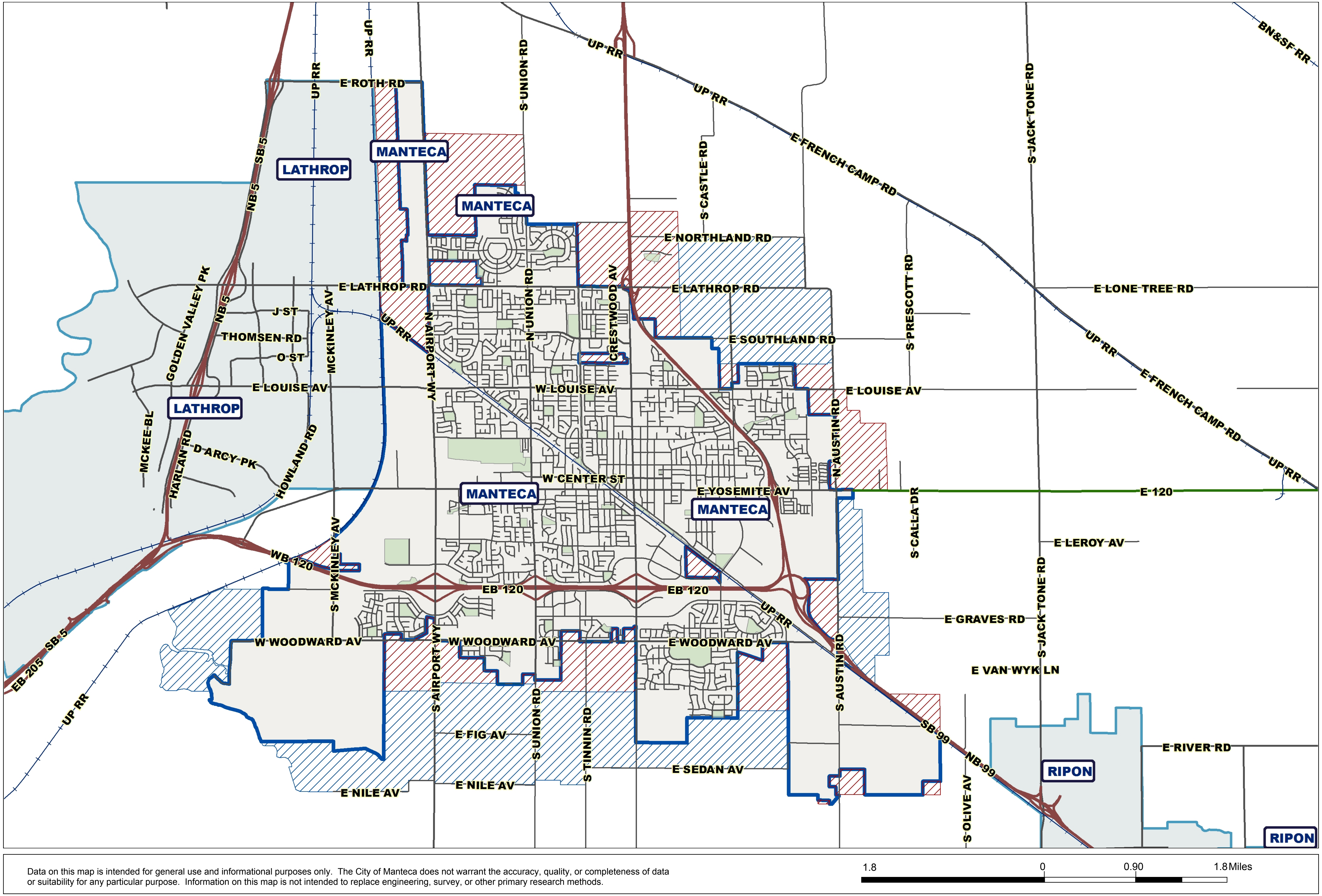
- Parks
- Woodbridge Irrigation District Canal
- Mokelumne River
- Lodi City Limits
- Railroad
- Interstate
- Highway
- HighwayRamps
- Major
- Minor
- County
- Private

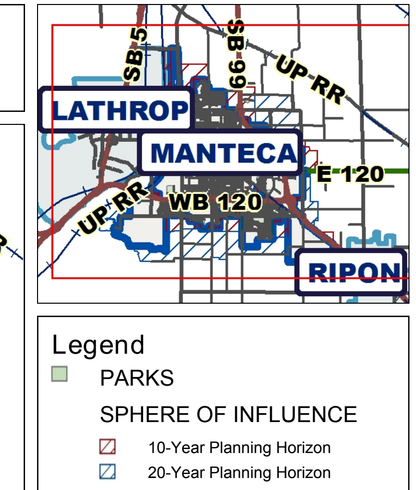
N W E S

1 inch = 2,500 feet

Path: K:\DESIGN\Projects\GIS\SD_Permit_Boundary.mxd

CITY OF MANTECA

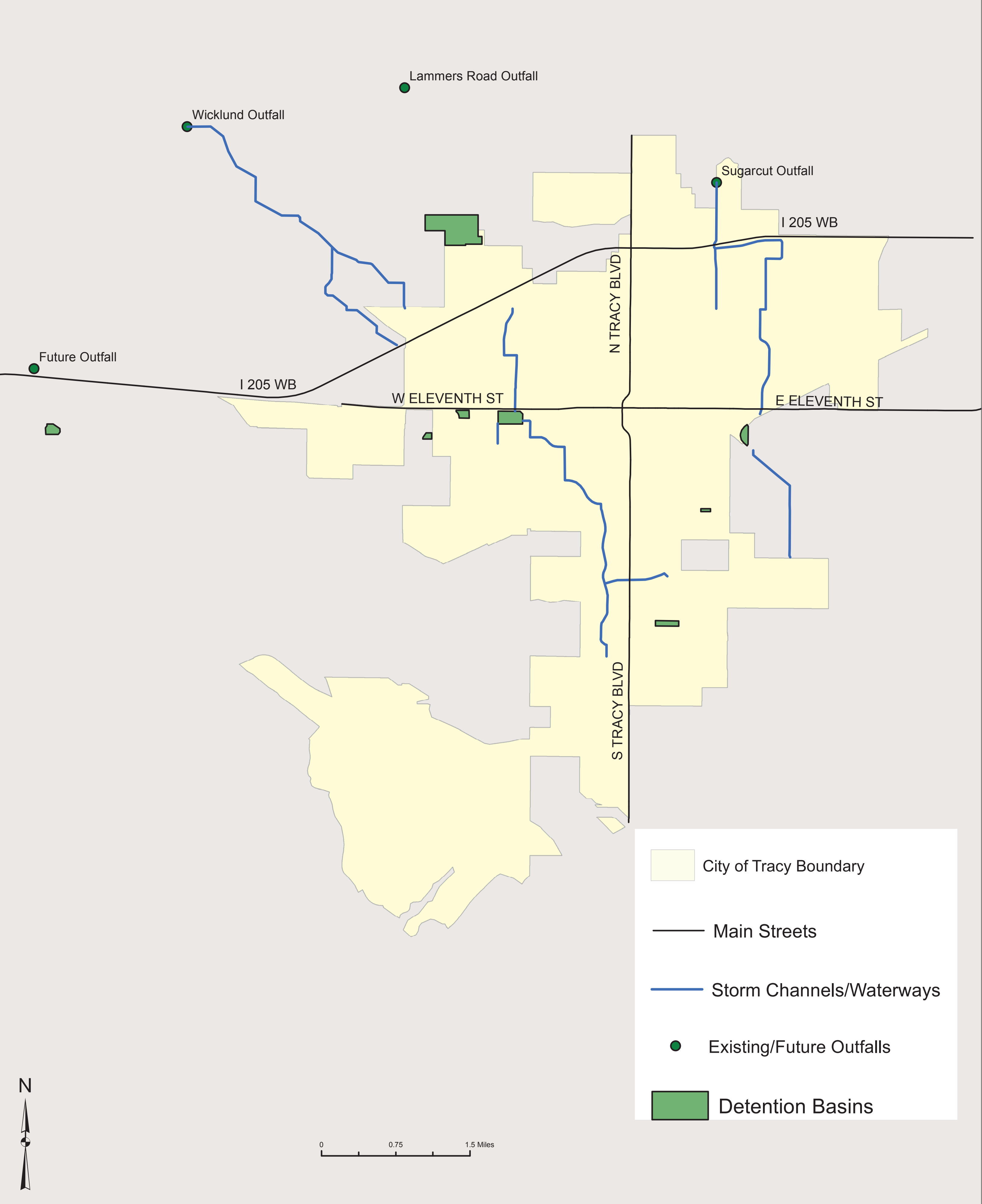


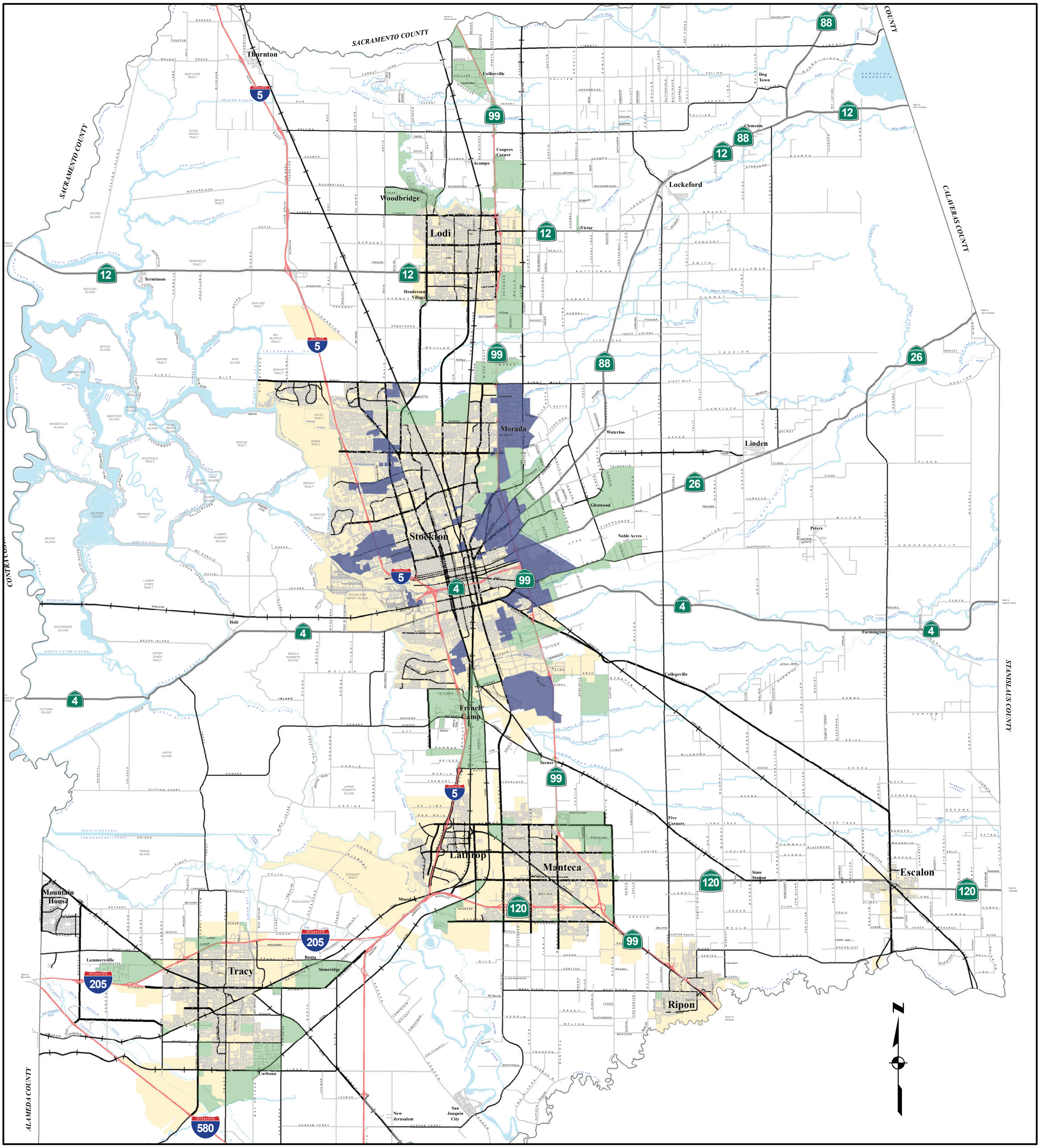


Data on this map is intended for general use and informational purposes only. The City of Manteca does not warrant the accuracy, quality, or completeness of data or suitability for any particular purpose. Information on this map is not intended to replace engineering, survey, or other primary research methods.

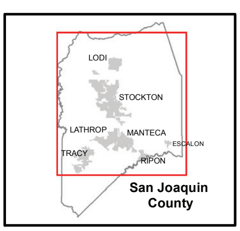
LEMON AVE
EUCALYPTUS AVE
OLIVE AVE
ELM AVE
WALNUT AVE
E LAS PALMAS AVE
SYCAMORE AVE
ORANGE AVE
HIGHWAY 33
ZACHARIAS ROAD
ROGERS ROAD
BALDWIN ROAD
WARD AVE
DEL PUERTO CANYON ROAD
Villages of Patterson
Master Development Plan
Walnut Grove School
West Patterson
Business Park
Creekside Middle School
Apricot Valley Elementary
Villa Del Lago
SPERRY AVE
Master
Development
Plan
Lake
BARTCH AVE
ELFERS ROAD
W MARSHALL ROAD
City of Patterson
General Plan
Legend
City Limits
Sphere of Influence
Agriculture Transition Areas
Estate Residential
Low Density Residential
Medium Density Residential
High Density Residential
Downtown Residential
Highway Service Commercial
Downtown Core
General Commercial
Mixed Use
Medical Professional
Light Industrial
Heavy Industrial
Public/Quasi-Public
Parks/Open Space
Lake
0 0.25 0.5 1 Miles
N
W E
S
General Plan Adopted Nov. 2010

City of Tracy MS4 Permit Boundary Map





Phase 1 Area	Phase 2 Area	City Limits	1 " = 25,620.9 '



San Joaquin County NPDES Phase 2 Stormwater Program

(Phase 2 areas shown are based upon 2010 Census Urban and Rural Classification and Urban Area Criteria)

SAN JOAQUIN COUNTY

Department of Public Works, 1810 E. Hazelton Ave., Stockton, CA 95205

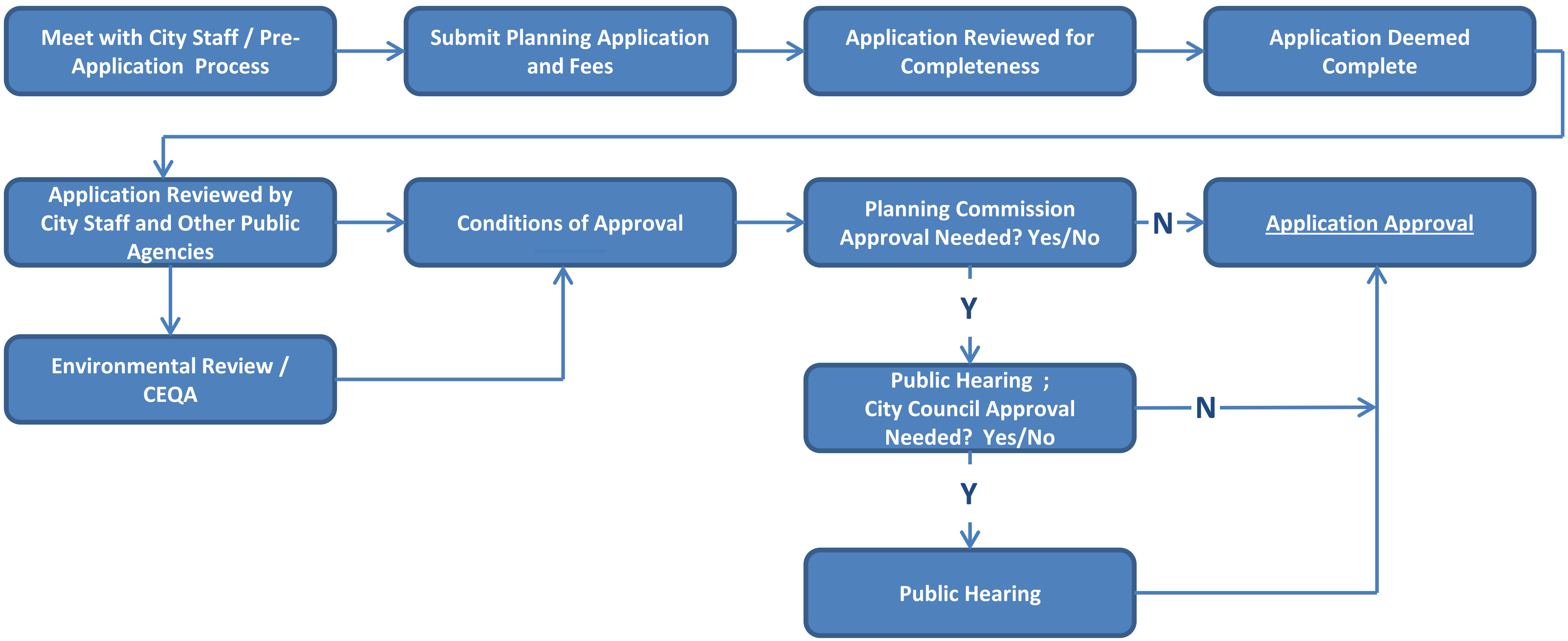
Gerardo Dominguez

Source: 2010 Census Data

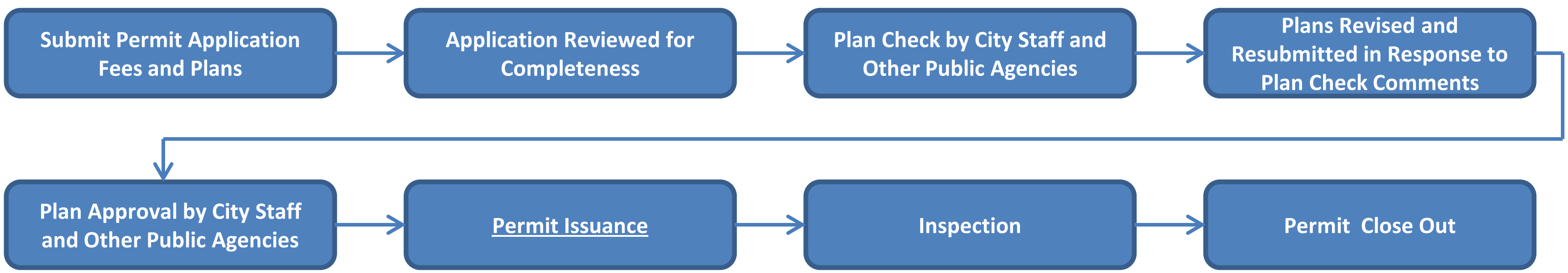
APPENDIX C

Project Stormwater Plan Review Processes

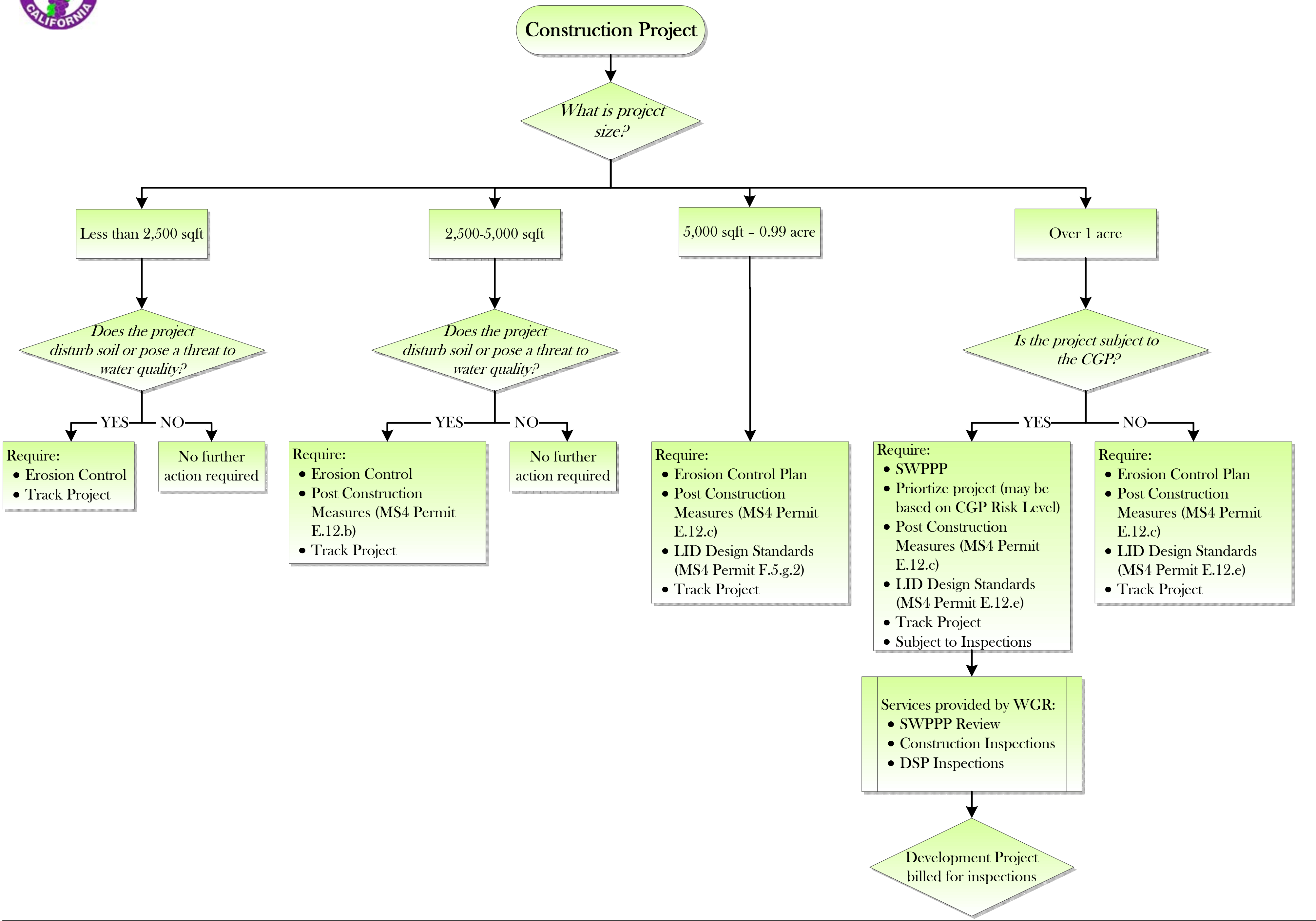
City of Lathrop Discretionary Approval Process



City of Lathrop Building Permit Approval Process

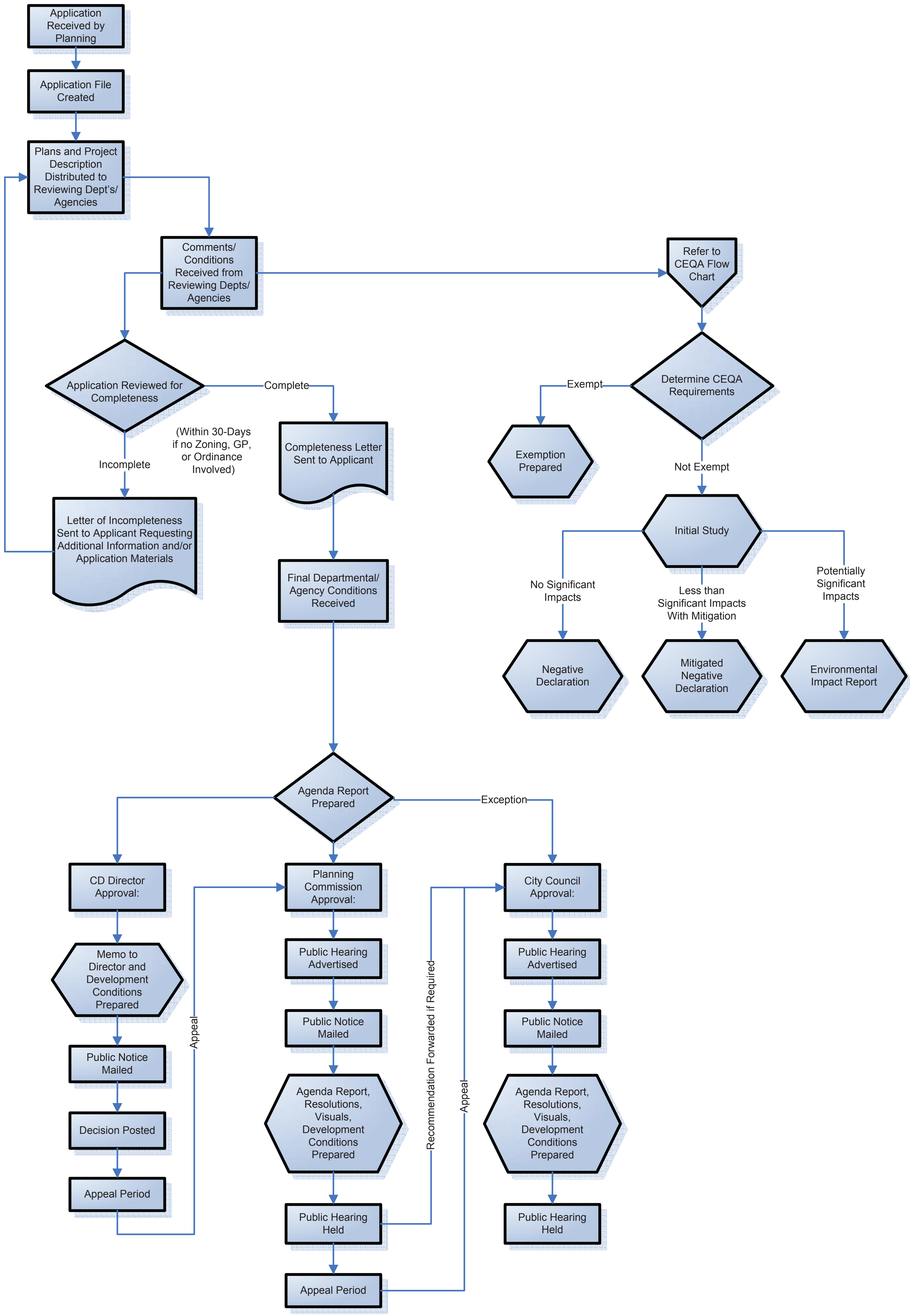


Construction Project Storm Water Compliance

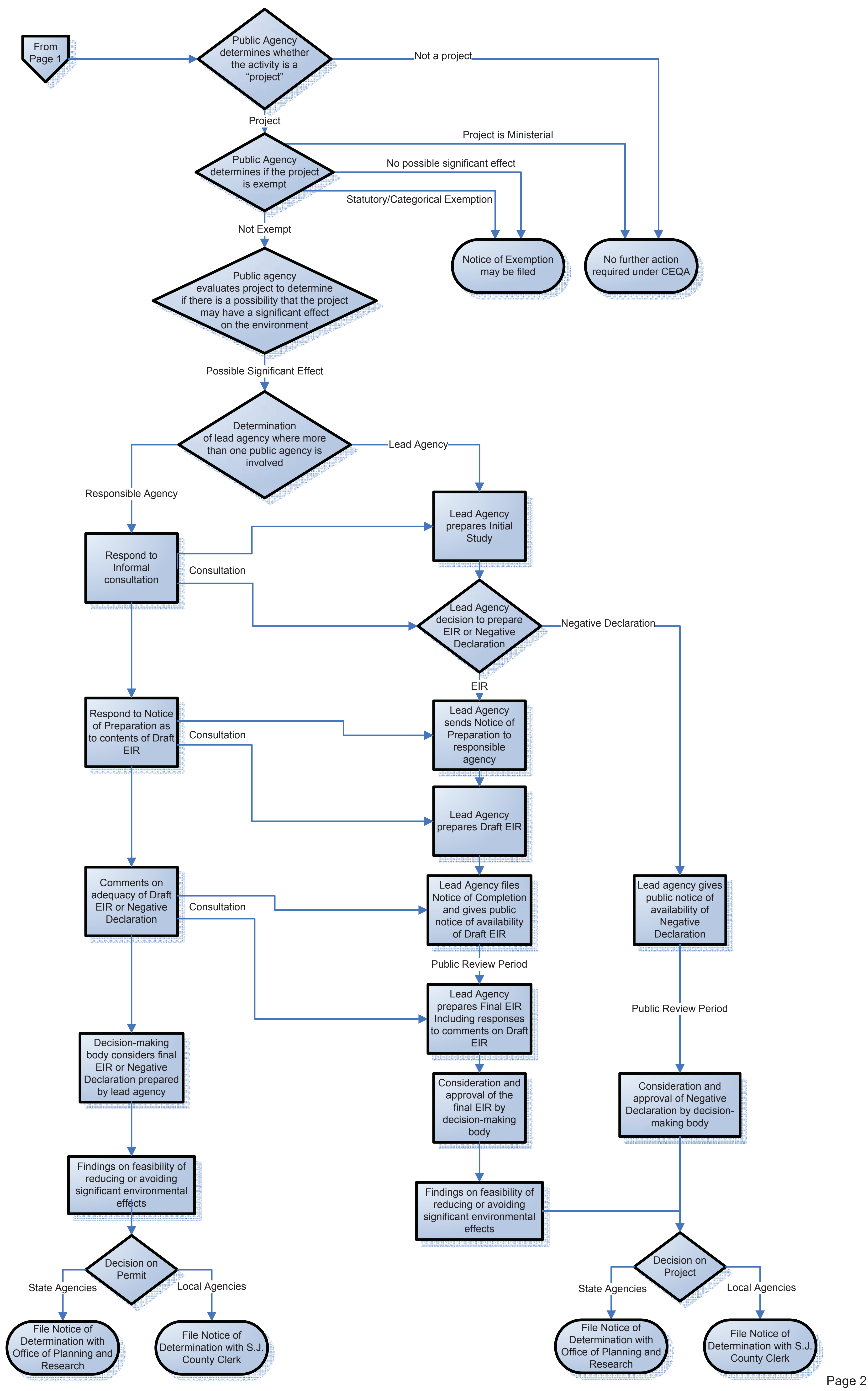


City of Manteca
Development Review Process Flow Chart

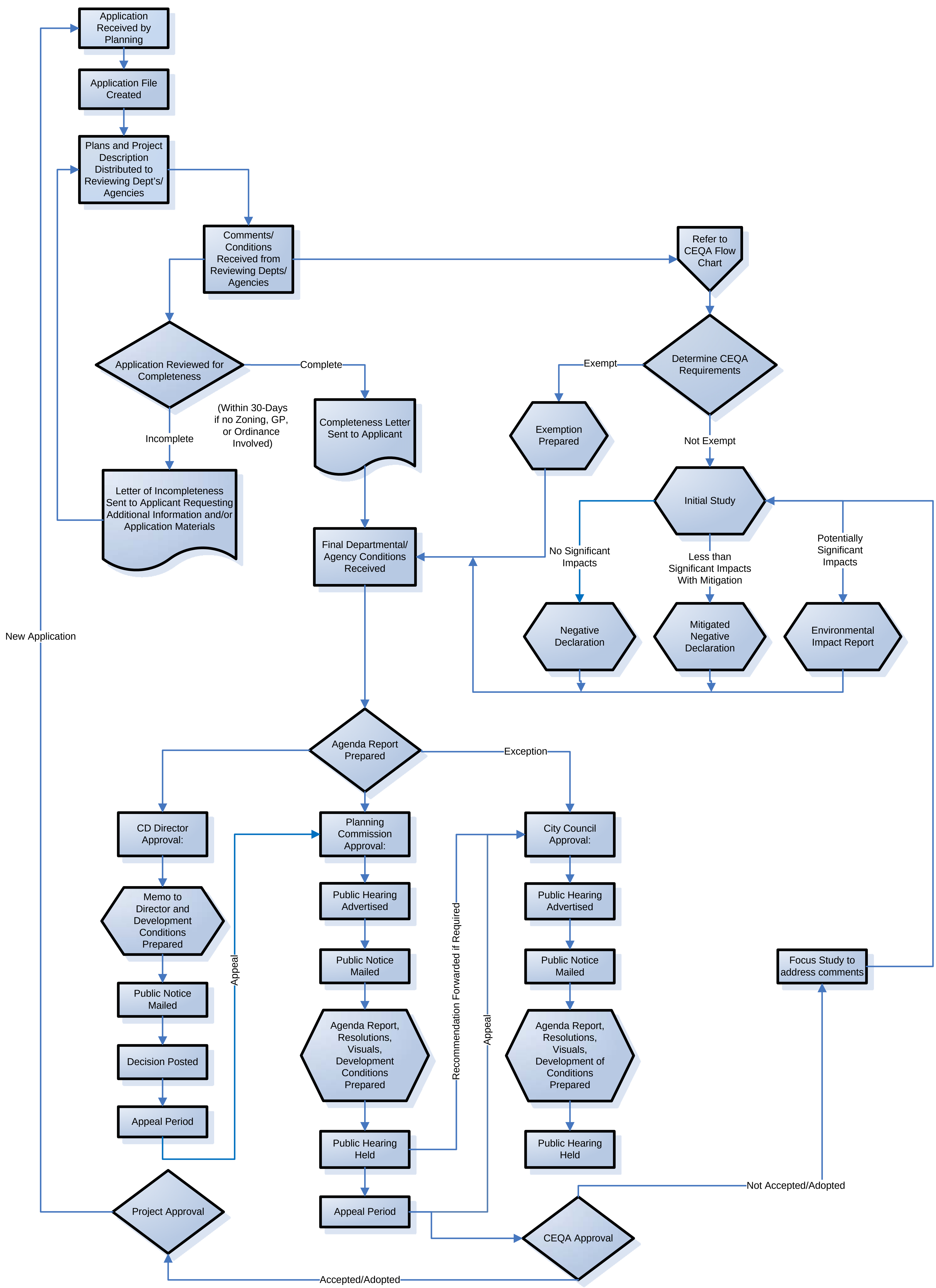
Thursday, January 8, 2009



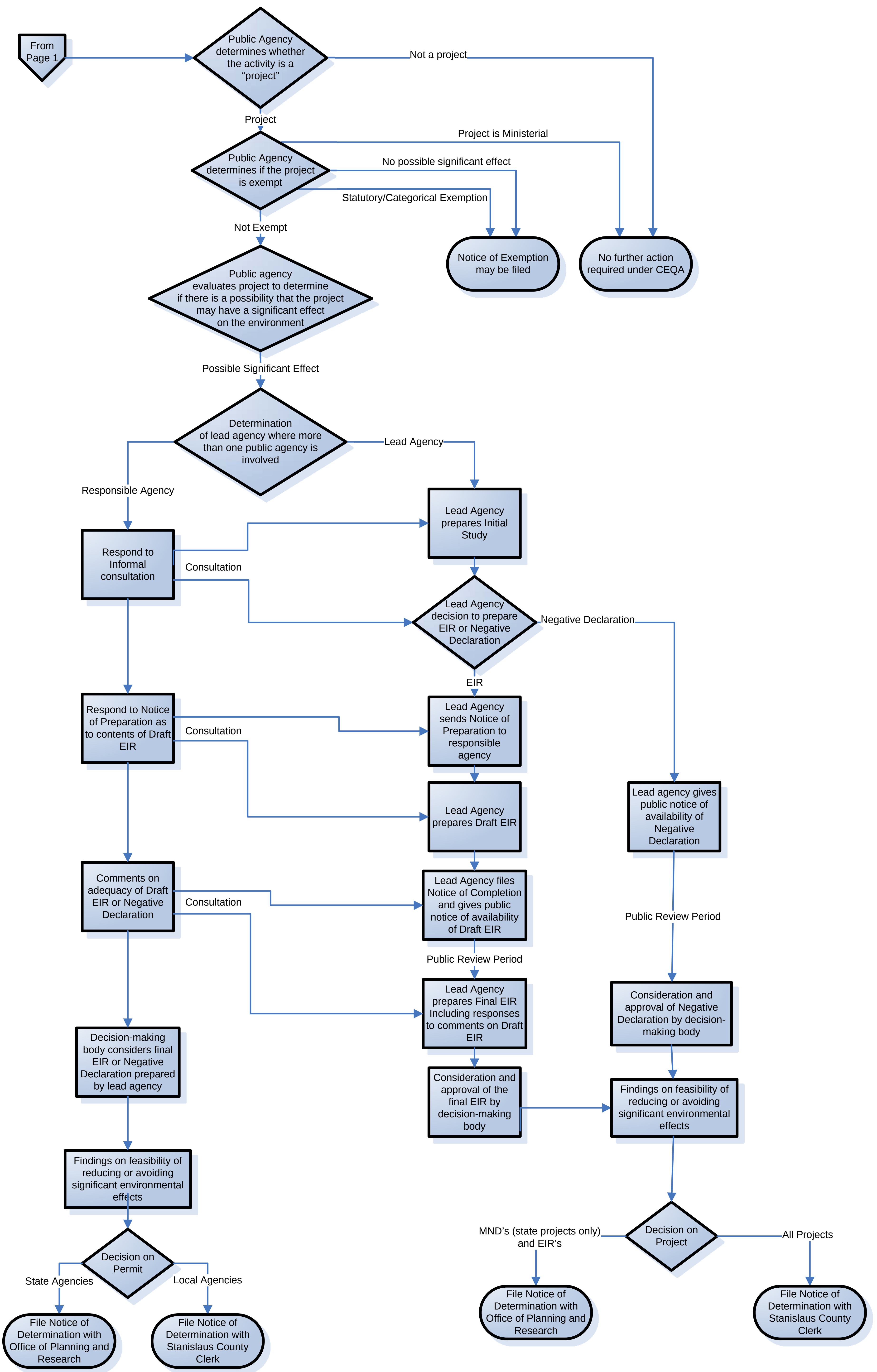
CEQA Process Flow Chart



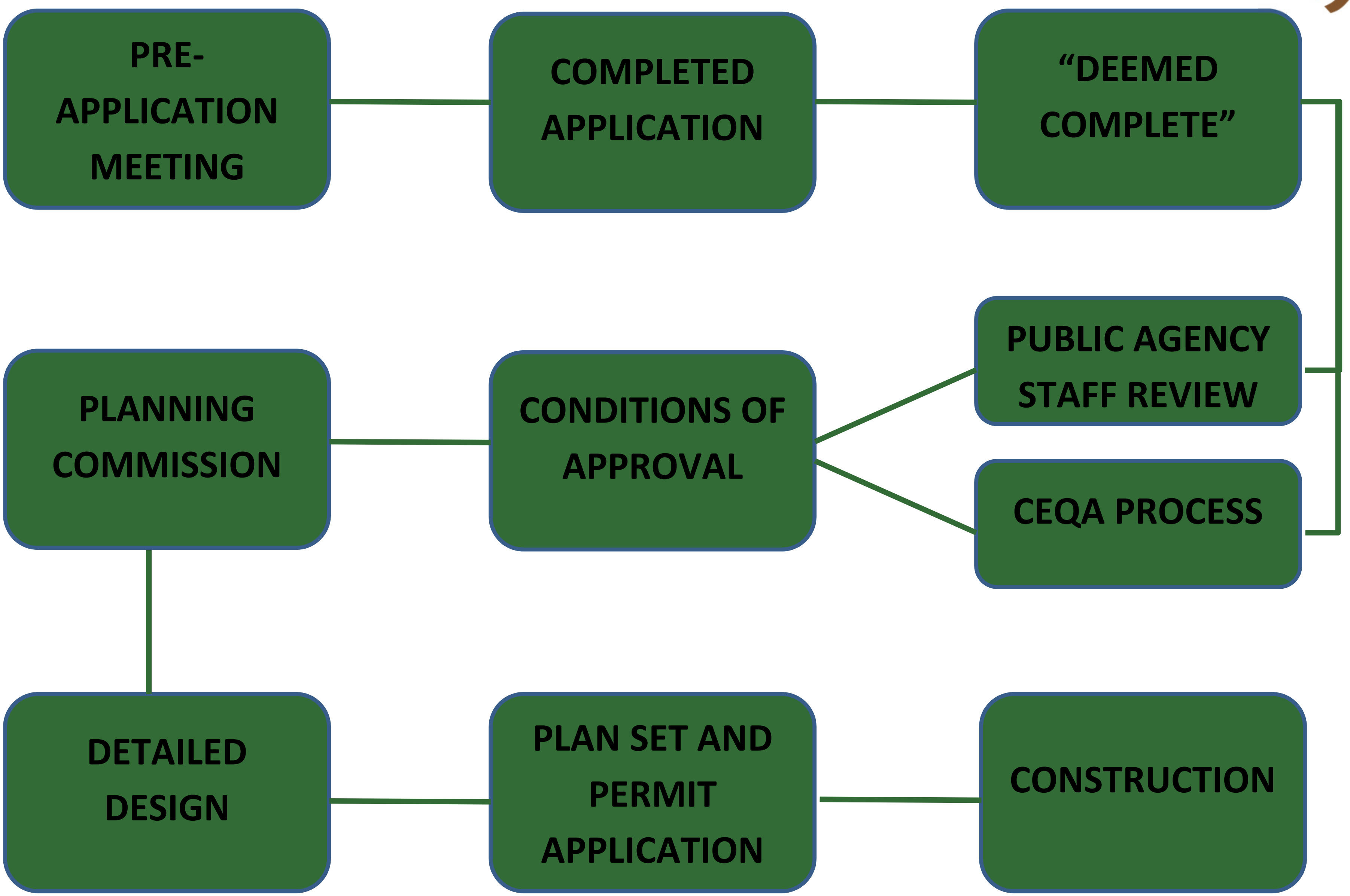
City of Patterson
Development Review Process Flow Chart



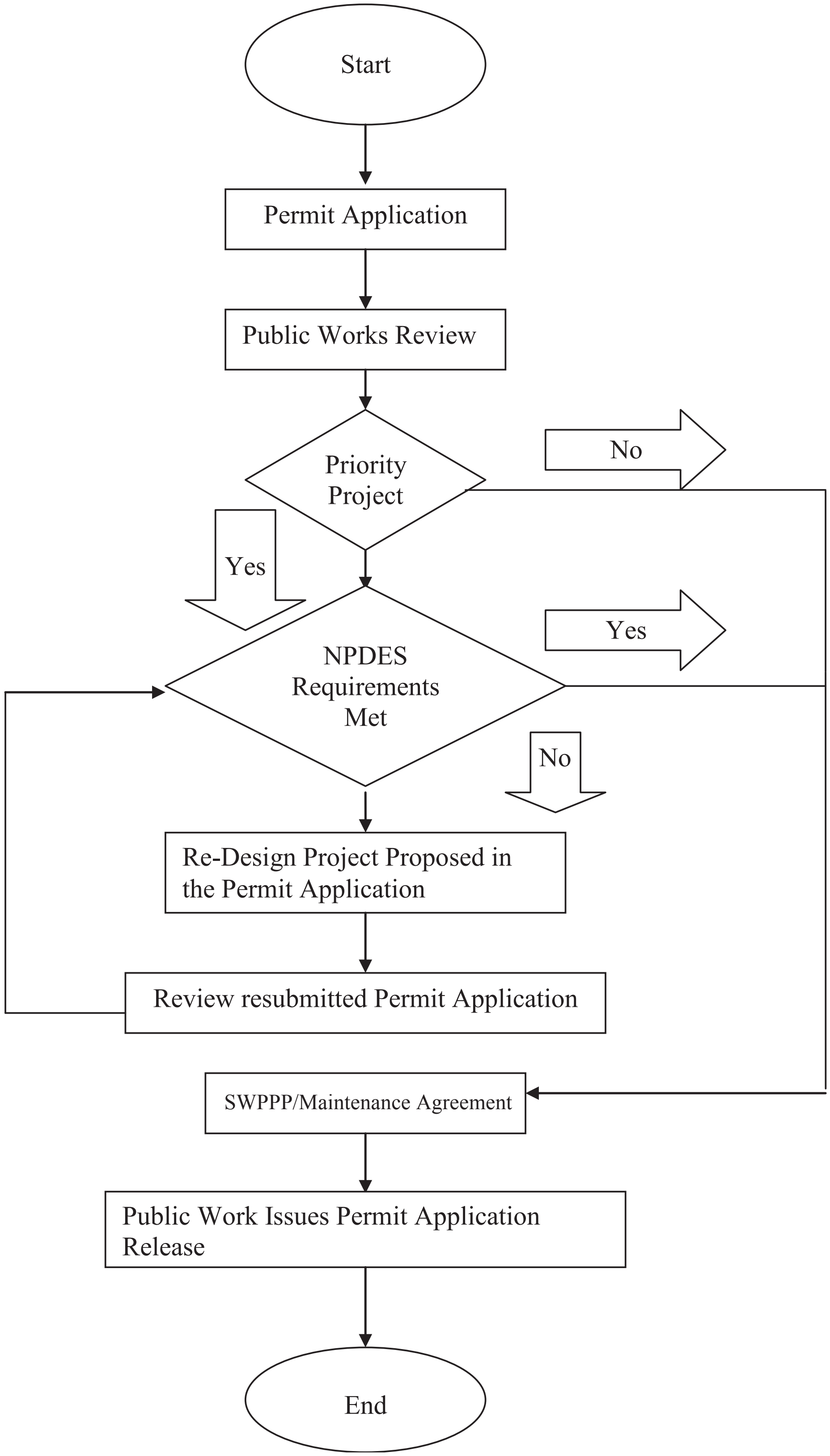
CEQA Process Flow Chart



City of Tracy
Development Review Process



San Joaquin County Development Review Process



APPENDIX D

Project Stormwater Plan Worksheets

Project Stormwater Plan

for

Project Name

Section 1: Basic Project Information

This worksheet must be filled out for all projects required to implement the *2015 Post-Construction Stormwater Standards Manual*. A licensed professional engineer or landscape architect is not required for the development of the project plan for Small Projects.

Project Site Address	
Owner Information	
Name	
Title, if applicable	
Company or Affiliation	
Address	
Telephone Number	
Email Address	
Professional Engineer/Landscape Architect Information (not required for Small Projects)	
Name	
Title	
Company or Affiliation	
Address	
Telephone Number	
Email Address	
Professional Engineer/ Landscape Architect Stamp and Signature	

Type of Project

Is the proposed project:

- ◻ A linear underground/overhead utility project (LUP) that creates and/or replaces at least 2,500, but less than 5,000 square feet of impervious surface?
- ◻ A detached single-family home that is not part of a common plan of development?
- ◻ A routine maintenance or repair project that maintains the original line and grade, hydraulic capacity, and original purpose of the facility?
  - ◻ Exterior wall surface replacement
  - ◻ Pavement resurfacing within an existing footprint
  - ◻ Replacement of damaged pavement (e.g., pothole repair, short-non-contiguous sections of roadway)
  - ◻ Re-roofing regardless of whether it is a full roof replacement or an overlay
- ◻ Interior remodels that do not modify the existing footprint?
- ◻ Excavation, trenching, and resurfacing associated with LUPs?
- ◻ Pavement grinding and resurfacing of existing roadways and parking lots?
- ◻ Construction of new sidewalks, pedestrian ramps, or bicycle lanes on existing roadways?
- ◻ Construction of sidewalks and bicycle lanes built as part of new streets or roads that are graded to runoff to adjacent vegetated areas?
- ◻ Construction of impervious trails that are graded to runoff to adjacent vegetated areas or other non-erodible areas?
- ◻ Construction of sidewalks, bicycle lanes, and trails with permeable surfaces?

The above projects are exempt from the requirements of the *2015 Post-Construction Stormwater Standards Manual*. See Section 1.5 of the *2015 Post-Construction Stormwater Standards Manual* for details on project exceptions. Submit Section 1 of the Project Stormwater Plan as part of the application submittal.

If the proposed project is not exempt as identified above, identify the type of project:

- □ Small Project – These are projects that create and/or replace at least 2,500, but less than 5,000 square feet of impervious surface; or detached single-family homes that create and/or replace a minimum of 2,500 square feet of impervious surface and are not part of a larger plan of development.
- □ Regulated Project – These are projects that create and/or replace greater than or equal to 5,000 square feet of impervious surface and LUPs that create 5,000 square feet or more of newly constructed contiguous impervious surfaces.
  - □ New development
  - □ Redevelopment that increases the impervious surface area by 50 percent or more of the existing development
  - □ Redevelopment that increases the impervious surface area by less than 50 percent of the existing development
- □ Hydromodification Management Projects – These are projects that create and/or replace one acre or more of impervious surface and result in a net increase of impervious surface

Description of the Project

Provide a description of the proposed project.

____

____

____

____

Owner Certification and Signature

The undersigned owner of the subject property is responsible for the implementation of the provisions of this Project Stormwater Plan consistent with the requirements of the 2015 Post-Construction Stormwater Standards Manual, [City of ___________] [County of San Joaquin] [insert Ordinance citation], and Provision E.12 of the California State Water Resources Control Board Phase II Permit (Order No. 2013-0001-DWQ). If the undersigned transfers its interest in the property, its successors-in-interest shall bear the aforementioned responsibility to implement the Project Stormwater Plan. A copy of the final signed and fully approved Project Stormwater Plan shall be available on the subject site throughout the course of the development.

Owner Signature ____

Date ____________________

Section 2: Small Projects

This worksheet is applicable to only Small Projects.

Small Projects are required to implement at least one site design measure and calculate the change in the pre-project and post-project stormwater runoff using the State Water Resources Control Board's Post-Construction Calculator, which is available at: http://www.swrcb.ca.gov/water_issues/programs/stormwater/phase_ii_municipal.shtml. More information is available in Sections 3.5 and 5.4 of the *2015 Post-Construction Stormwater Standards Manual*.

For the proposed project, identify the following information:

Pre-Project Stormwater Runoff Volume (ft^3) __________________

Post-Project Stormwater Runoff Volume without credits(ft^3) __________________

Proposed Site Design Measure	Stormwater Runoff Volume Credit (ft^3)
□ Stream setbacks and buffers	
□ Soil quality improvement and maintenance	
□ Tree planting and preservation	
□ Rooftop and impervious area disconnection	
□ Porous pavement	
□ Vegetated swales	
□ Rain barrels/cisterns	
Total Stormwater Runoff Volume Credit (ft^3)	

The project applicant must include a printout of the Post-Construction Calculator results as part of the Project Stormwater Plan.

Section 3: Regulated and Hydromodification Management Projects

The following worksheets are applicable to Regulated and Hydromodification Management Projects.

Site Assessment Worksheet

Regulated and Hydromodification Management Projects are required to assess conditions at the project site. This information is used to plan the project site layout and identify potential sources of pollutants of concern. Complete the Site Assessment Worksheet as part of the Project Stormwater Plan submittal. More information is available in Sections 3.1 and 3.3 of the *2015 Post-Construction Stormwater Standards Manual*.

Site Planning Worksheet

Regulated and Hydromodification Management Projects are required to consider, and implement if feasible, site planning principles to maximize the effectiveness of stormwater management for the project site. Complete the Site Planning Worksheet as part of the Project Stormwater Plan submittal. More information is available in Section 3.4 of the *2015 Post-Construction Stormwater Standards Manual*.

Source Control Measures

Regulated and Hydromodification Management Projects are required to implement source control measures to prevent pollutants from contacting stormwater runoff or prevent discharge of contaminated stormwater runoff from the project site. All proposed projects that include landscape irrigation must implement the source control measure for landscape irrigation described in Section 4 of the *2015 Post-Construction Stormwater Standards Manual*. Complete a Source Control Measures Worksheet as part of the Project Stormwater Plan submittal.

Drainage Management Area Worksheet

Regulated and Hydromodification Projects are required to delineate discrete drainage management areas for a project site and manage stormwater runoff according to those drainage management areas (DMA). Complete the Drainage Management Area Worksheet for <u>each</u> DMA at the project site. More information is available in Section 3.2 of the *2015 Post-Construction Stormwater Standards Manual*.

Site Design Measures

Regulated and Hydromodification Management Projects are required to implement site design measures to the extent technically feasible and calculate the stormwater runoff volume credit using the State Water Resources Control Board's Post-Construction Calculator for <u>each</u> DMA. The Post-Construction Calculator is available at: http://www.swrcb.ca.gov/water_issues/programs/stormwater/phase_ii_municipal.shtml. More information is available in Sections 3.5 and 5.4 of the *2015 Post-Construction Stormwater Standards Manual*. Complete a Site Design Measure Worksheet for <u>each</u> DMA as part of the Project Stormwater Plan submittal.

Stormwater Treatment and Baseline Hydromodification Control Measures

Regulated and Hydromodification Management Projects are required to implement stormwater treatment control measures to manage the portion of the stormwater runoff not mitigated by site design measures. Bioretention is the preferred stormwater treatment control measure unless (1) it is determined to be infeasible and an alternative treatment control measure that is equivalent to bioretention is proposed and justified, or (2) a specific exception applies. More information is available in Sections 5 and 6 of the *2015 Post-Construction Stormwater Standards Manual*. Complete a Stormwater Treatment Control Measure Worksheet for each DMA where proposed site design measures do not manage the fully manage stormwater runoff of the DMA and submit as part of the Project Stormwater Plan.

Other Requirements of the Project Stormwater Plan

In addition to completing the applicable worksheets, Regulated and Hydromodification Management Projects must also include the following information:

- Site Conditions Report, prepared by or under the supervision of a competent, licensed professional, that addresses and discusses relevant findings of the geotechnical evaluation. Geotechnical evaluations must be conducted in accordance with local standards, including, but not limited to, approved investigation, evaluation, and testing methodologies.
- Site Layout Plan that, at a minimum, illustrates:
    - Existing natural hydrologic features (e.g., depressions, watercourses, wetlands, riparian corridors, undisturbed areas) and significant natural resources);
    - Proposed locations and footprints of improvements creating new, or replaced impervious surfaces;
    - Existing and proposed site drainage system and connections to off-site drainage;
    - Proposed locations and footprints stormwater control measures (e.g., site design measures, source control measures, stormwater treatment control measures) implemented to manage stormwater runoff;
    - All DMAs with unique identifiers; and
    - Maintenance areas of the project site.
- Operations and Maintenance Plan

Site Assessment Worksheet

General Project Site Information

Latitude ______ Longitude ______ Elevation ______

Total Project Area (A_T) (ft^2) ______

Total Existing Impervious Area (ft^2) ______ Total Post-Project Impervious Area (ft^2) ______

Receiving Water(s) ______

Describe location(s) of discharge from the project site.

______

______

Describe Environmentally Sensitive Areas, if applicable.

______

______

Pollutants of Concern

Post-Project Land Use Type(s) ______

Describe expected pollutant-generating activities.

Pre-project ______

______

Post-project ______

______

Identify pollutants of concern.

______

______

Site Planning Worksheet

Describe how the following site planning principles were considered and implemented in developing and optimizing the site layout for the project.

Define the development envelope and protected areas, identifying areas that are most suitable for development and areas to be left undisturbed.

____

____

Concentrate development on portions of the site with less permeable soils and preserve areas that can promote infiltration.

____

____

Limit overall impervious coverage of the site with paving and roofs.

____

____

Set back development from creeks, wetlands, and riparian habitats.

____

____

Preserve significant trees.

____

____

Conform the site layout along natural landforms.

____

____

Avoid excessive grading and disturbance of vegetation and soils.

____

____

Replicate the site’s natural drainage patterns.

____

____

Detain and retain stormwater runoff throughout the site.

____

____

Source Control Measures Worksheet

Describe source control measures to be implemented for each potential pollutant generating activity or source present at the project site. If a potential pollutant generating activity or source is not present at the project site, indicate it as “N/A”.

Parking/storage areas and maintenance

____

____

Landscape/outdoor pesticide use

____

____

Building and grounds maintenance

____

____

Refuse areas

____

____

Outdoor storage of equipment or materials

____

____

Vehicle and equipment cleaning

____

____

Vehicle and equipment repair and maintenance

____

____

Fuel dispensing areas

____

____

Pools, spas, ponds, decorative fountains, and other water features

____

____

Source Control Measures Worksheet (cont'd)

Indoor and structural pest control

Accidental spills or leaks

Restaurants, grocery stores, and other food service operations

Interior floor drains

Industrial processes

Loading docks

Fire sprinkler test water

Drain or wash water from boiler drain lines, condensate drain lines, rooftop equipment, drainage sumps, and other sources

Unauthorized non-stormwater discharges

Drainage Management Area Worksheet

Drainage Management Area (DMA) # ______________

Type of DMA:

- ☐ Self-treating area
- ☐ Self-retaining area
- ☐ Areas draining to self-retaining areas
- ☐ Areas draining to bioretention facility

Describe the DMA ____

____

Total Drainage Area (ft^2) ______________

Existing Impervious Area (ft^2) ______________ Soil Type __________

Post-Project Impervious Area (ft^2) ______________ Infiltration Rate (in/hr) __________

Mean Annual Runoff-Producing Rainfall Depth (P_6) (in) __________

Drawdown time (t_{max}) (hr) (48) __________

Regression constant (a) (1.963 for 48-hr drawdown) __________

Pre-Project Condition:

Imperviousness ratio (i) = Existing Impervious Area ÷ Total Drainage Area (decimal) __________

Stormwater runoff coefficient (C) = $0.858 \times i^3 - 0.78 \times i^2 + 0.774 \times i + 0.04$ __________

Unit stormwater volume (P_0) (in) = $a \times C \times P_6$ __________

Stormwater Runoff Volume for the DMA (ft^3) __________

Post-Project Condition:

Imperviousness ratio (i) = Post-Project Impervious Area ÷ Total Drainage Area (decimal) __________

Stormwater runoff coefficient (C) = $0.858 \times i^3 - 0.78 \times i^2 + 0.774 \times i + 0.04$ __________

Unit stormwater volume (P_0) (in) = $a \times C \times P_6$ __________

Stormwater Design Volume for the DMA (SDV) (ft^3) = $A \times P_0 \div 12$ __________

Site Design Measure Worksheet

Drainage Management Area (DMA) # ______________

For this DMA, identify the following information:

Stormwater Design Volume without credits (ft^3) = SDV ______________

Stormwater Design Volume with credits (ft^3) = SDV_{adj} = SDV - SDM_{credit}
(This volume must be treated by stormwater treatment control measures.) ______________

Do proposed site design measures completely manage the SDV for this DMA?

- □ Yes, stormwater management requirement met for this DMA.
- □ No, proceed to Stormwater Treatment and Baseline Hydromodification Measure Worksheet.

Proposed Site Design Measure	Stormwater Runoff Volume Credit (ft^3)
□ Stream setbacks and buffers	______________
□ Soil quality improvement and maintenance	______________
□ Tree planting and preservation	______________
□ Rooftop and impervious area disconnection	______________
□ Porous pavement	______________
□ Vegetated swales	______________
□ Rain barrels/cisterns	______________
Total Stormwater Runoff Volume Credit (SDM_{credit})	______________

For site design measures not implemented for this DMA, describe why they are not selected.

____

____

____

____

____

Stormwater Treatment and Baseline Hydromodification Control Measure Design Worksheet

For <u>each</u> drainage management area (DMA), in which proposed site design measures did not fully manage the difference in pre- and post-project stormwater runoff volume, complete this worksheet.

Drainage Management Area (DMA) # ______________

Design bioretention facility to manage the adjusted stormwater design volume (SDV_{adj}). Calculate the bottom surface area of a bioretention facility:

Stormwater Design Volume for the DMA (SDV) (ft^3)
See Drainage Management Area Worksheet. ______________

Total Stormwater Runoff Credit Volume (SDM_{credit}) (ft^3)
See Site Design Measure Worksheet. ______________

Adjusted Stormwater Design Volume (SDV_{adj}) (ft^3) = SDV - SDM_{credit} ______________

Design infiltration rate of underlying soils (f_{design}) (in/hr) ______________

Ponding zone depth (d_{pz}) (ft) (0.5-1.5 ft) ______________

Planting media layer depth (d_{pm}) (ft) (min 1.5 ft) ______________

Planting media porosity (η_{pm}) ______________

Gravel layer depth (d_{gl}) (ft) (min 1 ft) ______________

Gravel layer porosity (η_{gl}) ______________

Bottom surface area of a bioretention facility (ft^2) = $\frac{SDV_{adj}}{d_{pz}+(\eta_{pm}\times d_{pm})+(\eta_{gl}\times d_{gl})}$ ______________

Verify that: $d_{pz} + (\eta_{pm} \times d_{pm}) + (\eta_{gl} \times d_{gl}) \leq f_{design} \times t_{max} \div 12$. If not, redesign factors above.

Verify that the DMA has adequate space to implement bioretention facility sized above. If not, redesign factors above or provide additional stormwater treatment control measures to manage remaining portion of the SDV.

Describe and provide justification for any variations to the bioretention facility for site-specific conditions. See Section 6.2 of the *2015 Post-Construction Stormwater Standards Manual* for more information.

____

____

____

____

Describe and provide justification if an alternative stormwater treatment control measure is proposed in lieu of a bioretention facility. An alternative stormwater treatment control measure proposed for a project must meet all the requirements of Section 6.2 of the *2015 Post-Construction Stormwater Standards Manual*.

____

____

____

____

Describe and provide justification for any exceptions to the requirements for bioretention. Exception to bioretention must meet all the requirements of Section 6.2 of the *2015 Post-Construction Stormwater Standards Manual*. Identify and describe the proposed biotreatment or media filter system that will be used in lieu of bioretention.

____

____

____

____

Summary of Stormwater Treatment and Baseline Hydromodification Control Measure Design

Stormwater Design Volume for DMA (SDV) (ft^3) ____________

1. Total Stormwater Runoff Credit Volume (SDM_{credit}) (ft^3) ____________
2. Volume of Stormwater Runoff Managed by Bioretention Facility (ft^3) ____________
3. Volume of Stormwater Runoff Managed by Other Stormwater Treatment Control Measure (identify each control measure)
   a. ____________
   b. ____________

Total Stormwater Runoff Volume Managed for DMA (ft^3) = sum of items 1-3 above. ____________

If Total Stormwater Runoff Volume Managed for this DMA equals or exceeds the Stormwater Design Volume for this DMA, then design for stormwater management for this DMA is complete. If the Total Stormwater Runoff Volume Managed for this DMA is less than the Stormwater Design Volume for this DMA, redesign site design measures and stormwater treatment control measures until the entire Stormwater Design Volume for this DMA has been managed. Complete this exercise for each DMA.

Section 4: Hydromodification Management Projects (only)

For projects that create and/or replace one acre or more of impervious surface and result in a net increase of impervious surface, full hydromodification is required. For these projects, the post-construction stormwater runoff flow rate shall not exceed the pre-construction stormwater runoff flow rate for the 2-year, 24-hour design storm event. Hydrologic routing modeling for the drainage management areas (DMAs) must be conducted to calculate the peak stormwater runoff response time and the peak project stormwater runoff flow rate for the entire project site.

Precipitation for 2-year, 24-hour storm event (in) ____________

From hydrologic routing modeling:

Pre-Project Total Stormwater Runoff Response Time ($T_{c,pre}$) (min) ____________

Pre-Project Peak Stormwater Runoff Flow Rate ($Q_{p,pre}$) (ft^3/s) ____________

Post-Project Total Stormwater Runoff Response Time ($T_{c,post}$) (min) ____________

Post-Project Peak Stormwater Runoff Flow Rate ($Q_{p,post}$) (ft^3/s) ____________

Describe and provide justification for proposed hydromodification management control measures to be implemented to meet the full hydromodification requirements.

____

Does the project meet the full hydromodification requirements?

- ☐ Yes
- ☐ No. Re-evaluate proposed hydromodification management control measure and provide additional capacity or implement additional hydromodification management control measure(s) to meet the full hydromodification requirements.

APPENDIX E

Source Control Measure Fact Sheets

Table of Contents

S-1: Accidental Spills and Leaks

Background

Spills and leaks are one of the largest contributors of pollutants in stormwater, and if not properly controlled, can adversely impact the storm drain system and receiving waters. Many activities have the potential for spills (accidental or illegal) and leaks. Proper spill response planning and preparation can result in effective response and mitigation to problems when they occur and potentially minimize the discharge of pollutants into the environment. An effective plan should have spill prevention and response procedures that identify potential spill areas, specify material handling and spill response procedures, and provide spill cleanup equipment and materials. Proper training of personnel is also necessary to prevent or control future spills.

Pollution Prevention Activities and Best Management Practices

A Spill Prevention and Control Plan must be developed to standardize the procedures for preventing, mitigating, and responding to spills on-site, which can discharge to the storm drain system. The Spill Prevention and Control Plan must include the following information:

- Description of the site, site address, owner, owner contact information, and activities and chemicals present on-site;
- Site map, which includes locations where chemicals and/or materials are stored;
- Notification and evacuation procedures;
- Clean-up instructions;
- Identification of appropriate contacts (e.g., owner, operator, regulatory agencies, emergency responders);
- Reporting procedures; and
- Identification of key spill response personnel.

Implement, if feasible, the following BMPs:

- Post “No Dumping” signs with appropriate contact information for reporting illegal dumping and disposal. Signs should also indicate fines and penalties for illegal dumping. Bright lighting and/or entrance barriers may also be used to discourage illegal dumping.
- Store and contain liquid materials such that if the storage unit failed, the contents will not discharge, flow, or be washed into the storm drain system or receiving waters. If necessary, provide secondary containment. If the material stored will separate from and float in water, install a spill control device in the catch basin that collects runoff from the storage tank area.

- Regularly inspect tanks and other storage facilities for leaks and spills. Replace tanks that are leaking, corroded, or otherwise damaged with tanks in good condition. Place drip pans or absorbent materials beneath mounted taps and at all potential drip and/or spill locations during filling and unloading storage tanks. Collected liquids or soiled absorbent materials may be reused or recycled or properly disposed of.
- Label all containers according to its contents. Provide hazardous materials labels if necessary.
- Sweep and clean the storage area regularly if it is paved. Do not hose down the area that conveys to a storm drain.
- Provide appropriate spill cleanup materials in a location near the storage facilities.
- Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

In the event that a spill occurs, conduct the following activities:

- Follow the Spill Prevention and Control Plan.
- Clean up spills and leaks immediately. On paved surfaces, use physical and/or dry cleanup methods (e.g., brooms, sweepers, shovels) if possible. Use rags for small spills, a damp mop for general cleanup, and absorbent materials for larger spills. For large spills, specialized contractors may be necessary. Properly dispose of all materials used to clean up spills and leaks.
- Minimize the amount of water used to clean up spills and leaks.
- Report spills to the proper agencies, which may include the following:
  - San Joaquin County Environmental Health Department;
  - Central Valley Regional Water Quality Control Board;
  - State Water Resources Control Board;
  - United States Environmental Protection Agency; and
  - Local fire and/or police department.
- Spill information, such as type of material and quantity, patterns of occurrence, responsible parties, must be recorded.

S-2: Interior Floor Drains

Background

Interior floor drains typically collect process waters, cooling waters, wash waters, and sanitary wastewater. These discharges can carry pollutants such paint, oil, fuel and other automotive fluids, chemicals and other pollutants into the storm drain system and receiving waters. Pollution prevention activities and BMPs outlined in this fact sheet are designed to reduce and/or eliminate pollutants in potential discharges through interior floor drains.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce potential pollutants that are discharged into the storm drain system through interior floor drains include the following:

- Label interior floor drains, by paint or stencil, to indicate where they flow (e.g., treatment or storage device, sanitary sewer system, storm drain system, receiving water).
- Identify all interior floor drains on a site and/or facility map.
- Remove and properly dispose of trash and debris regularly so they do not enter the floor drain.
- Direct accumulated water from interior floor drains to treatment devices (e.g., oil and water separator) or the sanitary sewer system, if permitted.
- In areas where there are high-risk pollutants or a high risk of pollutant mobilization, seal interior floor drains and use alternative dry methods (e.g., sweeping) or wet vacuums to collect waste.
- Do not store materials that can be washed, blown, or otherwise mobilized near interior floor drains.
- If necessary, verify that interior floor drains do not connect to the storm drain system by smoke and/or dye testing or closed-circuit television inspection.
- Consider hydraulically-isolating interior floor drains with berms.
- Train, including providing periodic refresher training, personnel on proper disposal methods.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Other spill prevention measures include:

- Spot clean leaks and drips routinely to prevent runoff of spillage. Place drip pans or absorbent materials under leaks.
- Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

S-3: Parking and Storage Areas and Maintenance

Background

Parking lots and storage areas may be a source of various pollutants, including trash, solids, hydrocarbons, oil and grease, and heavy metals that may be conveyed by stormwater and non-stormwater runoff to the storm drain system and/or receiving waters. Pollution prevention activities, BMPs, and design considerations outlined in this fact sheet are designed to reduce and/or eliminate pollutants in potential discharges from parking and storage areas.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential pollutants coming in contact with stormwater runoff include the following:

- Label drains, by paint or stencil, to indicate where they flow (e.g., treatment or storage device, sanitary sewer system, storm drain system, receiving water).
- Remove and properly dispose of trash and debris regularly. Post “No Littering” signs and enforce an anti-littering laws.
- Establish a frequency of cleaning and sweeping. Sweep all parking lots at least once before the wet season.
- For wet cleaning, block the storm drain, if present, or contain runoff. Dispose of wash water to a pervious surface or discharge to the sanitary sewer system, if permitted.
- For oily deposits, use absorbent materials prior to sweeping or washing.
- Train, including providing periodic refresher training, personnel on proper maintenance protocols for parking and storage areas.

If repairs to the parking or storage areas are needed, implement the following practices:

- Do not store materials near storm drain inlets. Cover and seal nearby storm drain inlets, where applicable, and manholes before applying seal coat, slurry seal, etc. Leave covers in place until the surface repair activities are completed. Clean and properly dispose of debris from the covered storm drain inlets or manholes.
- Apply concrete, asphalt, and seal coat during dry weather to prevent contamination from stormwater runoff.
- Use the minimum amount of water for dust control to minimize the potentially for site runoff.
- Use absorbent materials or pans to catch drips from paving equipment. Dispose of materials properly.

Design Considerations

For parking and storage areas that may be located in areas with a high risk of pollutant discharge, an impervious surface must be constructed using Portland cement concrete or an equivalent material. For parking and storage areas that may be located in areas with a low risk of pollutant discharge, permeable pavement may be used to help mitigate stormwater runoff volumes.

In general, downspouts and roofs should be directed away from parking and storage areas. To the maximum extent practicable, parking and storage areas should be designed (i.e., graded, bermed) to prevent stormwater run-on and runoff and contain spills. Storm drains should not be located in the immediate vicinity of parking and storage areas. Stormwater runoff, non-stormwater runoff, and spills must be disposed of in accordance with local, state, and federal laws. Design site to convey stormwater runoff from parking and storage areas to a stormwater treatment control measure for treatment.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Other spill prevention measures include:

- Spot clean leaks and drips routinely to prevent runoff of spillage. If the parking or storage area is periodically washed, place a temporary plug in the downstream drain and pump out and properly dispose of accumulated water.
- Place drip pans or absorbent materials under leaks.
- Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

S-4: Indoor and Structural Pest Control

Background

Indoor pest control is unlikely to be a source of pollution in stormwater. Structural pest control, if conducted using chemicals outside of the structure where it is exposed to stormwater runoff may mobilize chemicals into the storm drain system and receiving waters. Pollution prevention activities and BMPs outlined in this fact sheet are designed to reduce and/or eliminate the potential for discharge of pollutants in stormwater runoff from indoor and structural pest control activities.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential pollutants coming in contact with stormwater runoff include the following:

- Implement an integrated pest management (IPM) program, which is a sustainable approach for managing pests by using biological, cultural, physical, and chemical tools.
- Use baits for controlling pests and remove baits if pests are gone.
- Follow all federal, state, and local laws and regulations governing the use, storage, and disposal of pesticides and other chemicals and training of applicators and pest control advisors.
- Use pesticides only if there is an actual pest problem and not on a regular preventative schedule.
- Do not use pesticides outdoors if rain is expected. Apply pesticides only when wind speeds are low (less than 5 miles per hour). Calibrate pesticide application equipment to avoid excessive application. Employ techniques to minimize off-target application (i.e., spray drift) of pesticides.
- Do not mix or prepare pesticides for application near storm drains.
- Purchase only the amount of pesticides that can be reasonably used in the given time period (i.e., within expiration period).
- Triple rinse containers and use rinse water as product. Dispose of unused pesticides as hazardous waste. Dispose of empty containers according to the instructions on the label.
- Train, including providing periodic refresher training, personnel on proper use of pesticides. Pesticide application must be conducted under the supervision of a California qualified pesticide applicator. Train and encourage personnel to use of IPM methods to minimize use of chemical treatments.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Other spill prevention measures include:

- Regularly inspect chemical storage containers and application equipment to ensure that they are not leaking. If chemical storage containers are leaking, provide secondary containment. If application equipment is damaged or leaking, repair or if necessary, replace the equipment.
- Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

S-5: Landscape and Outdoor Pesticide Use

Background

Landscape maintenance and outdoor pest control may include the application of herbicides and pesticides. Stormwater and non-stormwater runoff may mobilize herbicides and pesticides into the storm drain system and receiving waters where these chemicals may cause environmental harm to aquatic life. Pollution prevention activities and BMPs outlined in this fact sheet are designed to reduce and/or eliminate the use of herbicides and pesticides in landscape maintenance and outdoor pest control activities that can impact receiving waters and wildlife.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential pollutants coming in contact with stormwater runoff include the following:

- Implement an integrated pest management (IPM) program, which is a sustainable approach for managing pests by using biological, cultural, physical, and chemical tools.
- Follow all federal, state, and local laws and regulations governing the use, storage, and disposal of herbicides, pesticides, and other chemicals and training of applicators and pest control advisors.
- Use pesticides only if there is an actual pest problem and not on a regular preventative schedule.
- Do not use herbicides or pesticides if rain is expected. Apply herbicides or pesticides only when wind speeds are low (less than 5 miles per hour). Calibrate herbicide or pesticide application equipment to avoid excessive application. Employ techniques to minimize off-target application (i.e., spray drift) of herbicides and pesticides.
- Do not mix or prepare herbicides or pesticides for application near storm drains.
- Purchase only the amount of herbicides or pesticides that can be reasonably used in the given time period (i.e., within expiration period).
- Triple rinse containers and use rinse water as product. Dispose of unused herbicides or pesticides as hazardous waste. Dispose of empty containers according to the instructions on the label.
- Use mechanical methods, including hand weeding, of vegetation removal rather than herbicides.
- Collect removed vegetation if it is near storm drain inlets by either bagging or manually picking up the material. Otherwise, certain vegetation may be left on-site to allow for decomposition and return of nutrients back into the soils.
- Provide erosion control if soils become exposed.

- Train, including providing periodic refresher training, personnel on proper use of herbicides and pesticides for landscape maintenance and outdoor use. Pesticide application must be conducted under the supervision of a California qualified pesticide applicator. Train and encourage personnel to use of IPM methods to minimize use of chemical treatments.

Design Considerations

For landscaping, climate-appropriate vegetation must be selected. Generally, climate-appropriate vegetation will reduce the use of herbicides and pesticides and require less irrigation necessary to maintain the health of the vegetation. Design the irrigation system to reduce excessive irrigation runoff in accordance with Section 4 of the 2015 Post-Construction Stormwater Standards Manual.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Other spill prevention measures include:

- Regularly inspect chemical storage containers and application equipment to ensure that they are not leaking. If chemical storage containers are leaking, provide secondary containment. If application equipment is damaged or leaking, repair or if necessary, replace the equipment.
- Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

S-6: Pools, Spas, Ponds, Fountains, and Other Water Features

Background

Pools, spas, ponds, fountains, and other water features may be periodically cleaned, including draining of the water feature, to maintain aesthetic appearances. Waters from these features may contain pollutants of concern (e.g., chlorine, algaecides) that may be toxic to aquatic life if these waters are discharged to the storm drain system or receiving water. Pollution prevention activities and BMPs outlined in this fact sheet are designed to reduce and/or eliminate pollutants in potential discharges from these water features.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential pollutants coming in contact with stormwater runoff include the following:

- Prevent issues with algae through regular maintenance activities including maintaining consistent chlorine levels and water treatment and circulation systems.
- Prevent corrosion of copper pipes by maintaining water chemistry characteristics (e.g., pH, hardness).
- For pools, spas, and fountains:
  - If algae control is needed, use alternatives control methods (e.g., sodium bromide) instead of copper-based algaecides.
  - Do not discharge water to a street or the storm drain system when draining pools, spas, or fountains. If permitted by the Agency, discharge water to the sanitary sewer system. If water is dechlorinated, it may be recycled and used for landscape irrigation.
  - If permitted to discharge to the sanitary sewer, prevent backflow when draining a pool, spa, or fountain by maintaining an air gap between the discharge line and the sanitary sewer pipe (i.e., do not seal the connection between the two lines).
  - Provide drip pans or buckets beneath the drain pipe connections to catch leaks.
  - Do not clean filters in the street or near a storm drain. Rinse filters in a self-treating area (e.g., landscaped or turfed area). If this is not possible, discharge rinse water to the sanitary sewer system, if permitted.
- For ponds and other large water features:
  - Minimize and eliminate, if possible, the use of fertilizers around the water body. Fertilizers can biostimulate algae growth.

    - Consider introducing fish species into the pond that consume algae. Contact the California Department of Fish and Wildlife for more information.
    - Mechanically remove pond scum (blue-green algae) using a net.
    - Discourage the public from feeding wildlife (i.e., place signs that prohibit the feeding wildlife) to control bacteria.
    - Control erosion by:
        - Maintaining vegetated cover on the banks to prevent soil erosion. Apply mulch or leave clippings to serve as additional cover for soil stabilization and to reduce the stormwater runoff rate.
        - Designing areas to prevent non-stormwater runoff and erosion.
        - Promoting efficient irrigation practices.
        - Providing energy dissipation along the banks to minimize the potential for erosion.
        - Storing, confining, and covering excavated materials in areas away from ponds.
- Conduct inspections to detect illegal dumping and illicit discharges.
- Remove trash and debris regularly. Provide and maintain trash receptacles. Increase trash collection during peak months.
- Train, including providing periodic refresher training, personnel on proper maintenance protocols for pools, spas, ponds, fountains, and other water features.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks.

S-7: Restaurants, Grocery Stores, and Other Food Service Operations

Background

Restaurants, grocery stores, and other food service operations typically contain multiple areas (e.g., parking lot, trash storage area, outdoor eating areas) that may contribute to pollution of stormwater. Pollutants of concern for stormwater runoff from these facilities include cleaning chemicals, oil and grease, trash, food waste, and pesticides. Pollution prevention activities, BMPs, and design considerations outlined in this fact sheet are designed to reduce and/or eliminate pollutants in potential discharges from these facilities.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential pollutants coming in contact with stormwater runoff include the following:

- Develop standard operating procedures to mitigate and/or eliminate the potential of discharge from food service operations.
- Label drains, by paint or stencil, to indicate where they flow (e.g., treatment or storage device, sanitary sewer system, storm drain system, receiving water).
- In general, use dry cleaning methods (e.g., sweeping) to clean facilities. Regularly remove and properly dispose of trash and litter. Separate recyclable materials from other trash.
- If chemicals are used (e.g., cleaning), purchase the least toxic products available. These chemicals are typically labeled “non-toxic”, “non-petroleum based”, “free of ammonia, phosphates, dye, or perfume”, or “readily biodegradable”. Avoid chlorinated compounds, petroleum distillates, phenols, formaldehyde, and caustic or acidic products. Use water-based products.
- Dispose of all discharge from cooling equipment into the sanitary sewer system and not the street, gutter, or storm drain system.
- Inspect and clean all waste grease removal devices (e.g., grease traps, grease interceptors) to keep them properly functioning.
- Collect oil, grease, and large quantities of oily liquids and properly dispose of it. Do not pour these substances into sinks, floor drains, storm drain system, or sanitary sewer system.
- Install screens and traps in sinks and floor drains to capture large solids. Clean these devices regularly.
- To minimize the potential for pests, keep facility clean and free from food wastes, dispose of trash daily into a closed trash container, properly store all food, and seal gaps in the facility (e.g., doors, windows, walls).

- For trash storage areas:
    - Store and transfer all solid and liquid wastes in watertight covered containers. Bag and seal food waste before putting it into the trash container. Do not place uncontained liquids or leaking containers or garbage bags into the trash container.
    - Provide an adequate number of trash containers. Inspect trash containers for damage and replace if necessary. Ensure that trash containers have covers. Lock trash containers to prevent illegal dumping.
    - Do not use water to wash out trash containers. Have the trash container leasing company clean out dirty trash containers.
- For equipment and outdoor cleaning:
    - Clean floor mats and filters in mop sink, floor drain, or proper outside area connected an oil and water separator prior to discharge to the sanitary sewer system. Do not wash these items in the parking lot, alley, sidewalk, or street.
    - Dispose of all wash water into the sanitary sewer system.
- For landscape and grounds maintenance:
    - If pesticides are used, do not over apply or apply when precipitation is forecasted.
    - Do not dispose of pesticides in the sink, floor drains, gutter, street, sanitary sewer system, or storm drain system. Leftover pesticides must either be used up or disposed of as hazardous waste.
    - If fountains are present on-site and algae control is needed, use alternatives control methods (e.g., sodium bromide) instead of copper-based algaecides.
- Train, including providing periodic refresher training, personnel on proper cleaning, disposal, and maintenance protocols.

Design Considerations

All design specifications for restaurants, grocery stores, and other food service operations are regulated by local building and fire codes, ordinances, and zoning requirements. In general, downspouts and roofs should be directed away from the structures, trash storage areas, and cleaning areas. Stormwater runoff, non-stormwater runoff, and spills must be disposed of in accordance with local, state, and federal laws. The following source control measures and their design features may be applicable to restaurants, grocery stores, and other food service operations:

- S-3: Parking/Storage Areas and Maintenance;
- S-4: Indoor and Structural Pest Control;
- S-5: Landscape and Outdoor Pesticide Use;

- S-6: Pools, Spas, Ponds, Fountains, and Other Water Features;
- S-8: Refuse Areas
- S-10: Outdoor Storage of Equipment or Materials;
- S-11: Vehicle and Equipment Cleaning;
- S-12: Vehicle and Equipment Repair and Maintenance; and
- S-14: Loading Docks

The project applicant must assess the applicability of the pollution prevention activities, BMPs, and design considerations associated with the source control fact sheets listed above.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Other spill prevention measures include:

- Check trash containers regularly for leaks and replace if necessary.
- Provide drip pans or absorbent materials if drips or leaks are detected.
- Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, signs) must be maintained by the owner/operator as required by local codes and ordinances. Restaurants, grocery stores, and other food service operations must be inspected periodically to ensure containment of accumulated water, prevention of stormwater run-on, and proper handling of stormwater runoff. Failure to properly maintain building and property may subject the property owner to citation.

S-8: Refuse Areas

Background

Wastes from multi-family, commercial, and industrial sites are typically hauled away for disposal by either public or commercial carriers. Stormwater runoff from areas where trash is stored or handled can be polluted. Loose trash and debris can be easily transported by water or wind into nearby storm drain inlets, channels, and/or receiving waters. Waste handling operations (i.e., dumpsters, litter control, waste piles) may be sources of stormwater pollution. Pollution prevention activities, BMPs, and design considerations outlined in this fact sheet are designed to reduce and/or eliminate pollutants in potential discharges from refuse areas. This source control measure is not intended for single-family detached housing units.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential pollutants coming in contact with stormwater runoff include the following:

- Label drains, by paint or stencil, to indicate where they flow (e.g., treatment or storage device, sanitary sewer system, storm drain system, receiving water).
- Sweep and clean the refuse areas regularly. Do not wash the refuse area if it drains to the storm drain system. If the refuse area is washed down, collect wash water and dispose of it to the sanitary sewer system.
- Provide an adequate number of trash containers. Periodically clean out the trash containers to prevent spillage. Inspect trash containers for damage and replace if necessary. Ensure that trash containers have covers.
- If hazardous chemicals are being stored for disposal, provide secondary containment.

Design Considerations

In designing refuse areas, it is important to note that waste haulers may have specific requirements for the refuse area. The recommendations in this fact sheet are not intended to conflict with the requirements established by the waste hauler. The waste hauler should be contacted prior to the design of trash storage and collection areas to determine established and accepted guidelines for designing trash collection areas. All hazardous waste must be handled in accordance with the legal requirements established in Title 22 of the California Code of Regulations. Refuse areas should be designed as follows:

- Construct/pave outdoor refuse storage and waste handling areas with Portland cement concrete or an equivalent impervious surface. Berm and/or grade the refuse area to prevent run-on, including diverting stormwater runoff from adjoining roofs and pavements away from the refuse area. Locate the refuse area at least 35 feet from storm drains.

- Install a screen or wall around the refuse area to prevent off-site transport of loose trash. Use lined bins or dumpsters to reduce leaking of liquid waste. Use waterproof lids on bins and dumpsters or provide a roof to cover the refuse area to prevent precipitation from entering the containers.
- Post signs on all dumpsters and/or inside the refuse area prohibiting the disposal of liquids and hazardous waste materials in accordance with any Agency waste disposal ordinance.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Other spill prevention measures include:

- Check trash containers regularly for leaks and replace if necessary.
- Provide drip pans or absorbent materials in the refuse area if drips or leaks are detected.
- Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, signs) must be maintained by the owner/operator as required by local codes and ordinances. Refuse areas must be inspected periodically to ensure containment of accumulated water, prevention of stormwater run-on, and proper handling of stormwater runoff. Failure to properly maintain building and property may subject the property owner to citation.

S-9: Industrial Processes

Background

Industrial processes, particularly if they are located outdoors, have the potential to contaminate stormwater runoff and the receiving waters. Depending on the activities on-site, there may be a variety of potential pollutants of concern. Pollution prevention activities and BMPs outlined in this fact sheet are designed to reduce and/or eliminate pollutants in potential discharges from areas where there are industrial processes.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential pollutants coming in contact with stormwater runoff include the following:

- Label drains, by paint or stencil, to indicate where they flow (e.g., treatment or storage device, sanitary sewer system, storm drain system, receiving water).
- Perform industrial process activities during dry weather periods.
- Consider enclosing the industrial process in a building and connecting the floor drains to the sanitary sewer system.
- Cover the work area with a permanent roof if possible.
- Properly store equipment and materials to prevent contact with stormwater runoff.
- Hydraulically-isolate the industrial process to minimize contact of stormwater runoff and run-on by berming the process area. This will also help contain spills that may occur.
- Clean the industrial process area regularly and properly dispose of all wastes. If possible, use dry cleaning methods. If the industrial process area must be washed, collect wash water and properly dispose of it.
- Regularly remove and properly dispose of trash and litter.
- Use least toxic chemicals when possible.

Design Considerations

All design specifications for industrial processes are regulated by local building and fire codes, ordinances, and zoning requirements. In general, downspouts and roofs should be directed away from industrial processes. Storm drains should not be located in the immediate vicinity of industrial processes. Stormwater runoff, non-stormwater runoff, and spills must be disposed of in accordance with local, state, and federal laws. Depending on the industrial processes on-site, apply other source control measures as needed.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Other spill prevention measures include:

- Regularly inspect equipment and check for leaks and drips. If leaks or drips are detected, repair, if necessary, the equipment, provide drip pans or absorbent materials, and spot clean leaks and drips routinely to prevent runoff of spillage.
- Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, signs) must be maintained by the owner/operator as required by local codes and ordinances. Industrial process areas must be inspected periodically to ensure containment of accumulated water, prevention of stormwater run-on, and proper handling of stormwater runoff. Failure to properly maintain building and property may subject the property owner to citation.

S-10: Outdoor Storage of Equipment or Materials

Background

Outdoor facilities may be used to store equipment and/or materials. Equipment that is exposed to precipitation may mobilize pollutants. Materials, including raw materials, by-products, finished products, and waste products, stored outdoors can become sources of pollutants in stormwater runoff if not properly managed. Materials may be stored in a variety of ways, including bulk piles, containers, shelving, stacking, and tanks. The type of pollutants associated with equipment and materials stored outdoors will vary depending on the type of activity present on-site. Materials are classified into three categories based on the potential risk of pollutant release associated with stormwater runoff contact – high risk, medium risk, and low risk. General types of materials under each category are presented in **Table E-1**.

Table E-1. Classification of Materials for Potential Pollutant Risk

High Risk Materials	Medium Risk Materials	Low Risk Materials
• Recycled materials with discharge potential • Corrosives • Food items • Chalk/gypsum products • Scrap or salvage goods • Feedstock/grain • Fertilizers • Pesticides • Compost • Asphalt • Lime/lye/soda ash • Animal/human wastes • Rubber and plastic pellets or other small pieces • Uncured concrete/cement • Lead and copper, and any metals with oil/grease coating	• Clean recycled materials without discharge potential • Metal (excluding lead and copper, and any metals with oil/grease coating) • Sawdust/bark chips • Sand/soil • Unwashed gravel/rock	• Washed gravel/rock • Finished lumber (non-pressure treated) • Rubber or plastic products (excluding small pieces) • Clean, precast concrete products • Glass products (new) • Inert products • Gaseous products • Products in containers that prevent contact with stormwater (fertilizers and pesticides excluded)

Contamination of stormwater runoff may be prevented by eliminating the possibility of stormwater runoff contact with the equipment and material storage areas either through diversion, cover, or capture of the stormwater runoff. Pollution prevention activities, BMPs, and design considerations outlined in this fact sheet are designed to reduce and/or eliminate pollutants in potential discharges from outdoor equipment and material storage areas.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential pollutants coming in contact with stormwater runoff include the following:

- Label drains, by paint or stencil, to indicate where they flow (e.g., treatment or storage device, sanitary sewer system, storm drain system, receiving water).
- Keep the outdoor equipment and material storage area as clean and orderly as possible to reduce the potential for stormwater runoff to contact and/or mobilize potential pollutants of concern.
- Minimize the inventory of materials.
- Identify all storage areas for equipment and chemical and/or waste materials, including a tank/drum schedule indicating tank capacities, materials of construction, and contents, on site maps and/or plans.
- Accurately tracking the materials stored on-site.
- Try to keep materials in their original containers. Provide proper labeling of materials stored on-site.
- Train, including providing periodic refresher training, personnel on proper equipment and material handling procedures.

Design Considerations

All design specifications for equipment and material storage areas are regulated by local building and fire codes, ordinances, and zoning requirements. In general, downspouts and roofs should be directed away from outdoor equipment and materials storage areas. Stormwater runoff, non-stormwater runoff, and spills must be disposed of in accordance with local, state, and federal laws.

Outdoor equipment and material storage areas should be designed as follows:

- For high-risk equipment or materials:
    - Construct/pave storage area with Portland cement concrete or an equivalent impervious surface. Ensure that the surfacing material is chemically-resistant to the materials being stored.
    - Place equipment or materials in an enclosure (e.g., shed, cabinet) that prevents contact with stormwater or cover the entire storage area with a permanent canopy, roof, or awning to prevent precipitation from making contact with and collecting within the storage area. If the cover does not include sidewalls, include a roof overhang that extends beyond the grade break. Covers that are 10 feet high or less should extend a minimum of 3 feet beyond the perimeter of the storage area. Covers higher than 10 feet should extend a minimum of either 20 percent of the cover’s height or 5 feet beyond the perimeter of the storage area, whichever is greater.

    - Hydraulically-isolate the storage area with grading, berms, drains, dikes, or curbs to prevent stormwater run-on from surrounding areas or roof drains. Direct stormwater runoff from the cover away from the storage area to an approved stormwater discharge location.
- For medium-risk equipment or materials:
    - Construct/pave storage area with Portland cement concrete or an equivalent impervious surface.
    - At a minimum, completely cover equipment or material with temporary plastic sheeting during storm events.
    - For erodible material, provide grading and a structural containment barrier on at least three sides to prevent stormwater runoff from surrounding areas and migration of material due to wind erosion.
- For low-risk equipment or materials:
    - There are no requirements for surfacing or enclosures or covers.
    - Provide appropriate drainage from the storage area to minimize contact with the equipment or materials.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, signs) must be maintained by the owner/operator as required by local codes and ordinances. Outdoor equipment and material storage areas must be inspected periodically to ensure containment of accumulated water, prevention of stormwater run-on, and proper handling of stormwater runoff. Any enclosures and secondary/spill containment areas must be checked periodically to ensure spills are contained efficiently. Failure to properly maintain building and property may subject the property owner to citation.

S-11: Vehicle and Equipment Cleaning

Background

Washing vehicles and equipment in areas where wash water flows onto the ground can pollute stormwater runoff and adversely impact receiving waters. Pollutants of concern in wash water include oil and grease, heavy metals, solvents, phosphates, and suspended solids. By containing, collecting, diverting, and properly disposing of wash water from vehicle and equipment cleaning areas to the sanitary sewer system, transport of these potential pollutants to the storm drain system and receiving waters is limited. Pollution prevention activities, BMPs, and design considerations outlined in this fact sheet are designed to reduce and/or eliminate pollutants in potential discharges from vehicle and equipment cleaning areas.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential pollutants coming in contact with stormwater runoff include the following:

- If possible, use properly maintained off-site commercial washing businesses. These businesses are typically better equipped to handle and properly dispose of wash water.
- If it is not possible to wash vehicles and equipment off-site,
    - Use biodegradable, phosphate-free detergent for washing activities.
    - Mark the area clearly as a wash area and that only washing is permitted in this area (e.g., do not allow oil changes and other maintenance to occur in this area).
    - Provide trash containers in the wash area.
    - Label drains, by paint or stencil, to indicate where they flow (e.g., treatment or storage device, sanitary sewer system, storm drain system, receiving water).
    - Use hoses with nozzles that automatically turn off when left unattended.
- Evaluate the feasibility of implementing a closed-loop recycling system that treats and reuses wash water. This type of system will also reduce the use of potable water. Do not discharge wash water into the storm drain system.
- Train, including providing periodic refresher training, personnel on proper cleaning and maintenance procedures.

Design Considerations

All design specifications for vehicle and equipment cleaning areas are regulated by local building and fire codes, ordinances, and zoning requirements. In general, downspouts and roofs should be directed away from vehicle and equipment cleaning areas, and such areas should slope towards a dead-end sump to collect stormwater runoff, non-stormwater runoff, and spills. If a dead-end sump is not used to collect stormwater, install an oil/water separator. Stormwater runoff, non-stormwater runoff, and spills must be disposed of in accordance with local, state, and federal laws. Vehicle and equipment cleaning areas should be designed as follows:

- Construct/pave cleaning areas with Portland cement concrete or an equivalent impervious surface.
- If possible, cover the cleaning area with a permanent canopy, roof, or awning to prevent precipitation from making contact with and collecting within the storage area. If the cover does not include sidewalls, include a roof overhang that extends beyond the grade break. Covers that are 10 feet high or less should extend a minimum of 3 feet beyond the perimeter of the cleaning area. Covers higher than 10 feet should extend a minimum of either 20 percent of the cover's height or 5 feet beyond the perimeter of the cleaning area, whichever is greater. Grade or berm the cleaning area to contain wash water within the covered area.
- If covering the cleaning area is not possible, provide an approved stormwater runoff diversion system along with a clarifier and sample box. Diverted stormwater runoff may require pretreatment and verification of pollutant concentrations.
- Direct wash water to treatment and recycle or pretreatment (e.g., clarifier) and proper connection to the sanitary sewer system. Obtain approval from the proper agency before discharging to the sanitary sewer system.
- Hydraulically-isolate the cleaning area with grading, berms, drains, dikes, or curbs to prevent stormwater run-on from surrounding areas or roof drains. Direct stormwater runoff from the cover away from the cleaning area to an approved stormwater discharge location.
- Do not locate storm drain inlets in the immediate vicinity of the cleaning area.
- Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or accumulated water from entering the storm drain system. All wash water and hazardous and toxic wastes must be prevented from entering the storm drain system.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Other spill prevention measures include:

- Regularly inspect vehicles and equipment for leaks. Place drip pans or absorbent materials under vehicles or equipment if they are leaking.
- Check incoming vehicles and equipment for leaking oil and fluids. Do not allow leaking vehicles or equipment on-site.
- Promptly transfer used fluids to the proper waste or recycling containers. Do not leave full drip pans or other open containers lying around.

- Oil filters disposed of in trash cans or dumpsters can leak oil and contaminate stormwater. Place the oil filter in a funnel over a waste oil recycling container to drain excess oil before disposal. Oil filters can be recycled.
- Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., covers, signs) must be maintained by the owner/operator as required by local codes and ordinances. Vehicle and equipment cleaning areas must be inspected periodically to ensure containment of accumulated water, prevention of stormwater run-on, and proper handling of stormwater runoff. Failure to properly maintain building and property may subject the property owner to citation.

S-12: Vehicle and Equipment Repair and Maintenance

Background

Activities in vehicle and equipment repair and maintenance areas that can contaminate stormwater runoff include engine repair, service, and parking (e.g., leaking engines or parts). Pollutants of concern from these facilities include oil and grease, solvents, car battery acid, coolant, and gasoline as well as heavy metals and suspended solids. Pollution prevention activities, BMPs, and design considerations outlined in this fact sheet are designed to reduce and/or eliminate pollutants in potential discharges from vehicle and equipment repair and maintenance areas.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential pollutants coming in contact with stormwater runoff include the following:

- Switch to non-toxic chemicals for maintenance when possible and use cleaning agents that can be recycled.
- Minimize the use of solvents. Use water-based solvents for cleaning.
- Recycle used oils and other vehicle or equipment fluids and parts.
- Keep accurate maintenance logs to evaluate materials removed.
- Label drains, by paint or stencil, to indicate where they flow (e.g., treatment or storage device, sanitary sewer system, storm drain system, receiving water). Do not pour waste materials down storm drains.
- Keep vehicles and equipment clean and do not allow a build-up of oil and grease.
- Train, including providing periodic refresher training, personnel on proper area maintenance and waste disposal procedures.

Design Considerations

All design specifications for vehicle and equipment repair and maintenance areas are regulated by local building and fire codes, ordinances, and zoning requirements. In general, downspouts and roofs should be directed away from outdoor vehicle and equipment repair and maintenance areas, and such areas should slope towards a dead-end sump to collect stormwater runoff, non-stormwater runoff, and spills. If a dead-end sump is not used to collect stormwater, install an oil/water separator. Stormwater runoff, non-stormwater runoff, and spills must be disposed of in accordance with local, state, and federal laws. Vehicle and equipment repair and maintenance areas should be designed as follows:

- Construct/pave vehicle and equipment repair and maintenance area with Portland cement concrete or an equivalent impervious surface. Cover or enclose the vehicle and equipment repair and maintenance area. Where possible, conduct repair and maintenance activities indoors.

- Berm or grade vehicle and equipment repair and maintenance area to prevent stormwater run-on and runoff and contain spills.
- A pretreatment system may be necessary to treat wastes prior to disposal.
- Cover areas where parts and fluids are stored.
- Do not locate storm drains in the immediate vicinity of vehicle and equipment repair and maintenance area.
- Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or accumulated water from entering the storm drain system. All wash water and hazardous and toxic wastes must be prevented from entering the storm drain system.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Other spill prevention measures include:

- Perform all fluid removal or changing inside or under cover to prevent run-on of stormwater and runoff of spills. Use secondary containment (e.g., drain pan, drop cloth) to catch spills or leaks when removing or changing fluids.
- Regularly inspect vehicles and equipment for leaks, and repair immediately.
- Check incoming vehicles and equipment for leaking oil and fluids. Do not allow leaking vehicles or equipment on-site.
- Store wrecked vehicles or damaged equipment under cover.
- Place drip pans or absorbent materials under heavy equipment when not in use.
- Promptly transfer used fluids to the proper waste or recycling containers. Do not leave full drip pans or other open containers lying around.
- Oil filters disposed of in trash cans or dumpsters can leak oil and contaminate stormwater. Place the oil filter in a funnel over a waste oil recycling container to drain excess oil before disposal. Oil filters can be recycled.
- Store all batteries in secondary containment.
- Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., covers, signs) must be maintained by the owner/operator as required by local codes and ordinances. Vehicle and equipment repair and maintenance areas must be inspected periodically to ensure containment of accumulated water, prevention of stormwater run-on, and proper handling of stormwater runoff. Failure to properly maintain building and property may subject the property owner to citation.

S-13: Fuel Dispensing Areas

Background

Spills and leaks at fuel dispensing areas can be a significant source of pollution because fuels contain toxic materials and heavy metals that are not easily removed by stormwater treatment control measures. When stormwater runoff mixes with fuel spilled or leaked onto the ground, it becomes contaminated with petroleum-based materials that are harmful to humans, fish, and wildlife. Contamination can occur at large industrial sites or at small commercial sites such as retail gas outlets and convenience stores. Materials such as oil and grease, car battery acid, and coolant also have the potential to contribute to stormwater pollution due to spills at fuel dispensing areas. Pollution prevention activities, BMPs, and design considerations outlined in this fact sheet are designed to reduce and/or eliminate pollutants in potential discharges from fuel dispensing areas.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential pollutants coming in contact with stormwater runoff include the following:

- Provide overflow protection devices on tank systems to warn the operator to automatically shut down transfer pumps when the storage tank reaches capacity.
- Clearly label all valves to reduce the potential for human error.
- Spot clean leaks and drips routinely to prevent runoff of spillage. If the fuel dispensing area is periodically washed, place a temporary plug in the downstream drain and pump out and properly dispose of accumulated water.
- Cover drains during transfer of fuel from the fuel truck to the fuel storage tank.
- Train, including providing periodic refresher training, personnel on proper fueling and cleanup procedures.

Design Considerations

All design considerations for fuel dispensing areas are regulated by local building and fire codes, ordinances, and zoning requirements. In general, downspouts and roofs should be directed away from fuel dispensing areas, and such areas should slope towards a dead-end sump to collect stormwater runoff, non-stormwater runoff, and spills. If a dead-end sump is not used to collect stormwater, install an oil/water separator. Stormwater runoff, non-stormwater runoff, and spills must be disposed of in accordance with local, state, and federal laws. Fuel dispensing areas should be designed as follows:

- Label drains, by paint or stencil, to indicate where they flow (e.g., treatment or storage device, sanitary sewer system, storm drain system, receiving water).

- Construct/pave fuel dispensing area with Portland cement concrete, or an equivalent smooth impervious surface. Do not use asphalt concrete to construct/pave the fuel dispensing/maintenance area. The fuel dispensing area is defined as extending 6.5 feet from the corner of each fuel dispenser or the length at which the hose and nozzle assembly may be operated plus 1 foot, whichever is greater. Paving around the fuel dispensing area may exceed the minimum dimensions listed above. Use asphalt sealant to protect asphalt-paved areas surrounding the fuel dispensing area.
- Cover the fuel dispensing area with a permanent canopy, roof, or awning to prevent precipitation from making contact with and collecting within the storage area. Covers that are 10 feet high or less should extend a minimum of 3 feet beyond the perimeter of the fuel dispensing area. Covers higher than 10 feet should extend 5 feet beyond the perimeter of the fuel dispensing area.
- For facilities designed to accommodate very large vehicles or equipment that would prohibit the use of covers, hydraulically-isolate the uncovered fuel dispensing area and direct stormwater runoff from the area through upstream controls to an approved stormwater discharge location.
- Design fuel dispensing area pad with a two to four percent slope to prevent ponding, and include a grade break that separates the area from the rest of the site. Prevent stormwater run-on from surrounding areas or roof drains from entering the fuel dispensing area by:
    - Installing a perimeter trench drain around the fuel dispensing area pad. The perimeter drain must drain to either the sanitary sewer system, if approved, or into an approved below-grade containment vault with at least 60 cubic feet of storage capacity. The containment vault must be emptied, as needed, and the contents disposed of in accordance with applicable laws; and/or
    - Elevating the entire fuel dispensing area pad and provide a perimeter drain to isolate the pad. The pad should be graded such that any spills will stay on the pad for clean up using dry methods.
- Direct stormwater runoff from the cover away from the fuel dispensing area to an approved stormwater discharge location. Do not locate storm drain inlets within 10 feet if the hydraulically-isolated fuel dispensing area.
- Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or accumulated from entering the storm drain system. When possible and appropriate, use dry cleanup methods, such as sweeping for removal of litter and debris and use of absorbents for liquid spills and leaks.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Other spill prevention measures include:

- Install vapor recovery nozzles to help control drips as well as air pollution.

- Discourage "topping-off" of fuel tanks.
- Use secondary containment when transferring fuel from the tank truck to the fuel tank.
- Fit the underground storage tanks with spill containment and overfill prevention systems meeting the requirements of Section 2635(b) of Title 23 of the California Code of Regulations.
- Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, signs) must be maintained by the owner/operator as required by local codes and ordinances. Fuel dispensing areas must be inspected periodically to ensure containment of accumulated water, prevention of stormwater run-on, and proper handling of stormwater runoff. Failure to properly maintain building and property may subject the property owner to citation.

S-14: Loading Docks

Background

Materials spilled, leaked, or lost during loading activities may collect on impervious surfaces or in the soil and be carried away by stormwater runoff or when the area is cleaned. Precipitation can also wash pollutants from machinery used to move materials. In particular, loading docks have the potential to contribute heavy metals, nutrients, suspended solids, oils, and grease to stormwater runoff due to the heavy truck traffic and loading activities. Depressed loading docks (e.g., truck wells) are contained areas that can also accumulate water. Pollution prevention activities, BMPs, and design considerations outlined in this fact sheet are designed to reduce and/or eliminate pollutants in potential discharges from loading docks.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential pollutants coming in contact with stormwater runoff include the following:

- Parking tank trucks and delivery vehicles in designated areas where spills and leaks can be contained.
- Limit exposure of material to precipitation whenever possible.
- Label drains, by paint or stencil, to indicate where they flow (e.g., treatment or storage device, sanitary sewer system, storm drain system, receiving water).
- Develop an operations plan that describes procedures for loading activities.
- Train, including providing periodic refresher training, personnel on proper loading and cleanup procedures.

Design Considerations

All design specifications for loading docks are regulated by local building and fire codes, ordinances, and zoning requirements. In general, downspouts and roofs should be directed away from loading docks, and such areas should slope towards a dead-end sump to collect stormwater runoff, non-stormwater runoff, and spills. If a dead-end sump is not used to collect stormwater, install an oil/water separator. Stormwater runoff, non-stormwater runoff, and spills must be disposed of in accordance with local, state, and federal laws. Loading docks should be designed as follows:

- Construct/pave loading docks with Portland cement concrete or an equivalent impervious surface. Ensure that the surfacing material is chemically-resistant to materials being handled in the loading dock area.
- Cover the loading dock to a distance of at least 10 feet beyond the loading dock or building face if there is no raised dock. If the cover or roof structure does not include sidewalls, then the roof overhang must extend beyond the grade break. The overhang must extend a minimum of 20 percent of the roof height.

- For interior transfer bays, provide a minimum 10-foot “No Obstruction Zone” to allow trucks or trailers to extend at least 5 feet inside the building. Identify “No Obstruction Zone” clearly on site plans and paint zone with high visibility floor paint. If covers or interior transfer bays are not feasible, install a seal or door skirt and provide a cover to shield all material transfers between trailers and building.
- For loading docks, hydraulically-isolate the first six feet of paved area measured from the building or dock face with grading, berms, or drains to prevent stormwater run-on from surrounding areas or roof drains. Direct stormwater runoff and drainage from surrounding areas away from hydraulically-isolated areas to an approved stormwater discharge point.
- For interior transfer bays or bay doors, prevent stormwater runoff from surrounding areas from entering the building with grading or drains. Do not install interior floor drains in the “No Obstruction Zone”. Hydraulically-isolate the “No Obstruction Zone” from any interior floor drains.
- Do not install direct connections to storm drains from depressed loading docks. Connect drains or direct drainage from hydraulically-isolated loading dock to an approved sediment/oil/water separator system connected an approved discharge location. Provide a manual emergency spill diversion valve upstream of separator system to direct flow, in the event of a spill, to an approved spill containment vault sized to contain a volume equal to 125% of largest container handled at the facility. Provide additional emergency means, such as drain plugs or drain covers, to prevent spills or contaminated stormwater runoff from entering the storm drain system.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Other spill prevention measures include:

- Use drip pans underneath hose, and pipe connections and other leak-prone areas during liquid transfer operations.
- Check equipment regularly for leaks, including valves, pumps, and connections.
- Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., covers, signs) must be maintained by the owner/operator as required by local codes and ordinances. Loading docks must be inspected periodically to ensure containment of accumulated water, prevention of stormwater run-on, and proper handling of stormwater runoff. Failure to properly maintain building and property may subject the property owner to citation.

S-15: Fire Sprinkler Test Water

Background

Water is discharged from fire sprinklers during testing and maintenance. If the water is allowed to leave the site and discharge into the storm drain system, it may mobilize pollutants. Pollution prevention activities and BMPs outlined in this fact sheet are designed to prevent pollutants from entering the storm drain system or receiving waters from discharge of fire sprinkler test water.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential pollutants coming in contact with fire sprinkler test water include the following:

- When preparing for a fire sprinkler test or maintenance, sweep or vacuum the area where the water is anticipated to flow to remove trash and other debris.
- Protect storm drain inlets using sandbags to create a berm to prevent water from flowing into it.
- Temporarily plug other nearby drains.
- Direct fire sprinkler test water to a vegetated area using portable berms and/or sandbags. If a vegetated area is not nearby, create a berm using sandbags to capture water and use a wet-vacuum to collect and dispose of fire sprinkler test water into the sanitary sewer system.
- Train, including providing periodic refresher training, personnel on proper disposal of fire sprinkler test water.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

S-16: Drain or Wash Water

Background

If drain or wash water from boiler drain lines, condensate drain lines, rooftop equipment, drainage sumps, and other sources is allowed to leave a site, the water may mobilize pollutants and enter the storm drain system or receiving water. Pollution prevention activities and BMPs outlined in this fact sheet are designed to prevent pollutants from entering the storm drain system or receiving waters from discharge of drain or wash water from boiler drain lines, condensate drain lines, rooftop equipment, drainage sumps, and other sources.

Pollution Prevention Activities and Best Management Practices

Direct drain or wash water from boiler drain lines, condensate drain lines, rooftop equipment, drainage sumps, and other sources to a vegetated area. If a vegetated area is not nearby, collect the water and dispose of it into the sanitary sewer system. Train, including providing periodic refresher training, personnel on proper disposal of this water.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

S-17: Unauthorized Non-Stormwater Discharges

Background

Non-stormwater discharges are flows that do not consistent entirely of stormwater. Some non-stormwater discharges (e.g., uncontaminated groundwater) do not contain pollutants and may be discharged to the storm drain. Other non-stormwater discharges may pose an environmental threat, including discharges originating from illegal dumping internal floor drains, appliances, industrial processes, sinks, and toilets that are connected to the storm drain system. These types of discharges, which may include process waters, cooling waters, wash waters, and sanitary wastewater, can carry pollutants such paint, oil, fuel and other automotive fluids, chemicals and other pollutants into the storm drain system and receiving waters. Pollution prevention activities and BMPs outlined in this fact sheet are designed to eliminate these unauthorized non-stormwater discharges.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may eliminate unauthorized non-stormwater discharges include the following:

- Label drains, by paint or stencil, to indicate where they flow (e.g., treatment or storage device, sanitary sewer system, storm drain system, receiving water).
- Develop protocols for identifying, investigating, and responding to unauthorized non-stormwater discharges. Train personnel, including law enforcement, to identify and document unauthorized non-stormwater discharges.
- Regularly inspect and cleanup hot spots and other storm drain areas where illegal dumping and disposal occurs. During inspections, look for evidence of non-stormwater discharges (e.g., discoloration, odors) and determine if it poses a threat to water quality. Implement proper spill cleanup procedures (S-1: Accidental Leaks and Spills).
- Investigate, and if possible, isolate the source and identify the responsible party, of the non-stormwater discharge. If necessary, conduct smoke and/or dye testing to identify cross-connections and/or use closed-circuit television systems to inspect pipes.
- Collect samples of non-stormwater discharge for water quality testing.
- Provide public education and outreach to reduce the potential for non-stormwater discharges and provide information about proper disposal of waste materials, including liquids. Provide the public with a mechanism (e.g., hotline, website) for reporting instances of non-stormwater discharges.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

S-18: Building and Grounds Maintenance

Background

Stormwater runoff from building and grounds maintenance activities can be contaminated with pollutants such as hydrocarbons, solvents, fertilizers, pesticides, solids, trash, heavy metals, and oil and grease. Pollution prevention activities, BMPs, and design considerations outlined in this fact sheet are designed to reduce and/or eliminate pollutants in potential discharges from building and grounds maintenance activities.

Pollution Prevention Activities and Best Management Practices

Pollution prevention activities and BMPs that may reduce the potential impacts from buildings and grounds maintenance activities include the following:

- Label drains, by paint or stencil, to indicate where they flow (e.g., treatment or storage device, sanitary sewer system, storm drain system, receiving water).
- Use non-toxic chemicals, including chemicals that can be recycled, for maintenance when possible.
- Remove and properly dispose of trash and debris regularly.
- Recycle materials (e.g., residual paints, solvents, lumber,) as much as possible.
- When washing buildings, rooftops, and other large structures, collect wash water using a sump pump, wet vacuum, or similar device and properly dispose of it. If soaps and detergents are not used, disperse wash water into vegetated areas.
- For building repair, remodeling, and construction:
    - Cover nearby storm drains prior to starting work.
    - Do not discharge any toxic substance or liquid waste on the pavement, ground, or near a storm drain.
    - Use ground or drop cloths under exterior painting, scraping, or sandblasting work. Properly dispose of materials.
    - Clean paintbrushes and tools with water-based paints such that wash water can be disposed of in the sanitary sewer. Paintbrushes and tools with non-water-based paints must be cleaned with solvents, which much be collected and recycled.
- Use mechanical methods, including hand weeding, of vegetation removal rather than herbicides. Provide erosion control if soils become exposed. Recycle yard trimmings on-site.
- For fertilizer and pest management:

  - Implement an integrated pest management (IPM) program, which is a sustainable approach for managing pests by using biological, cultural, physical, and chemical tools.
  - Follow all federal, state, and local laws and regulations governing the use, storage, and disposal of fertilizers, pesticides, and other chemicals and training of applicators and pest control advisors.
  - Use pesticides only if there is an actual pest problem and not on a regular preventative schedule.
  - Do not use fertilizers or pesticides if rain is expected. Apply fertilizers or pesticides only when wind speeds are low (less than 5 miles per hour). Calibrate fertilizer or pesticide application equipment to avoid excessive application. Employ techniques to minimize off-target application (i.e., spray drift) of fertilizers and pesticides.
  - Do not mix or prepare fertilizers or pesticides for application near storm drains.
  - Purchase only the amount of fertilizers or pesticides that can be reasonably used in the given time period (i.e., within expiration period).
  - Work fertilizers into the soil rather than dumped or broadcast onto the surface. Clean pavement and sidewalk if fertilizer is spilled on these surfaces.
  - Triple rinse containers and use rinse water as product. Dispose of unused fertilizers or pesticides as hazardous waste. Dispose of empty containers according to the instructions on the label.
- Collect removed vegetation if it is near storm drain inlets by either bagging or manually picking up the material. Otherwise, certain vegetation may be left on-site to allow for decomposition and return of nutrients back into the soils.
- Train, including providing periodic refresher training, personnel on proper procedures for conducting building and grounds maintenance activities. This training should also include proper use of chemicals.

Design Considerations

For landscaping, climate-appropriate vegetation must be selected. Generally, climate-appropriate vegetation will reduce the use of fertilizers, pesticides, and other chemicals and require less irrigation necessary to maintain the health of the vegetation. Design the irrigation system to reduce excessive irrigation runoff in accordance with Section 4 of the 2015 Post-Construction Stormwater Standards Manual.

Spill Prevention and Response

Refer to S-1 for Accidental Spills and Leaks. Other spill prevention measures include:

- Regularly inspect chemical storage containers and application equipment to ensure that they are not leaking. If chemical storage containers are leaking, provide secondary containment. If application equipment is damaged or leaking, repair or if necessary, replace the equipment.
- Train, including providing periodic refresher training, personnel on spill prevention and cleanup procedures.

APPENDIX F

Alternative Stormwater Treatment Control Measure Fact Sheets

Table of Contents

LID-1: Infiltration Basin

Description

An infiltration basin is a shallow earthen basin constructed in naturally permeable soil designed for retaining and infiltrating stormwater runoff into the underlying soils and the groundwater table. The bottoms of the basins are typically vegetated with dry-land grasses or irrigated turf grass. Infiltration basins can provide stormwater runoff treatment through a variety of natural mechanisms (i.e., filtration, adsorption, biological degradation) as water flows through the soil profile.

Because stormwater runoff is infiltrated into an infiltration basin, the potential for groundwater contamination or mobilization of existing soil or groundwater contamination must be carefully considered. Infiltration basins are typically not suitable for sites that use or store chemicals or hazardous materials, unless these materials are prevented from entering the basin, or un-remediated “brownfield sites” where there is known groundwater or soil contamination.

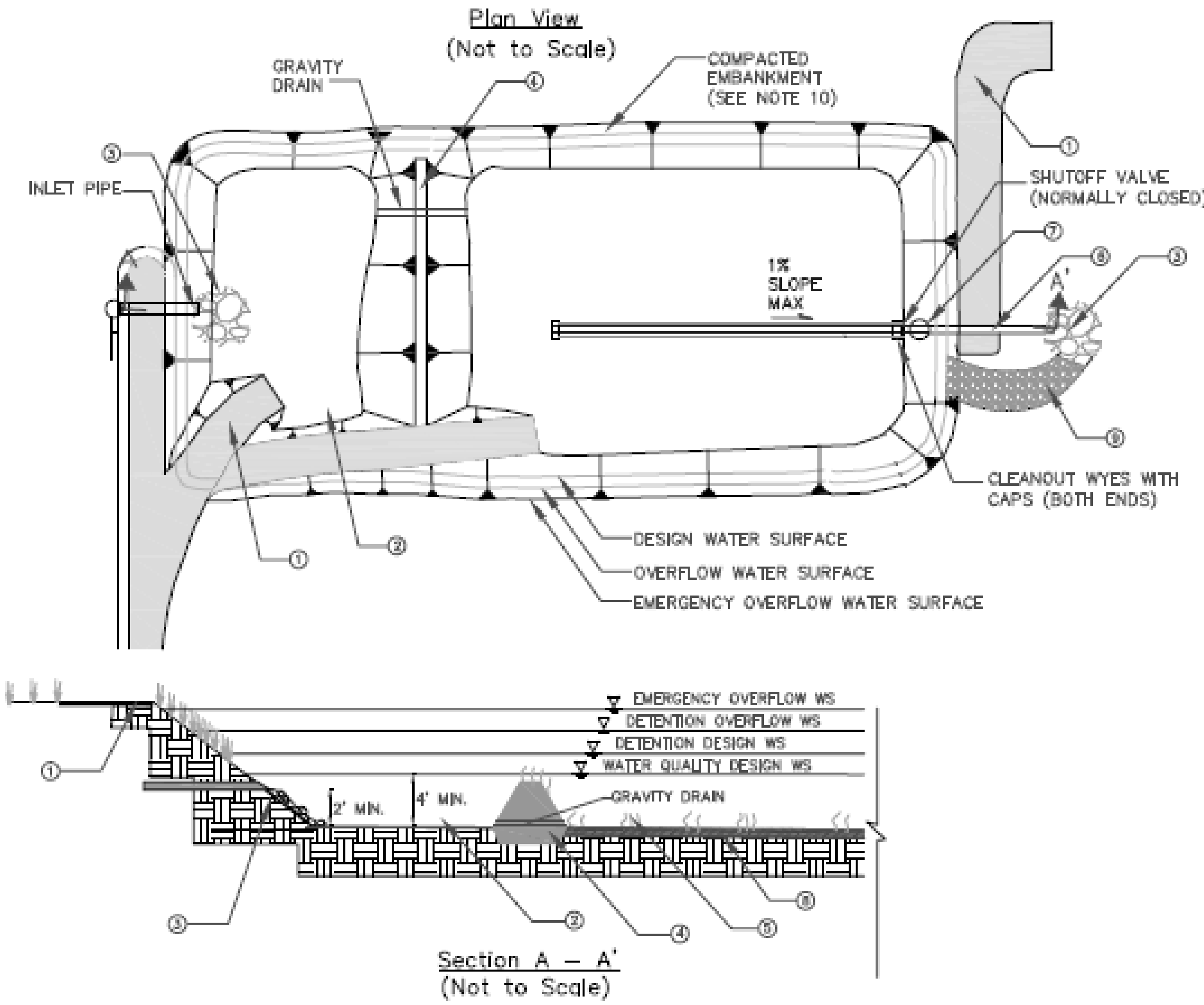
An example schematic of a typical infiltration basin is presented in **Figure F-1**.

Use and Applicability

The Phase II Permit (Provision E.12.e.(f)) identifies bioretention as the standard stormwater treatment control measure unless (1) it is determined to be infeasible and an alternative stormwater treatment control measure that is equivalent to bioretention is proposed and demonstrated (Provision E.12.e.(g)), or (2) a specific exemption applies (Provision E.12.e.(i)). An infiltration basin can be proposed as an alternative to bioretention if it meets <u>all</u> of the following measures of equivalent effectiveness:

- Equal or greater amount of stormwater runoff infiltrated or evapotranspired;
- Equal or lower pollutant concentrations in stormwater runoff that is discharged after biotreatment;
- Equal or greater protection against shock loadings and spills; and
- Equal or greater accessibility and ease of inspection and maintenance.

An infiltration basin, which is designed to infiltrate stormwater runoff, is an acceptable alternative to bioretention.



NOTES:

1. MAINTENANCE RAMP SHOULD BE PAVED. SLOPE SHOULD NOT EXCEED 12%. MAINTENANCE RAMP SHOULD PROVIDE ACCESS TO BOTH THE FIRST CELL AND MAIN BASIN.
2. UPSTREAM PRETREATMENT SHALL BE PROVIDED. SEDIMENT FOREBAY WITH VOLUME EQUAL TO 25% OF TOTAL INFILTRATION BASIN VOLUME MAY BE USED IN LIEU OF UPSTREAM PRETREATMENT. DEPTH SHALL BE 4' MIN TO 8' MAX PLUS AN ADDITIONAL 1 FOOT MIN SEDIMENT STORAGE DEPTH.
3. RIP RAP APRON OR OTHER ENERGY DISSIPATION.
4. EXTEND EARTHEN BERM ACROSS ENTIRE WIDTH OF THE INFILTRATION BASIN.
5. INFILTRATION BASIN BOTTOM AND SIDE SLOPES SHALL BE PLANTED WITH DROUGHT TOLERANT VEGETATION. DEEP ROOTED VEGETATION PREFERRED FOR BASIN BOTTOM. NO TOPSOIL SHALL BE ADDED TO INFILTRATION BASIN BED.
6. SIZE OUTLET PIPE FOR FLOOD CONTROL FLOW
7. WATER QUALITY OUTLET STRUCTURE.
8. OVER EXCAVATE BASIN BOTTOM 1 FOOT. RE—PLACE EXCAVATED MATERIAL UNIFORMLY WITHOUT COMPACTION. AMENDING EXCAVATED MATERIAL WITH 2" — 4" OF COARSE SAND IS RECOMMENDED FOR SOILS WITH BORDER LINE INFILTRATION CAPACITY.
9. INSTALL EMERGENCY OVERFLOW SPILLWAY AS NEEDED. SEE FIGURE 2—4 FOR DETAILS
10. EMBANKMENT SIDE SLOPES SHALL BE NO STEEPER THAN 3H:1V BOTH OUTSIDE AND INSIDE.

Figure F-1. Example Infiltration Basin Schematic

Design Specifications

The following sections provide design specifications for infiltration basins.

Geotechnical

Due to the potential to contaminate groundwater and/or soils, cause slope instability, impact surrounding structures, and potential for insufficient infiltration capacity, a geotechnical investigation must be conducted during the site assessment process to verify the site suitability for infiltration. It is critical to understand how stormwater runoff will move through the soil (horizontally and vertically) and if there are any geological conditions that may inhibit the movement of water. Soil infiltration rates and the depth to the groundwater table must be evaluated to ensure that conditions are satisfactory for proper operation of an infiltration basin. Infiltration basins cannot be located on sites with a slope greater than 10 percent in order to promote infiltration and uniform ponding. A Site Conditions Report summarizing the relevant findings from the geotechnical investigation must be submitted with the Project Stormwater Plan.

Setbacks

Applicable setbacks must be implemented when siting an infiltration basin.

Pretreatment

Pretreatment, which refers to design features that provide settling of large particles before stormwater runoff enters a stormwater treatment control measure, is important to ensure proper operation of an infiltration basin and reduce the long-term maintenance burden. Pretreatment (e.g., vegetated swales, proprietary devices) must be provided to reduce the sediment load entering an infiltration basin in order to prevent the underlying soils from being occluded prematurely and maintain the infiltration rate of the infiltration basin. Additionally for sites with high infiltration rates, pretreatment is required to protect groundwater quality.

An alternative design for an infiltration basin can include a sediment forebay to remove sediment from stormwater runoff. The sediment forebay must be separated from the infiltration basin by a berm or similar feature, and must be equal to 25 percent of the total infiltration basin volume. The sediment forebay must be designed with a minimum length-to-width ratio of 2:1 and must completely drain to the main infiltration basin through an eight-inch (minimum) low-flow outlet. All inlets must enter the sediment forebay. If there are multiple inlets into the sediment forebay, the length-to-width ratio is based on the average flow path length for all inlets.

Flow Entrance and Energy Dissipation

The drainage management area(s) (DMA[s]) tributary to the infiltration basin must be graded to minimize erosion as stormwater runoff enters the basin or by providing energy dissipation devices at the inlet. Piped entrances must include rock, splash blocks, or other erosion controls at the entrance to dissipate energy and disperse flows. If a sediment forebay is included in the design, the energy dissipation devices must be installed at the inlet to the sediment forebay. Flow velocity into the sediment forebay must be 4 ft/s or less.

Drainage

Infiltration basins provide stormwater runoff storage above ground and must completely drain within 48 hours. The underlying soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive stormwater runoff from subsequent storm events, maintain infiltration rates, maintain adequate soil oxygen levels for healthy soil biota and vegetation, and provide proper soil conditions for biodegradation and retention of pollutants. The use of vertical piping, either for distribution or infiltration enhancement, is prohibited. This application may be classified as a Class V Injection Well per 40 CFR Part 146.5(e)(4).

Sizing

Step 1: Determine the SDV_{adj}

Infiltration basins are designed to capture and retain the SDV_{adj}, which is the difference between the SDV (Section 5.2) and the volume of stormwater runoff managed through site design measures (Section 5.5), for the tributary DMA(s).

Step 2: Determine the design infiltration rate

Determine the in-situ infiltration rate of the underlying soil using the Double-Ring Infiltrometer standard (ASTM D3385). Apply a safety factor to the in-situ infiltration rate to determine the design infiltration rate (f_{design}). A typical safety factor of 4 can be used (i.e., multiply in-situ infiltration rate by 0.25). The design infiltration rate must be between 0.5 and 5.0 in/hr. Soil amendments may be used to improve the flow of stormwater runoff into the underlying soil if the design infiltration rate is less than 0.5 in/hr. The infiltration rate will decline between maintenance cycles as the surface of the infiltration basin becomes occluded and particulates accumulate in the infiltrative layer.

Step 3: Calculate the surface area of the infiltration basin

Determine the required size of the infiltration surface by assuming the SDV_{adj} will fill the available ponding depth. The maximum depth of stormwater runoff that can be infiltrated within the maximum drawdown time (48 hrs) is calculated using the following equation:

$$d_{max} = \frac{f_{design}}{12} \times t$$

Where:

d_{max} = Maximum depth of water that can be infiltrated within the required drawdown time [ft];
f_{design} = Design infiltration rate [in/hr]; and
t = Maximum drawdown time (max 48 hrs) [hr].

Select the ponding depth (d_p) such that:

$$d_{max} \geq d_p$$

Where:

d_{max} = Maximum depth of water that can be infiltrated within the maximum drawdown time [ft]; and
d_p = Ponding depth [ft].

Calculate the infiltrating surface area (bottom of the infiltration basin) required:

$$A = \frac{SDV_{adj}}{\frac{f_{design}}{12} \times T + d_p}$$

Where:

A = Surface area of the bottom of the infiltration basin [ft^2];
SDV_{adj} = Adjusted stormwater design volume [ft^3];
f_{design} = Design infiltration rate [in/hr];
T = Time to fill infiltration basin (use 2 hrs) [hr]; and
d_p = Ponding depth [ft].

The bottom of infiltration basin must be the underlying soil that is over-excavated at least one foot in depth with the soil replaced uniformly without compaction. Amending excavated soil with 2 to 4 inches of coarse sand (~15 to 30 percent porosity) is recommended.

Overflow Device

An overflow device is required at the ponding depth near the inlet of the infiltration basin to divert stormwater runoff in excess of the design capacity of the infiltration basin. The following, or equivalent, must be provided:

- A vertical PVC pipe (SDR 26) to act as an overflow riser.
- The overflow riser(s) should be at least eight inches in diameter so it can be cleaned without damage to the pipe.
- The inlet to the overflow riser must be at the ponding depth and capped with a spider cap to exclude floating debris. Spider caps must be screwed on and include a locking mechanism. The overflow device must convey stormwater

runoff in excess of the design capacity of the infiltration basin to an approved discharge location (e.g., another stormwater treatment control measure, storm drain system, receiving water).

Embankments

Embankments are earthen slopes or berms used to detain or redirect the flow of water. For infiltration basins, the embankments must be design with the following specifications:

- All earthworks must be conducted in accordance with the Agency’s Standard Specifications.
- The side slopes must be no steeper than 3:1 (H:V).
- The minimum top width of all berm embankments must be 20 feet, unless otherwise approved by the Agency.
- Berm embankments must be constructed on the consolidated underlying soil or adequately compacted and stable fill soils approved by a licensed geotechnical engineer. The soils must be free of loose surface soil materials, roots, and other organic debris.
- Berm embankments must be constructed of compacted soil (95 percent minimum dry density, Modified Proctor method per ASTM D1557) and placed in 6-inch lifts.
- Berm embankments greater than 4 feet in height must be constructed by excavating a key equal to 50 percent of the berm embankment cross-sectional height and width. This requirement may be waived if specifically recommended by a licensed geotechnical engineer.
- Low growing, climate-appropriate grasses must be planted on downstream embankment slopes.

Vegetation and Landscaping

- A thick mat of climate-appropriate grass must be established on the infiltration basin floor and embankment side slopes following construction. Grasses help prevent erosion and increase evapotranspiration, and their rhizomes discourage compaction within the root zone to help maintain infiltration rates. Additionally, active growing vegetation helps break up surface crusts that accumulate from sedimentation of fine particulates. Note that grass may need to be irrigated during the establishment period.
- Landscaping outside of the infiltration basin, but within the easement/right-of-way, may be included as long as it does not hinder maintenance access and operations.
- Trees or shrubs must not be planted within 10 feet of inlet or outlet pipes or manmade drainage structures such as spillways, flow spreaders, or earthen embankments. Species with roots that seek water (e.g., willow, poplar) may not

be planted within 50 feet of pipes or manmade structures. Weeping willow (*Salix babylonica*) may not be planted in or near infiltration basins.

- Plant species that are not climate-appropriate are not permitted. A sample list of suitable vegetation species is included in Appendix H. Prior to installation, a landscape architect must certify that all proposed vegetation is appropriate for the project site.

Maintenance Access

Maintenance access must be provided to the structures associated with the infiltration basin (e.g., pretreatment, inlet, overflow devices) if it is publicly-maintained. Manhole and catch basin lids must be in or at the edge of the access road. An access ramp to the infiltration basin bottom is required to facilitate the entry of sediment removal and vegetation maintenance equipment without compacting the bottom and side slopes of the infiltration basin.

Unless otherwise required by the Agency, access roads must meet the following design specifications:

- All access ramps and roads must be paved with a minimum of six inches of concrete over three inches of crushed aggregate base material. This requirement may be modified depending on the soil conditions and intended use of the road at the discretion of the Agency.
- The maximum grade is 12 percent unless otherwise approved by the Agency.
- Centerline turning radius must be a minimum of 40 feet.
- Access roads less than 500 feet long must have a 12-foot wide pavement within a minimum 15-foot wide bench. Access roads greater than 500 feet long must have a 16-foot wide pavement within a minimum 20-foot wide bench.
- All access roads must terminate with turnaround areas of 40-feet by 40-feet. A hammer type turnaround area or a circle drive around the top of the infiltration basin is also acceptable.
- Adequate double-drive gates and commercial driveways are required at street crossings. Gates must be located a minimum of 25 feet from the street curb except in residential areas where the gates may be located along the property line provided there is adequate sight distance to see oncoming vehicles at the posted speed limit.

Restricted Construction Materials

Use of pressure-treated wood or galvanized metal at or around an infiltration basin is prohibited.

Construction Considerations

As part of the site planning process, the areas designated for an infiltration basin must be identified. Compaction of underlying soils near and at the infiltration basin at the project site must be avoided. Establish protective perimeters to prevent inadvertent compaction by construction activities. The equipment used to construct an infiltration basin should have extra-wide, low-pressure tires and must not enter the infiltration basin.

The area identified for an infiltration basin must be protected from construction-related sediment loads. During construction activities if possible, divert all flows around the areas intended for the infiltration basin. Sediment control measures should also be implemented to prevent sediment from impacting the areas identified for an infiltration basin. If the underlying soils are compacted or the area identified for an infiltration basin is occluded, ripping or loosening the top two inches of the underlying soils prior to construction of the infiltration basin may be needed to improve infiltration. Final grading must produce a level basin bottom without low spots or depressions. After construction is completed, the entire tributary area to the infiltration basin must be stabilized before allowing stormwater runoff to enter it.

Maintenance Requirements

Maintenance and regular inspections must be conducted to ensure proper function of an infiltration basin. The following activities must be conducted to maintain infiltration basin:

- Conduct regular inspection and routine maintenance of pretreatment device(s).
- If a sediment forebay is included, remove sediment buildup exceeding 50 percent of the sediment storage capacity, as indicated by the steel markers. Remove sediment from the rest of the infiltration basin when it accumulates six inches. Test removed sediments for toxic substance accumulation in compliance with current disposal requirements if visual or olfactory indications of pollution are noticed. If toxic substances are detected at concentrations exceeding thresholds of Title 22, Section 66261 of the California Code of Regulations, dispose of the sediment in a hazardous waste landfill and investigate and mitigate the source of the contaminated sediments to the maximum extent possible.
- Remove and dispose of trash and debris, as needed, but at least prior to the beginning of the wet season.
- Inspect infiltration basin frequently to ensure that water infiltrates into the subsurface completely within the maximum drawdown time. If water is present in the infiltration basin more than 48 hours after a storm, the infiltration basin may be clogged. Maintenance activities triggered by a clogged basin include:
    - Check for debris/sediment accumulation, rake surface and remove sediment (if any), and evaluate potential sources of sediment and

  vegetative or other debris. If suspected upstream sources are outside of the Agency's jurisdiction, additional pretreatment may be necessary.
  - Determine if it is necessary to remove the top layer of the underlying soils to restore infiltrative capacity.

- Eliminate standing water to prevent vector breeding.
- Maintain vegetation as needed to sustain the aesthetic appearance of the site, and as follows:
  - Prune and/or remove vegetation, large shrubs, or trees that limit access or interfere with operation of the infiltration basin.
  - Mow grass to four to nine inches high and remove grass clippings.
  - Rake and remove fallen leaves and debris from deciduous plant foliage.
  - Remove invasive, poisonous, nuisance, or noxious vegetation and replace with climate-appropriate vegetation.
  - Remove dead vegetation if it exceeds 10 percent of area coverage. Replace vegetation immediately to maintain cover density and control erosion where soils are exposed.
  - Do not use herbicides or other chemicals to control vegetation
  - Re-establish vegetation, which may require replanting and/or reseeding, following sediment removal activities.
- Inspect inlet structure for erosion and re-grade if necessary.
- Inspect overflow devices for obstructions or debris, which should be removed immediately. Repair or replace damaged pipes upon discovery.

The Agencies require execution of a Maintenance Access Agreement to be recorded by the property owner for the on-going operation and maintenance of all privately-maintained stormwater treatment control measures. The property owner is responsible for compliance with the Maintenance Access Agreement. An example Maintenance Access Agreement is presented in Appendix G.

LID-2: Infiltration Trench

Description

An infiltration trench is a narrow trench constructed in naturally pervious soils designed for retaining and infiltrating stormwater runoff into the underlying soils and groundwater table. Infiltration trenches, which are typically filled with gravel and sand, provide stormwater runoff treatment through various natural mechanisms (i.e., filtration, adsorption, biological degradation) as water flows through the soil profile.

An infiltration trench differs from an infiltration basin in that the former is used for small drainage areas and stores stormwater runoff underground within the void spaces of rocks or stones while the latter is used for larger drainage areas and stormwater runoff is stored within a visible ponded surface.

Because stormwater runoff is infiltrated into an infiltration trench, the potential for groundwater contamination or mobilization of existing soil or groundwater contamination must be carefully considered. Infiltration trenches are typically not suitable for sites that use or store chemicals or hazardous materials, unless they are prevent from entering the trench, or un-remediated “brownfield sites” where it is known groundwater or soil contamination.

An example schematic of a typical infiltration trench is presented in **Figure F-2**.

Use and Applicability

The Phase II Permit (Provision E.12.e.(f)) identifies bioretention as the standard stormwater treatment control measure unless (1) it is determined to be infeasible and an alternative stormwater treatment control measure that is equivalent to bioretention is proposed and demonstrated (Provision E.12.e.(g)), or (2) a specific exemption applies (Provision E.12.e.(i)). An infiltration trench can be proposed as an alternative to bioretention if it meets all of the following measures of equivalent effectiveness:

- Equal or greater amount of stormwater runoff infiltrated or evapotranspired;
- Equal or lower pollutant concentrations in stormwater runoff that is discharged after biotreatment;
- Equal or greater protection against shock loadings and spills; and
- Equal or greater accessibility and ease of inspection and maintenance.

An infiltration trench, which is designed to infiltrate stormwater runoff, is an acceptable alternative to bioretention.

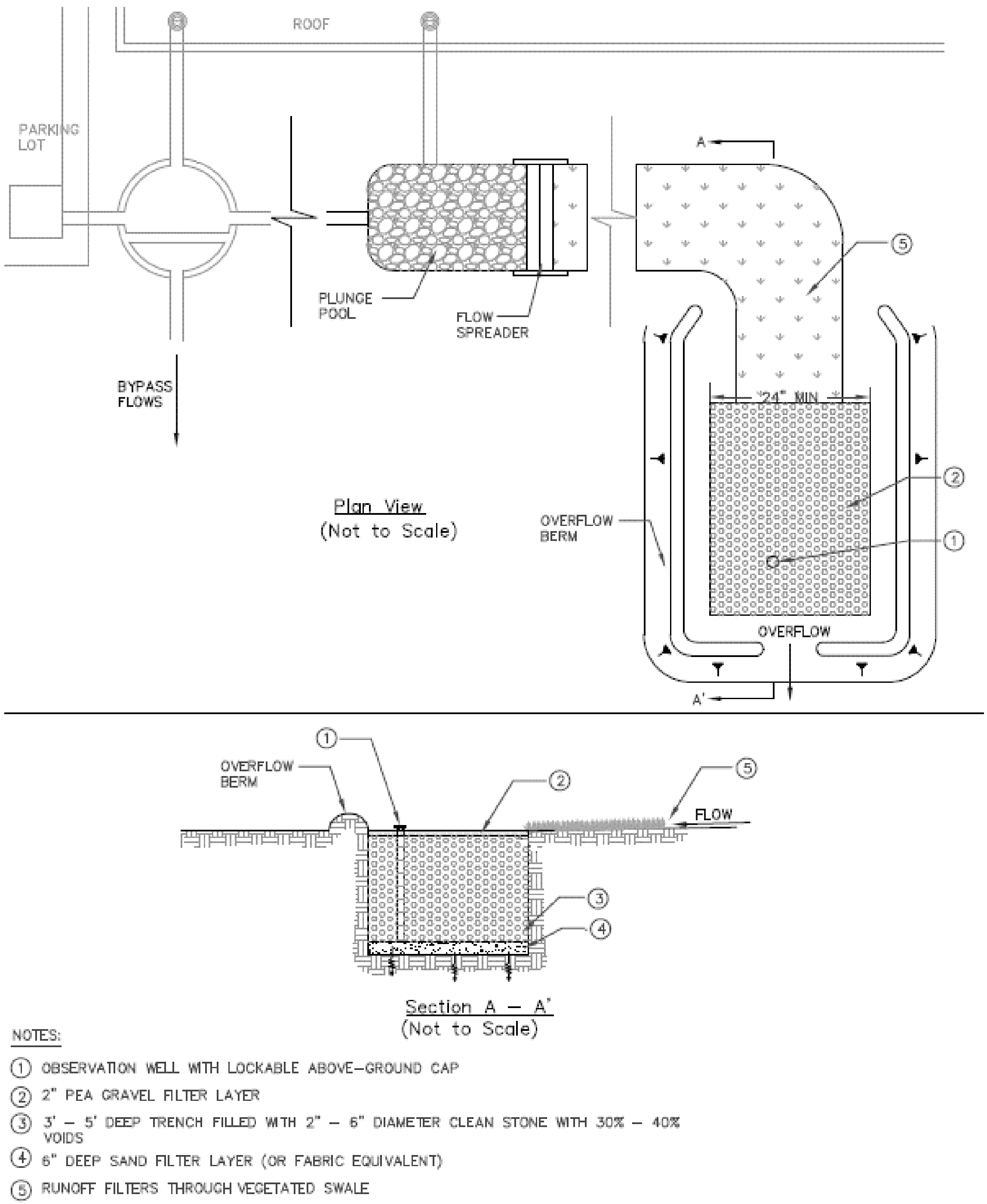


Figure F-2. Example Infiltration Trench Schematic

Design Specifications

The following sections provide design specifications for infiltration trenches.

Geotechnical

Due to the potential to contaminate groundwater and/or soils, cause slope instability, impact surrounding structures, and potential for insufficient infiltration capacity, a geotechnical investigation must be conducted during the site assessment process to verify the site suitability for infiltration. It is critical to understand how stormwater runoff will move through the soil (horizontally and vertically) and if there are any geological conditions that may inhibit the movement of water. Soil infiltration rates and the depth to the groundwater table must be evaluated to ensure that conditions are satisfactory for proper operation of an infiltration trench. Infiltration trenches cannot be located on sites with a slope greater than 15 percent. A Site Conditions Report summarizing relevant findings from the geotechnical investigation must be submitted with the Project Stormwater Plan.

Setbacks

Applicable setbacks must be implemented when siting an infiltration trench.

Pretreatment

Pretreatment, which refers to design features that provide settling of large particles before stormwater runoff enters a stormwater treatment control measure, is important to ensure proper operation of an infiltration trench and reduce the long-term maintenance burden. Pretreatment (e.g., vegetated swales, proprietary devices) must be provided to reduce the sediment load entering an infiltration trench in order to prevent the underlying soils from being occluded prematurely and maintain the infiltration rate of the infiltration trench. Additionally for sites with high infiltration rates, pretreatment is required to protect groundwater quality.

Flow Entrance and Energy Dissipation

The drainage management area(s) (DMA[s]) tributary to the infiltration trench must be graded to minimize erosion as stormwater runoff enters the trench by creating sheet flow conditions rather than a concentrated stream condition or by providing energy dissipation devices at the inlet. Typically, a minimum slope of 1 percent for pervious surfaces and 0.5 percent for impervious surfaces to the inlet of the infiltration trench should be maintained. The following types of flow entrances can be used for infiltration trenches:

- Level spreaders (e.g., slotted curbs) can be used to facilitate sheet flow.

- Dispersed low velocity flow across a landscape area. Dispersed flow may not be possible given space limitations or if the infiltration trench is controlling roadway or parking lot flows where curbs are mandatory.
- Dispersed flow across pavement or gravel and past wheel stops for parking areas.
- Flow spreading trench around perimeter of infiltration trench that may be filled with pea gravel or vegetated with 3:1 side slopes.
- Curb cuts for roadside or parking lot areas. Curb cuts must include rock or other erosion controls in the channel entrance to dissipate energy. The flow entrance should drop two to three inches from the curb line and provide an area for settling and periodic removal of sediment and coarse material before flow disperses to the remainder of the infiltration trench.
- Piped entrances that must include rock, splash blocks, or other erosion controls at the entrance to dissipate energy and disperse flows.

Drainage

Infiltration trenches provide stormwater runoff storage in the voids of the rock fill and must completely drain within 48 hours. The underlying soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive stormwater runoff from subsequent storm events, maintain infiltration rates, and provide proper soil conditions for biodegradation and retention of pollutants. The use of vertical piping, either for distribution or infiltration enhancement, is prohibited. This application may be classified as a Class V Injection Well per 40 CFR Part 146.5(e)(4).

Sizing

Step 1: Determine the SDV_{adj}

Infiltration trenches are designed to capture and retain the SDV_{adj}, which is the difference between the SDV (Section 5.2) and the volume of stormwater runoff managed through site design measures (Section 5.5), for the tributary DMA(s).

Step 2: Determine the design infiltration rate

Determine the in-situ infiltration rate of the underlying soil using the Double-Ring Infiltrometer standard (ASTM D3385). Apply a safety factor to the in-situ infiltration rate to determine the design infiltration rate (f_{design}). A typical safety factor of 4 can be used (i.e., multiply in-situ infiltration rate by 0.25). The design infiltration rate must be between 0.5 and 5.0 in/hr. Soil amendments may be used to improve the flow of stormwater runoff into the underlying soil if the design infiltration rate is less than 0.5 in/hr. The infiltration rate will decline between maintenance cycles as the surface of the infiltration trench becomes occluded and particulates accumulate in the infiltrative layer.

Step 3: Calculate the surface area

Determine the size of the required infiltration surface by assuming the SDV_{adj} will fill the available void spaces in the media layers. The maximum depth of stormwater runoff that can be infiltrated within the maximum drawdown time (48 hrs) is calculated using the following equation:

$$d_{max} = \frac{f_{design}}{12} \times t$$

Where:

d_{max} = Maximum depth of water that can be infiltrated within the maximum drawdown time [ft];
f_{design} = Design infiltration rate [in/hr]; and
t = Maximum drawdown time (max 48 hrs) [hr].

The maximum depth of water that can be infiltrated within the maximum drawdown time is constrained by the following equation:

$$d_{max} \geq n_t \times d_t$$

Where:

d_{max} = Maximum depth of water that can be infiltrated within the maximum drawdown time [ft];
n_t = Infiltration trench media layer porosity; and
d_t = Depth of infiltration trench fill [ft].

Calculate the infiltrating surface area (bottom of the infiltration trench) required:

$$A = \frac{SDV_{adj}}{\frac{f_{design}}{12} \times T + n_t \times d_t}$$

Where:

A = Surface area of the bottom of the infiltration trench [ft^2];
SDV_{adj} = Adjusted stormwater design volume [ft^3];
f_{design} = Design infiltration rate [in/hr];
T = Time to fill the infiltration trench (use 2 hrs) [hr];
n_t = Infiltration trench fill porosity; and
d_t = Depth of infiltration trench fill [ft].

Infiltration trenches must be designed and constructed to be at least 24 inches wide and 3 to 5 feet deep with a longitudinal slope not to exceed 3 percent. The media layers must have the following composition and thickness:

- Top layer: 2 inches of pea gravel

- Middle layer: 3 to 5 feet of washed 2- to 6-inch gravel with void spaces of approximately 30 to 40 percent
- Bottom layer: 6 inches of sand or hydraulic restriction layer.

The bottom of infiltration trench, below the media layers, must be the underlying soils that is over-excavated at least one foot in depth with the soil replaced uniformly without compaction. Amending the excavated soil with 2 to 4 inches of coarse sand (~15 to 30 percent porosity) is recommended.

Hydraulic Restriction Layer

The entire infiltrative area, including the side slopes must be lined with a hydraulic restriction layer to prevent soil from migrating into the top layer and reducing the infiltration capacity. If a hydraulic restriction layer is used in lieu of six inches of sand, it should be installed at the bottom of the infiltration trench prior to placing the media layers. The hydraulic restriction layer should be installed generously with overlapping seams. The specifications of the hydraulic restriction layer are presented in **Table F-1**.

Table F-1. Hydraulic Restriction Layer Specifications for Infiltration Trenches

Parameter	Test Method	Specifications
Material		Nonwoven geomembrane liner
Unit weight		8 oz/yd^3 (minimum)
Filtration rate		0.08 in/sec (minimum)
Puncture strength	ASTM D-751 (Modified)	125 lbs (minimum)
Mullen burst strength	ASTM D-751	400 lb/in^2 (minimum)
Tensile strength	AST D-1682	300 lbs (minimum)
Equiv. opening size	US Standard Sieve	No. 80 (minimum)

Observation Well

An observation well must be installed to check water levels, drawdown time, and evidence of clogging. The observation well is a vertical section of perforated PVC pipe, four- to six-inch diameter, installed flush with the top of the infiltration trench on a footplate and with a locking, removable cap.

Overflow Device

An overflow device is required near the inlet of the infiltration trench to divert stormwater runoff in excess of the design capacity of the infiltration trench. For rooftop drainage, the distance between the downspouts and the overflow device should be maximized in order to increase the opportunity for stormwater runoff retention and infiltration. The following, or equivalent, must be provided:

- A vertical PVC pipe (SDR 26) to act as an overflow riser.

- The overflow riser(s) should be at least eight inches in diameter so it can be cleaned without damage to the pipe.
- The inlet to the overflow riser must be at the top of the infiltration trench with a spider cap to exclude floating debris. Spider caps must be screwed and include a locking mechanism. The overflow device must convey stormwater runoff in excess of the design capacity of the infiltration basin to an approved discharge location (e.g., another stormwater treatment control measure, storm drain system, receiving water).

Vegetation

Infiltration trenches must be kept free of vegetation. Trees and other large vegetation must be planted away from infiltration trenches such that drip lines do not overhang the infiltration area.

Maintenance Access

The infiltration trench must be safely accessible during wet and dry weather conditions if it is publicly-maintained. An access road along the entire length of the infiltration trench is required unless the trench is located along an existing road or parking lot that can be safely used for maintenance access. If the infiltration trench becomes plugged and fails, access is needed to excavate the infiltration trench and replace the media layers. When rehabilitating an infiltration trench, all dimensions of the infiltration trench must be increased by a minimum of two inches to provide a fresh surface for infiltration. To prevent damage and compaction, access must able to accommodate a backhoe working at “arm’s length” from the infiltration trench.

Restricted Construction Materials

Use of pressure-treated wood or galvanized metal at or around an infiltration trench is prohibited.

Construction Considerations

As part of the site planning process, the areas designated for an infiltration trench must be identified. Compaction of underlying soils near and at the infiltration trench at the project site must be avoided. Establish protective perimeters to prevent inadvertent compaction by construction activities. The equipment used to construct an infiltration trench should have extra-wide, low-pressure tires and must not enter the infiltration trench.

The area identified for an infiltration trench must be protected from construction-related sediment loads. During construction activities if possible, divert all flows around the areas intended for the infiltration trench. Sediment control measures should also be implemented to prevent sediment from impacting the areas identified for an infiltration trench. If the underlying soils are compacted or the area identified for an infiltration trench is occluded, ripping or loosening the top two inches of the underlying soils prior to construction of the infiltration trench may be needed to improve infiltration. Final grading must produce a level bottom without low spots or depressions. Clean, washed gravel should be placed in the excavated trench in lifts and lightly compacted with a plate compactor. Unwashed gravel can result in clogging. After construction is completed, the entire tributary area to the infiltration trench must be stabilized before allowing stormwater runoff to enter it.

Maintenance Requirements

Maintenance and regular inspections must be conducted to ensure proper function of an infiltration trench. The following activities must be conducted to maintain an infiltration trench:

- Conduct regular inspection and routine maintenance for pretreatment device(s).
- Inspect infiltration trench and its observation well frequently to ensure that water infiltrates into the subsurface completely within the maximum drawdown time. If water is present in the observation well more than 48 hours after a storm, the infiltration trench may be clogged. Maintenance activities triggered by a potentially clogged facility include:
    - Check for debris/sediment accumulation, rake surface and remove sediment (if any), and evaluate potential sources of sediment and vegetative or other debris. If suspected upstream sources are outside of the Agency’s jurisdiction, additional pretreatment may be necessary.
    - Assess the condition of the top layer for sediment buildup and crusting. Remove the top layer of pea gravel and replace. If slow draining conditions persist, the entire infiltration trench may need to be excavated and replaced.
- Eliminate standing water to prevent vector breeding.
- Remove and dispose of trash and debris as needed, but at least prior to the beginning of the wet season.
- Inspect inlet structure for erosion and re-grade if necessary.
- Inspect overflow devices for obstructions or debris, which should be removed immediately. Repair or replace damaged pipes upon discovery.

The Agencies require execution of a Maintenance Access Agreement to be recorded by the property owner for the on-going operation and maintenance of all privately-maintained stormwater treatment control measures. The property owner is responsible for compliance with the Maintenance Access Agreement. An example Maintenance Access Agreement is presented in Appendix G.

LID-3: Dry Well

Description

A dry well is a bored, drilled, or driven shaft or hole whose depth is greater than its width. A dry well may either be a small excavated pit filled with aggregate or a prefabricated storage chamber or pipe segment. Dry well design and function are similar to infiltration trenches in that they are designed to temporarily store and subsequently infiltrate stormwater runoff. In particular, dry wells can be used to reduce the volume of stormwater runoff from building roofs. While generally not a significant source of pollution, roofs are one of the most important sources of new or increased stormwater runoff volume from land development sites. Dry wells can be used to indirectly enhance water quality by reducing the volume of stormwater runoff to be treated by other downstream stormwater treatment control measures.

Because stormwater runoff is infiltrated into by a dry well, the potential for groundwater contamination or mobilization of existing groundwater or soil contamination must be carefully considered. Dry wells are typically not suitable for sites that use or store chemicals or hazardous materials, unless they are prevent from entering the well, or un-remediated “brownfield sites” where it is known groundwater or soil contamination.

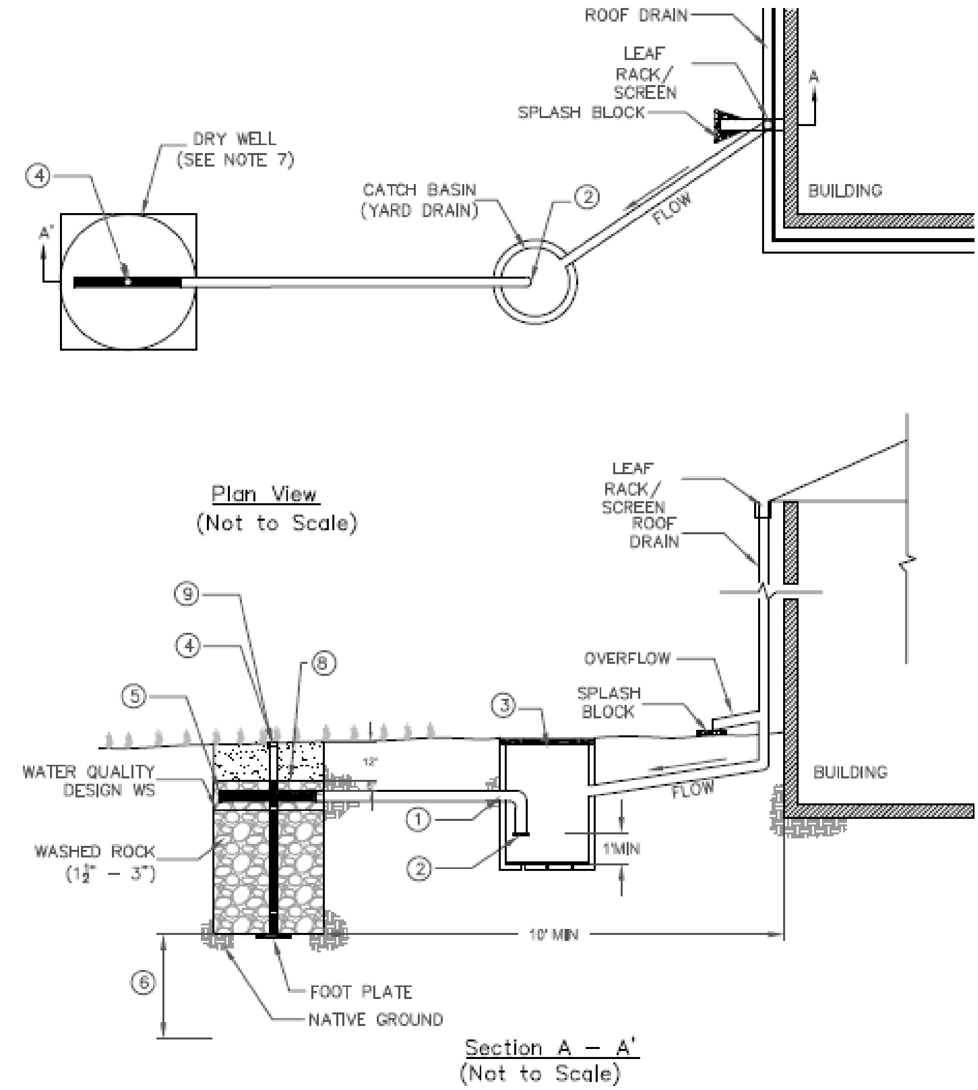
An example schematic of a typical dry well is presented in **Figure F-3**.

Use and Applicability

The Phase II Permit (Provision E.12.e.(f)) identifies bioretention as the standard stormwater treatment control measure unless (1) it is determined to be infeasible and an alternative stormwater treatment control measure that is equivalent to bioretention is proposed and demonstrated (Provision E.12.e.(g)), or (2) a specific exemption applies (Provision E.12.e.(i)). A dry well can be proposed as an alternative to bioretention if it meets <u>all</u> of the following measures of equivalent effectiveness:

- Equal or greater amount of stormwater runoff infiltrated or evapotranspired;
- Equal or lower pollutant concentrations in stormwater runoff that is discharged after biotreatment;
- Equal or greater protection against shock loadings and spills; and
- Equal or greater accessibility and ease of inspection and maintenance.

A dry well, which is designed to infiltrate stormwater runoff, is an acceptable alternative to bioretention.



NOTES:

1. MINIMUM 4" – 6" DIAMETER PVC PIPE. INSTALL AT FLAT SLOPE.
2. INSTALL FINE MESH SCREEN AT INLET TO DRY WELL. SET INLET ELEVATION AT 1' MINIMUM ABOVE CATCH BASIN BOTTOM.
3. CATCH BASIN (YARD DRAIN) INSTALLED WITH A SOLID LID FLUSH WITH GROUND SURFACE.
4. 4–6" VERTICAL PERFORATED PVC INSPECTION WELL WITH SCREW LID (NUT DOWN) FLUSH WITH GROUND SURFACE.
5. CAP END OF 4–6" HORZONTAL PERFORATED PVC DISPERSION PIPE.
6. MINIMUM 10' ABOVE SEASONAL HIGH GROUNDWATER TABLE AND 3' ABOVE BEDROCK.
7. DRY WELL CONFIGURATION MAY VARY (E.G. PRE–FAB MAY BE CIRCULAR).
8. CHOKING STONE LAYER SHALL BE PLACED ON TOP OF THE DRY WELL TO SEPARATE IT FROM THE TOPSOIL AND PREVENT CLOGGING.

Figure F-3. Dry Well Schematic

Design Specifications

The following sections provide design specifications for dry wells.

Geotechnical

Due to the potential to contaminate groundwater and/or soils, cause slope instability, impact surrounding structures, and potential for insufficient infiltration capacity, a geotechnical investigation must be conducted during the site assessment process to verify the site suitability for infiltration. It is critical to understand how stormwater runoff will move through the soil (horizontally and vertically) and if there are any geological conditions that may inhibit the movement of water. Soil infiltration rates and the depth to the groundwater table must be evaluated to ensure that conditions are satisfactory for proper operation of a dry well. Dry wells cannot be located on sites with a slope greater than 15 percent. A Site Conditions Report summarizing the relevant findings from the geotechnical investigation must be submitted with the Project Stormwater Plan.

Setbacks

Applicable setbacks must be implemented when siting a dry well.

Pretreatment

Pretreatment, which refers to design features that provide settling of large particles before stormwater runoff enters a stormwater treatment control measure, is important to ensure proper operation of a dry well and reduce the long-term maintenance burden. If dry wells are used to manage stormwater runoff from rooftops that drain directly to the dry well, pretreatment may not be necessary because stormwater runoff from rooftops are not expected to have large particles. For other applications of a dry well, pretreatment (e.g., vegetated swales, proprietary devices) is required to be provided to reduce the sediment load entering a dry well in order to prevent the underlying soils from being occluded prematurely and maintain the infiltration rate of the dry well. Additionally for sites with high infiltration rates, pretreatment is required to protect groundwater quality.

Flow Entrance and Energy Dissipation

The drainage management area(s) (DMA[s]) tributary to a dry well must be graded to minimize erosion as stormwater runoff enters the dry well by creating sheet flow conditions rather than a concentrated stream condition or by providing energy dissipation devices at the inlet. Typically, maintain a minimum slope of 1 percent for pervious surfaces and 0.5 percent for impervious surfaces to the inlet of the dry well. The following types of flow entrances can be used for dry wells:

- Level spreaders (e.g., slotted curbs) can be used to facilitate sheet flow.

- Dispersed low velocity flow across a landscape area. Dispersed flow may not be possible given space limitations or if the dry well is controlling roadway or parking lot flows where curbs are mandatory.
- Dispersed flow across pavement or gravel and past wheel stops for parking areas.
- Curb cuts for roadside or parking lot areas. Curb cuts must include rock or other erosion controls in the channel entrance to dissipate energy. The flow entrance should drop two to three inches from the curb line and provide an area for settling and periodic removal of sediment and coarse material before flow disperses to the remainder of the dry well.
- Flow spreading trench around perimeter of dry well that may be filled with pea gravel or vegetated with 3:1 side slopes.
- Piped entrances that must include rock, splash blocks, or other erosion controls at the entrance to dissipate energy and disperse flows.

If a dry well receives stormwater runoff from an underground pipe (i.e., stormwater runoff does not enter the top of the dry well from the ground surface), a fine mesh screen must be installed at the inlet. The inlet elevation should be 18 inches below the ground surface (i.e., below 12 inches of surface soil and 6 inches of dry well media).

Drainage

Dry wells provide stormwater runoff storage in the voids of the media layers and must completely drain within 48 hours. Soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive stormwater runoff from subsequent storm events, maintain infiltration rates, and provide proper soil conditions for biodegradation and retention of pollutants. The use of vertical piping, either for distribution or infiltration enhancement, is prohibited. This application may be classified as a Class V Injection Well per 40 CFR Part 146.5(e)(4).

Sizing

Step 1: Determine the SDV_{adj}

Dry wells are designed to capture and retain the SDV_{adj}, which is the difference between the SDV (Section 5.2) and the volume of stormwater runoff managed through site design measures (Section 5.5), for the tributary DMA(s).

Step 2: Determine the design infiltration rate

Determine the in-situ infiltration rate of the underlying soil using the Double-Ring Infiltrometer standard (ASTM D3385). Apply a safety factor to the in-situ infiltration rate to determine the design infiltration rate (f_{design}). A typical safety factor of 4 can be used (i.e., multiply in-situ infiltration rate by 0.25). The design infiltration rate must be between 0.5 and 5.0 in/hr. Soil amendments may be used to improve the flow of stormwater runoff into the underlying soil if the design infiltration rate is less than 0.5 in/hr. The infiltration rate will decline between maintenance cycles as the surface of the dry well becomes occluded and particulates accumulate in the infiltrative layer.

Step 3: Calculate the surface area

Determine the required size of the infiltration surface by assuming the SDV_{adj} will fill the available void spaces of the media layers. The maximum depth of stormwater runoff that can be infiltrated within the maximum drawdown time of 48 hours is calculated using the following equation:

$$d_{max} = \frac{f_{design}}{12} \times t$$

Where:

d_{max} = Maximum depth of water that can be infiltrated within the required drawdown time [ft];
f_{design} = Design infiltration rate [in/hr]; and
t = Maximum drawdown time (max 48 hrs) [hr].

The maximum depth of water that can be infiltrated within the maximum drawdown time is constrained by the following equation:

$$d_{max} \geq n_t \times d_t$$

Where:

d_{max} = Maximum depth of water that can be infiltrated within the maximum drawdown time [ft];
n_t = Dry well media porosity; and
d_t = Depth of dry well media [ft].

Calculate the infiltrating surface area (bottom of the dry well) required:

$$A = \frac{SDV_{adj}}{\frac{f_{design}}{12} \times T + n_t \times d_t}$$

Where:

A = Surface area of the bottom of the dry well [ft^2];
SDV_{adj} = Adjusted stormwater design volume [ft^3];
f_{design} = Design infiltration rate [in/hr];
T = Time to fill stormwater treatment control measure (use 2 hrs) [hr];
n_t = Dry well media porosity; and
d_t = Depth of dry well media [ft].

Dry well configurations vary, but generally have length and width top dimensions close to a square. The media layers must have the following composition and thickness, unless they are prefabricated dry wells:

- Top layer: 2 inches of pea gravel
- Middle layer: 3 to 5 feet of washed 2- to 6-inch gravel; void spaces should be approximately 30 to 40 percent
- Bottom layer: 6 inches of sand or hydraulic restriction layer.

Prefabricated dry wells are often circular with porosities of 80 to 95 percent.

The bottom of dry well must be the underlying soils that is over-excavated at least one foot in depth with the soil replaced uniformly without compaction. Amending the excavated soil with two to four inches of coarse sand is (~15 to 30 percent porosity) recommended.

Hydraulic Restriction Layer

The entire infiltrative area, including the side slopes must be lined with a hydraulic restriction layer to prevent soil from migrating into the top layer and reducing the infiltration capacity. If a hydraulic restriction layer is used in lieu of six inches of sand, it must be installed at the bottom of the dry well prior to placing the media layers. The hydraulic restriction layer should be installed generously with overlapping seams. The specifications of the hydraulic restriction layer are presented in **Table F-2**.

Table F-2. Hydraulic Restriction Layer Specifications for Dry Wells

Parameter	Test Method	Specifications
Material		Nonwoven geomembrane liner
Unit weight		8 oz/yd^3 (minimum)
Filtration rate		0.08 in/sec (minimum)
Puncture strength	ASTM D-751 (Modified)	125 lbs (minimum)
Mullen burst strength	ASTM D-751	400 lb/in^2 (minimum)
Tensile strength	AST D-1682	300 lbs (minimum)
Equiv. opening size	US Standard Sieve	No. 80 (minimum)

Observation Well

An observation well must be installed to check water levels, drawdown time, and evidence of clogging. The observation well is a vertical section of perforated PVC pipe, four- to six-inch diameter, installed flush with the top of the dry well on a footplate and with a locking, removable cap.

Overflow Device

An overflow device is required near the inlet of the dry well to divert stormwater runoff in excess of the design capacity of the dry well. The following, or equivalent, must be provided:

- A vertical PVC pipe (SDR 26) to act as an overflow riser.
- The overflow riser(s) should be at least eight inches in diameter so it can be cleaned without damage to the pipe.
- The inlet to the overflow riser must be at the top of the dry well with a spider cap to exclude floating debris. Spider caps must be screwed on and include a locking mechanism. The overflow device must convey stormwater runoff in excess of the design capacity of the infiltration basin to an approved discharge location (e.g., another stormwater treatment control measure, storm drain system, receiving water).

Vegetation

Dry wells must be kept free of vegetation. Trees and other large vegetation should be planted away from dry wells such that drip lines do not overhang the dry well.

Maintenance Access

The dry well must be safely accessible during wet and dry weather conditions if it is publicly-maintained. If the dry well becomes plugged and fails, access is needed to excavate the dry well and replace the media layers. To prevent damage and compaction, access must able to accommodate a backhoe working at “arm’s length” from the dry well.

Restricted Construction Materials

Use of pressure-treated wood or galvanized metal at or around a dry well is prohibited.

Construction Considerations

As part of the site planning process, the areas designated for a dry well must be identified. Compaction of underlying soils near and at the dry well at the project site must be avoided. Establish protective perimeters to prevent inadvertent compaction by construction activities. The equipment used to construct a dry well should have extra-wide, low-pressure tires and must not enter the dry well.

The area identified for a dry well must be protected from construction-related sediment loads. During construction activities if possible, divert all flows around the areas intended for the dry well. Sediment control measures should also be implemented to prevent sediment from impacting the areas identified for a dry well. If the underlying soils are compacted or the area identified for a dry well is occluded, ripping or loosening the top two inches of the underlying soils prior to construction of the dry well may be needed to improve infiltration. Final grading must produce a level bottom without low spots or depressions. Clean, washed gravel should be placed in the excavated dry well in lifts and lightly compacted with a plate compactor. Unwashed gravel can result in clogging. After construction is completed, the entire tributary area to the dry well must be stabilized before allowing stormwater runoff to enter it.

Maintenance Requirements

Maintenance and regular inspections are required to ensure proper function of a dry well. The following activities must be conducted to maintain a dry well:

- Conduct regular inspection and routine maintenance for pretreatment device(s).
- Inspect dry well and its observation well frequently to ensure that water infiltrates into the subsurface completely within maximum drawdown time. If water is present in the observation well more than 48 hours after a storm, the dry well may be clogged. Maintenance activities triggered by a potentially clogged facility include:
    - Check for debris/sediment accumulation and remove sediment (if any) and evaluate potential sources of sediment and vegetative or other debris. If suspected upstream sources are outside of the Agency's jurisdiction, additional pretreatment operations may be necessary.
    - Assess the condition of the top layer for sediment buildup and crusting. Remove the top layer of pea gravel and replace. If slow draining conditions persist, the entire dry well may need to be excavated and replaced.
- Eliminate standing water to prevent vector breeding.
- Remove and dispose of trash and debris as needed, but at least prior to the beginning of the wet season.
- Inspect inlet structure for erosion and re-grade if necessary.

The Agencies require execution of a Maintenance Access Agreement to be recorded by the property owner for the on-going operation and maintenance of all privately-maintained stormwater treatment control measures. The property owner is responsible for compliance with the Maintenance Access Agreement. An example Maintenance Access Agreement is presented in Appendix G.

T-1: Stormwater Planter

Description

A stormwater planter, or a flow-through planter, is a stormwater treatment control measure that is completely contained within an impermeable structure with an underdrain. Stormwater planters are similar to bioretention facilities and function as a soil- and plant-based filtration device that remove pollutants though a variety of physical, biological, and chemical treatment processes. A stormwater planter consists of a ponding area, mulch layer, planting media, plants, and an underdrain within the planter box. As stormwater runoff passes through the planting media, pollutants are filtered, adsorbed, and biodegraded by the soil and plants. Stormwater planters contain climate-appropriate vegetation that does not require fertilizers and can withstand wet soils for at least 48 hours. Stormwater planters are only capable of treating stormwater runoff from smaller areas (up to 15,000 square feet of impervious surfaces).

Stormwater planters may be placed adjacent to or near buildings, other structures, or sidewalks. Stormwater planters used directly adjacent to buildings beneath downspouts, which will disconnect the downspout, must be properly lined on the building side, and the overflow outlet discharges away from the building to ensure water does not percolate into footings or foundations. They can also be placed further away from buildings by conveying roof runoff in shallow engineered open conveyances, shallow pipes, or other drainage structures.

An example schematic of a typical stormwater planter is presented in **Figure F-4**.

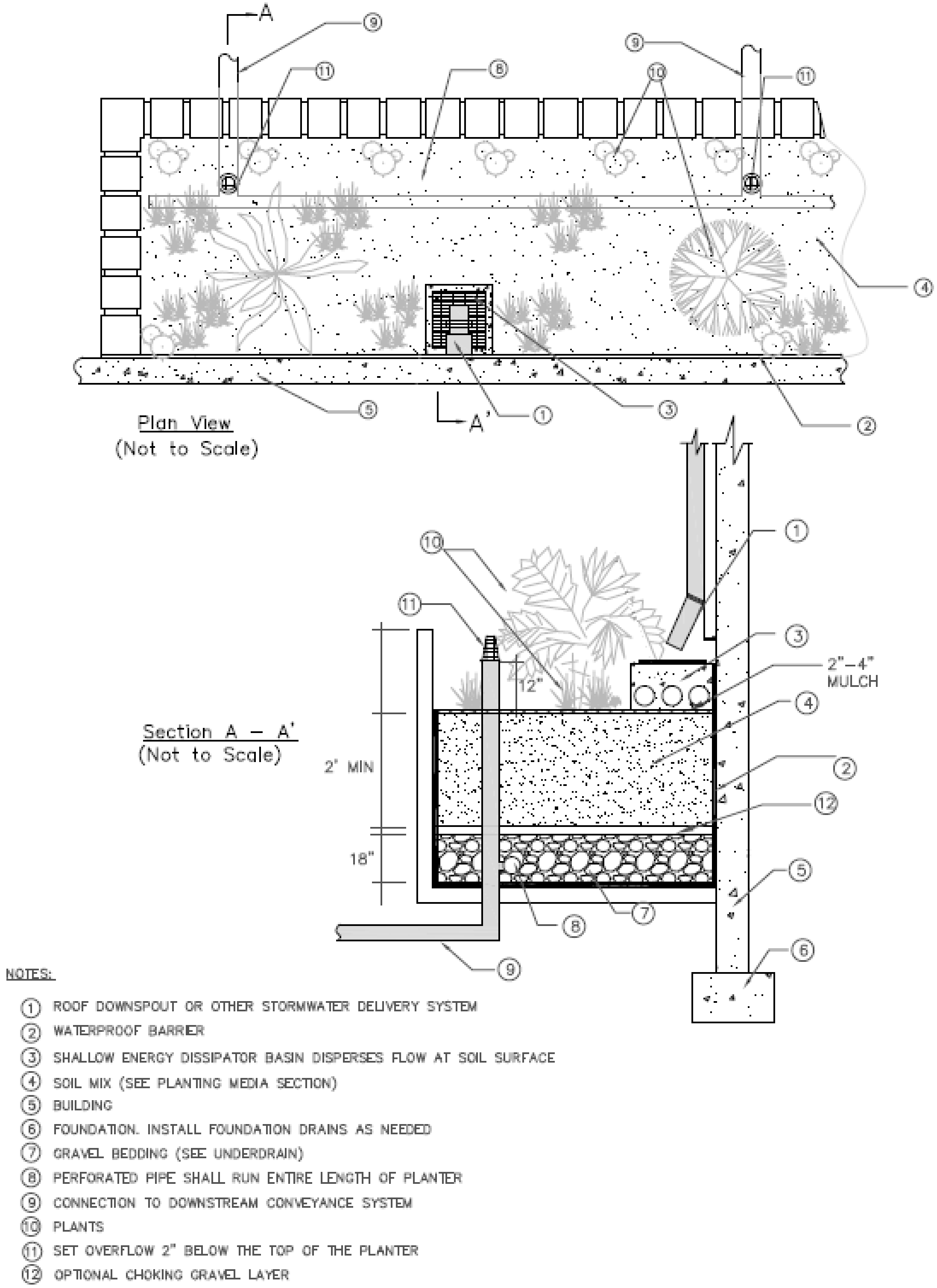


Figure F-4. Example Stormwater Planter Schematic

Use and Applicability

The Phase II Permit (Provision E.12.e.(f)) identifies bioretention as the standard stormwater treatment control measure unless (1) it is determined to be infeasible and an alternative treatment control measure that is equivalent to bioretention is proposed and justified (Provision E.12.e.(g)), or (2) a specific exemption applies (Provision E.12.e.(i)). Stormwater planters can be proposed as an alternative to bioretention if it meets all of the following measures of equivalent effectiveness:

- Equal or greater amount of stormwater runoff infiltrated or evapotranspired;
- Equal or lower pollutant concentrations in stormwater runoff that is discharged after biotreatment;
- Equal or greater protection against shock loadings and spills; and
- Equal or greater accessibility and ease of inspection and maintenance.

The Phase II Permit (Provision E.12.e.(h)) allows the use of stormwater planters in project areas with documented high concentrations of pollutants in the underlying soil or groundwater, where infiltration may contribute to a geotechnical hazard, and that are located on elevated plazas or adjacent to structures. Under these allowed variations for site-specific conditions, a hydraulic restriction layer may be incorporated or the underdrain may be located at the bottom of the gravel layer.

The Phase II Permit (Provision E.12.e.(i)) also allows the use of stormwater planters in project areas for the following types of Regulated Projects:

- Projects creating or replacing an acre or less of impervious area, and located in a designated pedestrian-oriented commercial district (i.e., smart growth projects), and having at least 85 percent of the entire project site covered by permanent structures;
- Facilities receiving runoff solely from existing (pre-project) impervious areas; and
- Historic sites, structures, or landscapes that cannot alter their original configuration in order to maintain their historic integrity.

Design Specifications

The following sections provide design specifications for stormwater planters.

Geotechnical

Due to the potential to contaminate groundwater and/or soils, cause slope instability, impact surrounding structures, and potential for insufficient infiltration capacity, a geotechnical investigation must be conducted during the site assessment process to verify the site suitability for a stormwater planter. It is critical to understand how stormwater runoff will move through the soil (horizontally and vertically) and if there are any geological conditions that may inhibit the movement of water. Soil infiltration rates and the depth to the groundwater table must be evaluated to ensure that conditions are satisfactory for proper operation of a stormwater planter. Stormwater planters can only be located on sites with a slope of less than 10 percent. A Site Conditions Report summarizing the relevant findings from the geotechnical investigation must be submitted with the Project Stormwater Plan.

Setbacks

Applicable setbacks must be implemented when siting a stormwater planter.

Pretreatment

Pretreatment, which refers to design features that provide settling of large particles before stormwater runoff enters a stormwater treatment control measure, is important to ensure proper operation of a stormwater planter and reduce the long-term maintenance burden. If stormwater planters are used to manage stormwater runoff from rooftops that drain directly to the planter, pretreatment may not be necessary because stormwater runoff from rooftops are not expected to have large particles. For other applications of a stormwater planter, pretreatment (e.g., vegetated swales, proprietary devices) is required to be provided to reduce the sediment load entering a stormwater planter in order to prevent the underlying soils from being occluded prematurely and maintain the infiltration rate of the stormwater planter.

Flow Entrance and Energy Dissipation

The drainage management area(s) (DMA[s]) tributary to a stormwater planter must be graded to minimize erosion as stormwater runoff enters the planter by creating sheet flow conditions rather than a concentrated stream condition or by providing energy dissipation devices at the inlet. Typically, a minimum slope of 1 percent for pervious surfaces and 0.5 percent for impervious surfaces to the inlet of the stormwater planter should be maintained. The following types of flow entrances can be used for a stormwater planter:

- Level spreaders (e.g., slotted curbs) can be used to facilitate sheet flow.
- Dispersed low velocity flow across a landscaped area. Dispersed flow may not be possible given space limitations or if the stormwater planter controls roadway or parking lot flows where curbs are mandatory.
- Dispersed flow across pavement or gravel and past wheel stops for parking areas.
- Flow spreading trench around perimeter of the stormwater planter that may be filled with pea gravel or vegetated with 3:1 side slopes.
- Curb cuts for roadside or parking lot areas. Curb cuts must include rock or other erosion controls in the channel entrance to dissipate energy. The flow entrance should drop two to three inches from curb line and provide an area for settling

and periodic removal of sediment and coarse material before flow disperses to the remainder of the stormwater planter.

- Piped entrances, such as roof downspouts, must include rock, splash blocks, or other erosion controls at the entrance to dissipate energy and disperse flows.

Drainage

Stormwater planters provide stormwater runoff storage in the ponding zone and in the voids of the planting media and gravel layers and must completely drain within 48 hours. The planting media and gravel layers must be allowed to dry out periodically in order to restore hydraulic capacity to receive stormwater runoff from subsequent storm events, maintain infiltration rates, maintain adequate soil oxygen levels for healthy soil biota and vegetation, and provide proper soil conditions for biodegradation and retention of pollutants.

Sizing

Step 1: Determine the Adjusted SDV (SDV_{adj})

Stormwater planters are designed to capture and retain the SDV_{adj}, which is the difference between the SDV (Section 5.2) and the volume of stormwater runoff managed through site design measures (Section 5.5), for the tributary DMA(s).

Step 2: Determine size of stormwater planter design layers

Stormwater planters consist of several layers that are designed to retain stormwater runoff. The design depths, which are used to size the stormwater planter, are presented in **Table F-3**. Other design parameters for these layers are discussed in further detail in the following sections.

Table F-3. Design Depths of Stormwater Planter Layers

Stormwater Planter Layer	Design depth
Ponding zone	0.5-1.0 ft
Planting media (excluding the mulch layer, if provided)	1.5-3.0 ft
Planting media/gravel layer separation zone [(1)]	2-4 in
Gravel	1 ft (min)
Hydraulic restriction layer	n/a

(1) In calculating the required bottom surface area of the stormwater planter, the planting media/ gravel layer separation zone is not considered because it is designed primarily to separate the planting media and gravel layer and not to retain stormwater runoff.

Step 3: Calculate the bottom surface area of the stormwater planter

Determine the bottom surface area (surface area at the base of side slopes, not at the top of side slopes) of the stormwater planter using the following equation:

$$A = \frac{SDV_{adj}}{d_{pz} + (\eta_{pm} \times d_{pm}) + (\eta_{gl} \times d_{gl})}$$

Where:

A = bottom surface area of stormwater planter [ft^2];
SDV_{adj} = adjusted stormwater design volume [ft^3];
d_{pz} = depth of ponding zone (0.5-1.0 ft) [ft];
η_{pm} = porosity of planting media [unitless];
d_{pm} = depth of planting media (min 1.5 ft) [ft];
η_{gl} = porosity of gravel layer [unitless]; and
d_{gl} = depth of gravel layer (min 1 ft) [ft].

Any stormwater planter shape configuration is possible as long as the other design specifications are met. The minimum stormwater planter width is 30 inches.

Stormwater Planter Walls

Stormwater planter walls must be made of stone, concrete, brick, clay, plastic, wood, or other stable, permanent material. The use of pressure-treated wood or galvanized metal at or around a stormwater planter is prohibited.

Planting Media Layer

Because stormwater planters are a variation of bioretention facilities, the Phase II Permit requires that the planting media layer:

- Have a minimum depth of 1.5 feet, excluding the mulch layer, if provided;
- Achieve a long-term, in-place minimum infiltration rate of at least 5 in/hr to support maximum stormwater runoff retention and pollutant removal; and
- Consist of 60 to 70 percent sand meeting the specifications of the American Society for Testing and Materials (ASTM) C33 and 30 to 40 percent compost.

Compost must be a well-decomposed, stable, weed-free organic matter source derived from waste materials including yard debris, wood wastes, or other organic material and not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product must be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program).

Mulch is recommended for the purpose of retaining moisture, preventing erosion, and minimizing weed growth. Projects subject to the California Model Water Efficiency Landscaping Ordinance (or comparable local ordinance) will be required to provide at least two inches of mulch. Aged mulch, also called compost mulch, reduces the ability of weeds to establish, keeps soil moist, and replenishes soil nutrients. If mulch is used for a stormwater planter, two to four inches (average three inches) of mulch should be used at the initiation of the planter. Annual placement (preferably in June after weeding) of one to two inches of mulch beneath plants will maintain the mulch layer.

Planting Media/Gravel Layer Separation Zone

The planting media and gravel layer must be separated by a permeable 2-4 inch layer of sand and stone that meets the grading requirements in **Table F-4**.

Table F-4. Planting Media/Gravel Layer Separation Layer Grading Requirements

Sieve Size	Percent Passing
1”	100
3/4”	90-100
3/8”	40-100
No. 4	25-100
No. 8	18-33
No. 30	5-15
No. 50	0-7
No. 200	0-3

Source: Caltrans Standard Specifications (2010) Class 2 Permeable Material

Gravel Layer

The gravel layer must consist of washed 1- to 2.5-inch diameter stone with a minimum 1-foot depth.

Hydraulic Restriction Layer

The hydraulic restriction layer, which can be a 60-mil PVC or 30-mil polyethylene pond liner with bentonite clay mats, must be placed below the gravel layer to prevent infiltration of stormwater runoff below the stormwater planter. If the stormwater planter is located near structures, the hydraulic restriction layer must also be applied along the walls of the stormwater planter to prevent stormwater runoff from percolating to these structures. The hydraulic restriction layer should be installed generously with overlapping seams prior to constructing the layers of the stormwater planter.

Underdrain

Stormwater planters require an underdrain to collect and discharge stormwater runoff that has been filtered through the planting media, but not infiltrated, to another stormwater treatment control measure, storm drain system, or receiving water. The underdrain must have a discharge elevation at the bottom of the gravel layer and a mainline diameter of six inches using slotted PVC SDR 26 or C900. Slotted PVC allows for pressure cleaning and root cutting, if necessary. The slotted pipe should have two to four rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots should be 0.04 to 0.1 inches wide with a length of 1 to 1.25 inches. Slots should be longitudinally-spaced such that the pipe has a minimum of one square inch opening per lineal foot and should face down. Underdrains should be sloped at a minimum of 0.5 percent in order to drain freely to an approved location.

Observation Well

A rigid non-perforated observation pipe with a diameter equal to the underdrain diameter must be connected to the underdrain to provide a clean-out port as well as an observation well to monitor infiltration rates. The wells/clean-out port must be connected to the slotted underdrain with the appropriate manufactured connections. The wells/clean-outs must extend six inches above the top elevation of the stormwater planter mulch and be capped with a lockable screw cap. The ends of the underdrain pipes not terminating in an observation well/clean-out port must also be capped.

Vegetation

It is recommended that a minimum of three climate-appropriate types of tree, shrub, and/or herbaceous groundcover species be incorporated in a stormwater planter to protect against failure due to disease and insect infestations of a single species. Select vegetation that:

- Can tolerate summer drought, ponding fluctuations, and saturated soil conditions for up to 48 hours.
- Will be dense and strong enough to stay upright, even in flowing water;
- Does not require fertilizers;
- Is not prone to pests and is consistent with Integrated Pest Management practices (IPM); and
- Is consistent with local water conservation ordinance requirements.

A sample list of suitable vegetation species is included in Appendix H. Prior to installation, a landscape architect must certify that all proposed vegetation is appropriate for the project site. Stormwater runoff must be diverted around the stormwater planter during the period of vegetation establishment.

Irrigation System

Provide an irrigation system to maintain viability of vegetation, if necessary. If possible, the general landscape irrigation system should incorporate the stormwater planter. The irrigation system must be designed to local code or ordinance specifications and must comply with the requirements of Section 4. Supplemental irrigation may be required for the establishment period even if it is not needed later.

Overflow Device

An overflow device is required at the ponding depth near the inlet of the stormwater planter to divert stormwater runoff in excess of the design capacity of the stormwater planter. For rooftop drainage, the distance between the downspouts and the overflow outlet should be maximized in order to increase the opportunity for stormwater runoff retention and filtration. The following, or equivalent, must be provided:

- A vertical PVC pipe (SDR 26) to act as an overflow riser.
- The overflow riser(s) should be eight inches or greater in diameter so it can be cleaned without damage to the pipe.
- The inlet to the riser should be at the ponding depth and capped with a spider cap to exclude floating mulch and debris. Spider caps must be screwed on and include a locking mechanism. The overflow device must convey stormwater runoff in excess of the design capacity of the stormwater planter to an approved discharge location (e.g., another stormwater treatment control measure, storm drain system, receiving water).

Construction Considerations

As part of the site planning process, the areas designated for a stormwater planter must be identified. The area identified for a stormwater planter must be protected from construction-related sediment loads. During construction activities if possible, divert all flows around the areas intended for the stormwater planter. Sediment control measures should also be implemented to prevent sediment from impacting the areas identified for a stormwater planter. Final grading must produce a level bottom without low spots or depressions. After construction is completed, the entire tributary area to the stormwater planter must be stabilized before allowing stormwater runoff to enter it.

Maintenance Requirements

Maintenance and regular inspections must be conducted to ensure proper function of a stormwater planter. A stormwater planter requires annual plant, soil, and mulch layer maintenance to ensure optimal infiltration, storage, and pollutant removal capabilities. Stormwater planter maintenance requirements, which consist primarily of landscape care procedures, include:

- Irrigate vegetation as needed during prolonged dry periods. In general, climate-appropriate vegetation will not require irrigation after establishment (two to three years). Regularly inspect the irrigation system, if provided, for clogs or broken pipes and repair as necessary.
- Inspect flow entrances, ponding area, and surface overflow areas periodically, and replace soil, vegetation, and/or mulch layer in areas if erosion has occurred. Properly-designed facilities with appropriate flow velocities should not cause erosion except potentially during in extreme events. If erosion occurs, the flow

velocities and gradients within the stormwater planter and energy dissipation and erosion protection strategies in the pretreatment area, if provided, or flow entrance should be reassessed. If sediment is deposited in the stormwater planter, identify the source of the sediment within the tributary area, stabilize the source, and remove excess surface deposits.

- Prune and remove dead vegetation as needed. Replace all dead vegetation, and if specific plants have a high mortality rate, assess the cause and, if necessary, replace with more appropriate species. Repair, seed, and re-plant damaged areas immediately.
- Remove weeds and other invasive, poisonous, nuisance, or noxious vegetation as needed until the vegetation is established. Weed removal should become less frequent if the appropriate species are used and planting density is attained.
- Remove and properly dispose of trash and other litter.
- Eliminate standing water to prevent vector breeding. If standing water is observed more than 48 hours after a storm event, it may be necessary to remove and replace the planting media and/or gravel layer to restore functionality of the stormwater planter.
- Inspect, and clean if necessary, the underdrain and observation well/clean-out port. Inspect overflow devices for obstructions or debris, which should be removed immediately. Repair or replace damaged pipes upon discovery.
- Repair structural deficiencies to the stormwater planter including rot, cracks, and failure.
- Implement IPM practices if pests are present in the stormwater planter.

The Agencies require execution of a Maintenance Access Agreement to be recorded by the property owner for the on-going operation and maintenance of all privately-maintained stormwater treatment control measures. The property owner is responsible for compliance with the Maintenance Access Agreement. An example Maintenance Access Agreement is presented in Appendix G.

T-2: Tree-Well Filter

Description

Source: Low Impact Development Center (top) and University of New Hampshire Stormwater Center (bottom)

A tree-well filter is similar to a stormwater planter and consists of one or multiple chambered pre-cast concrete boxes with a small tree or shrub planted in a bed filled with planting media. Tree-well filters are typically installed along the edge of a parking lot or roadway, where a street tree might normally be planted, and is designed to receive, retain, and infiltrate stormwater runoff from adjoining paved areas. During storm events, stormwater runoff enters the chamber and gradually infiltrates and filters through the planting media into the underlying soil, or collected by an underdrain system.

Treatment occurs through a variety of natural mechanisms as the stormwater runoff filters through the root zone of the vegetation and during detention of the stormwater runoff in the pore space of the planting media. A portion of stormwater runoff held in the root zone of the soil media is returned to the atmosphere through transpiration by the vegetation. Stormwater runoff that reaches the bottom of the tree-well filter and does not infiltrate into underlying soils is collected and discharged through an underdrain.

Tree-well filters are ideally suited for small areas such as parking lot islands, perimeter building planters, street medians, roadside swale features, and site entrance or buffer features. Tree-well filters can be integrated into other landscape areas. The maximum tributary area of a tree-well filter is one acre.

An example schematic of a typical tree-well filter is presented in **Figure F-5**.

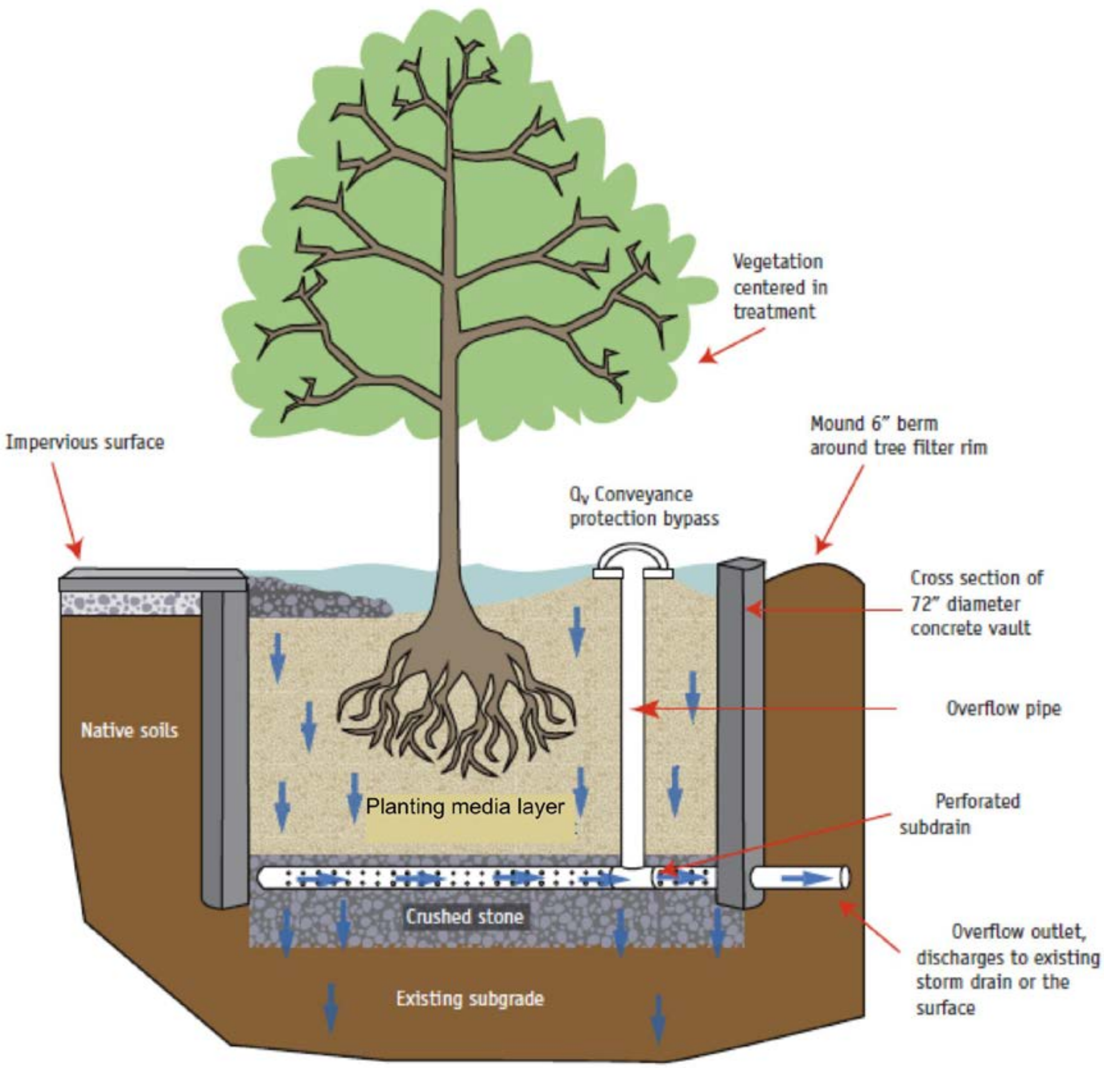


Figure F-5. Example Tree-Well Filter Schematic

Use and Applicability

The Phase II Permit (Provision E.12.e.(f)) identifies bioretention as the standard stormwater treatment control measure unless (1) it is determined to be infeasible and an alternative treatment control measure that is equivalent to bioretention is proposed and justified (Provision E.12.e.(g)), or (2) a specific exemption applies (Provision E.12.e.(i)). Tree-well filters can be proposed as an alternative to bioretention if it meets all of the following measures of equivalent effectiveness:

- Equal or greater amount of stormwater runoff infiltrated or evapotranspired;
- Equal or lower pollutant concentrations in stormwater runoff that is discharged after biotreatment;
- Equal or greater protection against shock loadings and spills; and

- Equal or greater accessibility and ease of inspection and maintenance.

The Phase II Permit (Provision E.12.e.(h)) allows the use of tree-well filters in project areas with documented high concentrations of pollutants in the underlying soil or groundwater, where infiltration may contribute to a geotechnical hazard, and that are located on elevated plazas or adjacent to structures. Under these allowed variations for site-specific conditions, a hydraulic restriction layer may be incorporated or the underdrain may be located at the bottom of the gravel layer.

The Phase II Permit (Provision E.12.e.(i)) also allows the use of tree-well filters in project areas for the following types of Regulated Projects:

- Projects creating or replacing an acre or less of impervious area, and located in a designated pedestrian-oriented commercial district (i.e., smart growth projects), and having at least 85 percent of the entire project site covered by permanent structures;
- Facilities receiving runoff solely from existing (pre-project) impervious areas; and
- Historic sites, structures, or landscapes that cannot alter their original configuration in order to maintain their historic integrity.

Design Specifications

The following sections provide design specifications for tree-well filters.

Geotechnical

Due to the potential to contaminate groundwater and/or soils, cause slope instability, impact surrounding structures, and potential for insufficient infiltration capacity, a geotechnical investigation must be conducted during the site assessment process to identify potential geotechnical hazards. It is critical to understand how stormwater runoff will move through the soil (horizontally and vertically) and if there are any geological conditions that may inhibit the movement of water. Soil infiltration rates and the depth to the groundwater table must be evaluated to ensure that conditions are satisfactory for proper operation of a tree-well filter. Tree-well filters can only be located on sites with a slope of less than 10 percent. A Site Conditions Report summarizing the relevant findings from the geotechnical investigation must be submitted with the Project Stormwater Plan.

Pretreatment

Pretreatment, which refers to design features that provide settling of large particles before stormwater runoff enters a stormwater treatment control measure, is important to ensure proper operation of a tree-well filter and reduce the long-term maintenance burden. If tree-well filters are used to manage stormwater runoff from rooftops that drain directly to the filter, pretreatment may not be necessary because stormwater runoff from rooftops are not expected to have large particles. For other applications of a stormwater planter, pretreatment (e.g., vegetated swales, proprietary devices) is required to be provided to reduce the sediment load entering a tree-well filter in order to prevent the underlying soils from being occluded prematurely and maintain the infiltration rate of the tree-well filter.

Flow Entrance and Energy Dissipation

The drainage management area(s) (DMA[s]) tributary to a tree-well filter must be graded to minimize erosion as stormwater runoff enters the filter by creating sheet flow conditions rather than a concentrated stream condition or by providing energy dissipation devices at the inlet. Typically, a minimum slope of 1 percent for pervious surfaces and 0.5 percent for impervious surfaces to the inlet of the tree-well filter should be maintained. The following types of flow entrances can be used for a tree-well filter:

- Level spreaders (e.g., slotted curbs) can be used to facilitate sheet flow.
- Dispersed low velocity flow across a landscaped area. Dispersed flow may not be possible given space limitations or if the tree-well filter controls roadway or parking lot flows where curbs are mandatory.
- Dispersed flow across pavement or gravel and past wheel stops for parking areas.
- Curb cuts for roadside or parking lot areas. Curb cuts must include rock or other erosion controls in the channel entrance to dissipate energy. The flow entrance should drop two to three inches from curb line and provide an area for settling and periodic removal of sediment and coarse material before flow disperses to the remainder of the tree-well filter.
- Piped entrances, such as roof downspouts, must include rock, splash blocks, or other erosion controls at the entrance to dissipate energy and disperse flows.

Drainage

Tree-well filters provide stormwater runoff storage in the ponding zone and in the voids of the planting media and gravel layers and must completely drain within 48 hours. The planting media and gravel layers must be allowed to dry out periodically in order to restore hydraulic capacity to receive stormwater runoff from subsequent storm events, maintain infiltration rates, maintain adequate soil oxygen levels for healthy soil biota and vegetation, and provide proper soil conditions for biodegradation and retention of pollutants.

Sizing

Step 1: Determine the Adjusted SDV (SDV_{adj})

Tree-well filters are designed to capture and retain the SDV_{adj}, which is the difference between the SDV (Section 5.2) and the volume of stormwater runoff managed through site design measures (Section 5.5), for the tributary DMA(s).

Step 2: Determine size of tree-well filter design layers

Tree-well filters consist of several layers that are designed to retain stormwater runoff. The design depths, which are used to size the tree-well filter, are presented in **Table F-5**. Other design parameters for these layers are discussed in further detail in the following sections.

Table F-5. Design Depths of Tree-Well Filter Layers

Tree-Well Filter Layer	Design depth
Ponding zone	0.5-1.0 ft
Planting media (excluding the mulch layer, if provided)	1.5-3.0 ft
Planting media/gravel layer separation zone (1)	2-4 in
Gravel	1 ft (min)
Hydraulic restriction layer	n/a

(1) In calculating the required bottom surface area of the tree-well filter, the planting media/gravel layer separation zone is not considered because it is designed primarily to separate the planting media and gravel layer and not to retain stormwater runoff.

Step 3: Calculate the bottom surface area of the tree-well filter

Determine the bottom surface area (surface area at the base of side slopes, not at the top of side slopes) of the tree-well filter using the following equation:

$$A = \frac{SDV_{adj}}{d_{pz} + (\eta_{pm} \times d_{pm}) + (\eta_{gl} \times d_{gl})}$$

Where:

A = bottom surface area of tree-well filter [ft^2];
SDV_{adj} = adjusted stormwater design volume [ft^3];
d_{pz} = depth of ponding zone (0.5-1.0 ft) [ft];
η_{pm} = porosity of planting media [unitless];
d_{pm} = depth of planting media (min 1.5 ft) [ft];
η_{gl} = porosity of gravel layer [unitless]; and
d_{gl} = depth of gravel layer (min 1 ft) [ft].

Tree-well filters can have a non-rectangular footprint to fit site landscape design.

Planting Media Layer

Because tree-well filters are a variation of bioretention facilities, the Phase II Permit requires that the planting media layer:

- Have a minimum depth of 1.5 feet, excluding the mulch layer, if provided;

- Achieve a long-term, in-place minimum infiltration rate of at least 5 in/hr to support maximum stormwater runoff retention and pollutant removal; and
- Consist of 60 to 70 percent sand meeting the specifications of the American Society for Testing and Materials (ASTM) C33 and 30 to 40 percent compost.

Compost must be a well-decomposed, stable, weed-free organic matter source derived from waste materials including yard debris, wood wastes, or other organic material and not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product must be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program).

Mulch is recommended for the purpose of retaining moisture, preventing erosion, and minimizing weed growth. Projects subject to the California Model Water Efficiency Landscaping Ordinance (or comparable local ordinance) will be required to provide at least two inches of mulch. Aged mulch, also called compost mulch, reduces the ability of weeds to establish, keeps soil moist, and replenishes soil nutrients. If mulch is used for a tree-well filter, two to four inches (average three inches) of mulch should be used at the initiation of the filter. Annual placement (preferably in June after weeding) of one to two inches of mulch beneath plants will maintain the mulch layer.

Planting Media/Gravel Layer Separation Zone

The planting media and gravel layer must be separated by a permeable 2-4 inch layer of sand and stone that meets the grading requirements in **Table F-6**.

Table F-6. Planting Media/Gravel Layer Separation Layer Grading Requirements

Sieve Size	Percent Passing
1”	100
3/4”	90-100
3/8”	40-100
No. 4	25-100
No. 8	18-33
No. 30	5-15
No. 50	0-7
No. 200	0-3

Source: Caltrans Standard Specifications (2010) Class 2 Permeable Material

Gravel Layer

The gravel layer must consist of washed 1- to 2.5-inch diameter stone with a minimum 1-foot depth.

Hydraulic Restriction Layer

The hydraulic restriction layer, which can be a 60-mil PVC or 30-mil polyethylene pond liner with bentonite clay mats, must be placed below the gravel layer to prevent infiltration of stormwater runoff below the tree-well filter. If the tree-well filter is located near structures, the hydraulic restriction layer must also be applied along the walls of the tree-well filter to prevent stormwater runoff from percolating to these structures. The hydraulic restriction layer should be installed generously with overlapping seams prior to constructing the layers of the tree-well filter.

Underdrain

Tree-well filters require an underdrain to collect and discharge stormwater runoff that has been filtered through the planting media, but not infiltrated, to another stormwater treatment control measure, storm drain system, or receiving water. The underdrain must have a discharge elevation at the bottom of the gravel layer and a mainline diameter of six inches using slotted PVC SDR 26 or C900. Slotted PVC allows for pressure cleaning and root cutting, if necessary. The slotted pipe should have two to four rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots should be 0.04 to 0.1 inches wide with a length of 1 to 1.25 inches. Slots should be longitudinally-spaced such that the pipe has a minimum of one square inch opening per lineal foot and should face down. Underdrains should be sloped at a minimum of 0.5 percent in order to drain freely to an approved location.

Observation Well

A rigid non-perforated observation pipe with a diameter equal to the underdrain diameter must be connected to the underdrain to provide a clean-out port as well as an observation well to monitor infiltration rates. The wells/clean-out port must be connected to the slotted underdrain with the appropriate manufactured connections. The wells/clean-outs must extend six inches above the top elevation of the tree-well filter mulch and be capped with a lockable screw cap. The ends of the underdrain pipes not terminating in an observation well/clean-out port must also be capped.

Vegetation

Select a tree that:

- Can tolerate summer drought, ponding fluctuations, and saturated soil conditions for up to 48 hours;
- Is suited to well-drained soil;
- Will be dense and strong enough to stay upright, even in flowing water;
- Does not require fertilizers;
- Is not prone to pests and is consistent with Integrated Pest Management (IPM) practices; and

- Is consistent with local water conservation ordinance requirements.

A sample list of suitable tree species is included in Appendix H. Prior to installation, a landscape architect must certify that proposed trees are appropriate for the project site.

Irrigation System

Provide an irrigation system to maintain viability of tree, if necessary. If possible, the general landscape irrigation system should incorporate the tree-well filter. The irrigation system must be designed to local code or ordinance specifications and must comply with the requirements of Section 4. Supplemental irrigation may be required for the establishment period even if it is not needed later.

Overflow Device

An overflow device is required at the ponding depth of the tree-well filter to divert stormwater runoff in excess of the design capacity of the tree-well filter. For rooftop drainage, the distance between the downspouts and the overflow outlet should be maximized in order to increase the opportunity for stormwater runoff filtration through the planting media. The following, or equivalent, must be provided:

- A vertical PVC pipe (SDR 26) to act as an overflow riser.
- The overflow riser(s) should be eight inches or greater in diameter so it can be cleaned without damage to the pipe.
- The inlet to the riser should be at the ponding depth and capped with a spider cap to exclude floating mulch and debris. Spider caps must be screwed on and include a locking mechanism. The overflow device should convey stormwater runoff in excess of the design capacity of the tree-well filter to an approved discharge location (e.g., another stormwater treatment control measure, storm drain system, receiving water).

Construction Considerations

As part of the site planning process, the areas designated for a tree-well filter must be identified. The area identified for a tree-well filter must be protected from construction-related sediment loads. During construction activities if possible, divert all flows around the areas intended for the tree-well filter. Sediment control measures should also be implemented to prevent sediment from impacting the areas identified for a tree-well filter. Final grading must produce a level bottom without low spots or depressions. After construction is completed, the entire tributary area to the tree-well filter must be stabilized before allowing stormwater runoff to enter it.

Maintenance Requirements

Maintenance and regular inspections must be conducted to ensure proper function of a tree-well filter. In general, tree-well filter maintenance requirements are typical landscape care procedures and include:

- Irrigate tree as needed during prolonged dry periods. In general, climate-appropriate trees will not require significant irrigation. Regularly inspect the irrigation system, if provided, for clogs or broken pipes and repair as necessary.
- Inspect flow entrances, ponding area, and surface overflow areas periodically, and replace planting media and/or mulch layer in areas if erosion has occurred. Properly designed facilities with appropriate flow velocities should not cause erosion except potentially during in extreme events. If erosion occurs, the flow velocities and gradients within the tree-well filter and flow dissipation and erosion protection strategies in the flow entrance should be reassessed. If sediment is deposited in the tree-well filter, identify the source of the sediment within the tributary area, stabilize the source, and remove excess surface deposits.
- Prune the tree as needed.
- Repair, seed, and re-plant damaged areas immediately.
- Remove weeds and other invasive, poisonous, nuisance, or noxious vegetation as needed until the vegetation is established. Weed removal should become less frequent if the appropriate species are used and planting density is attained.
- Eliminate standing water to prevent vector breeding. If standing water is observed more than 48 hours after a storm event, it may be necessary to remove and replace the planting media and/or gravel layer to restore functionality of the tree-well filter.
- Inspect, and clean if necessary, the underdrain and observation well/clean-out port. Inspect overflow devices for obstructions or debris, which should be removed immediately. Repair or replace damaged pipes upon discovery.
- Implement IPM practices if pests are present in the tree-well filter.

The Agencies require execution of a Maintenance Access Agreement to be recorded by the property owner for the on-going operation and maintenance of all privately-maintained stormwater treatment control measures. The property owner is responsible for compliance with the Maintenance Access Agreement. An example Maintenance Access Agreement is presented in Appendix G.

T-3: Sand Filter

Description

A sand filter operates similar to a stormwater planter; however, instead of filtering stormwater runoff through engineered planting media, stormwater runoff is filtered through a constructed sand bed with an underdrain system. Stormwater runoff enters a sand filter and spreads over the surface. As flows increase, water backs up on the surface of the filter where it is held until it can percolate through the sand. The treatment pathway is vertical (downward through the sand). High flows in excess of the design volume are diverted to prevent overloading of the filter. Stormwater runoff that percolates through the sand is collected with an underdrain that conveys it to another stormwater treatment control measure, storm drain system, or receiving water. As stormwater runoff passes through the sand, pollutants are trapped in the pore spaces between sand grains or adsorbed to the sand surface.

Sand filters can be placed underground and have the capability of reducing the peak stormwater runoff flow for small storms.

An example schematic of a typical sand filter is presented in **Figure F-6**.

Use and Applicability

The Phase II Permit (Provision E.12.e.(f)) identifies bioretention as the standard stormwater treatment control measure unless (1) it is determined to be infeasible and an alternative treatment control measure that is equivalent to bioretention is proposed and demonstrated (Provision E.12.e.(g)), or (2) a specific exemption applies (Provision E.12.e.(i)). An alternative to bioretention can be proposed if it meets <u>all</u> of the following measures of equivalent effectiveness:

- Equal or greater amount of stormwater runoff infiltrated or evapotranspired;
- Equal or lower pollutant concentrations in stormwater runoff that is discharged after biotreatment;
- Equal or greater protection against shock loadings and spills; and
- Equal or greater accessibility and ease of inspection and maintenance.

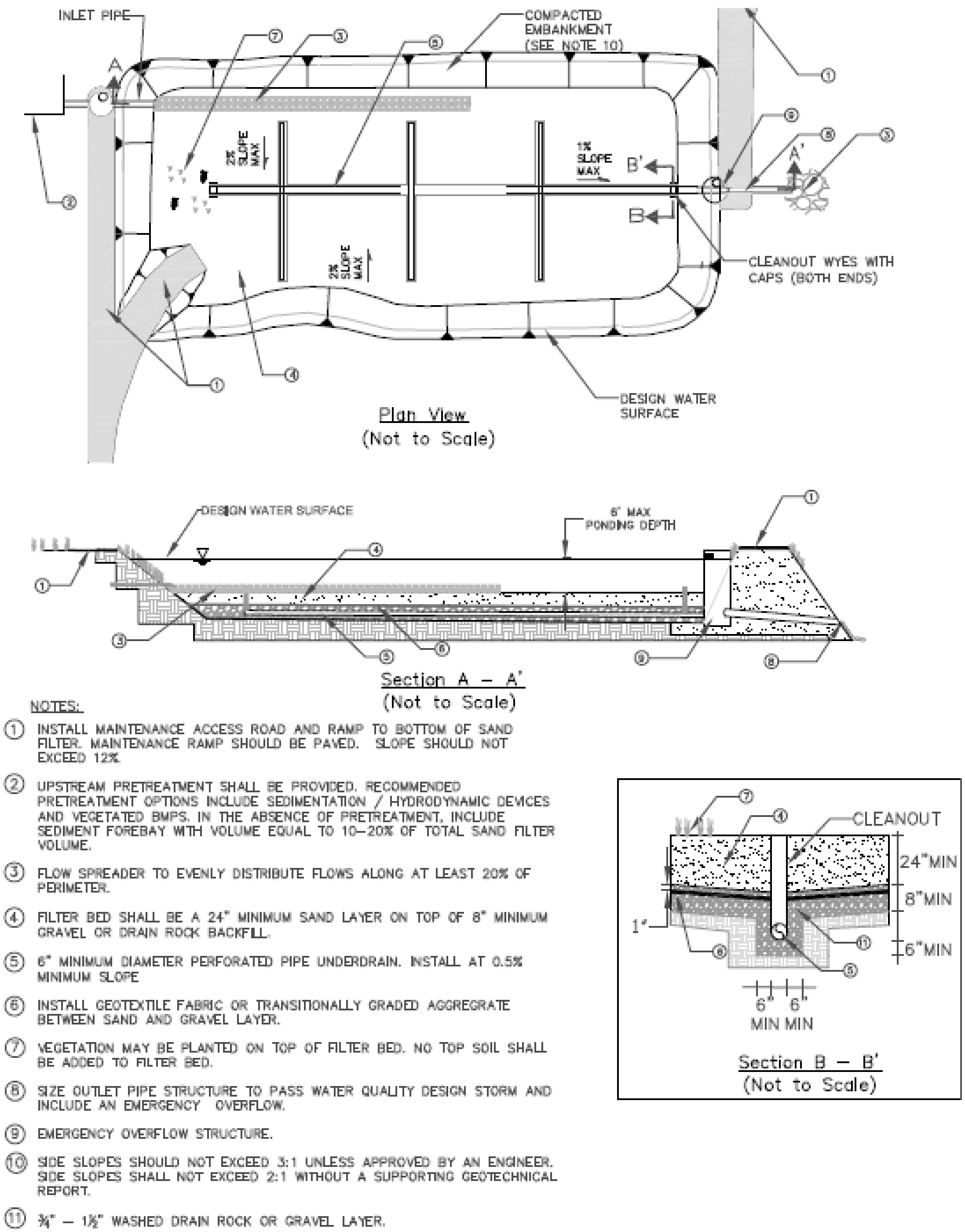


Figure F-6. Example Sand Filter Schematic

However, sand filters are unable to infiltrate or evapotranspire an equivalent amount of stormwater runoff when compared to bioretention. While sand filters cannot be used as an alternative to bioretention, there are two specific situations where they may be implemented as part of the stormwater management strategy at a project site. For project sites that have high-risk areas, such as fueling stations, truck stops, auto repairs, and heavy industrial sites, additional treatment may be required to address pollutants of concern unless these areas are isolated from stormwater runoff with little chance of spill migration.

The Phase II Permit (Provision E.12.e.(i)) also allows the use of sand filters in project areas for the following types of Regulated Projects:

- Projects creating or replacing an acre or less of impervious area, and located in a designated pedestrian-oriented commercial district (i.e., smart growth projects), and having at least 85 percent of the entire project site covered by permanent structures;
- Facilities receiving runoff solely from existing (pre-project) impervious areas; and
- Historic sites, structures, or landscapes that cannot alter their original configuration in order to maintain their historic integrity.

Design Specifications

The following sections provide design specifications for sand filters.

Setbacks

Applicable setbacks must be implemented when siting a sand filter.

Pretreatment

The primary challenge associated with sand filters is maintaining the filtration capacity, which is critical to its performance. If the flow entering the sand filter has high sediment concentrations, clogging of the sand filter is likely. Contribution of eroded soils or leaf litter may also reduce the filtration and associated treatment capacity of the sand filter.

Pretreatment, which refers to design features that provide settling of large particles before stormwater runoff enters a stormwater treatment control measure, is important to ensure proper operation of a sand filter and reduce the long-term maintenance burden. Pretreatment (e.g., vegetated swales, proprietary devices) must be provided to reduce the sediment load entering a sand filter in order to prevent the filtration media from being occluded prematurely and maintain the filtration capacity of the sand filter.

An alternative design for a sand filter can include a sediment forebay to remove sediment from stormwater runoff. The sediment forebay must be separated from the san filter by a berm or similar feature, which may be constructed out of earthen embankment material, grouted riprap, or other structurally-sound material, and must be equal to 10 to 20 percent of the total sand filter volume. A gravity drain outlet (minimum four-inch diameter) from the forebay must extend the entire width of the internal berm. The forebay outlet to the sand filter must be off-set from the inlet flow line to prevent short-circuiting. Permanent steel post depth markers must be placed in the forebay to identify the settled sediment removal limits at 50 and 100 percent of the forebay sediment storage depth.

Flow Entrance and Energy Dissipation

Sand filters must be placed off-line to prevent scouring of the filter bed by high flows. The drainage management area(s) (DMA[s]) tributary to the sand filter must be graded to minimize erosion as stormwater runoff enters the filter by creating sheet flow conditions rather than a concentrated stream condition. A flow spreader must be installed at the inlet along one side of the sand filter to evenly distribute stormwater runoff across the entire width of the sand filter and to prevent erosion of the filter surface. The flow spreader must be provided for a minimum of 20 percent of the filter perimeter. If the length-to-width ratio of the filter is 2:1 or greater, the flow spreader must be located on the longer side and for a minimum length of 20 percent of the perimeter of the sand filter. Erosion protection must be provided along the first foot of the sand filter bed adjacent to the flow spreader.

Drainage

Sand filters provide stormwater runoff storage in the ponding zone and in the voids of the sand media and must completely drain within 48 hours. The sand filter must be allowed to dry out periodically in order to restore hydraulic capacity to receive stormwater from subsequent storm events, maintain filtration rates, and provide proper conditions retention of pollutants.

Sizing

<u>Step 1: Determine the Adjusted SDV (SDV_{adj})</u>

Sand filters are designed to capture and retain the SDV_{adj}, which is the difference between the SDV (Section 5.2) and the volume of stormwater runoff managed through site design measures (Section 5.5), for the tributary DMA(s).

<u>Step 2: Determine maximum ponding depth</u>

Determine the maximum ponding depth (d_{pz}) above the sand filter. Aside from providing temporary storage of stormwater runoff, the ponding zone determines the hydraulic head over the filter bed surface, which increases the flow rate through the sand. This depth is defined as the depth at which water begins to overflow the reservoir above the sand filter and depends on the site topography and hydraulic constraints. The maximum ponding depth is six feet. There must also be a minimum freeboard of one foot.

<u>Step 3: Determine sand filter bed depth</u>

The depth of the sand filter bed (D) must be at least two feet, but three feet is preferred.

Step 4: Determine the design hydraulic conductivity

Determine the design saturated hydraulic conductivity (K) of the sand conditioned rather than clean. This approach represents the average sand bed condition as silt is captured and held in the sand bed instead of clean sand that will become occluded during the first use of the sand filter.

Step 5: Calculate the sand filter surface area

Determine the surface of the sand filter area using the following equation:

$$A_{sf} = \frac{SDV_{adj} \times R \times D}{K \times t \times (h + D)}$$

Where:

A_{sf} = surface area of the sand filter bed [ft^2];
SDV_{adj} = adjusted stormwater design volume [ft^3];
R = adjustment factor [use R=0.7];
D = sand filter bed depth (maximum 3 ft) [ft];
K = Design hydraulic conductivity [use 3 ft/day];
t = Maximum drawdown time [use 48 hours]; and
h = Average depth of ponding zone [ft, use $d_{pz}/2$].

The size of the sand filter is determined by assuming that the inflow is immediately discharged through the filter as if there was no ponding zone. An adjustment factor (0.7) is applied to compensate for the greater filter size resulting from this method.

Sand filters may be designed in any geometric configuration, but rectangular with a 1.5:1 length-to-width ratio or greater is preferred.

Sand Filter Walls

The walls of the sand filter may be vertical retaining walls, provided: (a) they are constructed of reinforced concrete; (b) a fence, which prevents access, is provided along the top of the wall (see fencing below) or further back; and (c) the design is approved by a licensed civil engineer and the Agency.

Interior side slopes up to the overflow device must be no steeper than 3:1 (H:V) unless stabilization has been approved by a licensed geotechnical engineer. Exterior side slopes shall be no steeper than 2:1 (H:V) unless stabilization has been approved by a licensed geotechnical engineer. For any slope (interior or exterior) greater than 2:1 (H:V), a geotechnical report must be submitted and approved by the Agency.

Sand Specification

The ideal effective diameter of the sand for a sand filter (d10) should be small enough to ensure a high quality effluent from the sand filter while preventing penetration of solids to such a depth that it cannot be removed by surface scraping (~2-3 inches). This effective diameter is between 0.20 and 0.35 mm. Additionally, the coefficient of uniformity, C_u = d60/d10, should be less than 3. The sand media should consist of a medium sand with very little fines meeting ASTM C33 size gradation (by weight) or equivalent as presented in **Table F-7**. Finally, the silica (SiO_2) content of the sand should be greater than 95 percent by weight.

Table F-7. Sand Filter Media Sand Specifications

U.S. Sieve Size	Percent Passing by Weight
3/8 inch	100%
U.S. No. 4	95-100%
U.S. No. 8	80-100%
U.S. No. 16	50-85%
U.S. No. 30	25-60%
U.S. No. 50	5-30%
U.S. No. 100	<10%

Hydraulic Restriction Layer

Either a hydraulic restriction layer, which can be a 60-mil PVC or 30-mil polyethylene pond liner with bentonite clay mats, or a 2-inch transition gradation layer (preferred) must be placed between the sand layer and the drain rock or gravel backfill layer. If a liner is used, one inch of drain rock or gravel backfill should be place above the liner to allow for a transitional zone between sand and gravel and reduce pooling of water at the liner interface. The hydraulic restriction layer should be installed generously with overlapping seams.

Underdrain

Sand filters are require an underdrain to collect and discharge treated stormwater runoff to another stormwater treatment control measure, storm drain system, or receiving water. There are several underdrain system options, which must be reinforced to withstand the weight of the overburden, that can be used:

- A central underdrain collection pipe with lateral collection pipes in a minimum eight-inch gravel backfill or drain rock bed.
- Longitudinal pipes in a minimum eight-inch gravel backfill or drain rock bed, with a collection pipe at the outfall of the sand filter.

- Small sand filters may use a single underdrain pipe in a minimum eight-inch gravel backfill or drain rock bed.

All underdrain pipes must have a minimum mainline diameter of six inches using perforated PVC to allow for pressure water cleaning, if necessary, and ensure free draining of the sand filter bed. Round perforations must be at least 0.5-inch in diameter and the pipe must be laid with perforations downward. The maximum perpendicular distance between any two lateral collection pipes or from the edge of the sand filter and the collection pipes is nine feet. All pipes must be placed with a minimum slope of 0.5 percent.

The underdrain must be placed in a gravel backfill where at least eight inches of gravel backfill must be maintained over all underdrain pipes, and at least six inches must be maintained on both sides and beneath the pipe to prevent damage by heavy equipment during maintenance. Either drain rock or gravel backfill may be used between pipes. The bottom gravel layer must have a diameter at least twice the size of the openings into the storm drain system. The grains should be hard, preferably rounded, with a specific gravity of at least 2.5, and free of clay, debris and organic impurities.

Clean-out risers with diameters equal to the underdrain pipes must be placed at the terminal ends of all pipes and extend to the surface of the filter. A valve box should be provided for access to the clean-outs and the clean-out assembly must be water tight to prevent short circuiting of the sand filter.

To prevent uses that may compact and damage the filter surface, permanent structures are not permitted on sand filters (i.e., playground equipment).

Vegetation

Sand filters must be located away from trees or other plants producing leaf litter.

Overflow Device

While sand filters may only be placed off-line, an overflow device near the inlet to the sand filter must still be provided to divert stormwater runoff in excess of the design capacity of the sand filter or in the event the sand filter becomes clogged. The following, or equivalent, must be provided:

- A vertical PVC pipe (SDR 26) to act as an overflow riser.
- The overflow riser(s) should be eight inches or greater in diameter so it can be cleaned without damage to the pipe.
- The inlet to the riser should be at the freeboard depth and capped with a spider cap to exclude floating debris. Spider caps must be screwed on and include a locking mechanism. The overflow device must convey stormwater runoff in excess of the design capacity of the sand filter to an approved discharge location

(e.g., another stormwater treatment control measure, storm drain system, receiving water).

Exterior Landscaping

Landscaping outside of the sand filter, but within the easement/right-of-way, is required and must adhere to the following specifications such that it will not hinder maintenance operations:

- No trees or shrubs may be planted within ten feet of inlet or outlet pipes or manmade drainage structures such as overflow devices, flow spreaders, or earthen embankments. Species with roots that seek water, such as willow or poplar, must not be used within 50 feet of pipes or manmade structures.
- Non-climate-appropriate plant species are not permitted.

Fencing

Safety is provided by fencing of the stormwater treatment control measure. Fences shall be designed and constructed in accordance with Agency standards and must be located at or above the top of overflow device elevation.

Maintenance Access

Maintenance access must be provided to the structures associated with the sand filter (e.g., pretreatment, inlet, overflow devices) if it is publicly-maintained. Manhole and catch basin lids must be in or at the edge of the access road. An access ramp to the sand filter bottom is required to facilitate the entry of sediment removal (and vegetation maintenance) equipment.

Unless otherwise required by the Agency, access roads must meet the following design specifications:

- All access ramps and roads must be paved with a minimum of six inches concrete over three inches of crushed aggregate base material. This requirement may be modified depending on the soil conditions and intended use of the road at the discretion of Agency.
- The maximum grade is 12 percent unless otherwise approved by the Agency.
- Centerline turning radius must be a minimum of 40 feet.
- Access roads less than 500 feet long must have a 12-foot wide pavement within a minimum 15-foot wide bench. Access roads greater than 500 feet long must have 16-foot wide pavement within a minimum 20-foot wide bench.
- All access roads must terminate with turnaround areas of 40-feet by 40-feet. A hammer type turn around area or a circle drive around the top of the sand filter is also acceptable.

- Adequate double-drive gates and commercial driveways are required at street crossings. Gates should be located a minimum of 25 feet from the street curb except in residential areas where the gates may be located along the property line provided there is adequate sight distance to see oncoming vehicles at the posted speed limit.

Restricted Construction Materials

The use of pressure-treated wood or galvanized metal at or around the sand filter is prohibited. The use of galvanized fencing is permitted if in accordance with the Fencing requirement above.

Construction Considerations

Sand filters are generally suited for sites where there is no base flow, and the sediment load is relatively low. For underground sand filters, the load-carrying capacity of the filter structure must be considered if it is located under parking lots, driveways, roadways, and certain sidewalks.

As part of the site planning process, the areas designated for a sand filter must be identified. The area identified for a sand filter must be protected from construction-related sediment loads. During construction activities if possible, divert all flows around the areas intended for the sand filter. Sediment control measures should also be implemented to prevent sediment from impacting the areas identified for a sand filter. Final grading must produce a level bottom without low spots or depressions. After construction is completed, the entire tributary area to the sand filter must be stabilized before allowing stormwater runoff to enter it.

Maintenance Requirements

Maintenance and regular inspections must be conducted to ensure proper function of sand filters. Sand filters are subject to clogging by fine sediment, oil and grease, and other debris (e.g., trash and organic matter such as leaves).The following activities must be conducted to maintain a sand filter:

- Inspect pretreatment devices and the sand filter every six months during the first year of operation. Inspections should also occur immediately following a storm event to assess the filtration capacity of the sand filter. Once it is determined that the sand filter is performing as designed, the frequency of inspection may be reduced to once per year.
- If a sediment forebay is included, remove sediment buildup exceeding 50 percent of the sediment storage capacity, as indicated by the steel markers. Test removed sediments for toxic substance accumulation in compliance with current disposal requirements if visual or olfactory indications of pollution are noticed. If toxic substances are detected at concentrations exceeding thresholds of Title 22, Section 66261 of the California Code of Regulations, dispose of the sediment in

a hazardous waste landfill and investigate and mitigate the source of the contaminated sediments to the maximum extent possible.

- Inspect the sand filter to ensure that water percolates into filter media completely within the maximum drawdown time. If water is present in the sand filter more than 48 hours after a storm, the sand filter may be clogged. Maintenance activities triggered by a clogged filter include:
    - Check for debris/sediment accumulation, rake surface and remove sediment (if any), and evaluate potential sources of sediment and vegetative or other debris. If suspected upstream sources are outside of the Agency's jurisdiction, additional pretreatment may be necessary.
    - Determine if it is necessary to remove and replace the top layer of the sand filter bed to restore filtration capacity.
- Remove and dispose of trash and debris, as needed, but at least prior to the beginning of the wet season.
- Eliminate standing water to prevent vector breeding.
- Inspect the inlet structures for erosion and re-grade if necessary.
- Inspect the flow spreader and level and/or clean it so that flows are spread evenly over the sand filter bed.
- Inspect, and clean if necessary, the underdrain system. Inspect overflow devices for obstructions or debris, which should be removed immediately. Repair or replace damaged pipes upon discovery.

The Agencies require execution of a Maintenance Access Agreement to be recorded by the property owner for the on-going operation and maintenance of all privately-maintained stormwater treatment control measures. The property owner is responsible for compliance with the Maintenance Access Agreement. An example Maintenance Access Agreement is presented in Appendix G.

T-4: Vegetated Swales

Description

Vegetated swales are open, shallow channels with low-lying vegetation covering the side slopes and bottom that collect and slowly convey stormwater runoff to a downstream stormwater treatment control measure, storm drain system, or receiving water. Vegetated swales can provide limited pollutant removal through settling and filtration in the vegetation (usually grasses) lining the channels, reduce stormwater runoff volume through infiltration and evapotranspiration, and reduce the flow velocity. An effective vegetated swale achieves uniform sheet flow over and through a densely vegetated area for a period of several minutes.

An example schematic of a typical vegetated swale is presented in **Figure F-7**.

Use and Applicability

Vegetated swales do not meet the measures of equivalent effectiveness (Provision E.12.e.(f) of the Phase II Permit) that is required in order to use this stormwater treatment control measure as an alternative to bioretention. However, vegetated swales can be used to convey stormwater runoff to downstream stormwater treatment control measures or as pretreatment.

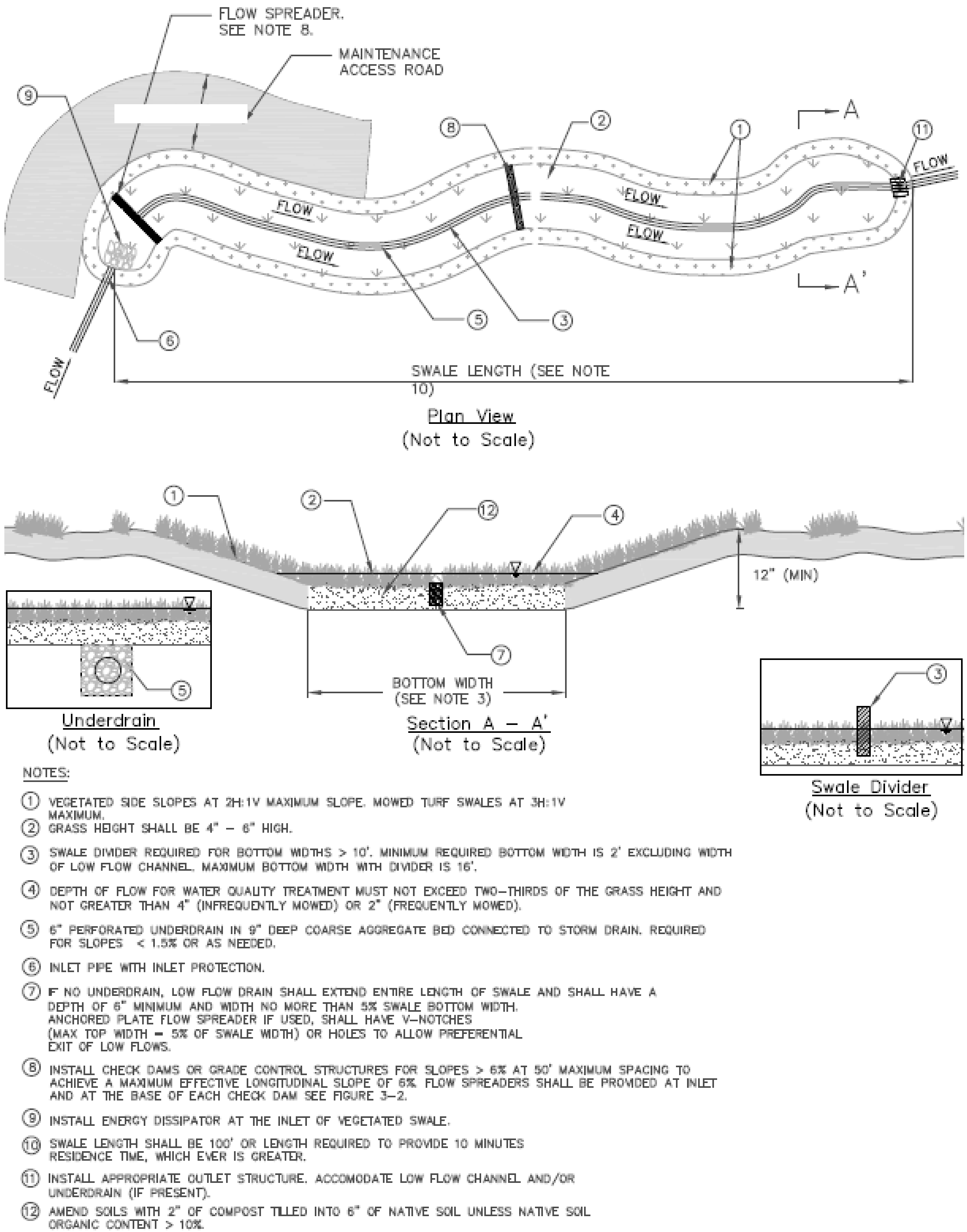


Figure F-7. Example Vegetated Swale Schematic

Design Specifications

The following sections provide design specifications for vegetated swales.

Geotechnical

Due to the potential to contaminate groundwater and/or soil, cause slope instability, and impact surrounding structures, a geotechnical investigation must be conducted during the site assessment to verify the site suitability for vegetated swales. It is important to understand how stormwater runoff will move through the soil (horizontally and vertically) and if there are any geological conditions that could inhibit the movement of water. Soil infiltration rates and the depth to the groundwater table must be evaluated to ensure that conditions are satisfactory for proper operation of vegetated swales. Vegetated swales cannot be located at sites with a slope greater than five percent to prevent channel erosion. For sites that have limited slop, ponding in the vegetated swale may occur. A Site Conditions Report summarizing the relevant findings from the geotechnical investigation must be submitted with the Project Stormwater Plan.

Setbacks

Applicable setbacks must be implemented when siting vegetated swales.

Flow Entrance and Energy Dissipation

The drainage management area(s) (DMA[s]) tributary to the vegetated swale must be graded to minimize erosion as stormwater runoff enters the swale or by providing energy dissipation devices at the inlet. An anchored plate flow spreader must be provided at the inlet to the vegetated swale. Equivalent methods for spreading flows evenly throughout the width the swale are acceptable. The specifications for the flow spreader are listed below:

- The top surface of the flow spreader plate must be level, projecting a minimum of two inches above the ground surface of the vegetated swale, or V-notched with notches six to ten inches on center and one to four inches deep (use shallower notches with closer spacing).
- The flow spreader plate must extend horizontally beyond the bottom width of the vegetated swale to prevent water from eroding the side slope. The horizontal extent should be such that the bank is protected for all flows up to the SDF_{adj} that will enter the swale.
- Flow spreader plates must be securely fixed in place.
- Flow spreader plates may be made of either concrete, stainless steel, or other durable material.
- Anchor posts are constructed of four inches square of concrete, tubular stainless steel, or other material resistant to decay.

The flow spreader will dissipate the entrance velocity and distribute flow uniformly across the whole vegetated swale. If check dams are used to reduce the longitudinal slope, a flow spreader must be installed at the toe of each vertical drop according to the specifications listed in the following Check Dams section below. If flow is to be introduced through curb cuts, the pavement should be placed slightly above the elevation of the vegetated areas. Curb cuts should be at least 12 inches wide to prevent clogging.

Drainage

Vegetated swales provide temporary stormwater runoff storage above ground as it conveys stormwater runoff to a downstream stormwater treatment control measure. Some stormwater runoff may infiltrate into the underlying soil.

Sizing

Step 1: Determine the SDF_{adj}

Vegetated swales are designed to capture and manage the SDF_{adj}, which is the difference between the SDF (Section 5.4) and the volume of stormwater runoff managed through site design measures (Section 5.5), for the tributary DMA(s).

Step 2: Calculate Bottom Width of Vegetated Swale

The width of the bottom of the vegetated swale is calculated using Manning's equation for open channel flow, as follows:

$$SDF_{adj} = \left(\frac{1.49}{n}\right) \times A \times R^{2/3} \times S^{0.5}$$

Where:

SDF_{adj} = stormwater design flow [ft^3/s];
n = Manning's roughness coefficient;
A = flow area [ft^2];
R = hydraulic radius [ft]; and
S = channel slope [ft/ft].

For shallow flow depths in vegetated swales, channel side slopes are ignored in the calculation of bottom width. Use the following equation (a simplified form of Manning's formula) to estimate the vegetated swale bottom width:

$$b = SDF_{adj} \times \left(\frac{1.49}{n_s}\right) \times y^{2/3} \times s^{0.5}$$

Where:

b = bottom width of vegetated swale [ft]
SDF_{adj} = stormwater design flow [ft^3/s];
n_s = Manning's roughness coefficient (use 0.2 for shallow conditions);
y = stormwater design flow depth [ft]; and
s = longitudinal slope (along direction of flow) [ft/ft].

Proceed to Step 3 if the calculated bottom width is between two and ten feet. A minimum two-foot bottom width is required. If the calculated bottom width is less than two feet, increase the width to two feet, and recalculate the design flow depth, y, using the same SDF_{adj} and n_s, but with b equal to two feet. The maximum allowable bottom width is ten feet. If the calculated bottom width exceeds ten feet, then one of the following steps is necessary to reduce the design bottom width:

- Increase the longitudinal slope (*s*) to a maximum of 6 feet in 100 feet (0.06 feet per foot);
- Increase the design flow depth (*y*) to a maximum of four inches; or
- Place a divider lengthwise along the vegetated swale bottom (see **Figure F-7**) at least three-quarters of the vegetated swale length (beginning at the inlet), without compromising the design flow depth and lateral slope requirements. The vegetated swale width can be increased to a maximum of 16 feet if a divider is provided.

Step 3: Determine the Design Flow Velocity

To calculate the design flow velocity through the vegetated swale, use the flow continuity equation:

$$v = \frac{SDF_{adj}}{A}$$

Where:

v = design flow velocity [ft/s];
SDF_{adj} = stormwater design flow [ft^3/s]; and
$A = by + Zy^2$ = Cross-sectional area of flow at design depth [ft^2] where Z = side slope length per unit height (e.g., Z = 3 if side slope is 3:1 H:V) .

If the design flow velocity exceeds 1 ft/s, go back to Step 2 and modify one or more of the design parameters (i.e., longitudinal slope, bottom width, or flow depth) to reduce the design flow velocity to 1 ft/s or less. If the design flow velocity is calculated to be less than 1 ft/s, proceed to Step 4. It is ideal to have the design velocity as low as possible to improve treatment effectiveness, reduce re-suspension of sediment, and reduce vegetated swale length requirements.

Step 4: Calculate Length of Vegetated Swale

Use the following equation to determine the length of the vegetated swale to achieve a hydraulic residence time of at least 10 minutes (600 seconds):

$$L = 60 \times t_{hr} \times v$$

Where:

L = minimum allowable swale length [ft];
t_{hr} = hydraulic residence time [min]; and
v = design flow velocity [ft/s].

The minimum length for a vegetated swale is 100 feet. If the calculated length for the vegetated swale is less than 100 feet, increase the length to a minimum of 100 feet and leaving the bottom width unchanged. If a larger vegetated swale can be fitted on the project site, consider using a greater length to increase the hydraulic residence time and improve pollutant removal. If the calculated length is too long for the project site or if it would cause layout problems (e.g., encroachment into shaded areas), proceed to Step 5 to further modify the layout. If the length of the vegetated swale can be accommodated on the project site, sizing of the vegetated swale is completed.

Step 5: Adjust Vegetated Swale Layout to Fit On-site

If the length of the vegetated swale calculated in Step 4 is too long for the project site, the length can be reduced (minimum of 100 feet) by increasing the bottom width up to a maximum of 16 feet, as long as the 10-minute retention time is maintained. However, the length cannot be increased in order to reduce the bottom width because Manning's depth-velocity-flow rate relationships will not be preserved. If the bottom width is increased to greater than ten feet, a low flow berm is needed to divide the vegetated swale cross-section in half to prevent channelization.

The length can be adjusted by calculating the top area of the vegetated swale and providing an equivalent top area with the adjusted dimensions.

Calculate the top area of the vegetated swale based on its length in Step 4:

$$A_{top} = \left(b_i + b_{slope}\right) \times L_i$$

Where:

A_{top} = top area at the design depth [ft^2];
b_i = bottom width calculated in Step 2 [ft];
b_{slope} = additional top width above the side slope for the design depth (for 3:1 H:V side slope and a 4-inch water depth, b_{slope} = 2 ft) [ft]; and
L_i = initial length calculated in Step 4 [ft].

Use the vegetated swale top area and a reduced swale length, L_f, to increase the bottom width using the following equation:

$$L_f = \frac{A_{top}}{(b_f + b_{slope})}$$

Where:

L_f = reduced vegetated swale length [ft];
A_{top} = top area at the design depth [ft^2];
b_f = increased bottom width [ft]; and
b_{slope} = additional top width above the side slope for the design depth (for 3:1 H:V side slope and a 4-inch water depth, b_{slope} = 2 ft) [ft].

Recalculate the design flow velocity according to Step 3 using the revised cross-sectional area based on the increased bottom width. Revise the design as necessary if the design flow velocity exceeds 1 ft/s. If necessary, recalculate to ensure that the 10-minute hydraulic residence time is maintained.

Step 6: Design Other Vegetated Swale Features

Other sizing specifications for vegetated swales include the following:

- The water depth in the vegetated swale must not exceed four inches (or two-thirds of the expected vegetation height) except for frequently mowed turf swales. For mowed turf swales, the water depth must not exceed two inches. Once design specifications have been determined, the resulting flow depth for the design flow is checked. If the depth restriction is exceeded, swale parameters (e.g., longitudinal slope, width) must be adjusted to reduce the flow depth. Overall depth from the top of the side walls to the swale bottom shall be at least 12 inches.
- In general, trapezoidal channel shape is assumed for sizing calculations, but a more naturalistic channel cross-section is preferred.
- Vegetated swale length can be increased by meandering the swale. Gradual meandering bends in the swale are desirable for aesthetic purposes and to promote slower flow.
- The minimum width of the vegetated swale bottom is two feet to allow for ease of mowing. The maximum width of the vegetated swale bottom is ten feet unless a dividing berm is provided. If a dividing berm is provided, the maximum width of the vegetated swale bottom can be 16 feet.
- The longitudinal slope (along the direction of flow) must be between 1 and 6 percent. If the longitudinal slope is less than 1.5 percent and the soils are poorly drained (e.g., silts and clays), then an underdrain must be installed. If the longitudinal slope is greater than 6 percent, check dams with vertical drops of 12 inches or less must be provided to achieve a bottom slope of 6 percent or less between the drop structures.

- The lateral slope (horizontal to the direction of flow) is zero (flat) to discourage channelization.
- A side slope of 2:1 (H:V) is acceptable, but milder slopes are necessary if turf is used (maximum 3:1 H:V).
- A low flow drain must be provided for dry weather flows extending the entire length of the swale. The drain must have a minimum depth of six inches and a width no more than five percent of the calculated bottom swale width. The width of the drain is in addition to the required bottom width. If an anchored plate is used for flow spreading at the swale inlet, the plate wall must have V-notches (maximum top width = five percent of swale width) or holes to allow low flow into the drain. If an underdrain is installed, the vegetated swale does not require a low flow drain.

Check Dams

The effectiveness of vegetated swales may be enhanced by adding check dams at approximately 50 foot increments along the length. Check dams maximize retention time within the vegetated swale, decrease flow velocity, and promote particulate settling. However, check dams may not be appropriate if prolonged ponding occurs.

If check dams are required, they can be designed using riprap, earthen berms, or removal stop logs. Check dams must be placed to achieve the desired slope (less than 6 percent) and desired velocity (less than 1 ft/s for the SDF_{adj}) at a maximum of 50 feet apart. If riprap is used, the material should consist of well-graded stone consisting of a mixture of rock sizes. The following is an example of an acceptable gradation:

Particle Size	% Passing by Weight
24 in	100%
15 in	75%
9 in	50%
4 in	10%

Swale Divider

- If a swale divider is used, the divider must be constructed of a firm material (e.g., concrete, compacted soil seeded with grass) that will resist weathering and not erode. Use of treated wood is prohibited. Selection of divider material must take into account maintenance activities, such as mowing.
- The divider must have a minimum height of one inch greater than the design depth.
- Earthen berms must be no steeper than 2:1(H:V).
- Material other than earth must be embedded to a depth sufficient to be stable.

Underlying Base

The underlying soil for a vegetated swale must be amended with two inches of well-rotted compost, unless the organic content is already greater than 10 percent. The compost must be mixed into the underlying soils to a depth of six inches to prevent soil layering and washout of compost. The compost must contain no sawdust, green or under-composted material, unsterilized manure, or any other toxic or harmful substance.

Underdrain

If necessary, an underdrain may be included in the design of a vegetated swale to convey stormwater runoff that has been filtered through the soil media, but not infiltrated, to another stormwater treatment control measure, storm drain system, or receiving water. The underdrain must have a mainline diameter of six inches using slotted PVC SDR 26 or C900. Slotted PVC allows for pressure water cleaning and root cutting, if necessary. The slotted pipe should have two to four rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots should be 0.04 to 0.1 inches wide with a length of 1 to 1.25 inches. Slots should be longitudinally-spaced such that the pipe has a minimum of one square inch opening per lineal foot and should face down. Underdrains should be sloped at a minimum of 0.5 percent in order to drain freely to an approved location.

The underdrain must be placed in a gravel envelope (Class 2 Permeable Material per Caltrans Spec. 68-1.025) that measures three feet wide and six inches deep. The underdrain is elevated from the bottom of the vegetated swale by six inches within the gravel envelope. The top and sides of the underdrain pipe should be covered with gravel to a minimum depth of 12 inches. The underdrain and gravel envelope must be covered with a hydraulic restriction layer to prevent clogging. The following aggregate can be used for the gravel envelope:

Particle Size (ASTM D422)	% Passing by Weight
¾ inch	100%
¼ inch	30-60%
#8	20-50%
#50	3-12%
#200	0-1%

Clean-out risers with diameters equal to the underdrain pipe must be placed at the terminal ends of the underdrain and can be incorporated into the flow spreader and outlet structure to minimize maintenance obstacles in the vegetated swale. Intermediate clean-out risers may also be placed in the check dams or grade control structures. The clean-out risers shall be capped with a lockable screw cap.

Vegetation

The vegetated swale must be vegetated with a mix of erosion-resistant, climate-appropriate plants that effectively bind the soil and require less maintenance, including chemical treatments. Vegetated swales can provide some stormwater runoff treatment through maximization of water contact with vegetation and the soil surface. Vegetation must meet the following specifications:

- Above the design elevation, a typical climate-appropriate lawn mix or landscape plants can be used provided they do not shade the vegetated swale.
- Vegetated swales must be located away from large trees that may drop leaves or needles. Excessive tree debris may smother the grass or impede stormwater runoff flow through the swale.
- Climate-appropriate grasses must be specified to minimize irrigation requirements. Irrigation may be required if seeds are planted in spring or summer.
- Vegetative cover should be at least four inches in height, although six inches is preferred.

A sample list of suitable vegetation species is included in Appendix H. Prior to installation, a landscape architect must certify that all proposed vegetation is appropriate for the project site. Stormwater runoff must be diverted around the vegetated swale during the period of vegetation establishment.

Irrigation System

Provide an irrigation system to maintain the viability of vegetation, if necessary. If possible, the general landscape irrigation system should be incorporate the vegetated swales. The irrigation system must be designed to local code or ordinance specifications and must comply with the requirements in Section 4. Supplemental irrigation may be required for the establishment period even if it is not needed later.

Restricted Construction Materials

Use of pressure-treated wood or galvanized metal at or around the vegetated swale is prohibited.

Construction Considerations

Areas to be used for vegetated swales should be clearly marked before site work begins to avoid soil disturbance and compaction during construction. No vehicular traffic, except that specifically used to construct the vegetated swale, should be allowed within 10 feet of the swale areas. Vegetated swales can be integrated into roadside buffers or parking lot landscaping. For parking lots, if tire curbs are provided and parking stalls are shortened, cars may overhang the vegetated swale.

As part of the site planning process, the areas designated for vegetated swales must be identified. The area identified for vegetated swales must be protected from construction-related sediment loads. During construction activities if possible, divert all flows around the areas intended for the vegetated swales. Sediment control measures should also be implemented to prevent sediment from impacting the areas identified for vegetated swales. After construction is completed, the entire tributary area to the vegetated swales must be stabilized before allowing stormwater runoff to enter it.

Maintenance Requirements

Maintenance and regular inspections must be conducted to ensure proper function of vegetated swales. The following activities must be conducted to maintain vegetated swales:

- Inspect vegetated swales for erosion or damage to vegetation after every storm greater than 0.50 inches. Vegetated swales should be checked for debris and litter and areas of sediment accumulation.
- Remove sediment and debris from the flow spreader if it is blocking flows. Repair splash pads, as needed, to prevent erosion. Check and re-level the flow spreader if necessary.
- Remove sediment if vegetation growth is inhibited in more than 10 percent of the swale or if sediment is blocking even distribution and entry of stormwater runoff. Re-plant and/or re-seed vegetation, as needed, following sediment removal activities to re-establish vegetation.
- Stabilize slopes with appropriate erosion control measures if the underlying soils are exposed or erosion channels are forming.
- Remove trash and debris, as needed, but at least annually prior to the beginning of the wet season.
- Inspect vegetation for health and density to ensure that it is providing sufficient treatment and protecting the underlying soils from erosion. As needed, conduct the following maintenance activities for the vegetation:
    - Replenish mulch to ensure survival of vegetation.
    - Prune and/or remove vegetation, large shrubs, or trees that interfere with the operation of the vegetated swale.
    - Mow grass to four to six inches and remove grass clippings.
    - Remove fallen leaves and debris from deciduous plant foliage.
    - Remove invasive, poisonous, nuisance, and noxious vegetation and replace with climate-appropriate vegetation
    - Remove dead vegetation if greater than 10 percent of area coverage or when swale function is impaired. Replace and establish vegetation before the wet season to maintain cover density and control erosion where soils

are exposed. It may be necessary to re-grade eroded areas prior to replacing vegetation.

- Eliminate standing water to prevent vector breeding. If standing water is observed more than 72 hours after a storm event, it may be necessary to till the underlying soils and re-vegetate.
- Inspect, and repair if necessary, check dams that are causing altered water flow and/or channelization. Remove obstructions as needed.
- Inspect, and clean if necessary, the underdrain pipe. Repair or replace damaged pipes upon discovery.

The Agencies require execution of a Maintenance Access agreement to be recorded by the property owner for the on-going operation and maintenance of all privately-maintained stormwater treatment control measures. The property owner is responsible for compliance with the Maintenance Access Agreement. An example Maintenance Access Agreement is presented in Appendix G.

T-5: Proprietary Stormwater Treatment Control Measures

Introduction

The 2015 Post-Construction Stormwater Standards Manual provides information for selecting and designing the more common stormwater treatment control measures for projects. Stormwater treatment control measures included in this appendix are non-proprietary (public domain) designs that have been reviewed and evaluated by the Agencies and determined to be generally acceptable.

Proprietary devices are commercial products that typically aim at providing stormwater treatment in space-limited applications, often using patented innovative technologies. The most commonly encountered classes of proprietary stormwater treatment control measures include hydrodynamic separation, catch basin insert technologies, cartridge filter-type controls, and proprietary biotreatment devices.

Hydrodynamic separation devices (alternatively, swirl concentrators) are devices that remove trash, debris, and coarse sediment from incoming flows using screening, gravity settling, and centrifugal forces generated by forcing the influent into a circular motion. By having the water move in a circular fashion, rather than a straight line, it is possible to obtain significant removal of suspended sediments and attached pollutants with less space as compared to wet vaults and other settling devices. Hydrodynamic separation has been adapted for stormwater treatment by several manufacturers and is currently used to remove trash, debris, and other coarse solids down to sand-sized particles. Several types of hydrodynamic separation devices are also designed to remove floating oils and grease using sorbent media.

Catch basin inserts are manufactured filters or fabric placed in a drop inlet to remove sediment and debris and may include sorbent media to remove floating oils and grease. Most types of catch basin inserts fall into one of three configurations: socks, boxes, and trays. Sock-type filters, which are intended for vertical (drop) inlets, are typically constructed of a fabric (e.g., polypropylene) that may be attached to a frame or the grate of the inlet. Boxes, which are typically constructed of plastic or wire mesh, include a polypropylene “bag”, shaped as a box, that is placed in the wire mesh to allow for settling and filtration of stormwater runoff. Trays are designed to hold different types of media (e.g., polypropylene, porous polymer, treated cellulose, activated carbon) to treat stormwater runoff. Catch basin inserts are an easy, inexpensive retrofitting option because drain inlets are already a component of most storm drain systems. Inserts are usually only suitable for mitigating relatively small tributary areas (less than one acre) because they are limited by treatment capacity and influent flow rate.

Cartridge filter-type devices typically consist of a series of vertical filters contained in a vault or catch basin that provide treatment through filtration and sedimentation. The vault may be divided into multiple chambers where the first chamber acts as a pre-settling basin for removal of coarse sediment while another chamber acts as the filter bay and houses the filter cartridges. The performance and capacity of a cartridge filter installation depends on the properties of the media contained in the cartridges.

Cartridge filter manufacturers often provide an array of media types each with varying properties, targeting various pollutants and a range of particle sizes. Commonly used media include media that target solids, such as perlite, and media that target both dissolved and non-dissolved constituents, such as compost leaf media, zeolite, and iron-infused polymers. Manufacturers try to distinguish their products through innovative designs that aim at providing self-cleaning and draining, uniformly loaded, and clog resistant cartridges that functional properly over a wide range of hydraulic loadings and pollutant concentrations.

Proprietary biotreatment devices are devices that are manufactured to mimic natural systems such as wetlands by incorporating plants, soil, and microbes engineered to provide treatment at higher flow rates or higher volumes and with smaller footprints than their natural counterparts. Influent flows are typically filtered through natural media (e.g., mulch, compost, soil, plants, microbes) and either infiltrated or collected by an underdrain and delivered to the storm drain system. Tributary areas for biotreatment devices tend to be limited to 0.5 to 1.0 acres.

The vendors of the various proprietary stormwater treatment control measures provide detailed documentation for device selection, sizing, and maintenance requirements. Tributary area sizes are limited to the capacities of the largest available model. The latest manufacturer supplied documentation must be used for sizing and selection of all proprietary devices.

Proprietary stormwater treatment control measure vendors are constantly updating and expanding their product lines, so refer to the latest design guidance from the vendors. General guidelines on the performance, sizing, and operation and maintenance of proprietary devices are provided in the following sections.

Use and Applicability

In order to provide a rationale and basis for approval of proprietary treatment control measures, the Agencies have elected to recognize, as approved for general and pilot use, those proprietary treatment control measures that are approved for general, conditional, or pilot use by other selected major stormwater programs that have established and are actively conducting a comprehensive testing protocol and approval process. Currently, the Agencies recognize the lists of proprietary treatment control measures approved for general, condition, and pilot use from the following stormwater programs:

- Sacramento Stormwater Quality Partnership (http://www.beriverfriendly.net/newdevelopment/propstormwatertreatdevice)
- State of Washington Department of Ecology Stormwater Program (http://www.ecy.wa.gov/programs/wq/stormwater/newtech/technologies.html)

The Agencies may recognize lists from other stormwater programs in the future and will update this list accordingly.

The Phase II Permit (Provision E.12.e.(f)) identifies bioretention as the preferred stormwater treatment control measure unless (1) it is determined to be infeasible and an alternative treatment control measure that is equivalent to bioretention is proposed and demonstrated (Provision E.12.e.(g)), or (2) a specific exemption applies (Provision E.12.e.(i)). Proprietary devices may be proposed as an alternative to bioretention if it meets all of the following measures of equivalent effectiveness:

- Equal or greater amount of stormwater runoff infiltrated or evapotranspired;
- Equal or lower pollutant concentrations in stormwater runoff that is discharged after biotreatment;
- Equal or greater protection against shock loadings and spills; and
- Equal or greater accessibility and ease of inspection and maintenance.

In general, proprietary treatment control measures may not be able to meet all measures of equivalent effectiveness listed above in order to be accepted as an alternative to bioretention. However, proprietary treatment control measures may be used in combination with other stormwater treatment control measures (e.g., pretreatment) to reduce sediment and pollutant loads.

Expected Performance

For hydrodynamic devices, it has been stated with respect to combined sewer overflows that the practical lower limit of hydrodynamic separation is a particle with a settling velocity of 12 to 16.5 ft/hr (0.10 to 0.14 cm/s). As such, the focus for hydrodynamic separation in combined sewer overflows has been with settleable solids generally 200 μm and larger, given the presence of the lighter organic solids. For inorganic sediment, the above settling velocity range represents a particle diameter of 50 to 100 μm. Thus, hydrodynamic separation devices are effective for removal of course sediment, trash, and debris and useful for pretreatment in combination with other types of stormwater treatment control measures that target smaller particle sizes.

Because there is a wide range of catch basin insert configurations, it is not possible to generalize the expected performance. Inserts are primarily used for catching coarse sediments and floatable trash and are effective for pretreatment in combination with other types of stormwater treatment control measures. Trash and large objects can greatly reduce the effectiveness of catch basin inserts with respect to sediment and hydrocarbon capture. Frequent maintenance and the use of screens and grates to keep trash out may decrease the likelihood of clogging and prevent obstruction and bypass of incoming flows.

Cartridge filters are proven to provide efficient removals for both dissolved and non-dissolved pollutants. However, cartridge filters are less adept at handling high flow rates when compared to catch basin inserts and hydrodynamic devices due to the enhanced treatment provided through the filtration mechanism.

Because proprietary biotreatment devices are relatively new compared to the other types of proprietary treatment devices discussed in this fact sheet, there are fewer third party studies on proprietary biotreatment devices. The available performance information is mostly vendor-supplied. According to the vendors, like their natural counterparts, proprietary biotreatment devices are highly efficient at mitigating dissolved metals, nutrients, and suspended solids.

Sizing

Hydrodynamic devices, catch basin inserts, and cartridge filters are flow-based stormwater treatment control measures, but can be sized to capture and treat a design stormwater runoff volume with additional facilities to manage stormwater runoff flow. Proprietary biotreatment devices on the other hand include both volume-based and flow-based stormwater treatment control measures. Volume-based proprietary devices should be sized to capture and treat the design stormwater runoff volume if used as a standalone stormwater treatment control measure.

Auxiliary components of proprietary devices such as sorbent media, screens, baffles, and sumps are selected based on site-specific conditions such as the expected loading and the desired frequency of maintenance. Sizing of proprietary devices is reduced to a simple process whereby a model can simply be selected from a table or a chart based on a few known quantities (e.g., tributary area, location, design flow rate, design volume). Some manufacturers can size devices for potential clients or offer calculators on their websites that simplify the design process even further and lessens the possibility of using obsolete design information. For the latest sizing guidelines, refer to the manufacturer’s website.

Operation and Maintenance

The Agencies require execution of a Maintenance Access agreement to be recorded by the property owner for the on-going operation and maintenance of all privately-maintained stormwater treatment control measures, including proprietary treatment control measures. The property owner is responsible for compliance with the Maintenance Access Agreement. An example Maintenance Access Agreement is presented in Appendix G.

Hydrodynamic Separation Devices

Hydrodynamic separators do not have moving parts and are not maintenance intensive. However, maintenance is important to ensure that the device operates as efficiently as possible. Proper maintenance involves frequent inspections throughout the first year of installation, especially after major storm events. These systems are considered full when the sediment level is within one foot from the top of the unit, at which point it must be cleaned out. Removal of sediment can be performed with a sump vacuum or vactor truck. Some hydrodynamic separator devices may contribute to mosquito breeding if they do not fully drain stormwater runoff between storm events. Refer to manufacturer's guidelines for inspection and maintenance activities.

Catch Basin Inserts

Catch basin inserts can be maintenance-intensive because of their susceptibility for accumulating trash and debris. Regular maintenance activities include the clean-up and removal of accumulated trash and sediment while major maintenance activities include replacing filter media (if expended) and/or repairing/replacing fabrics. Refer to manufacturer's guidelines for inspection and maintenance activities.

Cartridge Filters

For cartridge filters, maintenance activities include periodically removing trash, debris, and sediment from the vault floor, typically twice per year depending on the accumulation rate, using a sump vacuum or vactor truck. The cartridges may need to be replaced when they become saturated, which will occur approximately every other year depending on the pollutant accumulation rate. The manufacturers of these devices typically provide contract operation and maintenance services.

All stormwater vaults that contain standing water can become a breeding area for vectors. Manufacturers have developed systems, such as a perforated pipe installed in the bottom of the vault that is encased in a filter sock to prevent clogging, to completely drain the vault.

Biotreatment Devices

Maintenance of biotreatment devices can be provided by the manufacturer and typically consists of routine inspection and hand removal of accumulated trash and debris. Vactor trucks or mechanical maintenance activities are not needed for biotreatment devices.

HM-1: Extended Detention Basin

Description

Extended detention basins are permanent basins formed by excavation and/or construction of embankments to temporarily detain stormwater runoff to allow for settling of sediment particles before the stormwater runoff is discharged. An extended detention basin reduces peak stormwater runoff flow rates and provides stormwater runoff treatment and hydromodification control. Extended detention basins are designed to drain completely between storm events over a specified period of time.

Stormwater runoff enters a sediment forebay where coarse solids are removed prior to flowing into the main cell of the basin where finer sediment and associated pollutants settle as stormwater is detained and slowly released through a controlled outlet structure. The slopes, bottom, and forebay of extended detention basins are typically vegetated. During storm events that exceed the design capacity, stormwater runoff will pass through the extended detention basin and discharge over a primary overflow outlet untreated, or during extreme events, over a spillway.

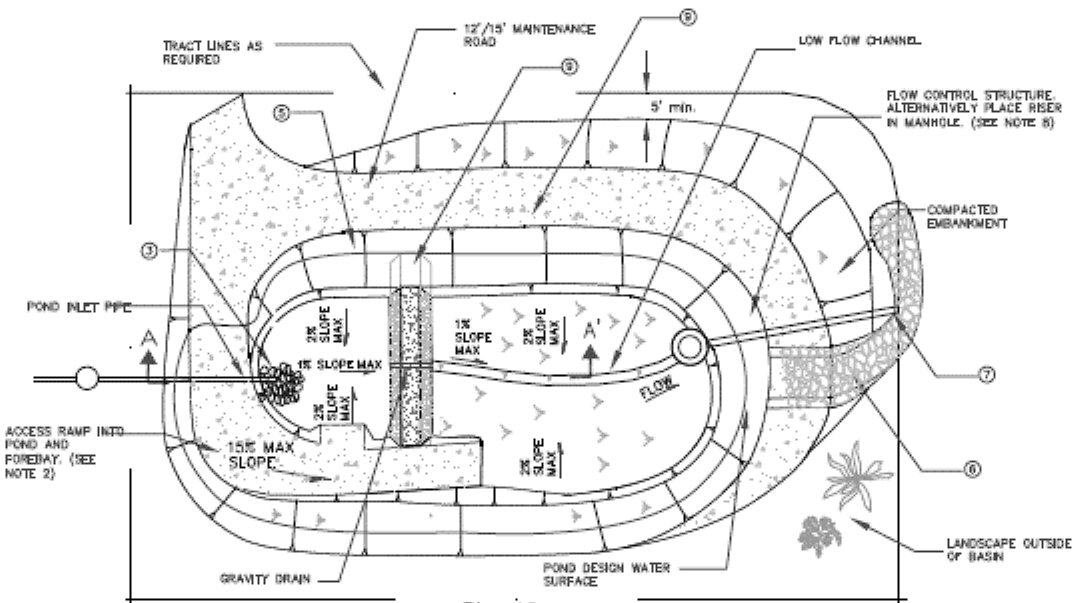
An example schematic of a typical extended detention basin is presented in **Figure F-8**.

Use and Applicability

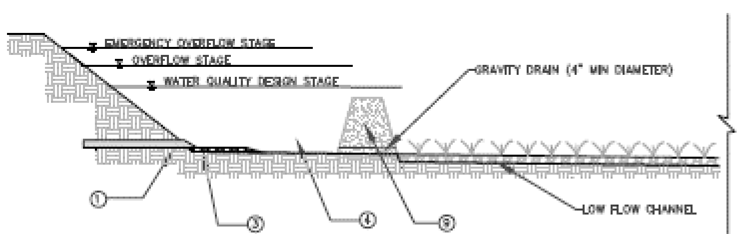
The Phase II Permit (Provision E.12.e.(f)) identifies bioretention as the standard stormwater treatment control measure unless (1) it is determined to be infeasible and an alternative treatment control measure that is equivalent to bioretention is proposed and demonstrated (Provision E.12.e.(g)), or (2) a specific exemption applies (Provision E.12.e.(i)). An alternative to bioretention can be proposed if it meets all of the following measures of equivalent effectiveness:

- Equal or greater amount of stormwater runoff infiltrated or evapotranspired;
- Equal or lower pollutant concentrations in stormwater runoff that is discharged after biotreatment;
- Equal or greater protection against shock loadings and spills; and
- Equal or greater accessibility and ease of inspection and maintenance.

An extended detention basin is typically used to meet hydromodification and flood control requirements.



Plan View
(Not to Scale)



Section A – A'
(Not to Scale)

NOTES:

1. INLET PIPE SHALL BE DESIGNED AND LOCATED SO THAT NON–EROSIVE VELOCITIES OCCUR IN THE FOREBAY
2. MAINTENANCE RAMP SHOULD BE PAVED. SLOPE SHOULD NOT EXCEED 12%. MAINTENANCE RAMP SHOULD PROVIDE ACCESS TO BOTH THE FOREBAY AND MAIN BASIN.
3. RIP RAP APRON OR OTHER INLET ENERGY DISSIPATION SHALL BE PROVIDED SUCH THAT VELOCITIES IN THE FOREBAY ARE < 4 FT/S.
4. SEDIMENT FOREBAY SHOULD BE SIZED TO PROVIDE 25% OF THE TOTAL BASIN VOLUME.
5. SIDE SLOPES SHOULD NOT EXCEED 3:1 UNLESS APPROVED BY AN ENGINEER. SIDE SLOPES SHALL NOT EXCEED 2:1 WITHOUT A SUPPORTING GEOTECHNICAL REPORT.
6. EMERGENCY SPILLWAY MUST BE SIZED TO PASS CAPITAL DEVELOPMENT PEAK FLOW FOR ON–LINE BASINS, AND WATER QUALITY DESIGN FLOW FOR OFF–LINE BASINS.
7. OUTLET PIPE. ENERGY DISSIPATION SHALL BE PROVIDED UNLESS DISCHARGE IS TO PIPE OR HARDENED CHANNEL
8. OUTLET STRUCTURE SHOULD BE SIZED TO DRAIN WATER QUALITY VOLUME IN 36 – 48 HOURS. ALTERNATIVELY PLACE RISER STRUCTURE IN A MANHOLE
9. INSTALL EARTHEN BERM OR EQUIVALENT. TOP OF BERM SHALL BE 2' MINIMUM BELOW DESIGN WATER QUALITY STAGE. BERM SHALL BE KEYED INTO EMBANKMENT A MINIMUM OF 1' ON BOTH SIDES.

Figure F-8. Example Extended Detention Basin Schematic

Design Specifications

The following sections provide design specifications for extended detention basins.

Geotechnical

A geotechnical investigation must be conducted during the site assessment process to verify site conditions for an extended detention basin. It is critical to understand how stormwater runoff will move through the soil (horizontally and vertically) and if there are any geologic conditions that may impact the movement of water. Soil infiltration rates and the depth to the groundwater table must be evaluated to ensure that conditions are satisfactory for proper operation of an extended detention basin. Extended detention basins can be used with almost all soils and geology with design adjustments for rapidly draining soils. If rapidly draining soils are present, extended detention basins must be designed by a licensed geotechnical engineer to include lower permeability soils in the subgrade to prevent rapid, untreated infiltration. Extended detention basins are typically located on sites with a slope no greater than 15 percent. A Site Conditions Report summarizing the relevant findings from the geotechnical investigation must be submitted with the Project Stormwater Plan.

Setbacks

Applicable setbacks must be implemented when siting an extended detention basin.

Pretreatment

Pretreatment, which refers to design features that provide settling of large particles before stormwater runoff enters a stormwater treatment control measure, is important to ensure proper operation of an extended detention basin and reduce the long-term maintenance burden. Pretreatment (e.g., vegetated swales, proprietary devices) may be provided to reduce the sediment load entering an extended detention basin in order to prevent sediment buildup that will reduce the capacity of the detention basin.

If a sediment forebay is used for pretreatment to remove coarse solids, it may be constructed with an internal berm made out of earthen embankment material, grouted riprap, or other structurally-sound material. The sediment forebay must be designed as follows:

- All inlets to the extended detention basin must enter the sediment forebay first.
- The sediment forebay must have a minimum volume equal to 25 percent of the total extended detention basin volume.
- Permanent steel post depth markers must be placed in the sediment forebay to identify the settled sediment removal limits at 50 and 100 percent of the sediment storage depth.

- The longitudinal slope (direction of flow) in the sediment forebay will be one percent.
- A gravity drain outlet from the sediment forebay (minimum four-inch diameter) must extend the entire width of the internal berm.
- The sediment forebay outlet must be off-set from the inflow flow line to prevent short-circuiting.

Flow Entrance and Energy Dissipation

The drainage management area(s) (DMA[s]) tributary to the extended detention basin must be graded to minimize erosion as stormwater runoff enters the basin or by providing energy dissipation devices at the inlet. Piped entrances must include rock, splash blocks, or other erosion controls at the entrance to dissipate energy and disperse flows. If a sediment forebay is included in the design, the energy dissipation devices must be installed at the inlet to the sediment forebay. Flow velocities into the sediment forebay must be 4 ft/s or less.

Drainage

Extended detention basins provide stormwater runoff storage above ground. Because extended detention basins are used primarily to meet hydromodification and flood control requirements, the basin must completely drain within 72 hours in order to allow the basin to receive stormwater runoff from subsequent storm events and prevent vector breeding.

Sizing

Step 1: Determine the Stormwater Runoff Volume

If the extended detention basin is demonstrated and approved as an alternative to bioretention, it must be designed to capture and manage the SDV_{adj}, which is the difference between the SDV (Section 5.2) and the volume of stormwater runoff managed through site design measures (Section 5.5), for the tributary DMA(s).

If the extended detention basin is used for hydromodification management, it must be designed to capture, detain, and discharge the stormwater runoff volume determined from hydrologic routing modeling (Section 7.2) to mitigate the peak stormwater runoff flow rate.

Step 2: Design Extended Detention Basin Dimensions

The dimensions of the extended detention basin must meet the following specifications:

- The total extended detention basin volume must be the volume of stormwater runoff (Step 1) that must be managed plus an additional five percent to allow for total suspended solids (TSS) accumulation. The extended detention basin must also have a minimum freeboard of one foot above the maximum water surface elevation over the spillway.

- To improve TSS removal, the length-to-width ratio at half basin depth must be a minimum of 1.5:1.
- The cross-sectional geometry across the width of the extended detention basin should be approximately trapezoidal with a maximum interior side slope of 3:1 (H:V) unless otherwise permitted by the Agency.
- Pond walls may be vertical retaining walls provided: (a) they are constructed of reinforced concrete; (b) a fence is provided along the top of the wall (see Fencing below) or further back; and (c) the design is stamped by a licensed civil engineer and approved by the Agency.
- A low flow channel, which is a narrow, shallow trench filled with pea gravel (or equivalent) that runs the length of the extended detention basin, must be provided to drain the basin of dry weather flows. Lining the low flow channel with concrete is recommended to prevent erosion. The low flow channel must have a depth of six inches and a width of one foot and tie into the outlet structure.
- The longitudinal slope (direction of flow) in the main basin may range from zero to one percent. The bottom of the extended detention basin must have a two percent slope toward the low flow channel.

Outlet Structure

An extended detention basin must drain within 72 hours after a storm event. The outlet structure is designed to release the bottom 50 percent of the detention volume (half-full to empty) over 24 to 36 hours and the top 50 percent (full to half-full) in 48 to 72 hours. Detention of low flows, which account for the majority of incoming flows, for longer periods enhances stormwater runoff treatment.

A trash rack or gravel pack around perforated risers may be provided to protect outlet orifices from clogging. Trash racks are better suited for use with perforated vertical plates for outlet control and allow easier access to outlet orifices for purposes of inspection and cleaning. Trash racks must be sized to prevent clogging of the primary outlet without restricting the hydraulic capacity of the outlet control orifices.

The two options that can be used for the outlet structure are:

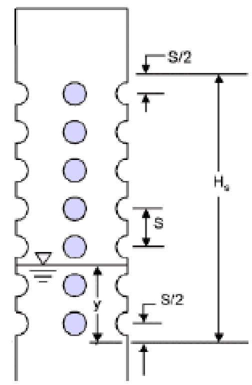
- Uniformly perforated riser structures; and
- Multiple orifice structures (orifice plate).

The primary overflow (typically a riser pipe connected to the outlet works) must be sized to pass the stormwater runoff volumes exceeding the design stormwater runoff volume. The primary overflow is intended to protect against overtopping or breaching of the extended detention basin embankment. Seepage collars may need to be installed on outlet pipes to prevent seepage through embankments. The outlet structure can be placed in the extended detention basin with a debris screen (see **Figure F-9**) or housed in a standard manhole (see **Figure F-10**).

Uniformly Perforated Riser Outlet Sizing Methodology (**Figure F-9**)

The following characteristics influence the perforated riser outlet sizing:

- Shape of the extended detention basin (i.e., trapezoidal);
- Depth and volume of the extended detention basin;
- Elevation and depth of first row of holes;
- Elevation and depth of last row of holes;
- Size of holes;
- Number of rows and number of holes per row; and
- Desired drawdown time.



The rate of discharge from a perforated riser structure with uniform holes at equal spacing can be calculated using the following:

$$Q = C_p \times \frac{2 \times A_p}{3 \times H_s} \times \sqrt{2 \times g} \times H^{3/2}$$

Where:

Q = riser discharge rate [ft^3/s];
C_p = discharge coefficient for perforations (use 0.61);
A_p = cross-sectional area of all the holes [ft^2];
H_s = distance from s/2 below the lowest row of holes to s/2 above the top row of holes (McEnroe 1988) [ft];
s = Center to center vertical spacing between perforations [ft];
g = Acceleration due to gravity (use 32.2 ft/s); and
H = Effective head on the orifice (measured from the center of orifice to water surface) [ft].

For the iterative computations needed to size the holes in the riser and determine the riser height, a simplified version of the equation above may be used, as shown below:

$$Q = k \times H^{3/2}$$

Where:

$$k = C_p \times \frac{2 \times A_p}{3 \times H_s} \times \sqrt{2 \times g}$$

Uniformly perforated riser designs are defined by the depth or elevation of the first row of perforations, the length of the perforated section of pipe, and the size or diameter of each perforation.

Multiple Orifice (Non-Uniform Outlet) Sizing Methodology (**Figure F-10**)

The following characteristics influence the multiple orifice outlet sizing:

- Shape of the extended detention basin (i.e., trapezoidal);
- Depth and volume of the extended detention basin;
- Elevation of each orifice; and
- Desired drawdown time.

The rate of discharge from a single orifice can be calculated using the following equation:

$$Q = C \times A \times (2 \times g \times H)^{0.5}$$

Where:

Q = orifice discharge rate [ft^3/s];
C = discharge coefficient;
A = cross-sectional area of orifice or pipe [ft^2];
g = acceleration due to gravity (use 32.2 ft/s);
H = effective head on the orifice (measured from the center of orifice to water surface) [ft].

Multiple orifice designs are defined by the depth (or elevation) and the size (or diameter) of each orifice.

Overflow Structure and Spillway

An overflow spillway or overflow riser must be provided. If an overflow spillway potentially discharges to a steep slope, an overflow riser and a spillway must be provided. The overflow device must be designed to pass the maximum storm size diverted to the extended detention basin, with a minimum one-foot freeboard, directly to an approved discharge location (e.g., another stormwater treatment control measure, storm drain system, receiving water).

The emergency overflow spillway must be constructed of grouted riprap and designed to withstand the energy of the spillway flows (**Figure F-11**). Spillways must meet the California Department of Water Resources, Division of Safety of Dams *Guidelines for the Design and Construction of Small Embankment Dams* (www.water.ca.gov/damsafety/docs/GuidelinesSmallDams.pdf).

Embankments

Embankments are earthen slopes or berms used to detain or redirect the flow of water. For extended detention basins, the embankments must be designed with the following specifications:

- All earthworks must be conducted in accordance with the Agency's Standard Specifications.
- The interior side slopes up to the overflow water surface must be no greater than 3:1 (H:V) unless stabilization has been approved by a licensed geotechnical engineer.
- The exterior side slopes must be no greater than 2:1 (H:V) unless stabilization has been approved by a licensed geotechnical engineer.
- The minimum top width of all berm embankments must be 20 feet, unless otherwise approved by the Agency.
- Berm embankments must be constructed on consolidated underlying soils or adequately compacted and stable fill soils approved by a licensed geotechnical engineer. Soils must be free of loose surface soil materials, roots, and other organic debris.
- Berm embankments must be constructed of compacted soil (95 percent minimum dry density, Modified Proctor method per ASTM D1557) and placed in six inch lifts.
- Berm embankments greater than 4 feet in height must be constructed by excavating a key equal to 50 percent of the berm embankment cross-sectional height and width. This requirement may be waived if specifically recommended by a licensed geotechnical engineer.
- Low growing, climate-appropriate grasses must be planted on the exterior embankment slopes.

Vegetation and Landscaping

- A thick mat of climate-appropriate grass must be established on the extended detention basin floor and embankment side slopes following construction. Grasses help prevent erosion and increase evapotranspiration. Additional active growing vegetation helps break up surface crusts that accumulate from sedimentation of fine particulates. Note that grass may need to be irrigated during the establishment period.
- Landscaping outside of the extended detention basin, but within the easement/right-of-way, may be included as long as it does not hinder maintenance access and operations.
- Trees or shrubs must not be planted within 10 feet of inlet or outlet pipes or manmade drainage structures such as spillways or earthen embankments.

Species with roots that seek water (e.g., willow, poplar) must not be planted within 50 feet of pipes or manmade drainage structures. Weeping willow (*Salix babylonica*) may not be planted in or near extended detention basins.

- Plant species that are not climate-appropriate are not permitted. A sample list of suitable vegetation species is included in Appendix H. Prior to installation, a landscape architect must certify that all proposed vegetation is appropriate for the project site.

Fencing

Safety is provided by fencing of the stormwater treatment control measure. Fences shall be designed and constructed in accordance with Agency standards and must be located at or above the top of overflow structure elevation.

Maintenance Access

Maintenance access must be provided to the structures associated with the extended detention basin (e.g., pretreatment, inlet, outlet, overflow structure) if it is publicly-maintained. Manhole and catch basin lids must be in or at the edge of the access road. An access ramp to the extended detention basin bottom is required to facilitate the entry of sediment removal and vegetation maintenance equipment.

Access roads must meet the following design specifications:

- All access ramps and roads must be paved with a minimum of six inches concrete over three inches of crushed aggregate base material. This requirement may be modified depending on the soil conditions and intended use of the road at the discretion of the Agency.
- The maximum grade is 12 percent unless otherwise approved by the Agency.
- Centerline turning radius must be a minimum of 40 feet.
- Access roads less than 500 feet long must have 12-foot wide pavement within a minimum 15-foot wide bench. Access roads greater than 500 feet long must have 16-foot wide pavement within a minimum 20-foot wide bench.
- All access roads must terminate with turnaround areas of 40-feet by 40-feet. A hammer type turn around area or a circle drive around the top of the extended detention basin is also acceptable.
- Adequate double-drive gates and commercial driveways are required at street crossings. Gates should be located a minimum of 25 feet from the street curb except in residential areas where the gates may be located along the property line provided there is adequate sight distance to see oncoming vehicles at the posted speed limit.

Restricted Construction Materials

The use of pressure-treated wood or galvanized metal at or around an extended detention basin is prohibited. The use of galvanized fencing is permitted if in accordance with the Fencing requirement above.

Construction Considerations

In general, approximately 0.5 to 2 percent of the tributary development area is required for an extended detention basin. If constructed early in the development project, an extended detention basin can serve as a sediment trap for the tributary area. Depending on the underlying soil, extended detention basins may provide incidental infiltration of stormwater runoff; however, extended detention basins are not designed for this purpose. In areas with rapidly percolating soils, the underlying soils may need to be amended under the guidance of a licensed geotechnical engineer or an impermeable liner may be need to be installed to prevent significant infiltration of stormwater runoff into the soils. The areas planned for extended detention basins should be clearly marked before site work begins to avoid soil disturbance and minimize compaction during construction. After construction is completed, the entire tributary area to the extended detention basin must be stabilized.

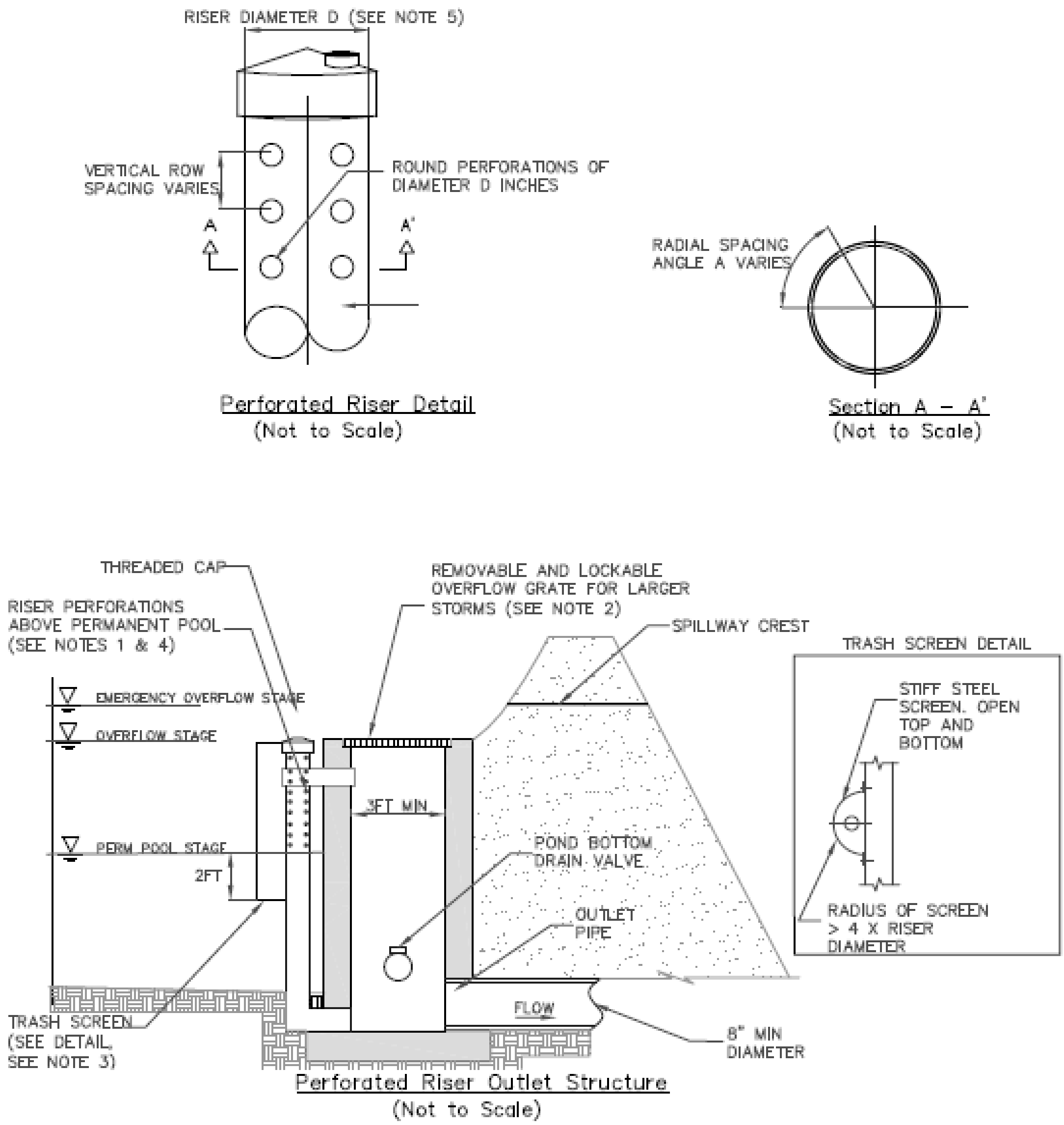
Maintenance Requirements

Maintenance and regular inspections must be conducted to ensure proper function of an extended detention basin. The following activities must be conducted to maintain an extended detention basin:

- At a minimum, inspect the extended detention basin annually. Inspections after major storm events are encouraged.
- Remove sediment accumulation exceeding 50 percent of the sediment storage capacity in the sediment forebay, as indicated on the permanent steel post depth markers. Remove sediment from the remainder of the basin when six inches of sediment accumulates. Test removed sediments for toxic substance accumulation in compliance with current disposal requirements if visual or olfactory indications of pollution are noticed. If toxic substances are detected at concentrations exceeding thresholds of Title 22, Section 66261 of the California Code of Regulations, dispose of the sediment in a hazardous waste landfill and investigate and mitigate the source of the contaminated sediments to the maximum extent possible.
- Remove trash and debris, as needed, but at least annually prior to the beginning of the wet season.
- Maintain vegetation as needed to sustain the aesthetic appearance of the site and to prevent clogging of outlets as follows:

  - Prune and/or remove vegetation, large shrubs, or trees that limit access or interfere with operation of the extended detention basin.
  - Mow grass to four to nine inches high and remove grass clippings.
  - Rake and remove fallen leaves and debris from deciduous plant foliage.
  - Remove invasive, poisonous, nuisance, or noxious vegetation and replace with climate-appropriate vegetation.
  - Remove dead vegetation if it exceeds 10 percent of area coverage. Replace vegetation immediately to maintain cover density and control erosion where soils are exposed. It may be necessary to re-grade eroded areas prior to replacing vegetation.
  - Do not use herbicides or other chemicals to control vegetation.
- Inspect inlet structure for erosion and re-grade if necessary.
- Inspect overflow structure for obstructions or debris, which should be removed immediately. Repair or replace damaged structures if necessary.

The Agencies require execution of a Maintenance Access Agreement to be recorded by the property owner for the on-going operation and maintenance of all privately-maintained stormwater treatment control measures. The property owner is responsible for compliance with the Maintenance Access Agreement. An example Maintenance Access Agreement is presented in Appendix G.



NOTES:

1. RISER PIPE SHALL BE SIZED TO PROVIDE 36 TO 48–HOUR FULL BRIM DRAW DOWN TIME.
2. TOTAL OUTLET CAPACITY: CAPITAL DEVELOPED PEAK FLOW FOR ON–LINE BASINS AND WATER QUALITY DESIGN FLOW FOR OFF–LINE BASINS.
3. SCREEN OPENINGS SHALL BE AT LEAST 1/4" AND SHALL NOT EXCEED THE DIAMETER OF THE PERFORATIONS ON THE RISER.
4. RISER PIPE PERFORATION DIAMETER SHALL BE NO LESS THAN 1/2" AND NO MORE THAN 2"
5. MINIMUM PIPE DIAMETER (D) IS 2'
6. RISER PIPE MATERIAL IS CMP

Figure F-9. Perforated Riser Structure

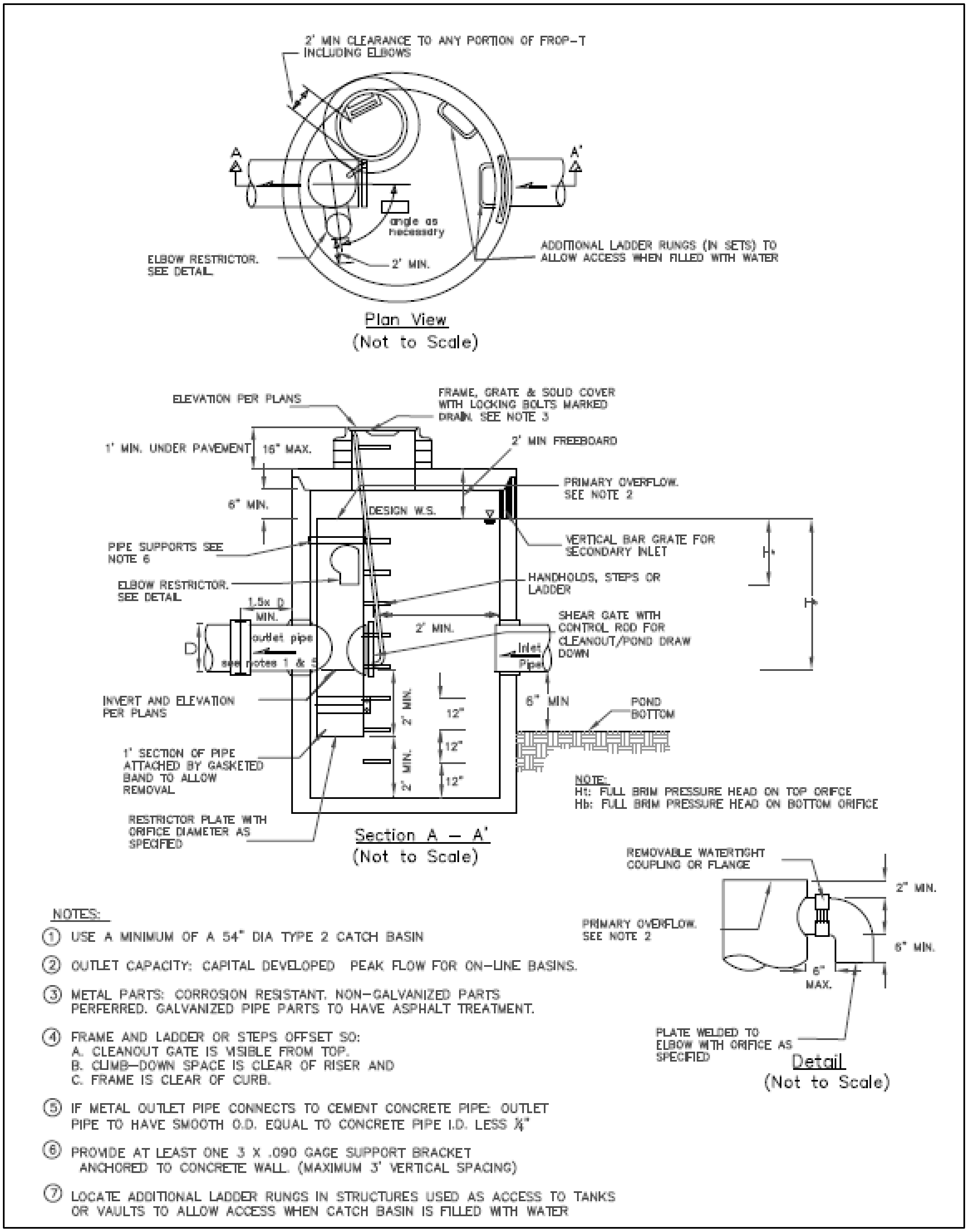


Figure F-10. Multiple Orifice Outlet

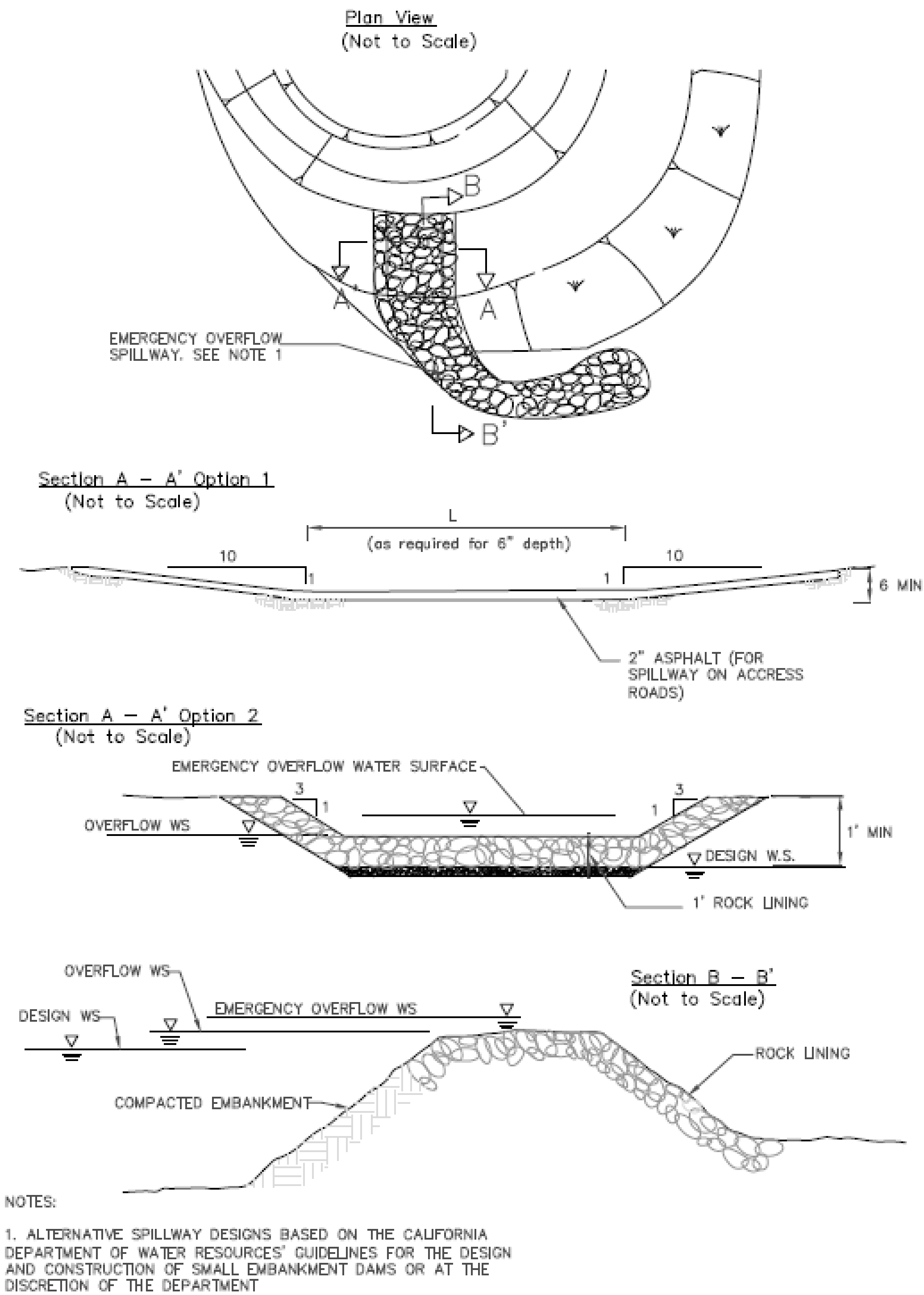


Figure F-11. Spillway Design Schematic

HM-2: Wet Pond

Description

Wet ponds are open earthen basins that feature a permanent pool of water that is displaced by stormwater runoff, in part or in total, during storm events. Like extended detention basins, wet ponds are designed to temporarily retain stormwater runoff, which reduces peak stormwater runoff flow rates and provides some stormwater runoff treatment and hydromodification control. Wet ponds differ from extended detention basins in that influent stormwater runoff mixes with and displaces the permanent pool as it enters the pond. A dry weather base flow is required to maintain a permanent pool in the wet pond. The primary treatment mechanism is sedimentation as stormwater runoff resides in this pool, but pollutant removal, particularly nutrients, also occurs through biological activity in the wet pond.

Wet ponds may also be designed with extended detention above the permanent pool. The extended detention portion of the wet pond above the permanent pool, if provided, functions like an extended detention basin to provide additional hydromodification control. If there is no extended detention provided, wet ponds must be sized to provide a minimum permanent pool volume.

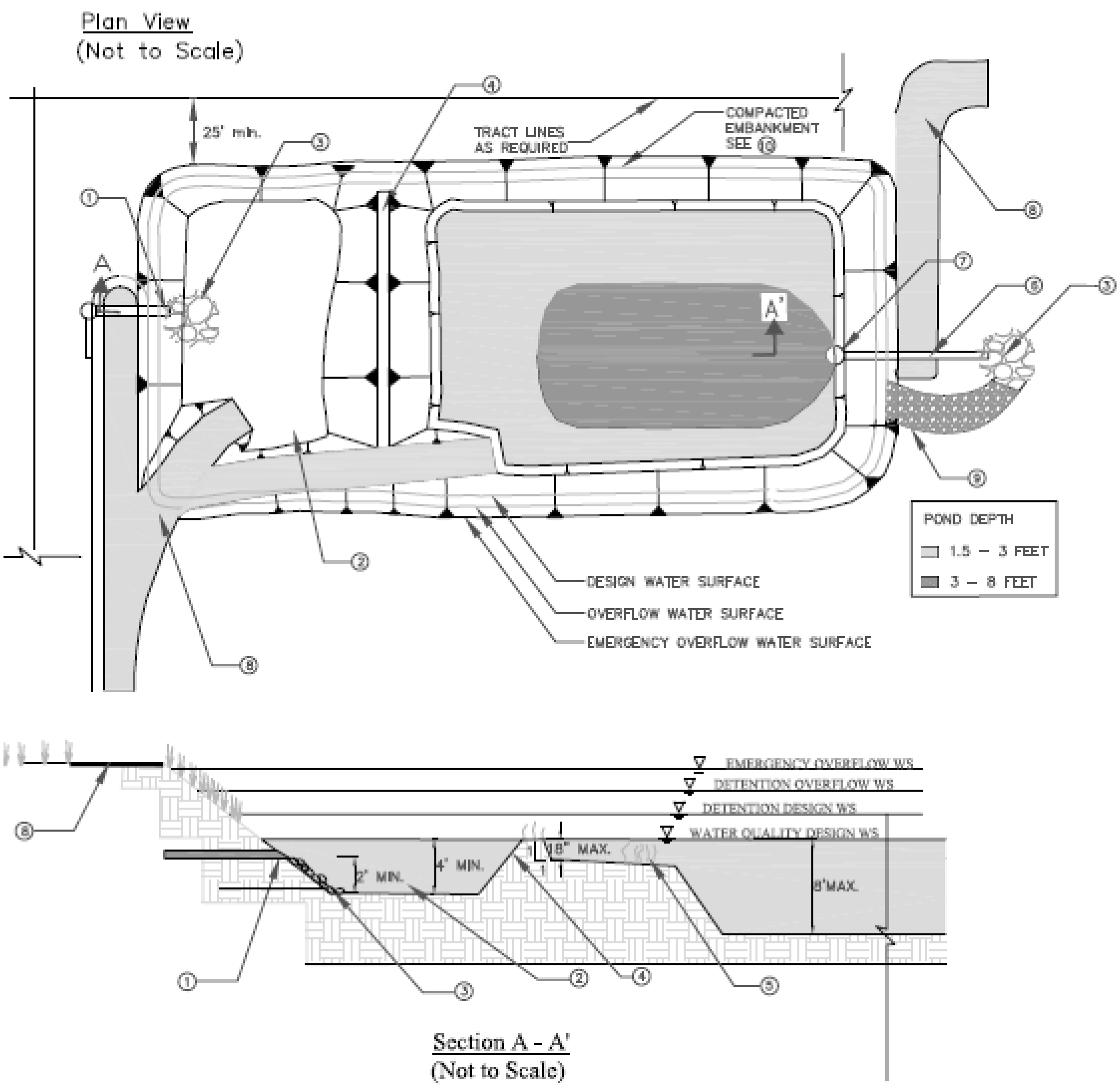
An example schematic of a wet pond with extended detention is presented in **Figure F-12**.

Use and Applicability

The Phase II Permit (Provision E.12.e.(f)) identifies bioretention as the standard stormwater treatment control measure unless (1) it is determined to be infeasible and an alternative treatment control measure that is equivalent to bioretention is proposed and demonstrated (Provision E.12.e.(g)), or (2) a specific exemption applies (Provision E.12.e.(i)). An alternative to bioretention can be proposed if it meets all of the following measures of equivalent effectiveness:

- Equal or greater amount of stormwater runoff infiltrated or evapotranspired;
- Equal or lower pollutant concentrations in stormwater runoff that is discharged after biotreatment;
- Equal or greater protection against shock loadings and spills; and
- Equal or greater accessibility and ease of inspection and maintenance.

A wet pond is typically used to meet hydromodification and flood control requirements.



NOTES:

① INLET PIPE SHOULD BE SUBMERGED WITH A MINIMUM OF 2' DISTANCE FROM THE BOTTOM

② FIRST CELL VOLUME SHALL EQUAL 25% TO 35% OF TOTAL WETPOND VOLUME. DEPTH SHALL BE 4' MIN TO 8' MAX PLUS AN ADDITIONAL 1' MIN SEDIMENT STORAGE DEPTH.

③ RIP RAP APRON OR OTHER ENERGY DISSIPATION.

④ BERM SHALL EXTEND ACROSS ENTIRE WIDTH OF THE WETPOND.

⑤ EMERGENT VEGETATION SHALL BE PLANTED IN REGIONS OF THE POND THAT ARE 3' DEEP OR LESS.

⑥ SIZE OUTLET PIPE TO PASS 100-YEAR PEAK FLOW FOR ON-LINE PONDS AND WATER QUALITY PEAK FLOW FOR OFF-LINE PONDS.

⑦ WATER QUALITY OUTLET STRUCTURE.

⑧ MAINTENANCE ACCESS ROAD SHOULD PROVIDE ACCESS TO BOTH THE FIRST CELL AND MAIN BASIN.

⑨ INSTALL EMERGENCY OVERFLOW SPILLWAY AS NEEDED.

Figure F-12. Example Wet Pond Schematic

Design Specifications

The following sections provide design specifications for wet ponds.

Geotechnical

A geotechnical investigation must be conducted during the site assessment process to verify site conditions for a wet pond. It is critical to understand how stormwater runoff will move through the soil (horizontally and vertically) and if there are any geologic conditions that may impact the movement of water. Soil infiltration rates and the depth to the groundwater table must be evaluated to ensure that conditions are satisfactory for proper operation of a wet pond.

Implementation of a wet pond in an area with rapidly draining soils requires impermeable liners to maintain permanent pools and/or micro-pools in the pond. Liners can be either synthetic materials (geomembrane liner) or imported lower permeability soils (e.g., clays). A water balance must be conducted to determine whether a liner is required. The following conditions can be used as a guideline:

- The sediment forebay must retain at least three feet of water year-round in order for pre-settling to be effective.
- The permanent pool must retain water for at least ten months of the year. Because plants can adapt to periods of summer drought, a limited drought period is allowed in the permanent pond. This may allow for a soil liner rather than a synthetic liner.

If low permeability soils are used for the impermeable liner, a minimum of 18 inches of the underlying soil amended with topsoil or compost (one part compost mixed with three parts of the underlying soil) must be placed over the liner. If a synthetic liner is used, a soil depth of two feet is recommended to prevent damage to the liner during planting.

Wet ponds are typically located on sites with a slope no greater than 15 percent. A Site Conditions Report summarizing the relevant findings from the geotechnical investigation and water balance must be submitted with the Project Stormwater Plan.

Setbacks

Applicable setbacks must be implemented when siting a wet pond.

Pretreatment

Pretreatment, which refers to design features that provide settling of large particles before stormwater runoff enters a stormwater treatment control measure, is important to ensure proper operation of a wet pond and reduce the long-term maintenance burden. Pretreatment may be provided to reduce the sediment load entering a wet pond in order to prevent sediment buildup that will reduce the capacity of the wet pond.

For wet ponds, typically a sediment forebay is used for pretreatment to remove coarse solids. The sediment forebay may be constructed with an internal berm made out of earthen embankment material, grouted riprap, or other structurally-sound material. The sediment forebay must be designed as follows:

- All inlets to the wet pond must enter the sediment forebay first.
- The sediment forebay must have a minimum volume equal to 5 to 10 percent of the total wet pond volume.
- Permanent steel post depth markers must be placed in the sediment forebay to identify the settled sediment removal limits at 50 and 100 percent of the sediment storage depth.
- The depth of the sediment forebay must be between four and eight feet, excluding sediment storage. One foot of sediment storage must be provided in the sediment forebay.
- A gravity drain outlet from the sediment forebay (minimum four-inch diameter) must extend the entire width of the internal berm.
- The sediment forebay outlet must be off-set from the inflow flow line to prevent short-circuiting.
- The sediment forebay outlet must be off-set from the inflow flow line to prevent short-circuiting.

Flow Entrance and Energy Dissipation

The drainage management area(s) (DMA[s]) tributary to the wet pond must be graded to minimize erosion that may enter the wet pond. The inlet to the wet pond must be submerged with the inlet pipe invert a minimum of two feet from the bottom (not including sediment storage). The top of the inlet pipe should be submerged at least one foot, if possible. A submerged inlet will dissipate energy from incoming flow. The distance from the bottom is required to minimize resuspension of settled sediments. Alternative inlet designs that meet these objectives are acceptable.

Drainage

Wet ponds provide stormwater runoff storage above ground. Wet ponds must have a base flow to maintain the permanent pool at least ten months of the year.

Sizing

<u>Step 1: Calculate the Stormwater Runoff Volume</u>

If the wet pond is demonstrated and approved as an alternative to bioretention, it must be designed to capture and manage the SDV_{adj}, which is the difference between the SDV (Section 5.2) and the volume of stormwater runoff managed through site design m measures (Section 5.5), for the tributary DMA(s).

If the wet pond is used for hydromodification management, it must be designed to capture, detain, and discharge the stormwater runoff volume determined from hydrologic routing modeling (Section 7.2) to mitigate the peak stormwater runoff flow rate.

Step 2: Determine Active Design Volume for Wet Pond without Extended Detention

The active volume of the wet pond (V_a) is equal to the stormwater runoff volume (Step 1) plus an additional five percent for sediment accumulation.

$$V_a = 1.05 \times V_{SW}$$

Where:

V_a = active volume of wet pond [ft^3]; and
V_{SW} = stormwater runoff volume [ft^3].

Step 3: Determine Preliminary Geometry

Based on site constraints, determine the pond geometry and the storage available by developing an elevation-storage relationship for the wet pond. Note that a more natural geometry may be used and is in many cases recommended; the preliminary wet pond geometry calculations are used for sizing purposes only.

Calculate the width of the wet pond footprint (W_{tot}) as follows:

$$W_{tot} = \frac{A_{tot}}{L_{tot}}$$

Where:

W_{tot} = total width of wet pond [ft];
A_{tot} = total surface area of wet pond footprint [ft^2]; and
L_{tot} = total length of wet pond [ft].

Calculate the length of the active volume surface area (L_{av-tot}), including the internal berm, but excluding the freeboard as follows:

$$L_{av-tot} = L_{tot} - 2 \times Z \times d_{fb}$$

Where:

L_{av-tot} = length of the active volume surface of wet pond [ft];
L_{tot} = total length of wet pond [ft];
Z = interior side slope as length per unit height [ft/ft]; and
d_{fb} = freeboard depth (minimum 1 ft) [ft].

Calculate the width of the active volume surface area (W_{av-tot}), including the internal berm, but excluding the freeboard as follows:

$$W_{av-tot} = W_{tot} - 2 \times Z \times d_{fb}$$

Where:

W_{av-tot} = width of the active volume surface of wet pond [ft];
W_{tot} = total width of wet pond footprint [ft];
Z = interior side slope as length per unit height [ft/ft]; and
d_{fb} = freeboard depth (minimum 1 ft) [ft].

Calculate the total active volume surface area (A_{av-tot}), including the internal berm, but excluding the freeboard as follows:

$$A_{av-tot} = L_{av-tot} \times W_{av-to}$$

Where:

A_{av-tot} = total active volume surface area [ft^2];
L_{av-tot} = length of total active volume surface of wet pond [ft]; and
W_{av-tot} = width of total active volume surface of wet pond [ft].

Calculate the area of the berm (A_{berm}) as follows:

$$A_{berm} = L_{berm} \times W_{berm}$$

Where:

A_{berm} = area of berm [ft^2];
L_{berm} = length of berm [ft]; and
W_{berm} = width of berm [ft].

Calculate the active volume surface area (A_{av-tot}), excluding the internal berm and freeboard as follows:

$$A = A_{av-tot} - A_{berm}$$

Where:

A = active volume surface area, including the internal berm, but excluding the freeboard [ft^2];
A_{av-tot} = total active volume surface area, including the internal berm, but excluding the freeboard [ft^2]; and
A_{berm} = Area of berm [ft^2].

Step 4: Determine Dimensions of Sediment Forebay (if included)

If a sediment forebay is included in the design, the wet pond must be divided into two cells separated by a berm. If a sediment forebay is not included in the design, skip this step and all subsequent design calculations will be zero or omitted for the purposing of sizing the sediment forebay. The sediment forebay must have a minimum volume equal to 5 to 10 percent of the total wet pond volume. The berm volume does not count as part of the total volume.

Calculate the active volume of the sediment forebay (V_f) as follows:

$$V_f = \frac{V_a \times \%V_f}{100}$$

Where:

V_f = active volume of sediment forebay [ft^3];
V_a = active volume of wet pond [ft^3]; and
$\%V_f$ = percent of stormwater runoff volume in sediment forebay (minimum 5 percent) [%].

Calculate the surface area for the active volume of sediment forebay (A_f) as follows:

$$A_f = \frac{V_f}{d_f}$$

Where:

A_f = surface area of active volume of sediment forebay [ft^2];
V_f = active volume of sediment forebay [ft^3]; and
d_f = average depth of the active volume of sediment forebay (2-4 ft) [ft].

Calculate the length of the sediment forebay (L_f). Note that the inlet(s) and outlet(s) of the sediment forebay should be configured to maximize the hydraulic residence time.

$$L_f = \frac{A_f}{W_f}$$

$$W_f = W_{av-tot} = L_{berm}$$

Where:

L_f = length of sediment forebay [ft];
A_f = surface area of active volume of sediment forebay [ft^2];
W_f = width of sediment forebay [ft];
W_{av-tot} = width of total active volume surface area [ft]; and
L_{berm} = length of berm [ft].

<u>Step 5: Determine Dimensions of Permanent Pool</u>

The permanent pool consists of the remainder of the active volume of the wet pond. Calculate the active volume of the permanent pool (V_p) as follows:

$$V_p = V_a - V_f$$

Where:

V_p = active volume of permanent pool of wet pond [ft^3];
V_a = active volume of wet pond [ft^3]; and
V_f = active volume of the sediment forebay [ft^3].

The minimum permanent pool surface area includes 0.3 acres of permanent pool per acre-foot of permanent pool volume. Calculate $A_{p,min}$:

$$A_{p,min} = 0.3 \frac{acres}{acre - ft} \times V_p$$

Where:

$A_{p,min}$ = minimum permanent pool surface area [ft^2]; and
V_p = Active volume of the permanent pool [ft^3].

Calculate the actual permanent pool surface area (A_p) as follows:

$$A_p = A - A_f$$

Where:

A_p = actual surface area of permanent pool [ft^2];
A = active volume surface area, including the internal berm, but excluding the freeboard [ft^2]; and
A_f = active volume of sediment forebay [ft^2].

Verify that A_p is greater than $A_{p,min}$. If A_p is less than $A_{p,min}$, modify the input parameters to increase A_p until it is greater than $A_{p,min}$. If site constraints limit this criterion, then another site for the wet pond may need to be selected.

Calculate the top length of the permanent pool (L_p) as follows:

$$L_p = \frac{A_p}{W_p}$$

$$W_p = W_f = W_{av-tot} = L_{berm}$$

Where:

A_p = surface area of permanent pool [ft^2];
W_p = width of permanent pool [ft];
W_f = width of sediment forebay [ft];
$W_{av\text{-}tot}$ = width of total active volume surface area [ft]; and
L_{berm} = length of berm [ft].

Verify that the length-to-width ratio of the permanent pool is at least 1.5:1 with greater than 2:1 preferred. If the length-to-width ratio is less than 1.5:1, modify the input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the wet pond may need to be selected.

Step 6: Design Other Wet Pond Features

Other sizing specifications for the wet pond include the following:

- A minimum freeboard of one foot above the maximum water surface elevation must be maintained.
- A 25-foot (minimum) buffer must be provided around the top perimeter of the wet pond.
- The flow path length-to-width ratio must be a minimum of 1.5:1, but preferably 3:1 or greater. A higher flow path length to width ratio increases the removal efficiency of total suspended solids (TSS).
- The edge of the wet pond should slope from the surface of the permanent pool to a depth of 12 to 18 inches at a slope of 1:1 (H:V) or greater. If soil conditions cannot support a 1:1 (H:V) slope, then the steepest slope that can be supported should be used or a shallow retaining wall constructed (18 inches maximum). Beyond the edge of the wet pond, a bench sloped at 4:1 (H:V) maximum should extend into the wet pond to a depth of at least three feet. A steeper slope may be used beyond the three foot depth to a maximum of eight feet. The steep slope at the water's edge will minimize very shallow areas that can support vector breeding.
- Wet ponds must be designed with a hydraulic residence time for dry weather flows of less than seven days to minimize vector breeding and stagnation issues.
- At least 25 percent of the permanent pool must be deeper than three feet to prevent growth of emergent vegetation across the entire pond. If greater than 50 percent of the permanent pool is deeper than six feet deep, a recirculation system (e.g., fountain, aerator) must be provided to prevent stratification, stagnation, and low dissolved oxygen conditions.

Step 7: Design Berm

The berm separating the sediment forebay, if one is provided, and the permanent pool must meet the following specifications:

- The top of the berm must be either at the stormwater runoff volume (Step 1) water surface or submerged one foot below the stormwater runoff volume water surface.
- The side slopes of the berm must meet the following specifications:
    - If the top of the berm is at the stormwater runoff volume water surface, the berm side slopes must be no steeper than 3:1 (H:V); or
    - If the top of berm is submerged one foot below the stormwater runoff volume water surface, the upstream side slope has a maximum slope of 2:1 (H:V).

Step 8: Design Extended Detention (if necessary)

If extended detention is included, then the extended detention volume must provide detention of 10 percent of the stormwater runoff volume (Step 1) while the surcharge volume makes up the remaining 90 percent of the sizing.

Outlet Structure

An outlet pipe and structure must be sized, at a minimum, to pass stormwater runoff volumes exceeding the design stormwater runoff volume (Step 1). The outlet pipe may be a perforated riser strapped to a manhole (**Figure F-13**) or placed in an embankment suitable for extended detention or may be back-sloped to a catch basin with a grated opening (jail house window) or manhole with a cone grate (birdcage) (**Figure F-14**). The grate or birdcage openings provide an overflow route should the wet pond outlet pipe become clogged. Seepage collars may be required on outlet pipes to prevent seepage through embankments. Energy dissipation controls must also be used at the outlet from the wet pond unless it discharges to the storm drain system or a hardened channel.

Overflow Structure and Spillway

An overflow spillway or overflow riser must be provided. If an overflow spillway potentially discharges to a steep slope, an overflow riser and a spillway must be provided. The overflow device must be designed to pass the maximum storm size diverted to the wet pond, with a minimum one-foot freeboard, directly to an approved discharge location (e.g., another stormwater treatment control measure, storm drain system, receiving water).

The emergency overflow spillway must be constructed of grouted riprap and designed to withstand the energy of the spillway flows (**Figure F-11**). Spillways must meet the California Department of Water Resources, Division of Safety of Dams *Guidelines for the Design and Construction of Small Embankment Dams* (www.water.ca.gov/damsafety/docs/GuidelinesSmallDams.pdf).

Embankments

Embankments are earthen slopes or berms used to detain or redirect the flow of water. For wet ponds, the embankments must be designed with the following specifications:

- All earthworks must be conducted in accordance with the Agency's Standard Specifications.
- The interior side slopes up to the overflow water surface must be no greater than 3:1 (H:V) unless stabilization has been approved by a licensed geotechnical engineer.
- The exterior side slopes must be no greater than 2:1 (H:V) unless stabilization has been approved by a licensed geotechnical engineer.
- The minimum top width of all berm embankments must be 20 feet, unless otherwise approved by the Agency.
- Berm embankments must be constructed on consolidated underlying soil or adequately compacted and stable fill soils approved by a licensed geotechnical engineer. Soils must be free of loose surface soil materials, roots, and other organic debris.
- Berm embankments must be constructed of compacted soil (95 percent minimum dry density, Modified Proctor method per ASTM D1557) and placed in six inch lifts.
- Berm embankments greater than 4 feet in height must be constructed by excavating a key equal to 50 percent of the berm embankment cross-sectional height and width. This requirement may be waived if specifically recommended by a licensed geotechnical engineer.
- Low growing, climate-appropriate grasses must be planted on the exterior of the embankment slopes.

Water Supply

A water balance must be conducted to demonstrate that adequate water supply will be present to maintain a permanent pool of water during a drought year when precipitation is 50 percent of average for the site. The water balance must consider evapotranspiration, infiltration, precipitation, spillway discharge, and nuisance flow (where appropriate). If a water balance indicates that losses will exceed inputs, a source of water must be provided to maintain the water surface elevation for at least ten months of the year. The water supply must be of sufficient quantity and quality to not have an adverse impact on the water quality of the wet pond.

Vegetation and Landscaping

- A thick mat of climate-appropriate grass must be established on the wet pond embankment exterior side slopes following construction. Grasses help prevent erosion. Note that grass may need to be irrigated during the establishment period.

- If the permanent pool is three feet or shallower, the bottom area must be planted with emergent wetland vegetation for 25 to 75 percent coverage. A mix of erosion-resistant plant species that effectively bind the soil must be used on the interior slopes and a diverse selection of climate-appropriate plants must be specified for the pool bottom. The pool bottom must not be planted with trees, shrubs, or other large woody plants that may interfere with maintenance activities.
- Landscaping outside of the wet pond, but within the easement/right-of-way, may be included as long as it does not hinder maintenance operations.
- Trees or shrubs must not be planted within 10 feet of inlet or outlet pipes or manmade drainage structures such as spillways or earthen embankments. Species with roots that seek water (e.g., willow, poplar) must not be planted used within 50 feet of pipes or manmade drainage structures. Weeping willow (*Salix babylonica*) may not be planted in or near wet ponds.
- Plant species that are not climate-appropriate are not permitted. A sample list of suitable vegetation species is included in Appendix H. Prior to installation, a landscape architect must certify that all proposed vegetation is appropriate for the project site.

Fencing

Safety is provided by fencing of the stormwater quality control measure. Fences shall be designed and constructed in accordance with Agency standards and must be located at or above the top of the overflow structure elevation.

Maintenance Access

Maintenance access must be provided to the structures associated with the wet pond (e.g., sediment forebay, inlet, outlet, overflow structure) if it is publicly-maintained. Manhole and catch basin lids must be in or at the edge of the access road. An access ramp to the wet pond bottom is required to facilitate the entry of sediment removal and vegetation maintenance equipment.

Access roads must meet the following design specifications:

- All access ramps and roads must be paved with a minimum of six inches concrete over three inches of crushed aggregate base material. This requirement may be modified depending on the soil conditions and intended use of the road at the discretion of the Agency.
- The maximum grade is 12 percent unless otherwise approved by the Agency.
- Centerline turning radius must be a minimum of 40 feet.

- Access roads less than 500 feet long must have 12-foot wide pavement within a minimum 15-foot wide bench. Access roads greater than 500 feet long must have 16-foot wide pavement within a minimum 20-foot wide bench.
- All access roads must terminate with turnaround areas of 40-feet by 40-feet. A hammer type turn around area or a circle drive around the top of the wet pond is also acceptable.
- Adequate double-drive gates and commercial driveways are required at street crossings. Gates should be located a minimum of 25 feet from the street curb except in residential areas where the gates may be located along the property line provided there is adequate sight distance to see oncoming vehicles at the posted speed limit.

Restricted Construction Materials

The use of pressure-treated wood or galvanized metal at or around a wet pond is prohibited. The use of galvanized fencing is permitted if in accordance with the Fencing requirement above.

Construction Considerations

In general, approximately two to three percent of the tributary development area is required for a wet pond. Wet ponds are most appropriate for sites with low-permeability soil, which help to maintain the permanent pool. Depending on the underlying soil, a wet pond may provide incidental infiltration of stormwater runoff; however, wet ponds are not designed for this purpose. An impermeable liner may be required to maintain the permanent pool in areas with rapidly draining soils. The areas planned for wet ponds should be clearly marked before site work begins to avoid soil disturbance. After construction is completed, the entire tributary area to the wet pond must be stabilized.

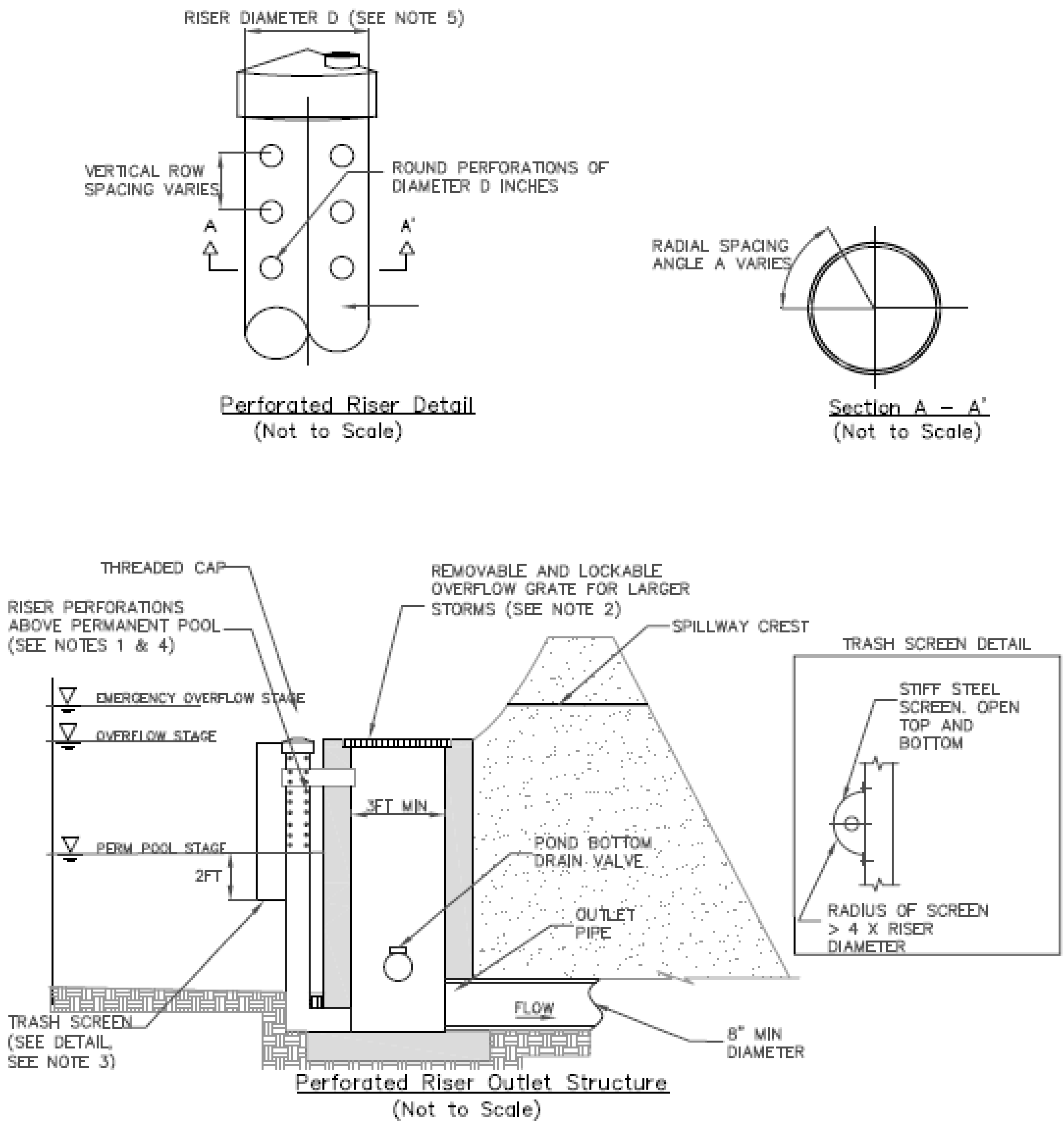
Maintenance Requirements

Maintenance and regular inspections must be conducted to ensure proper function of a wet pond. The following activities must be conducted to maintain a wet pond:

- At a minimum, inspect the wet pond annually. Inspections after major storm events are encouraged.
- Remove sediment accumulation exceeding 50 percent of the sediment storage capacity of the sediment forebay, as indicated on the permanent steel post depth markers. Test removed sediments for toxic substance accumulation in compliance with current disposal requirements if visual or olfactory indications of pollution are noticed. If toxic substances are detected at concentrations exceeding thresholds of Title 22, Section 66261 of the California Code of Regulations, dispose of the sediment in a hazardous waste landfill and investigate and mitigate the source of the contaminated sediments to the maximum extent possible.

- Remove trash and debris, as needed, but at least annually prior to the beginning of the wet season.
- Maintain site vegetation as frequently as necessary to maintain the aesthetic appearance of the site and to prevent clogging of outlets, creation of dead spaces, and barriers to mosquito fish to access pooled areas, and as follows:
    - Prune and/or remove vegetation, large shrubs, or trees that limit access or interfere with operation of the wet pond.
    - Remove invasive, poisonous, nuisance, or noxious vegetation and replace with climate-appropriate vegetation.
    - Remove dead vegetation if it exceeds 10 percent of area coverage. Replace vegetation immediately to maintain cover density and control erosion where soils are exposed. It may be necessary to re-grade eroded areas prior to replacing vegetation.
    - Do not use herbicides or other chemicals to control vegetation.
    - Remove algae mats that cover more than 20 percent of the surface of the wet pond.
- Inspect inlet structure for erosion and re-grade if necessary.
- Inspect overflow structure for obstructions or debris, which should be removed immediately. Repair or replace damaged structures if necessary.

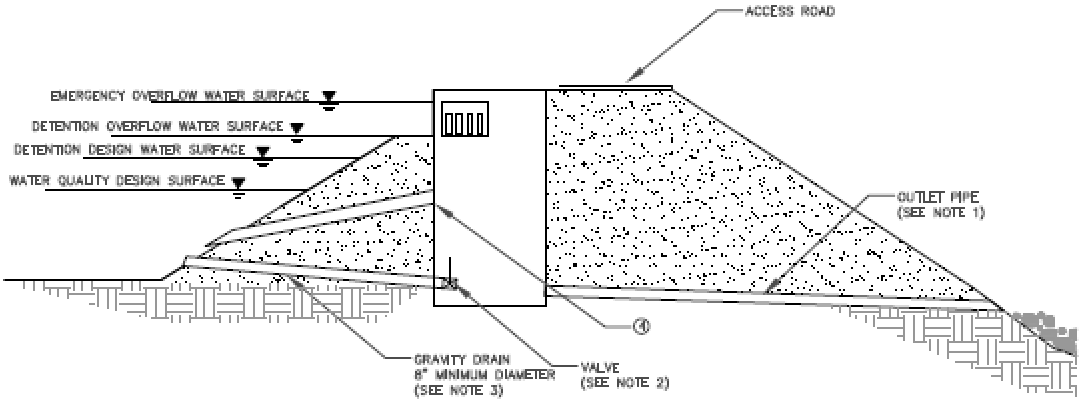
The Agencies require execution of a Maintenance Access Agreement to be recorded by the property owner for the on-going operation and maintenance of any privately-maintained stormwater treatment control measures. The property owner is responsible for compliance with the Maintenance Access Agreement. An example Maintenance Access Agreement is presented in Appendix G.



NOTES:

1. RISER PIPE SHALL BE SIZED TO PROVIDE 36 TO 48-HOUR FULL BRIM DRAW DOWN TIME.
2. TOTAL OUTLET CAPACITY: CAPITAL DEVELOPED PEAK FLOW FOR ON-LINE BASINS AND WATER QUALITY DESIGN FLOW FOR OFF-LINE BASINS.
3. SCREEN OPENINGS SHALL BE AT LEAST ¼" AND SHALL NOT EXCEED THE DIAMETER OF THE PERFORATIONS ON THE RISER.
4. RISER PIPE PERFORATION DIAMETER SHALL BE NO LESS THAN ½" AND NO MORE THAN 2"
5. MINIMUM PIPE DIAMETER (D) IS 2'
6. RISER PIPE MATERIAL IS CMP

Figure F-13. Riser Outlet Schematic



Inverted Pipe Outlet Structure
(Not to Scale)

NOTES:

1. SIZE OUTLET PIPE SYSTEM TO PASS CAPITAL PEAK FLOW FOR ON–LINE PONDS AND WATER QUALITY PEAK FLOW FOR OFF–LINE PONDS.
2. VALVE MAY BE LOCATED INSIDE MANHOLE OR OUTSIDE WITH APPROVED OPERATIONAL ACCESS
3. INVERT OF DRAIN SHALL BE 6" MINIMUM BELOW TOP OF INTERNAL BERM. LOWER PLACEMENT IS DESIRABLE. INVERT SHALL BE 6" MINIMUM ABOVE BOTTOM OF POND.
4. OUTLET PIPE INVERT SHALL BE AT WETPOOL WATER SURFACE ELEVATION

Figure F-14. Inverted Pipe Outlet Schematic

APPENDIX G

Example Maintenance Access Agreement

Example Maintenance Access Agreement

(Long Form)

Recorded at the request of:

City/County of____

After recording, return to:

City/County of____

City/County Clerk

____

____

STORMWATER TREATMENT CONTROL MEASURE
MAINTENANCE ACCESS AGREEMENT

OWNER: ____

PROPERTY ADDRESS:______________________________________

APN:____

THIS AGREEMENT is made and entered into in_____________________, California, this___day of________________, by and between________________________, hereinafter referred to as "Owner" and the CITY/COUNTY OF________________ ______, a municipal corporation, located in the County of _______________, State of California hereinafter referred to as "CITY/COUNTY";

WHEREAS, the Owner owns real property ("Property") in the City/County of __________ ______, County of _______, State of California, more specifically described in Exhibit "A" and depicted in Exhibit "B", each of which exhibits is attached hereto and incorporated herein by this reference;

WHEREAS, at the time of initial approval of development project known as___________ ________________________________within the Property described herein, the City/County required the project to employ on-site control measures to minimize pollutants in urban runoff;

WHEREAS, the Owner has chosen to install (a/n) ______________________________ _____________________________________, hereinafter referred to as "Stormwater Treatment Control Measure(s)", as the on-site control measure to minimize pollutants in urban runoff;

WHEREAS, said Stormwater Treatment Control Measure(s) has/have been installed in accordance with plans and specifications accepted by the City/County;

WHEREAS, said Stormwater Treatment Control Measure(s), with installation on private property and draining only private property, is a private facility with all maintenance or replacement, therefore, the sole responsibility of the Owner in accordance with the terms of this Agreement;

WHEREAS, the Owner is aware that periodic and continuous maintenance, including, but not necessarily limited to, vegetation management, filter material replacement, and sediment removal, is required to assure peak performance of the Stormwater Treatment Control Measure(s) and that, furthermore, such maintenance activity will require compliance with all Local, State, or Federal laws and regulations, including those pertaining to confined space and waste disposal methods, in effect at the time such maintenance occurs;

WHEREAS, the Owner is required to implement the Operations and Maintenance Plan, more specifically described in Exhibit “C”, which is attached hereto and incorporated herein by this reference;

NOW THEREFORE, it is mutually stipulated and agreed as follows:

1) Owner hereby provides the City/County or City’s/County’s designee complete access, of any duration, to the Stormwater Treatment Control Measure(s) and its immediate vicinity at any time, upon reasonable notice, or in the event of emergency, as determined by City’s/County’s Director of Public Works no advance notice, for the purpose of inspection, sampling, testing of the Stormwater Treatment Control Measure(s), and in case of emergency, to undertake all necessary repairs or other preventative measures at Owner’s expense as provided in paragraph 3 below. City/County shall make every effort at all times to minimize or avoid interference with Owner’s use of the Property.

2) Owner shall use its best efforts diligently to operate and maintain the Stormwater Treatment Control Measure(s) in a manner assuring peak performance at all times in accordance with the Operation and Maintenance Plan, which is incorporated into this Agreement as Exhibit C. All reasonable precautions shall be exercised by Owner and Owner’s representative or contractor in the removal and extraction of material(s) from the Stormwater Treatment Control Measure(s) and the ultimate disposal of the material(s) in a manner consistent with all relevant laws and regulations in effect at the time. As may be requested from time to time by the City/County, the Owner shall provide the City/County with documentation identifying the material(s) removed, the quantity, and disposal destination.

3) In the event Owner, or its successors or assigns, fails to accomplish the necessary maintenance contemplated by this Agreement, within five (5) days of being given written notice by the City/County, the City/County is hereby authorized to cause any maintenance necessary to be done and charge the entire cost and expense to the Owner or Owner’s successors or assigns, including administrative costs, attorneys’ fees and interest thereon at the maximum rate authorized by the Civil Code from the date of the notice of expense until paid in full.

4) The City/County may require the Owner to post security in form and for a time period satisfactory to the City/County of guarantee of the performance of the obligations stated herein. Should the Owner fail to perform the obligations under the Agreement, the City/County may, in the case of a cash bond, act for the Owner using the proceeds from it, or in the case of a surety bond, require the sureties to perform the obligations of the Agreement. As an additional remedy, the Director may withdraw any previous stormwater related approval with respect to the Property on which a Stormwater Treatment Control Measure has been installed until such time as Owner repays to City/County its reasonable costs incurred in accordance with paragraph 3 above.

5) This Agreement shall be recorded in the Office of the Recorder of ________ ____________County, California, at the expense of the Owner and shall constitute notice to all successors and assigns of the title to said Property of the obligation herein set forth, and also a lien in such amount as will fully reimburse the City/County, including interest as herein above set forth, subject to foreclosure in event of default in payment.

6) In event of legal action occasioned by any default or action of the Owner, or its successors or assigns, then the Owner and its successors or assigns agree(s) to pay all costs incurred by the City/County in enforcing the terms of this Agreement, including reasonable attorney's fees and costs, and that the same shall become a part of the lien against said Property.

7) It is the intent of the parties hereto that burdens and benefits herein undertaken shall constitute covenants that run with said Property and constitute a lien there against.

8) The obligations herein undertaken shall be binding upon the heirs, successors, executors, administrators and assigns of the parties hereto. The term "Owner" shall include not only the present Owner, but also its heirs, successors, executors, administrators, and assigns. Owner shall notify any successor to title of all or part of the Property about the existence of this Agreement. Owner shall provide such notice prior to such successor obtaining an interest in all or part of the Property. Owner shall provide a copy of such notice to the City/County at the same time such notice is provided to the successor.

9) Time is of the essence in the performance of this Agreement.

10) Any notice to a party required or called for in this Agreement shall be served in person, or by deposit in the U.S. Mail, first class postage prepaid, to the address set forth below. Notice(s) shall be deemed effective upon receipt, or seventy-two (72) hours after deposit in the U.S. Mail, whichever is earlier. A party may change a notice address only by providing written notice thereof to the other party.

IF TO CITY/COUNTY:

____

____

____

IF TO OWNER:

____

____

____

IN WITNESS THEREOF, the parties hereto have affixed their signatures as of the date first written above.

APPROVED AS TO FORM:

____

City/County Attorney

OWNER:

____

Owner

Name: ___________________________

Title: ____________________________

CITY/COUNTY OF________________:

____

Name:____________________________

Title:_____________________________

OWNER:

____

Name:______________________________

Title:_______________________________

ATTEST:

____

City/County Clerk   Date

Notaries on Following Page

EXHIBIT A

(Legal Description)

EXHIBIT B

(Map/illustration)

EXHIBIT C

(Operations and Maintenance Plan)

(Short Form)

Recorded at the request of and mail to:

____

____

____

Covenant and Agreement Regarding

Stormwater Treatment Control Measure Maintenance and Access

The undersigned hereby certify that we are the owners of hereinafter legally described real property located in the City/County of ____________________, County of _______ ______, State of California.

Legal Description: ____

____

as recorded in Book _____________________, Page___________, Records of ______ County, which property is located and known as **(Address):** ________________.

And in consideration of the City/County of _______ allowing_____________________

____

on said property, we do hereby covenant and agree to and with said City/County to maintain according to the Operations and Maintenance Plan (Attachment 1), all structural stormwater treatment control measures including the following:

____

____.

This Covenant and Agreement shall run all of the above described land and shall be binding upon ourselves, and future owners, encumbrances, their successors, heirs, or assignees and shall continue in effect until released by the authority of the City/County upon submittal of request, applicable fees, and evidence that this Covenant and Agreement is no longer required by law.

NOTARIES ON FOLLOWING PAGE

OWNER'S CERTIFICATION
OPERATION AND MAINTENANCE PLAN
for
(PROJECT NAME)

This Operations and Maintenance Plan (Plan) was prepared for ______(Project Owner / Developer)___________ by ___(Name of Preparing Firm/Individual)____ ______. This Plan is intended to comply with all requirements specified in the City/County of ___________Stormwater Management and Discharge Control Ordinance . ___________.

The undersigned understands that stormwater treatment control measures are enforceable requirements under the Municipal Code. The undersigned, while owning the property on which such stormwater treatment control measures are to be implemented, is responsible for the implementation of the provisions of this Plan and for the operation and maintenance of all structural stormwater treatment control measures and agrees to ensure that the conditions on the project site conform to the requirements specified in the Municipal Code.

Once the undersigned transfers its interest in the project property, its successors-in-interest shall bear the aforementioned responsibility to maintain

Name of Owner: ____

Address of Owner: ____

Phone number of Owner: _____________________________________

Signature: ____

Print Name: ____

Title ____

Date ____

APPENDIX H

Suitable Vegetation Species

For stormwater treatment control measures designed for biotreatment (e.g., bioretention, stormwater planters, tree-well filters), the primary purposes of vegetation are to reduce pollutants in stormwater runoff and provide increased transpiration to reduce stormwater runoff volume. Vegetation also maintains soil porosity and prevents erosion. In selecting appropriate vegetation for stormwater treatment control measures, the following factors must be considered:

- Can the vegetation tolerate summer drought, ponding fluctuations, and saturated soil conditions following a storm event?
- Is the vegetation climate-appropriate?
- Is the vegetation dense and strong enough to stay upright even in flowing water?
- Does the vegetation require fertilizers or other nutrient supplements?
- Is the vegetation prone to pests or disease?
- What are the irrigation requirements for the vegetation?
- Is it consistent with local water conservation ordinance requirements?

A sample list of suitable vegetation species is provided in **Table H-1**. Information in **Table H-1** includes the plant type (i.e., perennial and ground cover, grasses, shrubs, trees), irrigation requirements, and saturation tolerance (i.e., Zones 1 or 2). The plant list, was adapted from Water Use Classification of Landscape Species (WUCOLS IV) database[1] and Appendix F of the Bay Area Stormwater Management Agencies Association Post-Construction Manual (July 2014)[2]. The Western Sunset Zone Guide[3] is another source that provides useful information on climate-appropriate plants.

In biotreatment systems Zone 1 is the lower area where the soil experience extended periods of saturation. Vegetation suitable for Zone 1 are common riparian, and wetland plants capable of surviving in saturated soils for long durations throughout the year. However, most of these types of plants are not drought-tolerant and require some irrigation throughout the growing season. Zone 2 is at the higher grade in the biotreatment system and the soil is saturated for shorter periods. Vegetation suitable for Zone 2 includes plants common in riparian/upland transition areas, moist woodlands, and seasonal wetlands. These plants are capable of surviving in saturated soils for

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[1] Water Use Classification of Landscape Species (http://ucanr.edu/sites/WUCOLS/, Last Accessed May 15, 2015).

[2] Bay Area Stormwater Management Agencies Association. *Design Guidance for Stormwater Treatment and Control for Projects in Marin, Sonoma, Napa, and Solano Counties*. July 14, 2014.

[3] Western Sunset Zone Guide (http://www.sunset.com/garden/climate-zones/climate-zones-intro-us-map, Last Accessed May 18, 2015).

shorter durations especially in the winter or spring and are drought-tolerant, but could benefit from some year-round irrigation.

The project applicant is not limited to the vegetation listed in **Table H-1** and may proposed other climate-appropriate vegetation suitable for biotreatment systems. Vegetation for biotreatment systems must be designed by a landscape architect experienced with biotreatment systems.

Table H-1. Suitable Vegetation Species

Species Name	Common Name	Vegetation Type				California Native	Irrigation Requirement			Saturation Tolerance	
		Perennial and Ground Cover	Grass	Shrub	Tree		Very Low	Low	Moderate	Zone 1	Zone 2
Scaevola 'Mauve Clusters'	fan flower	X						X			X
Artemisia douglasiana	California mugwort	X				X		X		X	X
Carex pansa	sand dune sedge	X				X			X	X	X
Carex praegracilis	California field sedge	X				X			X	X	X
Chondropetalum tectorum	cape reed	X						X		X	X
Epipactis gigantea	stream orchid	X				X			X	X	X
Erigeron glaucus	beach aster	X				X			X		X
Heuchera micrantha	crevice alum root	X				X			X		X
Iris douglasiana	Douglas iris	X				X		X			X
Juncus pallidus	pale rush	X							X	X	X
Mirabilis multiflora	four o' clock	X				X		X			X
Sisyrinchium californicum	golden-eyed grass	X				X			X	X	X
Verbena lasiostachys	robust verbena	X				X		X		X	X
Danthonia californica	California oatgrass		X			X			X	X	X
Festuca rubra	creeping red fescue		X			X			X		X
Muhlenbergia rigens	deer grass		X			X		X			X
Carpenteria californica	bush anemone			X		X		X		X	X
Heteromeles arbutifolia	toyon			X		X	X				X
Lonicera involucrata	twinberry			X		X			X		X

Species Name	Common Name	Vegetation Type				California Native	Irrigation Requirement			Saturation Tolerance	
		Perennial and Ground Cover	Grass	Shrub	Tree		Very Low	Low	Moderate	Zone 1	Zone 2
Physocarpus capitatus	ninebark			X		X			X	X	X
Rhamnus crocea	redberry			X		X		X			X
Ribes speciosum	fuchsia flowering gooseberry			X		X		X			X
Rosa californica	California wild rose			X		X		X		X	X
Rubus parviflorus	thimbleberry			X		X		X		X	X
Rubus spectabilis	salmonberry			X		X		X		X	X
Rubus ursinus	California blackberry			X		X		X		X	X
Acer negundo	box elder				X	X			X	X	X
Calocedrus decurrens	incense cedar				X	X			X		
Chilopsis linearis	desert willow				X	X	X			X	X
Fraxinus latifolia	Oregon ash				X	X			X	X	X
Fraxinus velutina	Arizona ash				X	X			X		X
Pittosporum eugenioides	tarata				X				X		X
Platanus racemosa	California sycamore				X	X			X		X
Populus fremontii	western cottonwood				X	X			X		X
Quercus agrifolia	coast live oak				X	X	X				X
Quercus chrysolepis	canyon live oak				X	X		X			X
Quercus douglasii	blue oak				X	X	X				X
Quercus lobata	valley oak				X	X		X			X
Quercus wislizeni	interior live oak				X	X	X				X
Umbellularia californica	California bay				X	X			X		X

APPENDIX I

Sample Calculations

Stormwater Design Volume

The following are examples of how to calculate the stormwater design volume (SDV) for two drainage management areas, one which is pervious and one which is impervious. For the purpose of these examples, it is assumed that a 30,000 ft^2 (20,000 ft^2 impervious, 10,000 ft^2 pervious) site will be developed in Stockton. The project will be designed with a 48-hour drawdown period.

Example 1: Pervious Drainage Management Area

Calculate the stormwater runoff coefficient using the following equation:

$$C = 0.858 \times i^3 - 0.78 \times i^2 + 0.774 \times i + 0.04$$
$$= 0.858 \times 0^3 - 0.78 \times 0^2 + 0.774 \times 0 + 0.04 = 0.04$$

Where:

C = stormwater runoff coefficient [unitless]; and
i = DMA imperviousness ratio [expressed as a decimal]. For pervious areas, this ratio is 0.

Calculate the unit stormwater volume using the following equation:

$$P_0 = (a \times C) \times P_6 = (1.963 \times 0.04) \times 0.36\ in = 0.028\ in$$

Where:

P_0 = unit stormwater volume [in];
a = regression constant (1.963 for 48-hr drawdown); and
P_6 = mean annual runoff-producing rainfall depth [in] (see Table 5-1 of the *2015 Post-Construction Stormwater Standards Manual*).

Calculate the SDV using the following equation:

$$SDV = A \times \frac{P_0}{12} = 10{,}000\ ft^2 \times \frac{0.028\ in}{12\ in/ft} = 24\ ft^3$$

Where:

SDV = stormwater design volume [ft^3];
A = total area of drainage management area [ft^2]; and
P_0 = unit stormwater volume [in].

In this example, the pervious drainage management area will generate 24 ft^3 of stormwater runoff that may need to be managed if the pervious area does not drain into self-treating or self-retaining areas.

Example 2: Impervious Drainage Management Area

Calculate the stormwater runoff coefficient using the following equation:

$$C = 0.858 \times i^3 - 0.78 \times i^2 + 0.774 \times i + 0.04$$
$$= 0.858 \times 1^3 - 0.78 \times 1^2 + 0.774 \times 1 + 0.04 = 0.89$$

Where:

C = stormwater runoff coefficient [unitless]; and
i = DMA imperviousness ratio [expressed as a decimal]. For impervious areas, this ratio is 1.

Calculate the unit stormwater volume using the following equation:

$$P_0 = (a \times C) \times P_6 = (1.963 \times 0.89) \times 0.36\ in = 0.63\ in$$

Where:

P_0 = unit stormwater volume [in];
a = regression constant (1.963 for 48-hr drawdown); and
P_6 = mean annual runoff-producing rainfall depth [in] (see Table 5-1 of the *2015 Post-Construction Stormwater Standards Manual*).

Calculate the SDV using the following equation:

$$SDV = A \times \frac{P_0}{12} = 20{,}000\ ft^2 \times \frac{0.63\ in}{12\ in/ft} = 1{,}050\ ft^3$$

Where:

SDV = stormwater design volume [ft^3];
A = total area of drainage management area [ft^2]; and
P_0 = unit stormwater volume [in].

In this example, the impervious drainage management area will generate 1,050 ft^3 of stormwater runoff that must be managed using stormwater control measures.

Stormwater Design Flow

The following are examples of how to calculate the stormwater design flow (SDF) for two drainage management areas, one which is pervious and one which is impervious. For the purpose of these examples, it is assumed that the project site is 30,000 ft^2 with 20,000 ft^2 of pavement and 10,000 ft^2 of managed turf overlaying Type A soils.

Example 3: Pervious Drainage Management Area

Calculate the SDF using the following equation:

$$SDF = 1.008 \times i \times A \times C_r = 1.008 \times 0.2\ in/hr \times 0.23\ ac \times 0.18 = 0.008\ cfs$$

Where:

SDF = stormwater design flow [ft^3/s or cfs];
1.008 = unit conversion factor;
i = design rainfall intensity [0.2 in/hr];
A = total area of drainage management area [acre]; and
C_r = stormwater runoff coefficient for drainage management area (see Table 5-2 of the *2015 Post-Construction Stormwater Standards Manual*).

In this example, the pervious drainage management area will generate a stormwater flow rate of 0.008 cfs that may need to be managed if the pervious area does not drain into self-treating or self-retaining areas.

Example 4: Impervious Drainage Management Area

Calculate the SDF using the following equation:

$$SDF = 1.008 \times i \times A \times C_r = 1.008 \times 0.2\ in/hr \times 0.46\ ac \times 0.95 = 0.088\ cfs$$

Where:

SDF = stormwater design flow [ft^3/s or cfs];
1.008 = unit conversion factor;
i = design rainfall intensity [0.2 in/hr];
A = total area of drainage management area [acre]; and
C_r = stormwater runoff coefficient for drainage management area (see Table 5-2 of the *2015 Post-Construction Stormwater Standards Manual*).

In this example, the impervious drainage management area will generate a stormwater flow rate of 0.088 cfs that must be managed using stormwater control measures.

Bioretention Facility Design

This example design of a bioretention facility is based on the SDV calculated in Example 2 above.

Step 1: Determine the Adjusted SDV (SDV_{adj})

For the purposes of this example, it is assumed that porous pavement will be implemented as a site design measure for this drainage management area. Using the State Water Resources Control Board's Post-Construction Calculator, the volume credit (SDM_{credit}) is 460 ft^3. The SDV_{adj} is calculated using the following equation:

$$SDV_{adj} = SDV - SDM_{credit} = 1{,}050\ ft^3 - 460\ ft^3 = 590\ ft^3$$

Where:

SDV_{adj} = adjusted stormwater design volume [ft^3];
SDV = stormwater design volume [ft^3]; and
SDM_{credit} = site design measure volume credit [ft^3].

Step 2: Determine the Design Infiltration Rate

For this example, the in-situ infiltration rate of the underlying soil is 2.80 in/hr. After applying a safety factor of 4, the design infiltration rate is 0.70 in/hr.

Step 3: Determine Size of Bioretention Facility Design Layers

The typical design depths of the layers of the bioretention facility are presented in Table 6-1 of the *2015 Post-Construction Stormwater Standards Manual*. For this example, the following design depths of the layers of the bioretention facility are used:

Bioretention Facility Layer	Design depth
Ponding zone	1.5 ft
Planting media (excluding the mulch layer, if provided)	2 ft
Planting media/gravel layer separation zone (1)	4 in
Gravel	1 ft

Step 4: Calculate the Bottom Surface Area of the Bioretention Facility

Calculate the bottom surface area of the bioretention facility (surface area at the base of side slopes, not at the top of side slopes) assuming porosities of the planting media and gravel layers of 0.25 and 0.40, respectively, using the following equation:

$$A = \frac{SDV_{adj}}{d_{pz} + (\eta_{pm} \times d_{pm}) + (\eta_{gl} \times d_{gl})} = \frac{590\ ft^3}{1.5\ ft + (0.25 \times 2\ ft) + (0.40 \times 1\ ft)} = 250\ ft^2$$

Where:

A = bottom surface area of bioretention facility [ft^2];
SDV_{adj} = adjusted stormwater design volume [ft^3];
d_{pz} = depth of ponding zone [ft];
η_{pm} = porosity of planting media [unitless];
d_{pm} = depth of planting media [ft];
η_{gl} = porosity of gravel layer [unitless]; and
d_{gl} = depth of gravel layer [ft].

To verify that the bioretention facility is designed to infiltrate stormwater runoff within the maximum drawdown time, verify that the following equation is satisfied:

$$d_{pz} + (\eta_{pm} \times d_{pm}) + (\eta_{gl} \times d_{gl}) \le \frac{f_{design}}{12} \times t_{max}$$

Where:

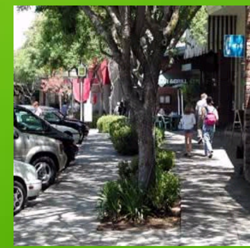
d_{pz} = depth of ponding zone [ft];
η_{pm} = porosity of planting media [unitless];
d_{pm} = depth of planting media [ft];
η_{gl} = porosity of gravel layer [unitless];
d_{gl} = depth of gravel layer [ft]
f_{design} = design infiltration rate [in/hr]; and
t_{max} = drawdown time (max 48 hrs) [hr].

$$1.5\ ft + (0.25 \times 2\ ft) + (0.40 \times 1\ ft) = 2.4\ ft \leq \frac{0.70\ in/hr}{12\ in/ft} \times 48\ hr = 2.8\ ft$$

The design of this bioretention facility will meet the maximum drawdown time.

APPENDIX J

Managing Wet Weather with Green Infrastructure Municipal Handbook Green Streets (EPA 833-F-08-009, December 2009)



Managing Wet Weather with Green Infrastructure

Municipal Handbook

Green Streets

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Municipal Handbook

Green Streets

prepared by

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Low Impact Development Center

The Municipal Handbook is a series of documents
to help local officials implement green infrastructure in their communities.

December 2008

EPA-833-F-08-009

Front Cover Photos
Top: rain garden; permeable pavers; rain barrel;
planter; tree boxes.
Large photo: green alley in Chicago

Green Streets

Introduction

By design and function, urban areas are covered with impervious surfaces: roofs, roads, sidewalks, and parking lots. Although all contribute to stormwater runoff, the effects and necessary mitigation of the various types of surfaces can vary significantly. Of these, roads and travel surfaces present perhaps the largest urban pollution sources and also one of the greatest opportunities for green infrastructure use.

The Federal Highway Administration (FHA) estimates that more than 20% of U.S. roads are in urban areas.[1] Urban roads, along with sidewalks and parking lots, are estimated to constitute almost two-thirds of the total impervious cover and contribute a similar ratio of runoff.[2] While a significant source of runoff, roads are also a part of the infrastructure system, conveying stormwater along gutters to inlets and the buried pipe network. Effective road drainage, translated as moving stormwater into the conveyance system quickly, has been a design priority while opportunities for enhanced environmental management have been overlooked especially in the urban environment.

Table 1. Examples of Stormwater Pollutants Typical of Roads.[3, 4]

Pollutant	Source	Effects
Trash	---	Physical damage to aquatic animals and fish, release of poisonous substances
Sediment/solids	Construction, unpaved areas	Increased turbidity, increased transport of soil bound pollutants, negative effects on aquatic organisms reproduction and function
Metals • Copper • Zinc • Lead • Arsenic	 • Vehicle brake pads • Vehicle tires, motor oil • Vehicle emissions and engines • Vehicle emissions, brake linings, automotive fluids	Toxic to aquatic organisms and can accumulate in sediments and fish tissues
Organics associated with petroleum (e.g., PAHs)	Vehicle emissions, automotive fluids, gas stations	Toxic to aquatic organisms
Nutrients	Vehicle emissions, atmospheric deposition	Promotes eutrophication and depleted dissolved oxygen concentrations

The altered flow regime from traditional roadways, increased runoff volume, more frequent runoff events, and high runoff peak flows, are damaging to the environment and a risk to property downstream. These erosive flows in receiving streams will cause down cutting and channel shifting in some places and excessive sedimentation in others. The unnatural flow regime destroys stream habitat and disrupts aquatic systems.

Compounding the deliberate rapid conveyance of stormwater, roads also are prime collection sites for pollutants. Because roads are a component of the stormwater conveyance system, are impacted by atmospheric deposition, and exposed to vehicles, they collect a wide suite of pollutants and deliver them into the conveyance system and ultimately receiving streams (See Table 1). The metals, combustion by-products, and automotive fluids from vehicles can present a toxic mix that combines with the ubiquitous nutrients, trash, and suspended solids.

While other impervious surfaces can be replaced, for example using green roofs to decrease the amount of impervious roof surface, for the most part, impervious roads will, for some time to come, constitute a significant percentage of urban imperviousness because of their current widespread existence. Reducing road widths and other strategies to limit the amount of impervious surface are critical, but truly addressing road runoff requires mitigating its effects.

> **Green Streets** achieve multiple benefits, such as improved water quality and more livable communities, through the integration of stormwater treatment techniques which use natural processes and landscaping.

Roads present many opportunities for green infrastructure application. One principle of green infrastructure involves reducing and treating stormwater close to its source. Urban transportation right-of-ways integrated with green techniques are often called "green streets". Green streets provide a source control for a main contributor of stormwater runoff and pollutant load. In addition, green infrastructure approaches complement street facility upgrades, street aesthetic improvements, and urban tree canopy efforts that also make use of the right-of-way and allow it to achieve multiple goals and benefits. Using the right-of-way for treatment also links green with gray infrastructure by making use of the engineered conveyance of roads and providing connections to conveyance systems when needed.

Green streets are beneficial for new road construction and retrofits. They can provide substantial economic benefits when used in transportation applications. Billions of dollars are spent annually on road construction and rehabilitation, with a large percentage focused on rehabilitation especially in urban areas. Coordinating green infrastructure installation with broader transportation improvements can significantly reduce the marginal cost of stormwater management by including it within larger infrastructure improvements. Also, and not unimportantly, right-of-way installations allow for easy public maintenance. A large municipal concern regarding green infrastructure use is maintenance; using roads and right-of-ways as locations for green infrastructure not only addresses a significant pollutant source, but also alleviates access and maintenance concerns by using public space.

In urban areas, roads present many opportunities for coordinated green infrastructure use. Some municipalities are capitalizing on the benefits gained by introducing green infrastructure in transportation applications. This paper will evaluate programs and policies that have been used to successfully integrate green infrastructure into roads and right-of-ways.

Green Street Designs

Green streets can incorporate a wide variety of design elements including street trees, permeable pavements, bioretention, and swales. Although the design and appearance of green streets will vary, the functional goals are the same: provide source control of stormwater, limit its transport and pollutant conveyance to the collection system, restore predevelopment hydrology to the extent possible, and provide environmentally enhanced roads. Successful application of green techniques will encourage soil and vegetation contact and infiltration and retention of stormwater.

Alternative Street Designs (Street Widths)

A green street design begins before any BMPs are considered. When building a new street or streets, the layout and street network must be planned to respect the existing hydrologic functions of the land (preserve wetlands, buffers, high-permeability soils, etc.) and to minimize the impervious area. If retrofitting or redeveloping a street, opportunities to eliminate unnecessary impervious area should be explored.

Implementation Hurdles

Many urban and suburban streets, sized to meet code requirements for emergency service vehicles and provide a free flow of traffic, are oversized for their typical everyday functions. The Uniform Fire Code requires that streets have a *minimum 20 feet of unobstructed width;* a street with parking on both sides would require a width of at least 34 feet. In addition to stormwater concerns, wide streets have many detrimental implications on neighborhood livability, traffic conditions, and pedestrian safety.[5]

Oregon State Code Granting Authority for Street Standards to Local Government

ORS 92.044 - Local governments shall *supersede and prevail over any specifications and standards for roads and streets set forth in a uniform fire code adopted by the State Fire Marshal, a municipal fire department or a county firefighting agency*.... Local governments shall consider the needs of the fire department or fire-fighting agency when adopting the final specifications and standards.

The Transportation Growth and Management Program of Oregon, through a Stakeholder Design Team, developed a guide for reducing street widths titled the *Neighborhood Street Design Guidelines.*[6] The document provides a helpful framework for cities to conduct an inclusive review of street design profiles with the goal of reducing widths. Solutions for accommodating emergency vehicles while minimizing street widths are described in the document. They include alternative street parking configurations, vehicle pullout space, connected street networks, prohibiting parking near intersections, and smaller block lengths.

Figure 1. The street-side swale and adjacent porous concrete sidewalk are located in the High Point neighborhood of Seattle, WA
(Source: Abby Hall, US EPA).

In 1997, Oregon, which has adopted the *Uniform Fire Code,* specifically granted local government the authority to establish alternative street design standards but requires them to consult with fire departments before standards are adopted. Table 2 provides examples of alternative street widths allowed in U.S. jurisdictions.[7]

Swales

Swales are vegetated open channels designed to accept sheet flow runoff and convey it in broad shallow flow. The intent of swales is to reduce stormwater volume through infiltration, improve water quality through vegetative and soil filtration, and reduce flow velocity by increasing channel roughness. In the simple roadside grassed form, they have been a common historical component of road design. Additional benefit can be attained through more complex forms of swales, such as those with amended soils, bioretention soils, gravel storage areas, underdrains, weirs, and thick diverse vegetation.

Implementation Hurdles

There is a common misconception of open channel drainage being at the bottom of a street development hierarchy in which curb and gutter are at the top. Seattle's Street Edge Alternative Project and other natural drainage swale pilot projects have demonstrated that urban swales not only mitigate stormwater impacts, but they can also enhance the urban environment.[8]

Table 2. Examples of Alternative Street Widths

Jurisdiction	Street Width	Parking Condition
Phoenix, AZ	28'	parking both sides
Santa Rosa, CA	30' 26'-28' 20' 20'	parking both sides, <1000ADT parking one side no parking neck downs @ intersection
Orlando, FL	28' 22'	parking both sides, res. Lots<55' wide parking both sides, res. Lots>55' wide
Birmingham, MI	26' 20'	parking both sides parking one side
Howard County, MD	24'	parking unregulated
Kirkland, WA	12' 20' 24' 28'	alley parking one side parking both sides – low density only parking both sides
Madison, WI	27' 28'	parking both sides, <3DU/AC parking both sides, 3-10 DU/AC

ADT: Average Daily Traffic DU/AC: dwelling units per acre

Bioretention Curb Extensions and Sidewalk Planters

Bioretention is a versatile green street strategy. Bioretention features can be tree boxes taking runoff from the street, indistinguishable from conventional tree boxes. Bioretention features can also be attractive attention grabbing planter boxes or curb extensions. Many natural processes occur within bioretention cells: infiltration and storage reduces runoff volumes and attenuates peak flows; biological and chemical reactions occur in the mulch, soil matrix, and root zone; and stormwater is filtered through vegetation and soil.

Figure 2. This bioretention area takes runoff from the street through a trench drain in the sidewalk as well as runoff from the sidewalk through curb cuts
(Source: Abby Hall, US EPA).

Implementation Hurdles

A few municipal DOT programs have instituted green street requirements in roadway projects, but as of yet, specifications for street bioretention have not yet been incorporated into municipal DOT specifications. Many cities do have street bioretention pilot projects; two of the well documented programs are noted in the table. Several concerns and considerations have prevented standard implementation of bioretention by DOTs.

Table 3. Municipalities with Swale Specifications and Standard Details

Municipality	Document	Section Title	Section #
City of Austin[9]	Standard Specifications and Standard Details	Grass-Lined Swale and Grass-Lined Swale with Stone Center	627S
City of Seattle[10]	2008 Standard Specifications for Municipal Construction	Natural Drainage Systems	7-21

Table 4. Municipalities with Bioretention Pilot Projects in the Right-of-Way

Municipality	Bioretention Type	Document
Maplewood, MN	Rain gardens	*Implementing Rainwater in Urban Stormwater Management* [11]
Portland, OR	• Curb extensions • Planters • Rain gardens	*2006 Stormwater Management Facility Monitoring Report* [12]

The diversity of shapes, sizes, and layouts bioretention can take is a significant obstacle to their incorporation with DOT specifications and standards. Street configurations, topography, soil conditions, and space availability are some of the factors that will influence the design of the bioretention facility. These variables make documentation of each new bioretention project all the more important. By building a menu of templates from local bioretention projects, future projects with similar conditions will be easier to implement and cost less to design. The documentation should include copies of the details and specifications for the materials used. A section on construction and operation issues, costs, lessons learned, and recommendations for similar designs should also be included in project documentation. Portland's Bureau of Environmental Services has proven adept at documenting each of its Green Streets projects and making them accessible online.[13]

Utilities are a chief constraint to implementing bioretention as a retrofit in urban areas. The Prince George's County, MD Bioretention Design Specifications and Criteria manual recommends applying the same clearance criteria recommended for storm drainage pipes.[14] Municipal design standards should specify the appropriate clearance from bioretention or allowable traversing.

Prince George's County, MD - 2.12.1.16 Utility Clearance

Utility clearances that apply to storm drainage pipe and structure placement also apply to bioretention. Standard utility clearances for storm drainage pipes have been established at 1' vertical and 5' horizontal. However, bioretention systems are shallow, non-structural IMP's consisting of mostly plant and soil components, (often) with a flexible underdrain discharge pipe. For this reason, other utilities may traverse a bioretention facility without adverse impact. Conduits and other utility lines may cross through the facility but construction and maintenance operations must include safeguard provisions. In some instances, bioretention could be utilized where utility conflicts would make structural BMP applications impractical.

Plants are another common concern of municipal staff, whether it is maintenance, salt tolerance, or plant height with regard to safety and security. Cities actively implementing LID practices in public spaces maintain lists of plants which fit the vegetated stormwater management practice niche. These are plants that flourish in the regional climate conditions, are adapted to periodic flooding, are low maintenance, and, if in cold climates, salt tolerant. Most often these plants are natives, but sometimes an approved non-native will best fit necessary criteria. A municipal plant list should be periodically updated based on maintenance experience, and vegetation health surveys.

Permeable Pavement

Permeable pavement comes in four forms: permeable concrete, permeable asphalt, permeable interlocking concrete pavers, and grid pavers. Permeable concrete and asphalt are similar to their impervious counterparts but are open graded or have reduced fines and typically have a special binder added. Methods for pouring, setting, and curing these permeable pavements also differ from the impervious versions. The concrete and grid pavers are modular systems. Concrete pavers are installed with gaps between them that allow water to pass through to the base. Grid pavers are typically a durable plastic matrix that can be filled with gravel or vegetation. All of the permeable pavement systems have an aggregate base in common which provides structural support, runoff storage, and pollutant removal through filtering and adsorption. Aside from a rougher unfinished surface, permeable concrete and asphalt look very similar to their impervious versions. Permeable concrete and asphalt and certain permeable concrete pavers are ADA compliant.

Implementation Hurdles

Of all the green streets practices, municipal DOTs have been arguably most cautious about implementing permeable pavements, though it should be noted that some DOTs have, for decades, specified open-graded asphalt for low use roadways because of lower cost; to minimize vehicle hydroplaning; and to reduce road noise. The reticence to implement on a large-scale, however, is understandable given the lack of predictability and experience behind impervious pavements. However, improved technology, new and ongoing research, and a growing number of pilot projects are dispelling common myths about permeable pavements.

Figure 3. Pervious pavers used in the roadway of a neighborhood development in Wilsonville, OR *(Source: Abby Hall, US EPA).*

The greatest concern among DOT staff seems to be a perceived lack of long-term performance and maintenance data. Universities and DOTs began experimenting with permeable pavements in parking lots, maintenance yards, and pedestrian areas as early as twenty years ago in the U.S., even earlier in Europe. There is now a wealth of data on permeable pavements successfully used for these purposes in nearly every climate region of the country. In recent years, the cities of Portland, OR, Seattle, WA, and Waterford, CT and several private developments have constructed permeable pavement pilots within the roadway with positive results.

The two typical maintenance activities are periodic sweeping and vacuuming. The City of Olympia, WA has experimented with several methods of clearing debris from permeable concrete sidewalks. Each of the methods was evaluated on the ease of use, debris removal, and the performance pace. The cost analysis by Olympia, WA found that the maintenance cost for pervious pavement was still lower than the traditional pavement when the cost of stormwater management was considered.

> Permeable pavement concerns in the roadway often raise concerns of safety, maintenance, and durability. Municipalities can replace impervious surfaces in other non-critical areas such as sidewalks, alleys, and municipal parking lots. These types of applications help municipalities build experience and a market for the technology.

Table 5. Municipalities with Permeable Pavement Specifications and Standard Details

Municipality	Document	Section Title	Section #
Portland	2007 Standard Construction Specifications	Unit Pavers (includes permeable pavers)	00760
Olympia	WSDOT Specification	Pervious Concrete Sidewalks	8-30

Freeze/thaw and snow plows are the major concerns for permeable pavements in cold climate communities. However, these concerns have proven to be generally unwarranted when appropriate design and maintenance practices are employed. A well designed permeable pavement structure will always drain and never freeze solid. The air voids in the pavement allow plenty of space for moisture to freeze and ice crystals to expand. Also, rapid drainage through the pavement eliminates the occurrence of freezing puddles and black ice. Cold climate municipalities will need to make adjustments to snow plowing and deicing programs for permeable pavement areas. Snow plow blades must be raised enough to prevent scraping the surface of permeable pavements, particularly paver systems. Also, sand should not be applied.

Table 6. A Study in Olympia, WA Comparison of the cost of permeable concrete sidewalks to the cost of traditional impervious sidewalks[15]

Traditional Concrete Sidewalk		Permeable Concrete Sidewalk	
Construction Cost	Maintenance Cost	Construction Cost	Maintenance Cost
$5,003,000*	$156,000	$2,615,000*	$147,000
Total = $5,159,000 $101.16 per square yard		Total = $2,762,000 $54.16 per square yard	

*The cost of stormwater management (stormwater pond) for the added impervious surface is factored into the significantly higher cost of constructing the traditional concrete sidewalk. Maintenance of the stormwater pond is also factored into the traditional concrete sidewalk maintenance cost.

Sidewalk trees and tree boxes

Figure 4. Trees planted at the same time but with different soil volumes, Washington DC
(Source: Casey Trees)

From reducing the urban heat island effect and reducing stormwater runoff to improving the urban aesthetic and improving air quality, much is expected of street trees. Street trees are even good for the economy. Customers spend 12% more in shops on streets lined with trees than on those without trees.[16] However, most often street trees are given very little space to grow in often inhospitable environments. The soil around street trees often becomes compacted during the construction of paved surfaces and minimized as underground utilities encroach on root space. If tree roots are surrounded by compacted soils or are deprived of air and water by impervious streets and sidewalks, their growth will be stunted, their health will decline, and their expected life span will be cut short. By providing adequate soil volume and a good soil mixture, the benefits obtained from a street tree multiply. To obtain a healthy soil volume, trees can simply be provided larger tree boxes, or structural soils, root paths, or "silva cells" can be used under sidewalks or other paved areas to expand root zones. These allow tree roots the space they need to grow to full size. This increases the health of the tree and provides the benefits of a mature sized tree, such as shade and air quality benefits, sooner than a tree with confined root space.

Table 7. Healthy Tree Volume and Permeable Pavement Specifications and Standard Details

Jurisdictions	Minimum Soil Volume	Section Title	Section #
Prince William County, VA	Large tree 970 cf Medium tree 750 cf Small tree 500 cf	Design Construction Manual (Sec 800)	Table 8-8
Alexandria, VA	300 cf	Landscape Guidelines	II.B. (2)

Implementation Hurdles

Providing an adequate root volume for trees comes down to a trade off between space in the right-of-way and added construction costs. The least expensive way to obtain the volume needed for roots to grow to full size is providing adequate space unhindered by utilities or other encroachments. However, it is often hard to reserve space dedicated just to street trees in an urban right-of-way with so many other uses competing for the room they need. As a result, some creative solutions, though they cost more to install, have become useful alternatives in crowded subsurface space. Structural soils, root paths, and "silva cells" leave void space for roots and still allow sidewalks to be constructed near trees.

Root Paths can be used to increase tree root volume by connecting a small tree root volume with a larger subsurface volume nearby. A tunnel-like system extends from the tree underneath a sidewalk and connects to an open space on the other side.

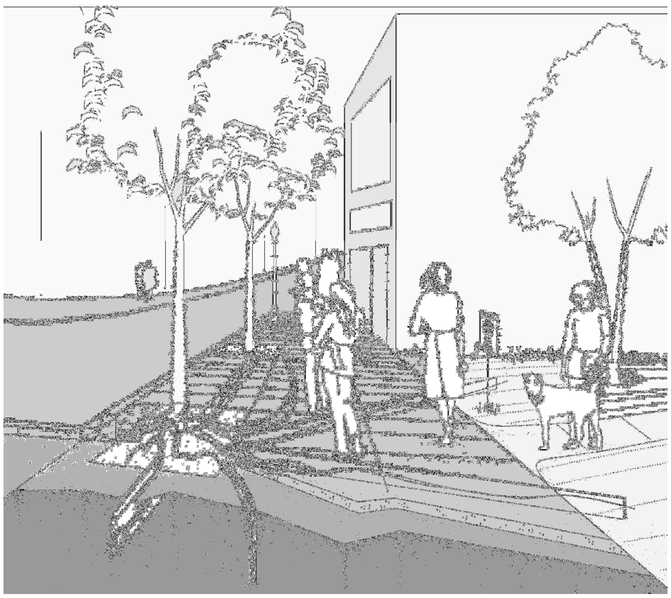

Figure 5. Root Paths direct tree roots under paving and into better soil areas for tree root growth
(Source: Arlington County, VA).

Silva Cells[17] are another option for supporting sidewalks near trees while still providing enough space for roots to grow. These plastic milk crate-like frames fit together and act as a supporting structure for a sidewalk while leaving room for uncompacted soil and roots inside the frame.

Permeable pavement sidewalks are another enhancement to the root space. They provide moisture and air to roots under sidewalks. Soils under permeable pavements can still become compacted. Structural soils[18] are a good companion tree planting practice to permeable pavement. When planting a tree in structural soils an adequate tree root volume is excavated and filled with a mix of stone and soil that still provides void space for healthy roots and allows for sidewalks, plazas or other paved surfaces to be constructed over them.

Case Studies

Portland, OR: Green Street Pilot Projects

Portland, Oregon is a national leader in developing green infrastructure. Portland's innovation in stormwater management was necessitated by the need to satisfy a Combined Sewer Overflow consent decree, Safe Drinking Water Act requirements, impending Total Maximum Daily Load limitations, Superfund cleanup measures and basement flooding. Through the 1990s, over 3 billion gallons of combined sewer overflow discharged to the Willamette River every year.[19] All of these factors plus leadership and local desires to create green solutions and industries compelled the city to implement green infrastructure as a complement to adding capacity to the sewer system with large pipe overflow interceptors. Despite gaps in long-term performance data, Portland took a proactive approach in implementing green infrastructure pilot projects.

Portland's green infrastructure pilot projects have their roots in the city's 2001 Sustainable Infrastructure Committee. The committee, consisting of representatives from Portland's three infrastructure management Bureaus, documented the city's ongoing efforts toward sustainable infrastructure, gathered research on green infrastructure projects from around the country, and identified opportunities for local pilots.[20, 21, 22]

Figure 6. Silva cell structures support the sidewalk while providing root space for street trees
(Source: Deep Root Partners, LP).

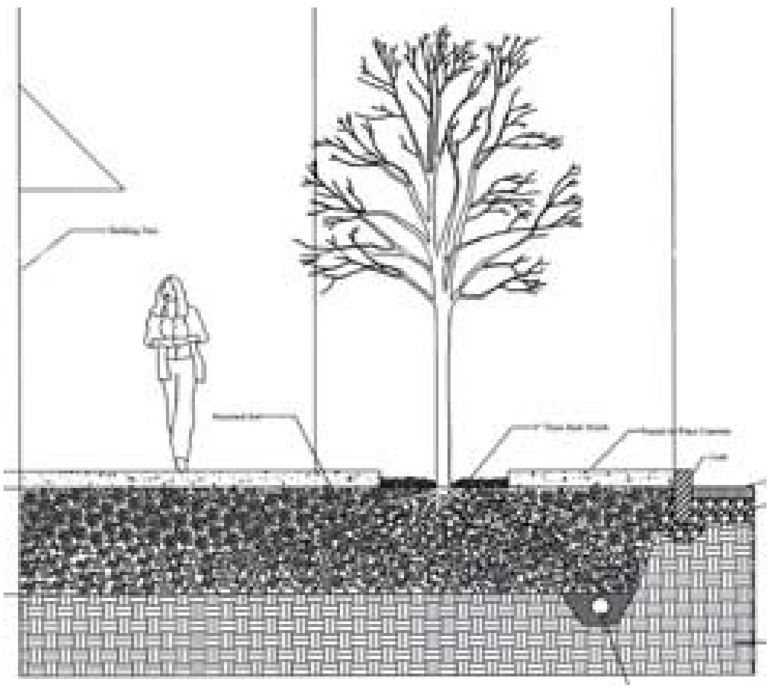

Figure 7. Structural soils provide void space for root growth and load-bearing for sidewalk
(Source: Urban Horticulture Institute, Cornell University).

One of the Bureau of Environmental Services' (BES) earliest green infrastructure retrofit projects within the right-of-way was a set of two stormwater curb extensions on NE Siskiyou Street. Portland had been retrofitting many streets with curb extensions for the purpose of pedestrian safety, but this was the first done for the purpose of treating street runoff. In a simulated 25-year storm event flow test, the curb extensions captured 85% of the runoff volume that would be discharged to the combined sewer system and reduced peak flow by 88%.[23]

Between 2003 and 2007, Portland designed and implemented a variety of Green Street pilots. Funding sources for these projects have come from BES, Portland Department of Transportation, U.S. EPA, and an Innovative Wet Weather Fund. BES combined funds with an EPA grant to create the Innovative Wet Weather Fund. In 2004, nearly $3 million from the Innovative Wet Weather Fund was budgeted for a long list of projects from city green roofs, public-private projects, and a number of pilot projects within the right-of-way.[24] Several pilots have been cost competitive with or less costly than conventional upgrades. The Bureau recognizes that costs will decrease once these projects become more routine. Many of the pilot project costs included one time costs such as the development of outreach materials and standard drawings.

Figure 8: NE Siskiyou Vegetated Curb Extensions
Source: City of Portland – Bureau of Environmental Services

Table 8. Portland, OR - Green Street Pilot Projects

Location	Design	Year Completed	Cost
NE Siskiyou b/w NE 35th Pl. and NE 36th Ave	Stormwater curb extension	2003	$20,000
3 blocks of the Westmoreland Neighborhood	Permeable Pavers in parking lanes and curb to curb	2004	$412,000
SE Ankeny b/w SE 56th and SE 57th Ave.	Stormwater curb extensions	2004	$11,946
NE Fremont b/w NE 131st and 132nd Av	Stormwater curb extension	2005	$20,400
SW 12th Ave b/w SW Montgomery and Mill	Stormwater planters	2005	$34,850
East Holladay Park	Pervious paver parking lot	2005	$165,000
4 blocks of North Gay Avenue b/w N Wygant and N Sumner	Porous concrete in curb lanes and curb to curb; porous asphalt in curb lanes and curb to curb	2005	--
SW Texas	Stormwater wetlands and swales	2007	$2.3 million
Division St. – New Seasons Market	Stormwater planters and swales	--	--
SE Tibbetts and SE 21st Ave.	Stormwater curb extension and planters	--	--

Source: Portland Bureau of Environmental Services, 2008
http://www.portlandonline.com/bes/index.cfm?c=44463&

Each of the pilot projects have been well documented by BES. A consistent format has been used to describe pilot background, features, engineering design, landscaping, project costs, maintenance, monitoring, and, most importantly, lessons learned. These case studies as well as other Green Street documentation can be found on BES's Sustainable Stormwater webpage, http://www.portlandonline.com/BES/index.cfm?c=34598. Due to physical factors (drainage, slope, soil, existing utilities, multiple uses) and development factors (retrofit, redevelopment, and new construction), there will be many variations on Green Streets. As part of the program, a continually updated Green Street Profile Notebook will catalog the successful green street projects. Users can use the Notebook for permitting guidance, to identify green streets facilities appropriate for various factors, but the document is not a technical document with standard details.

The Green Streets Team

The City of Portland, OR is widely acknowledged for long term, forward thinking, and comprehensive transportation and environmental planning. Portland recognized the fact that 66% of the City's total runoff is collected from streets and the right-of-way.[25] The city also saw the potential for transportation corridors to meet multiple objectives, including:

- Comprehensively address numerous City goals for neighborhood livability, sustainable development, increased green spaces, stormwater management, and groundwater protection;
- Integrate infrastructure functions by creating "linear parks" along streets that provide both pedestrian/bike areas and stormwater management;
- Avoid the key impacts of unmanaged stormwater whereby surface waterbodies are degraded, and water quality suffers;
- Manage stormwater with investments citizens can support, participate in, and see;
- Manage stormwater as a resource, rather than a waste;
- Protect pipe infrastructure investments (extend the life of pipe infrastructure, limit the additional demand on the combined sewer system as development occurs);
- Protect wellhead areas by managing stormwater on the surface; and
- Provide increased neighborhood amenities and value.

In a two phased process from 2005 to 2007, the Green Streets Team, a cross agency and interdisciplinary team, developed a comprehensive green streets policy and a way forward for the green streets agenda. Phase 1 identified challenges and issues and began a process for addressing them. Barriers to the public initiation of green street projects included a code and standards that would disallow or discourage green street strategies, long term performance unknowns, and maintenance responsibilities. To address these barriers, the Green Streets Team organized into subgroups focusing on outreach, technical guidance, infrastructure, maintenance, and resources.

Phase 2 of the Green Streets project synthesized the opportunities and solutions identified in Phase 1 into a citywide Green Streets Program. The first priority for this phase was the drafting of a binding citywide policy. The resolution was adopted by the Portland City Council in March 2007.

Prior to the start of the Portland effort, 90% of implemented green street projects were issued by private permits rather than city initiated projects.

Six Approaches to Implementing Green Streets	
Pathway	**Implementation**
City-initiated street improvement projects	City designs, manages, maintains
City-initiated stormwater retrofits	City designs, manages, maintains
Neighborhood-initiated LIDs	
Developer-initiated subdivisions with public streets	Developer designs and builds via City permit and review process, then turns over new right of way to the City after warranty period
Developer-initiated subdivisions with private streets	Developer designs and builds via City permit and review process, and turns over to home-owner association
Developer-related initiated frontage improvements on existing public streets	Developer designs and builds new sidewalks and curbs via City permit and review process, usually because the City required it via a building permit or via a land division

Source: Portland Green Streets, Phase 1

Portland City Council Approved Green Streets Policy

Goal: City of Portland will promote and incorporate the use of green street facilities in public and private development.

City elected officials and staff will:

1. Infrastructure Projects in the Right of Way:

   a. Incorporate green street facilities into all City of Portland funded development, redevelopment or enhancement projects as required by the City's September 2004 (or updated) Stormwater Management Manual. Maintain these facilities according to the May 2006 (or updated) Green Streets Maintenance Policy.

   If a green street facility (infiltrating or flow through) is not incorporated into the Infrastructure Project, or only partial management is achieved, then an off site project or off site management fee will be required.

   b. Any City of Portland funded development, redevelopment or enhancement project, that does not trigger the Stormwater Manual but requires a street opening permit or occurs in the right of way, shall pay into a "% for Green" Street fund. The amount shall be 1% of the construction costs for the project.
   Exceptions: Emergency maintenance and repair projects, repair and replacement of sidewalks and driveways, pedestrian and trail replacement, tree planting, utility pole installation, street light poles, traffic, signal poles, traffic control signs, fire hydrants, where this use of funds would violate contracted or legal restrictions.

2. Project Planning and Design:

   a. Foster communication and coordination among City Bureaus to encourage consideration of watershed health and improved water quality through use of green street facilities as part of planning and design of Bureau projects.
   b. Coordinate Bureau work programs and projects to implement Green Streets as an integrated aspect of City infrastructure.
   c. Plan for large-scale use of Green Streets as a means of better connecting neighborhoods, better use of the right of way, and enhancing neighborhood livability.
   d. Strive to develop new and innovative means to cost-effectively construct new green street facilities.
   e. Develop standards and incentives (such as financial and technical resources, or facilitated permit review) for Green Streets projects that can be permitted and implemented by the private sector. These standards and incentives should be designed to encourage incorporation of green street facilities into private development, redevelopment and enhancement projects.

3. Project and Program Funding:

   a. Seek opportunities to leverage the work and associated funding of projects in the same geographic areas across Bureaus to create Green Street opportunities.
   b. Develop a predictable and sustainable means of funding implementation and maintenance of Green Street projects.

4. Outreach:

   a. Educate citizens, businesses, and the development community/industry about Green Streets and how they can serve as urban greenways to enhance, improve, and connect neighborhoods to encourage their support, demand and funding for these projects.
   b. Establish standard maintenance techniques and monitoring protocols for green street facilities across bureaus, and across groups within bureaus.

5. Project Evaluation:

   a. Conduct ongoing monitoring of green street facilities to evaluate facility effectiveness as well as performance in meeting multiple City objectives for:
   - Gallons managed;
   - Projects distributed geographically by watershed and by neighborhood; and

The second priority for Phase 2 was developing communication and planning procedures for incorporating multi-bureaus plans into the scheduled Portland DOT Capital Improvement Program (CIP). Three timeframes for green street project planning were recommended. In the short term, the CIP Planning Group, backed by the citywide policy directive, will shift to a focus on "identifying and evaluating opportunities to partner." For example, coordinating Water Bureau and BES pipe replacement projects with DOT maintenance, repair, and improvement projects. The mid-term approach is more proactive and involves forecasting potential green street projects using existing bureau data and GIS tools. As for the long term, green street objectives will be incorporated into the citywide systems plan which guides city bureaus for the next 20 years.

The Green Street Team methodology propelled Portland's early green street pilot projects into a comprehensive, citywide multi-bureau program. The program built on previous efforts by the Sustainable Infrastructure Committee as well as other efforts such as the 2005 Portland Watershed Management Plan, established a City Council mandated policy, and institutionalized green street development. The outcome of this approach is multi-agency buy-in and responsibility for the effort. For instance, because of their knowledge of plant maintenance, Portland Parks and Recreation is responsible for the maintenance of some DOT installations.

Chicago, IL: Green Alleys Program

The City of Chicago, Illinois has an alley system that is perhaps the largest in the world. These 13,000 publicly owned alleys result in 1,900 miles, or 3,500 acres, of impermeable surfaces in addition to the street network. Because the alley system was not originally paved, there are no sewer connections as part of the original design. Over time the alleys were paved and flooding in garages and basements began to occur as a result of unmanaged stormwater runoff. Since the city already spends $50 million each year to clean and upgrade 4,400 miles of sewer lines and 340,000 related structures, the preferred solution to the flooded alleys is one that doesn't put more stress on an already overburdened and expensive sewer system.[26]

In 2003, the Chicago Department of Transportation (CDOT) used permeable pavers and French drain pilot applications to remedy localized flooding problems in alleys in the 48th Ward.[27] These applications proved to be successful and by 2006, CDOT launched its Green Alley Program with the release of the Chicago Green Alley Handbook (Handbook).[28]

The Chicago Green Alley Program is unique because it marries green infrastructure practices in the public right-of-way with green infrastructure efforts on private property. The user-friendly Handbook, which describes both facets of the program including the design techniques and their benefits, is an award winning document. The American Society of Landscape Architects awarded the creators of the Handbook the 2007 Communications Honor Award for the clear graphics and simple, yet effective, message.[29] The Handbook explains to the residents why green infrastructure is important, how to be good stewards of the Green Alley in their neighborhood, and what sorts of "green" practices they can implement on their property to reduce waste, save water, and help manage stormwater wisely.

While the initial impetus behind the Green Alley Program was stormwater management, Chicago decided to use this opportunity to address other environmental concerns as well as reducing the urban heat island effect, recycling, energy conservation, and light pollution.

Green Infrastructure in the Right-of-Way

Chicago's Green Alley Program uses the following five techniques in the public right-of-way to "green" the alley:

1. Changing the grade of the alley to drain to the street rather than pond water in the alley or drain toward garages or private property.

2. Using permeable pavement that allows water to percolate into the ground rather than pond on the surface.

3. Using light colored paving material that reflects sunlight rather than adsorbing it, reducing urban heat island effect.

4. Incorporating recycled materials into the pavement mix to reduce the need for virgin materials and reduce the amount of waste going into the landfill.
5. Using energy efficient light fixtures that focus light downward, reducing light pollution.

Figure 9: Permeable Asphalt Installation Using Ground Tire Rubber.
Source: Chicago Department of Transportation, Sustainable Development Initiatives; Streetscape and Urban Design Program, CDOT Division of Project Development.

Four design approaches were created using these techniques. Based on the local conditions, the most appropriate approach is selected. In areas where soils are well-draining, permeable pavement is used. In areas where buildings come right up to the edge of pavement and infiltrated water could threaten foundations, impermeable pavement strips are used on the outside with a permeable pavement strip down the middle. In areas where soils do not provide much infiltration capacity, the alley is regraded to drain properly and impermeable pavement made with recycled materials is used. Another approach utilizes an infiltration trench down the middle of the alley. Light colored (high albedo) pavement, recycled materials, and energy efficient, glare reducing lights are a part of each design approach.

Green Infrastructure on Private Property
The Handbook also describes actions that property owners can take to "green" their own piece of Chicago. The Handbook describes the costs, benefits, and utility of the following practices:

- Recycling;
- Composting;
- Planting a tree;
- Using native landscape vegetation;
- Constructing a rain garden;
- Installing a rain barrel;
- Using permeable pavement for patios;
- Installing energy efficient lighting; and
- Utilizing natural detention.

By bringing this wide range of "green" practices to the attention of homeowners, the positive impacts of the Green Alley Program spread beyond the boundaries of the right-of-way, increasing awareness and providing practical resources to help community members be a part of the solution.

Chicago Green Alley Cost Considerations
When the program began in 2006, repaving the alleys with impermeable pavement ranged in cost from $120,000 to $150,000, whereas a total Green Alley reconstruction was more along the lines of $200,000 to $250,000.[30] While less expensive conventional rehabilitation options may seem more attractive, they don't provide a solution to the localized flooding issues or the combined sewer system overflow problems. Sewer system connections could be established to solve the localized flooding problem, but it would add to the already overburdened sewer system and increase the cost of the reconstruction to that of the impermeable alley option. Consequently, the higher priced Green Alley option proved to be the best investment as it has multiple benefits in addition to solving localized flooding and reducing flow into the combined sewer system. The additional benefits of the Green Alley Program include not only urban heat

island effect reduction, material recycling, energy conservation, and light pollution reduction, but also the creation of a new market.

In 2006, when the Green Alley Program began, the city paid about $145 per cubic yard of permeable concrete. Just one year later, the cost of permeable concrete had dropped to only $45 per cubic yard. Compared with the cost of ordinary concrete, $50 per cubic yard, permeable concrete may have seemed like an infeasible option in the past to customers wanting to purchase concrete.[31] After the city's initial investment in the local permeable concrete market, the product cost has come down making permeable concrete a more affordable option for other consumers besides the city. This has resulted in an increased application of permeable concrete throughout the region.

Figure 10: Permeable Pavers and Permeable Concrete Chicago Alleys
(Source: Abby Hall, US EPA)

The success of the Chicago Green Alley Program is evident. Not only are the alleys been "greened" as a result of the program, the surrounding properties and even the surrounding neighborhoods are experiencing the positive impacts of the program's implementation.

Conclusions and Recommendations

Incorporating green streets as a feature of urban stormwater management requires matching road function with environmental performance. Enhancing roads with green elements can improve their primary function as a transportation corridor while simultaneously mitigating their negative environmental impacts. In theory and practice many municipalities are not far removed from dedicated green streets programs. Street tree and other greenscaping programs are often identified and promoted along urban transportation corridors. Adapting them to become fully functional green streets requires minor design modifications and an evaluation of how to maximize the benefits of environmental systems.

Portland's green streets program demonstrates how common road and right-of-way elements (e.g., traffic calming curb extensions, tree boxes) can be modified and optimized to provide stormwater management in addition to other benefits. The curb cuts and design variations to allow runoff to enter the vegetated areas are subtle changes with a significant impact and demonstrate how stormwater can be managed successfully at the source. One of the biggest successes of the program was reassessing common design features and realizing that environmental performance can be improved by integrating stormwater management.

Where Portland used vegetation, Chicago's Green Alley Program similarly demonstrates that hardscape elements can be an integral part of a greening program. By incorporating permeable pavements that simulate natural infiltration, Chicago enhances the necessary transportation function of alleys while enhancing infrastructure and environmental management. Portland also contrasts the "soft" and "hard" elements of green streets by using both permeable pavements and vegetated elements. The green options available demonstrate the flexibility of green infrastructure to satisfy road function and environmental objectives and highlight why transportation corridors are well suited for green infrastructure.

Elements necessary for a successful green streets program:

- **Pilot projects are critical.** The most successful municipal green street programs to date all began with well documented and monitored pilot projects. These projects have often been at least partially grant funded and receive the participation of locally active watershed groups working with the city infrastructure programs. The pilot projects are necessary to demonstrate that green streets can work in the local environment, can be relied upon, and fit with existing infrastructure. Pilot projects will help to dispel myths and resolve concerns.
- **Leadership in sustainability from the top.** The cities with the strongest green streets programs are those with mayors and city councils that have fully bought into sustainable infrastructure. Council passed green policies and mayoral sustainability mandates or mission statements are needed to institutionalize green street approaches and bring it beyond the token green project.
- **Buy-in from all municipal infrastructure departments.** By their nature, green streets cross many municipal programs. Green street practices impact stormwater management, street design, underground utilities, public lighting, green space planning, public work maintenance, and budgeting. When developing green streets, all of the relevant agencies must be represented. Also, coordination between the agencies on project planning is important for keeping green infrastructure construction costs low. Superior green street design at less cost occurs when sewer and water line replacement projects can be done in tandem with street redevelopment. These types of coordination efforts must happen at the long-term planning stage.
- **Documentation.** Green street projects need to be documented on two levels, the design and construction level and on a citywide tracking level. Due to the different street types and siting conditions, green street designs will take on many variations. By documenting the costs, construction, and design, the costs of similar future projects can be minimized and construction or design problems can be avoided or addressed. Tracking green street practices across the city is crucial for managing maintenance and quantifying aggregate benefits.
- **Public outreach.** Traditional pollution prevention outreach goes hand in hand with green street programs. Properly disposing of litter, yard waste, and hazardous chemicals and appropriately applying yard chemicals will help prolong the life of green street practices. An information campaign should also give the public an understanding of how green infrastructure works and the benefits and trade offs. In many cases, remedial maintenance of green street practices will be performed by neighboring property owners; they need to know how to maintain the practices to keep them performing optimally.

As public spaces, roads are prime candidates for green infrastructure improvements. In addition to enabling legislation, and technical guidance, developing a green streets program requires an institutional re-evaluation of how right-of-ways are most effectively managed. This process typically includes:

- Assessing the necessary function of the road and selecting the minimum required street width to reduce impervious cover;
- Enhancing streetscaping elements to manage stormwater and exploring opportunities to integrate stormwater management into roadway design; and
- Integrating transportation and environmental planning to capitalize on economic benefits.

The use of green streets offers the capability of transforming a significant stormwater and pollutant source into an innovative treatment system. Green streets optimize the performance of public space easing maintenance concerns and allowing municipalities to coordinate the progression and implementation of stormwater control efforts. In addition, green streets optimize the performance of both the transportation and water infrastructure. Effectively incorporating green techniques into the transportation network provides significant opportunity to decrease infrastructure demands and pollutant transport.

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