Model Standards & Specifications for Low Impact Development Practices

The City of Hughson, California

Adopted by the City Council
March 24, 2014

of Hughson, California

Contents

(Two cover photos courtesy of Thom Clark)

1.0

Introduction

In order to comply with existing and future stormwater discharge regulations, while promoting an efficient resource and a sustainable approach to reducing stormwater runoff pollution, the City of Hughson (City) has recognized the need to develop Low Impact Development (LID) standards and specifications. The City's General Plan provides the overarching policy framework for a more natural approach to drainage. This document provides specific guidance for LID solutions that are customized to the local context.

Land planning and drainage design should be integrated to **emphasize water conservation** and the use of on-site naturalized features to **protect water quality and downstream receiving water bodies**. To achieve this, natural and engineered hydrologic controls can mimic predevelopment hydrologic conditions to **improve water quality**, **reduce flooding,** and **improve overall watershed health**.

LID stormwater treatment standards **appropriate for the local conditions** will be used to **guide new development and redevelopment** projects. This guidance ensures more thoughtful and responsible stormwater management, stormwater pollution prevention, **reduction of community infrastructure costs,** and environmental enhancement in drainage designs.

As Hughson and other San Joaquin Valley cities have developed, stormwater runoff from impervious hardscape has had a substantial negative impact on the Tuolumne River, the San Joaquin Delta, and regional wildlife. By implementing standards and specifications for municipal LID planning and development, tributaries to the San Joaquin River, including the Tuolumne River, can realize water quality and ecological benefits – both on a watershed and local scale. LID standard practices of intercepting stormwater runoff at or near the source and using natural vegetation to settle and filter stormwater runoff pollutants can have a widespread beneficial impact to the rivers of the Central Valley and the ecological health of the Sacramento-San Joaquin Delta.

In addition to stormwater management and treatment, the implementation of LID practices can augment groundwater recharge, assist in the removal of air pollutants, mitigate urban heat island effect, and sequester carbon. Local communities will also benefit from pleasing landscape aesthetics, natural resource conservation, and habitat creation - all of which can provide stormwater treatment functions.

Although the techniques for LID implementation are well documented in many regions, there are limited LID standards or manuals developed specific to the unique conditions in the San Joaquin Valley. These conditions include seasonal rainfall patterns, arid climate, hardpan soils, high groundwater tables, and native vegetation. This manual provides design guidance for developers, designers and City staff to implement LID solutions at any scale for any land use.

How to Use This Document

The following flow chart summarizes the steps to be taken when implementing LID practices for a project.

Step 1: Site Context — *Section 1*

- Map your site and its preliminary design considerations
- Review local regulatory conditions and applicability to your proposed development
- Understand LID goals, benefits, and challenges

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Step 2: Site Assessment — *Section 2*

- Analyze your site to identify constraints and opportunities
  - Land Use/Existing Infrastructure
  - Hydrology
  - Groundwater
  - Topography
  - Soils and Geology
  - Space Constraints
  - Identify appropriate Best Management Practices (BMPs) using BMP Selection Matrix

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Step 3: Detailed LID Design — *Section 3*

- Understand site opportunities, goals, and constraints
- Review BMP Fact Sheets
  - Underground Infiltration
  - Bioretention Area
  - Vegetated Swale
  - Filter Strip
  - Detention Pond
  - Constructed Wetland
  - Permeable Pavement
  - Rainwater Harvesting
  - Green Roof
- Implement and design BMPs

Hughson Context

The City of Hughson General Plan 2005-2025 identifies 10 different land uses categories, as shown on the following page in Figure 2. LID opportunities and applications will vary across these different land uses. However for the purpose of this manual, land uses have been distilled into the following three simple categories:

- greenfields;
- infill areas; and
- special conditions

The purpose of developing these categories is to assist in identifying the type of BMPs and understanding the opportunities and constraints associated with each.

Figure 3 shows the historical growth patterns in the City. This map aids in identifying areas that may be more or less likely to experience development or redevelopment over the next 30 years. For example, residential areas built within the past 20 years are considered a stable land use and most of these are unlikely to see major change in the near future. By analyzing the City's growth patterns, in conjunction with other planning data (such as the Downtown Specific Plan), areas have been identified that fit within the categories of greenfield development, redevelopment, or special conditions sites. These opportunity sites are shown in Figure 1 below and discussed in more detail on the next pages.

The specific LID techniques and design guidance provided in this manual were developed by overlaying these potential development areas with the specific physical (e.g. soil, hardpan) and drainage conditions. The intent is to provide stormwater management techniques that are specific to the expected conditions that designers will encounter when developing in the Hughson area.

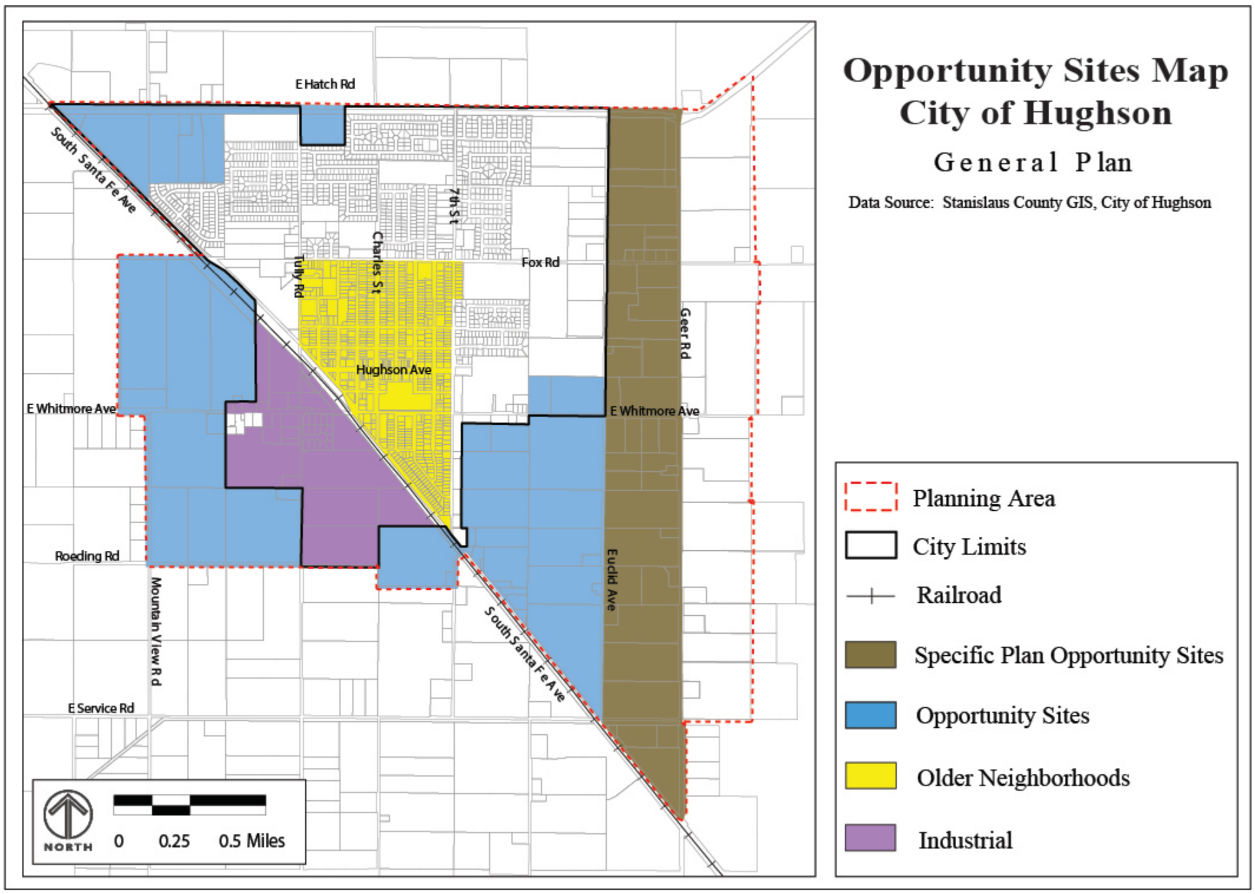


Figure 1: Opportunity Sites Map (Source: General Plan)

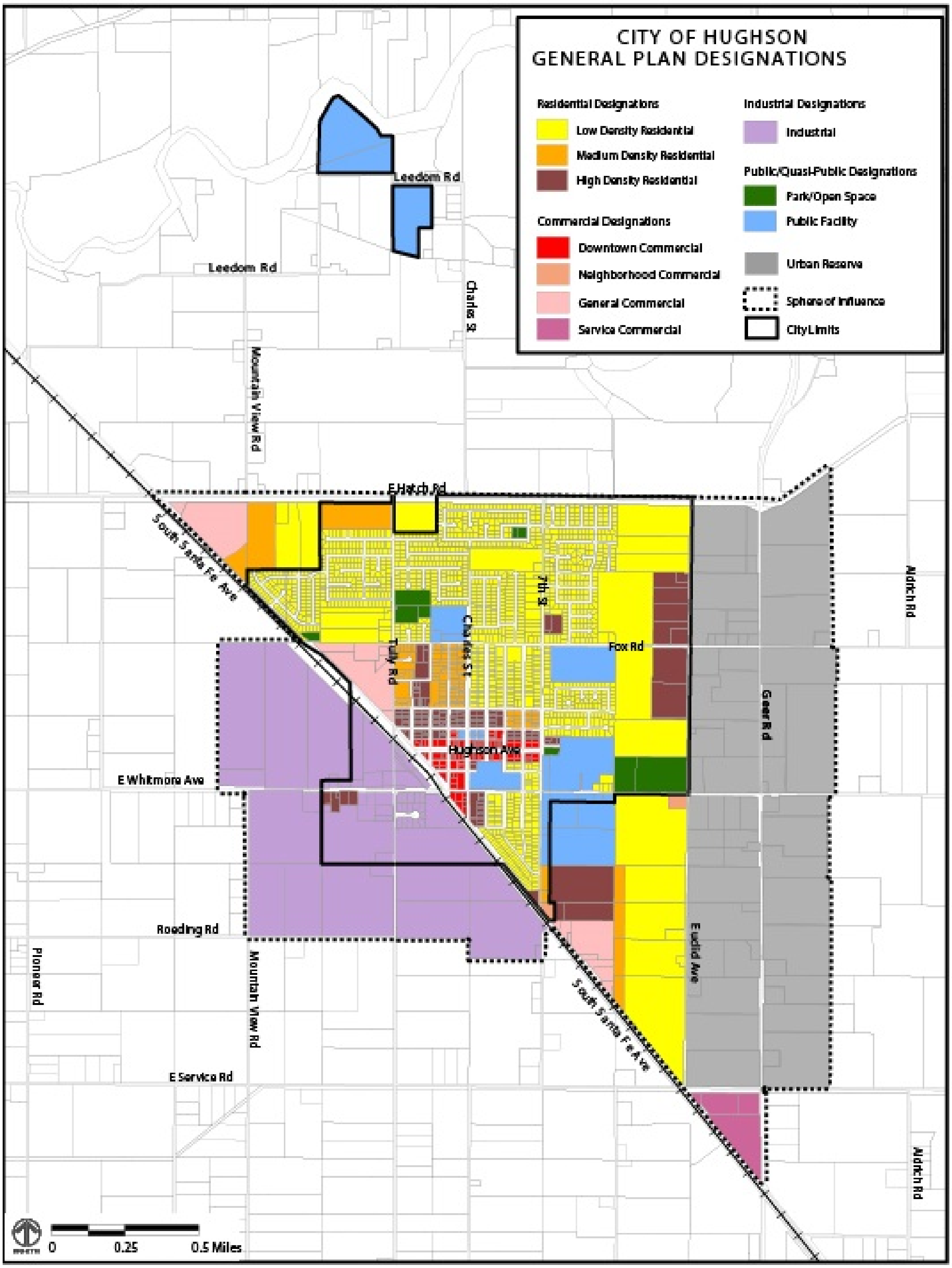


Figure 2: Existing Land Use Map (Source: General Plan)

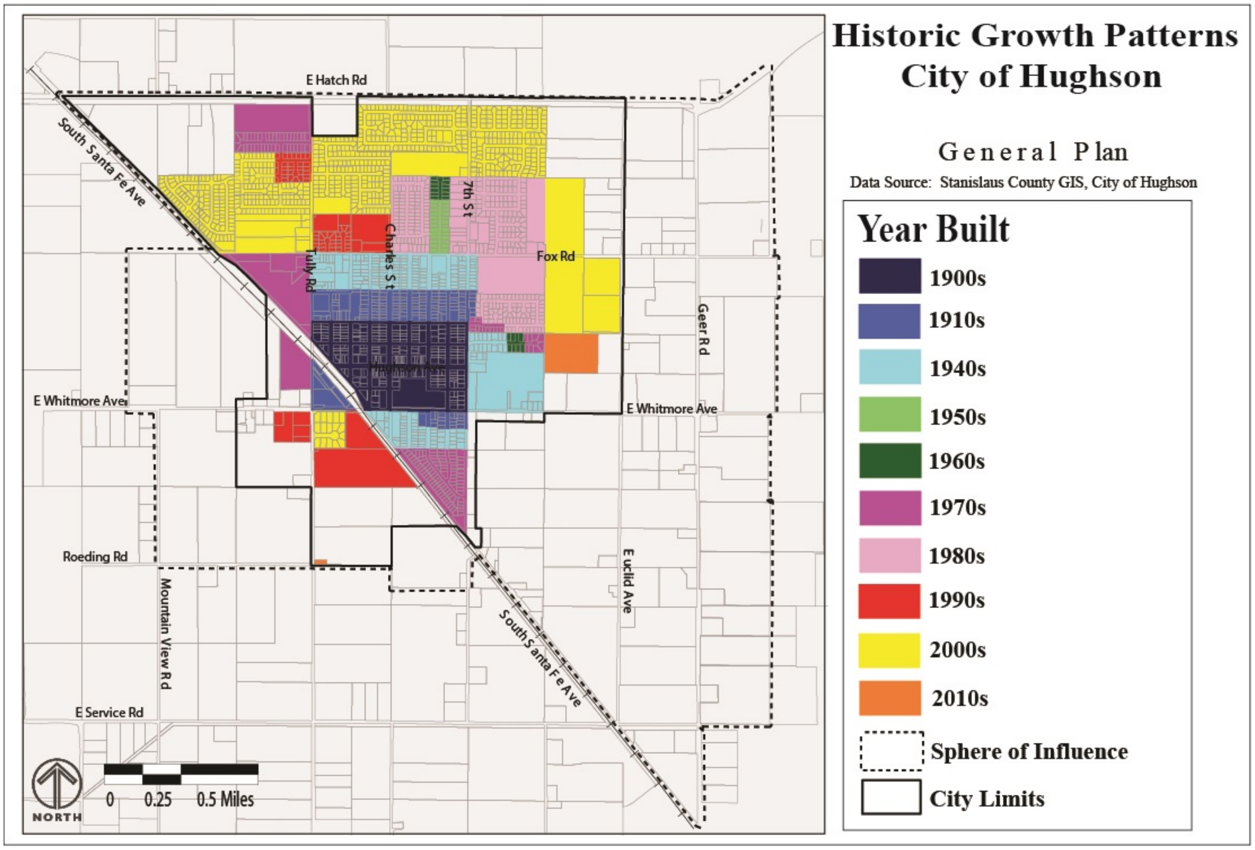


Figure 3: Historic Growth Patterns Map (Source: City of Hughson)

Greenfields

Greenfield lands are those areas that are undeveloped or are in a substantially natural state. The majority of the land within the Hughson Planning Area outside of City limits would be classified as greenfield (such as rural residential parcels, agricultural land, and undisturbed natural areas).

When developing within a greenfield area, it is important to maintain existing hydrological conditions by conserving natural areas and existing drainage features, where possible. Impervious hardscape surfaces (conventional roofs and paving) should be minimized and designed to discharge to pervious areas to help filter and infiltrate the stormwater runoff. To further aid infiltration, native soil compaction in landscaped areas should be minimized.

New infrastructure costs related to development can be reduced by incorporating LID techniques. Vegetated swales and permeable pavements can minimize or replace gutters and drain pipes. Retention and infiltration systems can reduce or eliminate the need for connections to storm drain mains. A rainwater harvesting system might avoid the need to upsize or install a new water supply line.

Infill Areas

Areas that have the most opportunity for redevelopment within the City include vacant lots and older neighborhoods in need of revitalization or necessary improvements. Though implementation of LID practices can be more challenging in redevelopment areas, they are of crucial importance in these locations. Within these more urbanized areas LID can provide substantial water quality benefits by removing pollutants and sediment currently reaching local streams and rivers.

Site design practices that provide hydrologic benefits and improve groundwater conditions in previously developed areas should be considered. These can include distributed BMPs that slow down or infiltrate water closer to its source, conversion of paved surfaces to permeable surfaces, rainwater harvesting retrofits, and rerouting runoff from impervious surfaces across naturalized and vegetated areas.

Greenfield areas with no prior development can use a wide array of treatment elements, but care should be taken to preserve the natural character of the site in order to minimize pollutants and changes to drainage patterns. (Photo courtesy of Thom Clark)

Retrofit or redevelopment sites present important opportunities to reduce the amount of impervious surface and treat runoff before it enters the storm drain system. (Photo: LA Times)

Regulatory Context

The State Water Resources Control Board (SWRCB) established the requirements for storm water discharges from small municipal separate storm sewer systems (MS4s). The City of Hughson incorporates these requirements and is designated as an MS4 operator.

Requirements include the prohibition of the discharge of any materials other than stormwater, implementation of BMPs to the maximum extent practicable (MEP) to protect water quality, the development and implementation of a Storm Water Management Plan (SWMP), reducing the discharge of pollutants to the MEP, and annually reporting on the progress of SWMP implementation to the Regional Water Quality Control Board (RWQCB).

The MS4 Permit includes specific post-construction design standards and BMP implementation procedures. These design standards are summarized on the following page. The BMPs implemented should focus on LID, source control, and treatment control.

Typical Development Process

Confirm Zoning. Areas are zoned to facilitate the development of compatible neighboring land uses. Zoning rules also set building and other standards or determine how much of a certain land use may occur.

Planning Review Process. Most projects are required to go through the Planning Review Process. Applicants have the option of submitting a Preliminary Proposal to the Planning Department for preliminary feedback, and would follow this with a full Planning Application. This application is then reviewed for approval.

Building Plan Review. Additional processes, such as obtaining a building or encroachment permit, may be required after planning approval and prior to the commencement of construction.

Inspections. The aim of the Building Division is to create partnerships with the development community, business community and citizens to accomplish mutually beneficial goals such as the safe, successful and timely completion of projects.

More information on these processes as well as associated forms, applications, guides, and fee schedules can be found on the City's website:

http://hughson.org/government/city-departments/community-development/

Relevant Documents
Fact Sheet for State Water Resources Control Board Water Quality Order No. 2003 – 0005 – DWQ, National Pollutant Discharge Elimination System (NPDES) General Permit No. CAS000004 This is the permit which contains the waste discharge requirements for stormwater discharges from MS4s. This is the primary guiding document for stormwater quality regulations in Hughson and is summarized on this and the following page. *www.swrcb.ca.gov/water_issues/programs/stormwater/docs/final_ms4_permit.pdf*
City of Hughson Storm Drain System Master Plan (June 2007) This plan serves as a basis for storm drain infrastructure and as an aide to assessing the impact of new and future development. It contains a summary of the existing storm drain system and recommended improvements. *City of Hughson Public Works Department*
Phase II Small Municipal Storm Sewer System (MS4) Permit Program (2013) This document establishes the four cities as co-permittees to the small MS4 Permit, characterizes the conditions of receiving streams, and describes proposed stormwater quality management activities and objectives. *www.waterboards.ca.gov/water_issues/programs/stormwater/phase_ii_municipal.shtml*
City of Hughson Standard Specifications, Section 7 - Storm Drains (2007) This document section contains the required City standard design parameters, specifications, and details for storm drain infrastructure built within the public right-of-way within the City. *City of Hughson Public Works Department*
Stanislaus County Standards and Specifications, Chapter 4 - Storm Drainage (2007) This document chapter contains the required County standard design parameters, specifications, and details for storm drain infrastructure built within, or to be maintained by, the County. Though not directly applicable to development in the City, this is useful for background and reference. *www.stancounty.com/publicworks/pdf/2007_Imp_stand.pdf*

Design Standards

The design standards apply to projects that fall into one of the following categories:

Applicable Development Categories
Commercial or Industrial Developments (of 100,000 square feet or more)
Automotive Repair Shops
Retail Gasoline Outlets
Restaurants
Home Subdivisions (with 10 housing units or more)
Parking Lots (5,000 sf or more or with 25 or more parking spaces and potentially exposed to stormwater runoff)

The following must be implemented for all categories:

- **Mitigate peak runoff flow rate.** Post-development peak stormwater discharge rates shall be equal to or less than the peak pre-development rates for developments where the increased runoff rate will result in increased potential for downstream erosion.
- **Conserve and create natural areas.** Developments shall incorporate and implement the following items:
  - concentrate development and minimize disturbance of remaining areas;
  - minimize the clearing of native vegetation;
  - maximize trees and vegetation, cluster tree areas, and promote native and/or drought tolerant plants in landscaped areas and parking lot islands; and
  - preserve any riparian areas and wetlands.
- **Minimize stormwater pollutants of concern.** Development must be designed to minimize the discharge of pollutants of concern (POC) to the MEP. The BMPs used must be chosen for the optimal removal of the POC. POC are pollutants that exhibit one or more of the following characteristics:
  - current loadings or historic deposits of the pollutant are impacting the beneficial uses of a receiving water;
  - elevated levels of the pollutant are found in sediments of a receiving water and/or have the potential to bioaccumulate in organisms; or
  - the detectable inputs of the pollutant are at concentrations or loads considered potentially toxic to humans and/or flora and fauna.
- **Protect slopes and channels.** Development must be designed to minimize erosion by:
  - conveying runoff safely from slope tops;
  - stabilizing disturbed slopes;
  - utilizing natural drainages to the MEP;
  - stabilizing permanent channel crossings;
  - vegetating slopes with native or drought tolerant vegetation, as appropriate; and
- **Provide storm drain stencilling and signage.** All inlets and catch basins within a project area should be labeled with standard warnings.
- **Properly design outdoor material and trash storage areas.** Trash and materials stored outdoors that have the potential to contaminate stormwater must be placed in a covered and enclosed structure that averts drainage from surrounding areas and prevents runoff and spillage from leaving.
- **Provide proof of ongoing BMP maintenance.** Permanent BMPs must have a system in place for maintenance, with an inspection at least annually.
- **Incorporate treatment control BMPs for water quality.** Pollutant levels in site stormwater runoff must be mitigated through the use of permanent post-construction treatment control BMPs designed to either a volumetric or flow-based standard. The LID techniques and stormwater BMP design standards contained in this manual are intended address this water quality requirement.

There are additional design provisions intended to further reduce the potential for pollutant discharge that apply to specific development categories. These are outlined in the table below.

Development Category	Additional Design Provisions
Commercial/Industrial	Loading Dock Areas, Repair/Maintenance Bays, Vehicle/Equipment Wash Areas
Auto Repair Shops	Loading Dock Areas, Repair/Maintenance Bays, Vehicle/Equipment Wash Areas, Fueling Areas
Retail Gasoline Outlets	Fueling Areas
Restaurants	Equipment/Accessory Wash Areas
Home Subdivisions	none
Parking Lots	Reduce Impervious Area, Infiltrate Runoff, Limit Oil Contamination

Overview of Low Impact Development (LID)

LID is an approach that seeks to mimic the natural processes occurring on a site, while addressing the small, frequent storms that, when combined, produce the majority of a site's runoff.

LID practices can greatly improve stormwater quality by encouraging processes (such as sedimentation, filtration, or evapotranspiration) which reduce the pollutants present in urban and suburban runoff.

Another primary purpose of LID is to preserve a site's pre-development hydrologic pattern by minimizing impervious surfaces, capturing the low-intensity events that contribute to erosion, and providing a measure of control over the larger events, which can cause both erosion and flooding.

LID stormwater management facilities, referred to as Best Management Practices (BMPs), are most effective when dispersed throughout a site to address runoff at its source. Draining sidewalks to vegetated filter strips, constructing parking lots with permeable pavement, and outletting roof leaders to the surface of a bioretention area can all provide treatment and attenuation of stormwater flows.

Though there are numerous reasons to implement LID on a site, there are also a variety of constraints that will limit certain practices and inform an ideal design. The site constraints summarized below are discussed in more detail in Section 2, with explanation of how each constraint will influence LID design.

Goals and Benefits

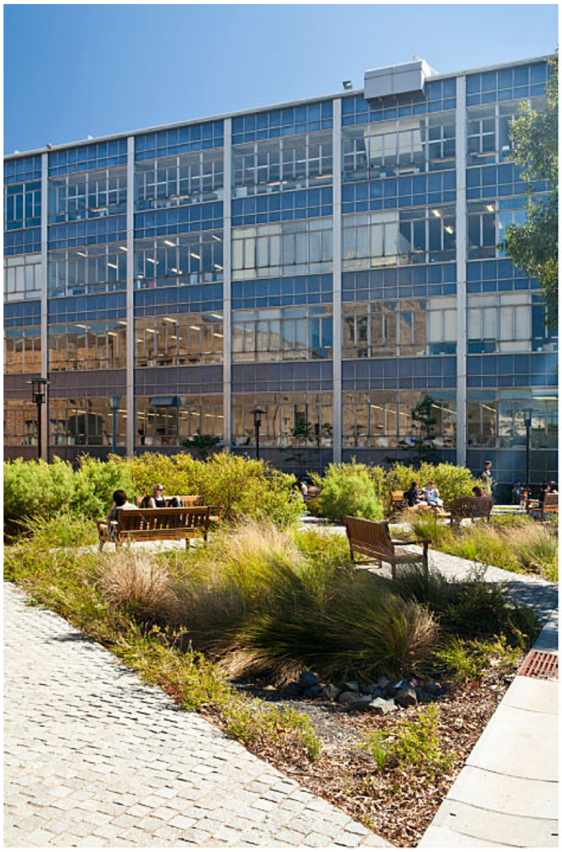
- **Improve water quality.** A primary goal is the protection of downstream receiving water bodies from increased pollutant loads. All BMPs have potential to provide treatment. However, site constraints can hamper this (underground infiltration and permeable pavement, for example, must be able to infiltrate in order to provide acceptable pollutant removal).
- **Attenuate flows.** LID can be very effective at mitigating flooding and erosion issues. The volume of stormwater can be reduced by capturing runoff in retention systems (which drain by infiltration or reuse) and the flow rate and velocity of runoff can be lowered, to varying degrees, by all BMPs.
- **Recharge groundwater.** By increasing pervious area and managing the runoff from impervious area, LID is able to help restore water to the aquifer through infiltration.
- **Reduce potable water consumption.** A central component of LID is an emphasis on water conservation, primarily through the harvesting of rainwater. Utilizing captured water allows a site to address stormwater challenges while also lowering municipal water use.
- **Habitat restoration.** In addition to their hydrological goals, with proper design many BMPs are able to serve as desirable habitat.
- **Improve aesthetics.** Landscape-based stormwater management facilities and preservation of natural areas offer development sites unique opportunities to create an appealing character.
- **Reduction of community infrastructure costs.** Widespread use of LID serves a community by helping to minimize costs, such as storm drain upsizing, erosion maintenance, and street repairs.

Potential Constraints

- Impermeable soils. Sites with high clay content in the native soils typically have low infiltration rates, limiting the use of infiltration practices.
- Shallow hardpan. This will influence the ability to provide infiltration.
- Shallow groundwater. Certain areas, especially closer to the river, have a shallow groundwater table which precludes the use of infiltration.
- Tributary area. BMPs differ in the amount of drainage needed to function properly. Some are only effective with smaller catchments, while others can handle, or even require, larger upstream areas.
- Available space. In areas with existing development, especially dense commercial areas, it can be difficult to fit BMPs into locations receiving drainage.
- Retrofit capability. It is often preferred to reuse a site's existing infrastructure, which may affect BMP siting or design. Infiltration practices must have a setback from building foundations and wells.

Regulatory Considerations

- Facilities should achieve the water quality standard targeting pollutants, especially pollutants of concern.
- Design facilities and lay out sites to promote and conserve natural and vegetated areas.
- Help mitigate potential runoff rate increases and erosive flows through dispersed retention, infiltration, and energy dissipation.



The deployment of BMPs on a site can take many forms, which allows the facilities to integrate with landscaping while still providing optimal stormwater functionality. These examples show bioretention areas within an outdoor courtyard (above left), a vegetated swale and filter strip serving as a buffer for homes (above right), and a rocky swale area meant to be appealing while dry but able to handle infrequent large flows.

2.0

Site Assessment

This section provides a framework for selecting appropriate LID BMPs. Proper site planning and BMP selection involves a comprehensive assessment to evaluate existing conditions, such as hydrology, land use, runoff water quality, topography, and soils.

This site assessment will help to identify and understand constraints that exist at the site that will influence the performance and applicability of different BMP options. The maps and selection matrix included in this section can be used to quickly identify which BMPs are most appropriate for a site. This initial assessment should always be followed up and validated by a detailed site investigation.

Floodplain

Areas within the floodplain (see Figure 4) have a high groundwater table and an increased likelihood for erosion. Although the only area within the floodplain is a portion of the wastewater treatment plant, it is essential that development in this area does not change the ground elevation in a manner that might result in an increased water surface elevation during a flood event.

Development should limit grading and the creation of surface features (such as berms or unreinforced channels) that could be washed-out or substantially eroded in a flood. Surface discharge from BMP facilities should be in the form of dispersed sheet-flow, with point discharges minimized or eliminated.

As noted above, the floodplain only affects the abandoned Lower Ponds at the City's Wastewater Treatment Plant.

Groundwater

Groundwater plays a significant role in the hydrologic process, and it is important to promote groundwater recharge, especially in areas with limited rainfall. LID features can facilitate groundwater recharge by promoting rainwater infiltration. Groundwater recharge maintains local water tables, provides base flow to streams and rivers during dry periods, and maintains the integrity of riparian habitats.

It is important to determine the depth to the groundwater table's surface (see Figure 5), as a high groundwater table that is close the surface must be protected from contamination. Infiltration into the subgrade soil of a BMP is not allowed if there is less than 10 feet of separation between the bottom of the BMP and the top of the seasonally high groundwater table. BMPs constructed in areas of high groundwater tables should be installed with an impermeable liner (such as a waterproof membrane or compacted native clay) if their design would promote infiltration.

As noted on Figure 5, depth to groundwater throughout the city limits is over 200 centimeters or 6.5 feet.

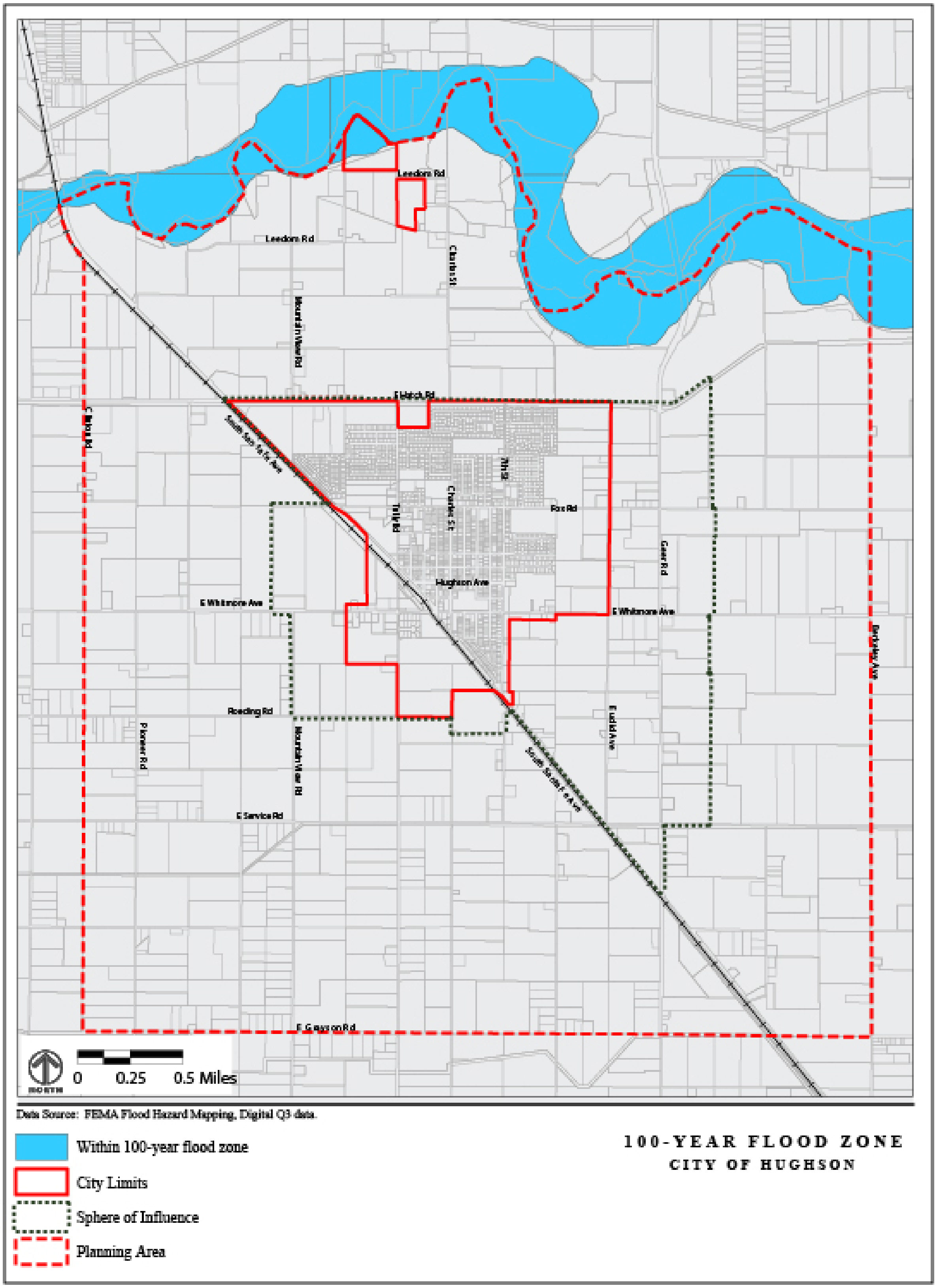
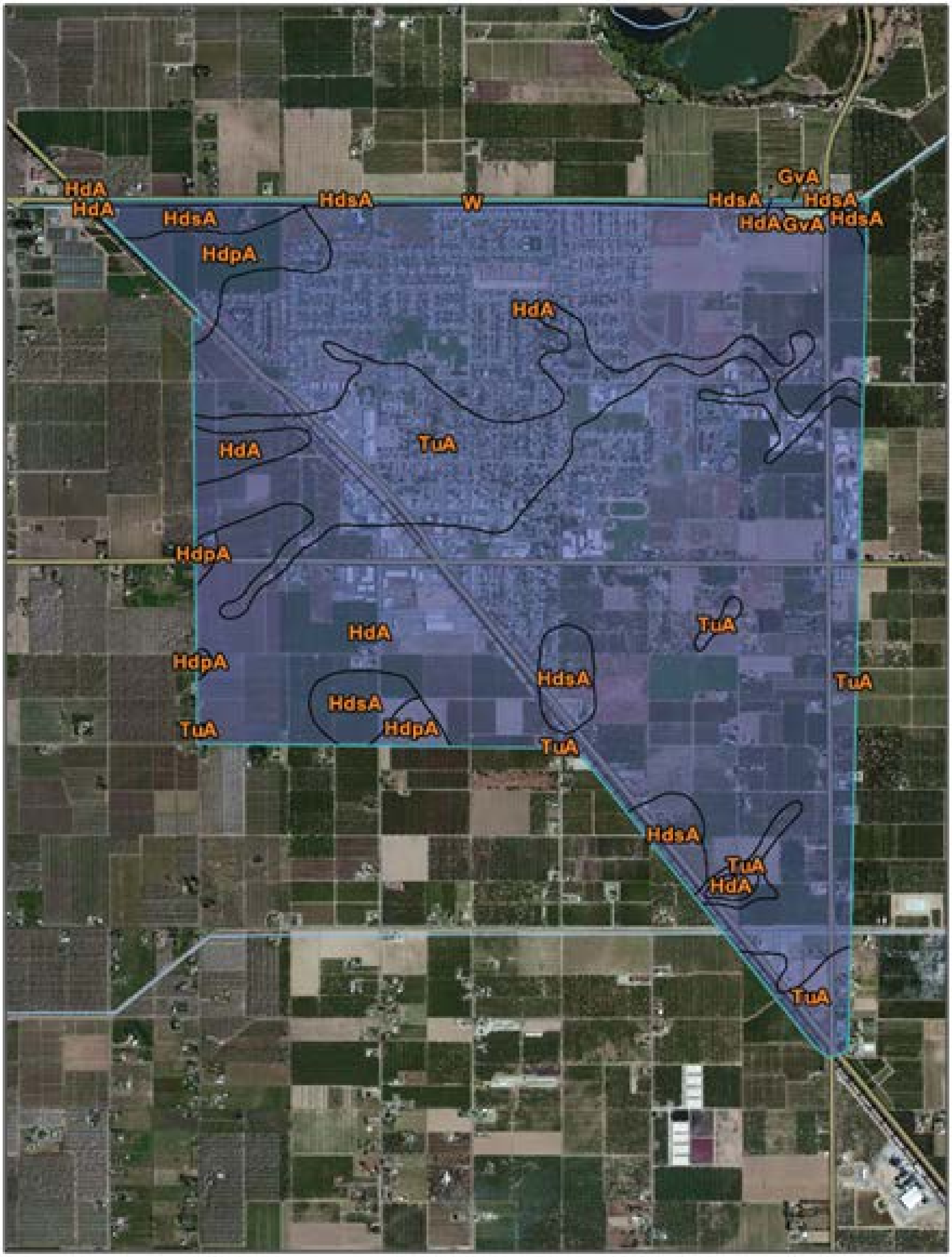


Figure 4: Flood Zones Map (Source: FEMA 2011)



DEPTH TO WATER TABLE

CITY OF HUGHSON

> 200 (Centimeters)

Figure 5: Expected Depth to Groundwater Map (Source: NRCS 2011)

Pollutants of Concern

Urban runoff can transport pollutants, including sediment, oils, metals, fertilizers, pesticides, bacteria, and trash into local surface water bodies. In the region, the Tuolumne River and downstream waters have been impacted by the application of pesticides and fertilizer as well as commercial extraction of natural resources. Urban runoff pollutants are becoming more of a concern as well. These include: organics, organophosphate, nitrogen, selenium, pyrethroids, pathogens, fecal coliform, and PCBs (industrial runoff). General guidance on the effectiveness of BMPs to remove common urban pollutants is included in Appendix B.

Topography

The topography of the site, including site slopes and locations of existing drainages, can impact the effectiveness of BMPs and must be considered. Steeper slopes (from 5%-15%) increase flow velocity (which may cause scour and reduced treatment effectiveness in both receiving and conveying stormwater) and make construction of larger volume facilities more difficult.

Infiltration practices are not recommended adjacent to or within very steep slopes, as water put into the ground could cause slope stability issues. There are very few extremely steep slopes in the Planning Area, mostly adjacent to the river floodplain.

Soils and Geology

One of the most important components of selecting appropriate LID features is the evaluation of existing soils and geologic conditions to determine soil group, texture, and permeability. Many LID strategies, especially retention BMPs, function optimally when they are able to infiltrate runoff. A minimum infiltration rate of 0.5 in/hr is typically required for infiltration facilities.

As a preliminary assessment, the Hydrologic Soil Group designation assigned by the National Resources Conservation Services (NRCS) to the site soils can be examined (see Figure 7). This rating describes the physical properties of each soil type.[1] Soils of Type A or B are typically better suited for infiltration practices (assuming all other site conditions are met). Soils of Type C or D have low permeability and are more susceptible to clogging and will, therefore, limit the applicability of infiltration.

The City of Hughson has only Type A soils. However, all LID potential project locations should have a geotechnical report that yields permeability information for at least 10 feet below the bottom of the proposed improvements.

Hardpan Condition

Infiltration strategies will also be affected by the hardpan condition found in the Hughson area (see Figure 8). The hardpan, a thick layer of dense soil found beneath the topsoil layer, is most likely very impervious and will require special design considerations. In locations of hardpan, there exists the possibility to break up the hardpan and install rock wells or other methods to convey treated stormwater below the hardpan layer. (All hardpan within the city limits is below 200 centimetres or 6.5 feet – see Figure 6).

The general strategy for considering infiltration within a hardpan area is as follows:

- If the depth to hardpan, as measured from the bottom of the BMP, is greater than 10 feet, infiltration is acceptable.
- If the depth to hardpan is less than 10 feet and the hardpan thickness is 4 feet or less, infiltration is acceptable if soils below the hardpan are well draining and rock well is installed through hardpan.
- If the depth to hardpan is less than 10 feet and the hardpan thickness is greater than 4 feet, infiltration is not acceptable.
- Separation of 10 feet between the bottom of the infiltration BMP or rock well and the groundwater surface elevation is also necessary.

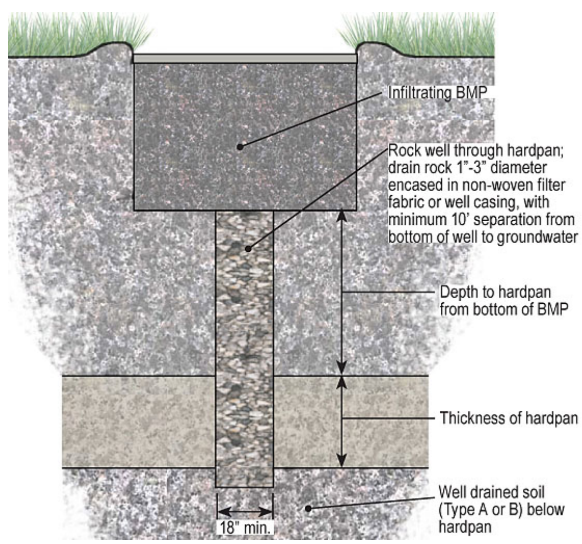


Figure 6: Typical rock well installed beneath an infiltrating BMP in an area with a hardpan layer close to the surface that is less than 4 feet thick.

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[1] Soils classified as Group A (gravel, sand, sandy loam) are highly permeable and produce the least surface runoff; Group B soils (silt loam, loam) have good permeability; Group C soils (sandy clay loam) offer fair to poor drainage characteristics; and Group D soils (clay loam, sandy clay, silty clay, clay) have very little infiltration potential and produce the greatest surface runoff.

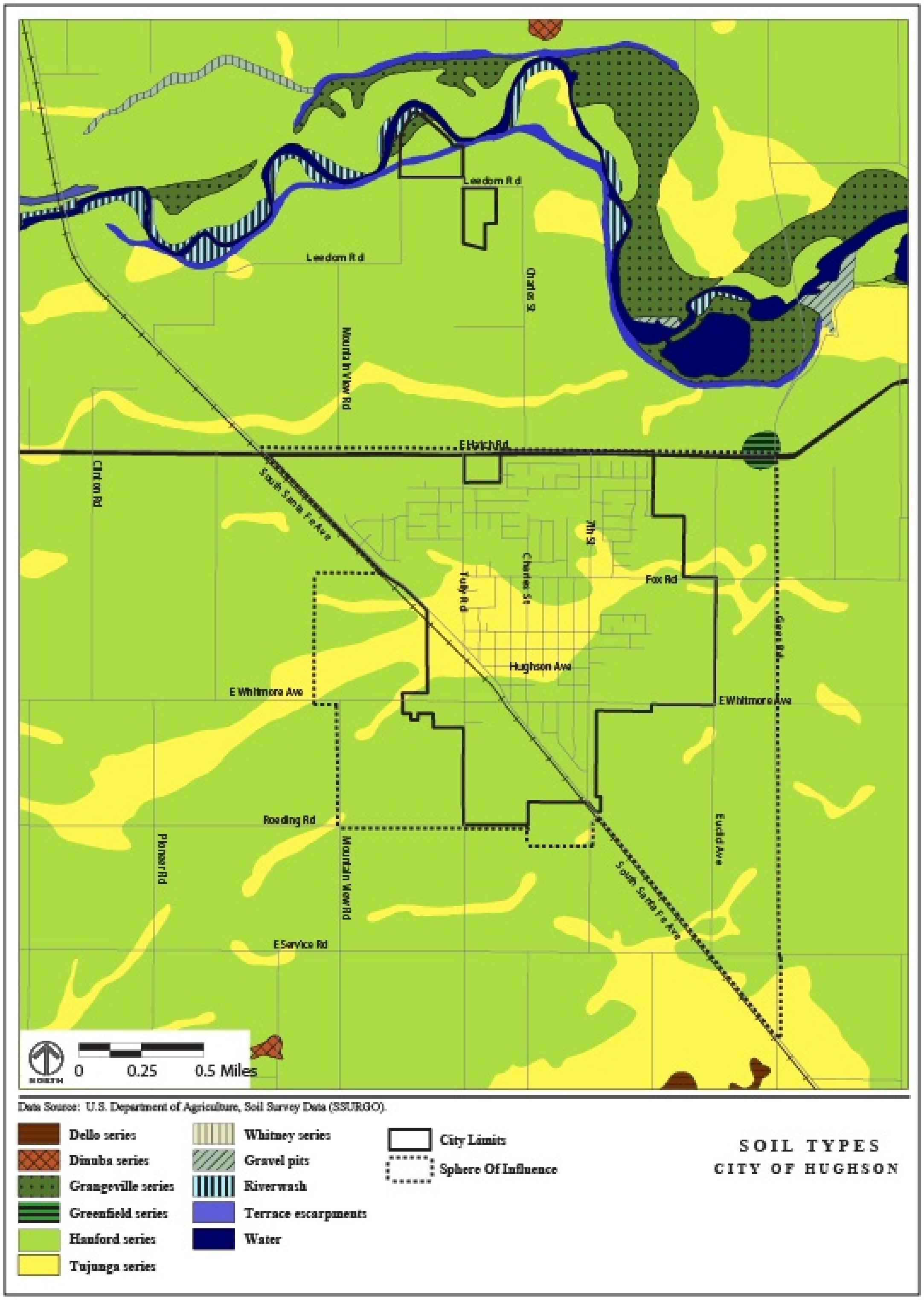


Figure 7: Soils Map (Source: NRCS 2011)

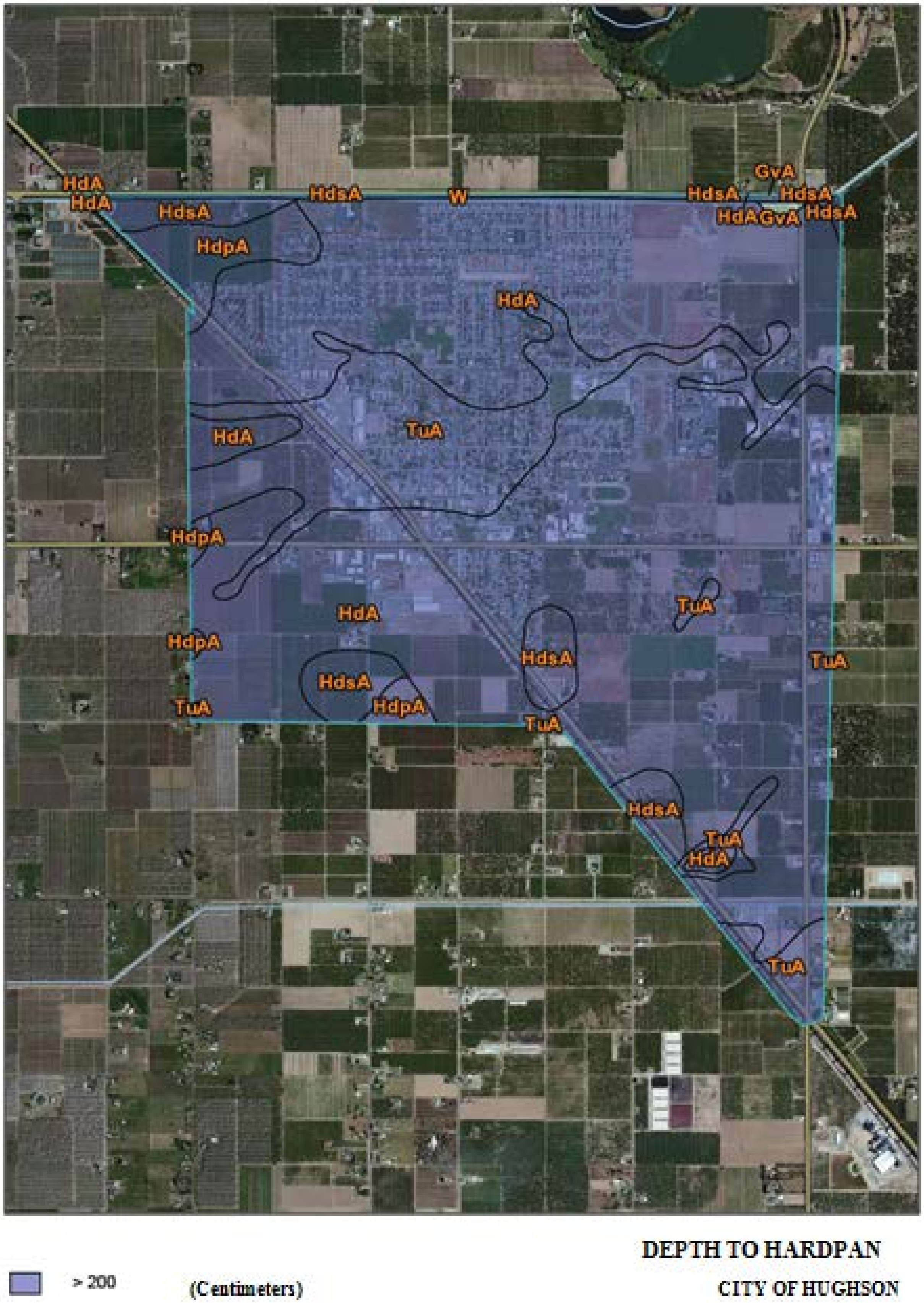


Figure 8: Depth to Hardpan Layer Map (Source: NRCS 2011)

Space Limitations

Another factor to consider when selecting BMP features is site configuration and available space. Some BMPs require more surface area than others. Therefore, it is important to evaluate the amount of space available and the best way to balance development goals and stormwater requirements.

If the characteristics of the site allow infiltration, consider piping runoff to underground infiltration systems, which can be located beneath many different surface types, or converting hardscape areas to permeable pavement. These systems can result in very little need to modify the layout or programming of a site, while still providing water management benefits. Similarly, a thin infiltration trench that is long and deep can provide the same function as a detention basin or wetland, only in a much smaller footprint.

Another strategy is to integrate numerous dispersed bioretention area cells into small open spaces on the site and strips of landscaping in the street. By locating many small areas throughout a project, runoff is captured and treated almost immediately. This allows the runoff to then be routed to existing infrastructure and eliminates the need for a larger facility to handle collected flows.

BMP Selection Matrix

The table below is intended to provide a quick and convenient method of identifying which BMPs are most appropriate for use on a given site. The left-hand column contains a list of questions that identify a possible site constraint. For any question answered "yes" the project should consider the BMPs marked with a green box, with any additional requirements for using a BMP listed within the green box.

For example, consider a site with a high groundwater table (less than 10' to the bottom of BMPs), steep slopes of around 6%, and Type C soils (but not located in a floodplain, having no hardpan layer, and with adequate space). The BMPs which are appropriate for this location are bioretention areas (if terraced and installed with a liner and underdrain), rainwater harvesting, and green roofs.

Constraint	Underground Infiltration	Bioretention Area	Vegetated Swale	Filter Strip	Vegetated Basin	Constructed Wetland	Permeable Pavement	Rainwater Harvesting	Green Roof
Located in floodplain?									
Less than 10-foot separation to groundwater table?		With liner and underdrain	With liner		With liner		With liner & underdrain (provides no treatment)		
Sited on steep slope (5-15%)?		If terraced							
Limited space for BMP facilities?			With adequate length						

Figure 9: BMP Selection Matrix

3.0

Stormwater BMP Design

The use of LID techniques can aid in addressing the water quality and hydrologic issues that are typically exacerbated by development. When planning and designing new development and redevelopment the goals of LID and requirements of the MS4 Permit should be incorporated and promoted. These site design goals include:

- conserve natural areas and drainages;
- minimize impervious surfaces, drain to pervious area;
- minimize soil compaction;
- mitigate peak runoff and associated erosion; and
- treat runoff in stormwater BMPs.

There are a number of BMPs recommended for use in the City and surrounding areas. These facilities, along with sizing criteria and design recommendations, are detailed in this section.

BMP Sizing Criteria

Treatment control BMPs, which provide post-construction water quality benefits, are most efficient and economical when they target the frequent, small storm events that produce the majority of annual rainfall. Larger, more intense storms are the basis of design for conveyance and flood control facilities, but there are only marginal improvements to runoff water quality when BMPs are designed to this standard.

BMPs for treatment of stormwater pollutants should be sized to either a flow-based or volume-based standard, or both. The MS4 permit lists three methods for volume-based sizing and two methods for flow-based sizing, summarized below.

Volume-based BMPs must be sized for:

- The volume of annual runoff based on unit basin storage water quality volume, to achieve 80% or more volume treatment by the method recommended in California Stormwater BMP Handbook (2003); or
- The 85th percentile 24-hour runoff event, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ ASCE Manual of Practice No. 87, (1998); or
- The runoff volume produced from a historical-record based reference 24-hour rainfall criterion for “treatment” that achieves similar pollutant reduction to the 85th percentile 24-hour runoff event.

Flow-based BMPs must be sized for:

- The flow produced from a rain event equal to at least twice the 85th percentile hourly rainfall intensity; or
- The flow that will result in treatment of the same portion of runoff as treated using volume-sizing.

Methods for sizing flow and volume-based BMPs are explained on the following page.

Larger or more complicated projects may benefit from the use of continuous simulation modelling in lieu of these simplified methods.

Flow-Based Sizing

Flow-based BMPs must be designed to carry or process the runoff resulting from the targeted water quality rainfall under flow conditions that promote treatment (specific to each BMP, but generally low velocity and minimal flow depth). The water quality flow (WQF) is the flow of runoff produced by a rain event equal to twice the 85th percentile hourly rainfall intensity, based on local rainfall data. For the Hughson area, the 85th percentile hourly rainfall intensity is approximately 0.10 inches per hour[1], resulting in a design rainfall intensity of **0.20 in/hr**.

To calculate the required treatment flow, first determine the size of the drainage area contributing runoff to the BMP and the composite stormwater runoff coefficient[2] for that drainage area. The rational method can then be used to calculate the flow rate:

WQF = C x i x A = 0.20 x C x A

Where:

- WQF = water quality flow (cfs)
- C = composite runoff coefficient for drainage area (unitless)
- i = design rainfall intensity (0.20 in/hr)
- A = drainage area (acres)

[1] Based on California State University, Sacramento Office of Water Programs' Basin Sizer, Version 1.45 (2007).

[2] Standard runoff coefficients for different land use types can be found in Section 4.3 of the City of Hughson Storm Drain System Master Plan (2008).

Volume-Based Sizing

Volume-based BMPs must be designed to capture and treat 80 percent or more of the annual runoff volume, determined using the methodology recommended in the California Stormwater BMP Handbook. The water quality volume (WQV) to which a BMP must be sized is based on the drainage area's unit basin storage volume, determined from local rainfall data and site characteristics. A volume-based BMP must also be designed to release this volume (typically through an orifice or via infiltration) within an acceptable drawdown time (generally 24-48 hours).

To calculate the required treatment capture volume, first determine the size of the drainage area contributing runoff to the BMP and the composite stormwater runoff coefficient for that drainage area. The Unit Basin Storage Volume (UBS) for the drainage area is determined from the sizing curve for 80% capture; find the composite runoff coefficient of the drainage area on the x-axis, follow it up until it intersects the line representing the desired drawdown time, and read the corresponding UBS value from the y-axis. Calculate the treatment volume by multiplying the UBS by the drainage area (convert to more convenient units, such as cubic feet or gallons, for use during design):

WQV = UBS x A

Where:

- WQV = water quality volume
- UBS = Unit Basin Storage Volume (inches)
- A = drainage area (acres)

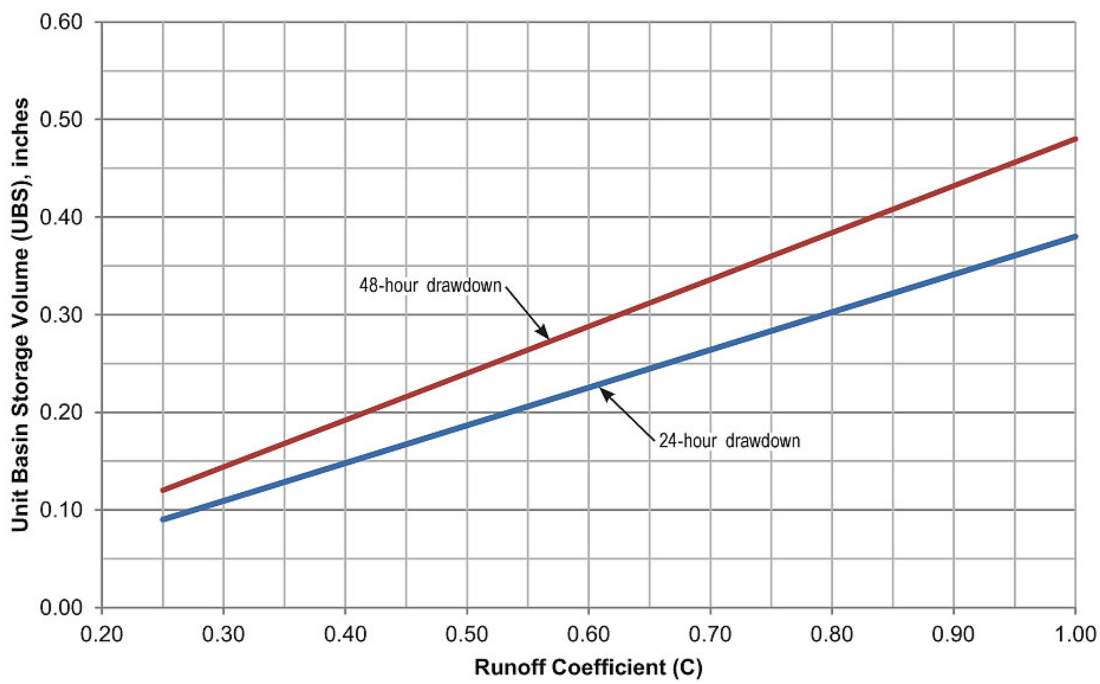


Figure 10: Unit Basin Storage Curves

Infiltration Feasibility

Typically, the preferred method of draining any stormwater BMP is through infiltration to the underlying subgrade soils. This allows for maximum treatment ability, groundwater recharge, and reductions in stormwater volume. Infiltration is not always possible though, as there are a variety of site constraints that can impede or prohibit the implementation of this function.

The table below summarizes the general parameters a site must meet in order for infiltration to be used and/or relied upon as a treatment or discharge method. More explanation of these constraints can be found in Section 2, and information on design considerations can be found in the BMP Fact Sheets which follow.

Site Constraint	Acceptable Condition
Hydrologic Soil Group	Type A or B
Soil infiltration rate	0.5 in/hr minimum
Slope	Less than 5% Note: terraced bioretention designs can accommodate slopes up to 15%
Separation from hardpan layer [1]	10-foot minimum (no minimum for thin hardpan with rock well installed through to underlying soils)
Separation from groundwater table [1, 2]	10-foot minimum
Setback from buildings foundations [2]	10-foot minimum
Setback from drinking water wells [2]	100-foot minimum
Soil or groundwater contamination [2]	Not allowed

[1] The acceptable 10’ separation is based on a statewide standard and is a conservative criterion to minimize risk. Available information from NRCS does not provide any resolution of hardpan and groundwater data for depths greater than about seven feet, therefore geotechnical investigation will be necessary to determine actual depth.

[2] BMPs with less than the minimum separation to groundwater, setback to foundations and wells, or in contaminated soils must be lined with an impermeable liner to protect those elements. Other constraints generally require the installation of an underdrain or orifice for primary drawdown of captured stormwater.

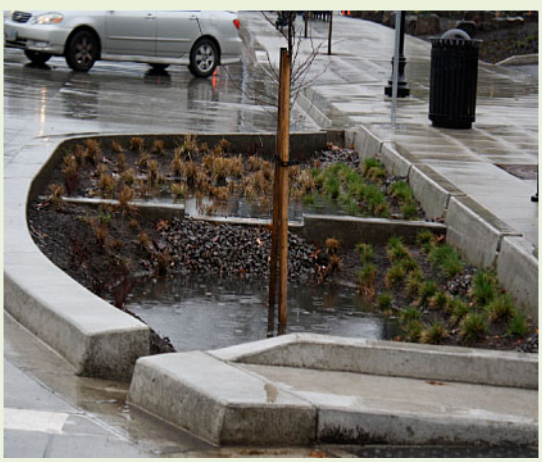
BMP Fact Sheets

Detailed information on the stormwater facilities recommended for LID design in the Hughson area is included in the BMP fact sheets that follow. Each fact sheet contains a description of the BMP, a retrofit opportunity example, technical design criteria, plant selection recommendations, and a list of benefits, constraints, and siting applications. This information is intended to aid in selecting, placing, and designing the various BMPs. Certain of the BMPs (in particular constructed wetlands, rainwater harvesting systems, and green roofs) will likely require prior experience or more detailed guidance to develop a design appropriate for construction.

BMP	Sizing Method	Other Sizing Criteria
Underground Infiltration	WQV	Drawdown time
Bioretention Area	WQV or WQF	Drawdown time
Vegetated Swale	WQF	Residence time, flow speed, flow depth
Filter Strip	WQF	Flow speed, flow depth, tributary width
Vegetated Basin	WQV	Drawdown time
Constructed Wetland	WQV	Drawdown time
Permeable Pavement	WQV	Drawdown time
Rainwater Harvesting	WQV	Drawdown time
Green Roof	WQF	Roof-based system

Sediment Forebay

Stormwater treatment facilities, especially those designed to treat catchment areas that are larger or have higher anticipated pollutant loads, benefit from pretreatment. One simple and effective pretreatment component is a sediment forebay, which helps prevent clogging of BMPs, eases maintenance requirements (such as easier cleanup of collected trash and debris), and can also be used to provide peak flow storage. A sediment forebay is a small basin located at the incoming discharge point or just upstream of a BMP. The forebay allows sediment to settle out and trash/debris to collect prior to runoff reaching the primary treatment area.



Tree-well Filter

Tree-well filters are systems which utilize one or more precast concrete chambers filled with engineered bioretention media. Stormwater is directed into the chambers and receives treatment as it flows through the filter media and then is collected and released by a perforated pipe. Proprietary systems are available which are designed for efficient pollutant removal at high flow rates and thus have a relatively small footprint compared to other LID facilities. Their unique attributes make tree-well filters suitable to almost any site. However, City approval must be obtained in order to use these devices.

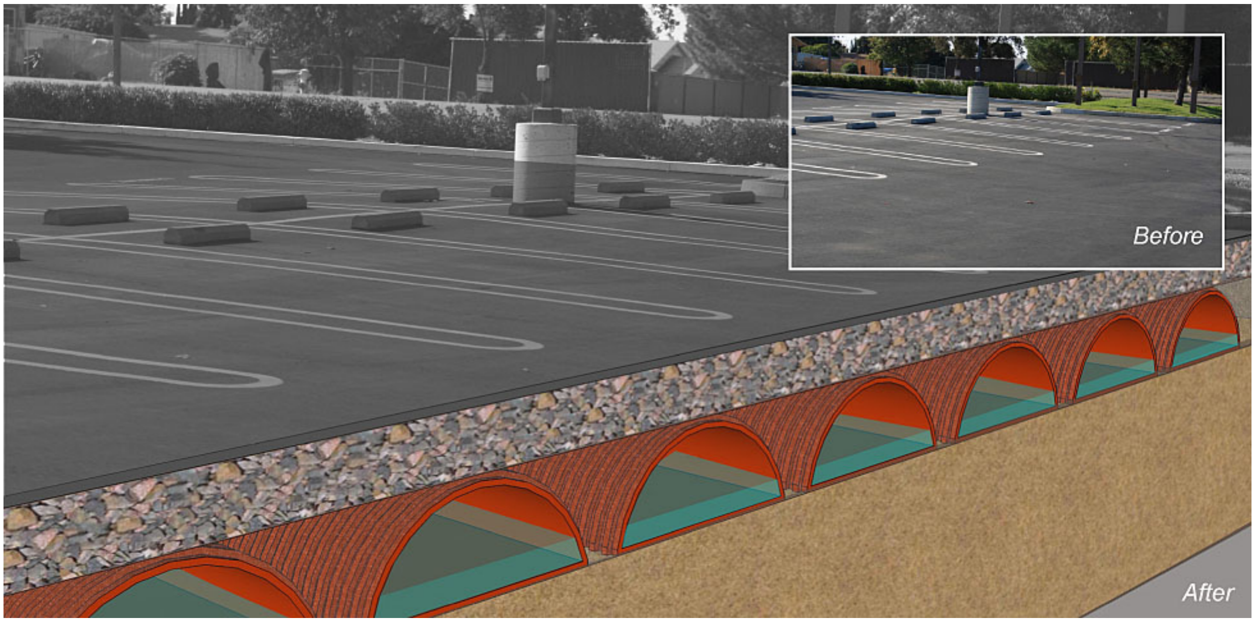
Note: Image courtesy of Filterra Bioretention Systems. Proprietary systems are included for representative purposes only and are not an endorsement of any specific product.

UNDERGROUND INFILTRATION

These systems can take different forms but provide identical function: controlled discharge of stormwater through infiltration. The primary pollutant removal mechanism of this practice is filtering through the native soil. An infiltration trench is a long, narrow, rock-filled trench with no outlet that receives stormwater runoff from upstream areas. A dry well is a small rock-filled pit that usually receives runoff from rooftops or other impervious areas with low sediment loading. Water is stored in the void space between the stones and percolates through the underlying soil matrix. If high sediment loads are expected, pretreatment is desirable to reduce the maintenance burden.

Underground infiltration systems can be integrated into a site to enhance and diversify the landscaping, in addition to providing stormwater improvements.

Retrofit Opportunities



Benefits

- Reduces runoff volume and attenuates peak flows
- Improves water quality - good for removing fine sediment and adsorbed pollutants
- Enhances groundwater recharge and contributes to stream base flow
- Minimal surface space requirements; located underground and thus visually unobtrusive
- Low construction and maintenance costs

Potential Constraints

- Requires permeable subgrade soils.
- Requires groundwater separation
- Contributing area should generally be less than 5 acres
- Not suitable on fill sites, steep slopes (>15%), contaminated soils, industrial sites, or sites where spills are likely to occur
- May encounter siting challenges in urban retrofit areas due to foundation setback and poor soil conditions

Siting Applications

- Mixed-use and commercial
- Roads and parking lots
- Parks and open spaces
- Single and multi-family residential

Technical Information

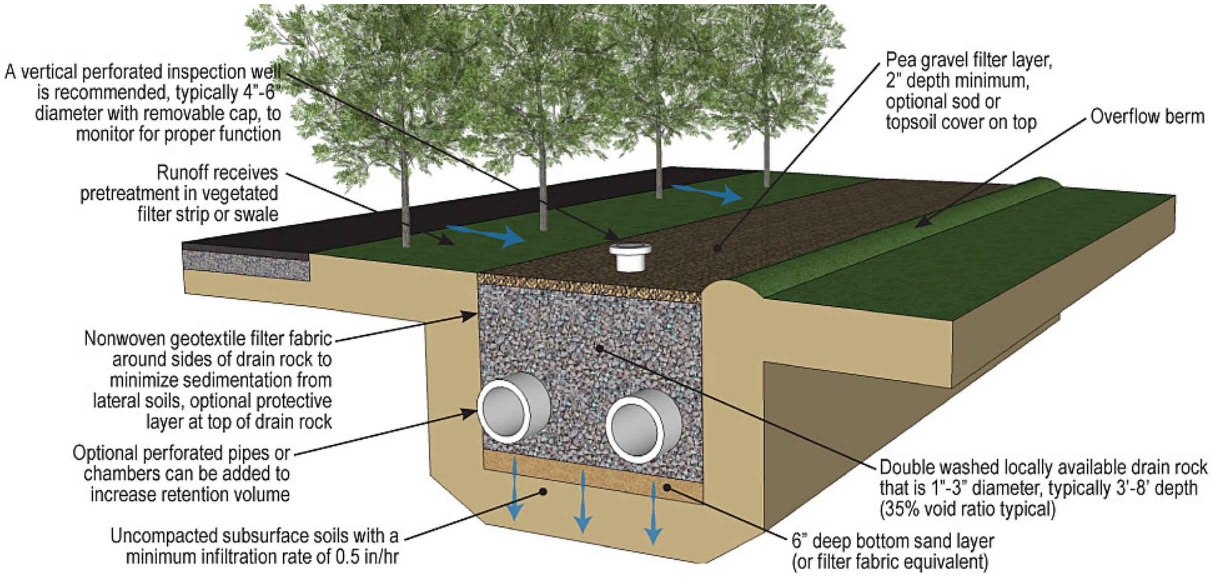


Figure: Infiltration trench typical detail

Design & Sizing Criteria

- Infiltration facilities are volume-based systems sized to capture the WQV within the void space of the storage layer and should infiltrate all stored runoff into the subsoils within a maximum 72 hour drawdown time.
- Requires a minimum subgrade soil infiltration rate of 0.5 in/hr minimum. If soil infiltration rates exceed 2.5 in/hr, runoff should be fully treated (with one or more upstream BMPs) prior to infiltration to protect groundwater quality.
- Requires a 10 foot minimum separation from the bottom of the facility to the seasonally high groundwater elevation.
- Should be placed a minimum of 10 feet from building foundations and 100 feet from drinking water wells.
- Should be installed with a flat bottom to promote uniform infiltration.
- To help prevent clogging and ease maintenance, it is important to provide upstream pre-treatment (using filter strips, swales, forebays, or manhole sumps) to remove coarse sediment, particles, and oils.
- If possible, system should be designed to avoid classification as a Class V injection well, which requires submission of an inventory form to the EPA. A Class V injection well is deeper than it is wide.
- If infiltration is not possible, can be installed with an orifice to provide flow and volume control functions without any water quality treatment.

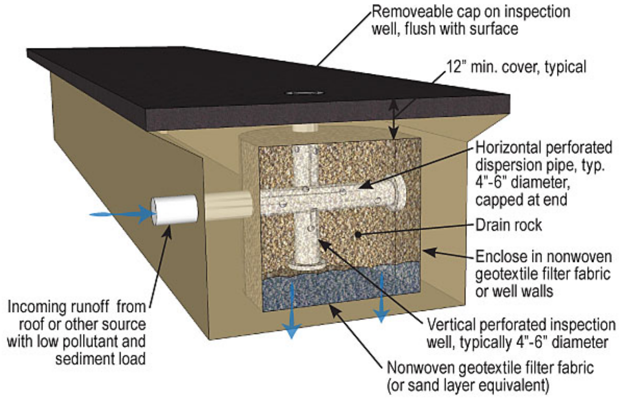


Figure: Dry well typical detail

Proprietary Systems

There are many retention systems designed to maximize subsurface capture volume and that include components for pretreatment and flow control.

Cudo Cubes are an example of a typical modular block system.

Triton stormwater chambers are a typical semi-circular linked chamber system.

Note: Proprietary systems are included for representative purposes only and are not an endorsement of any specific product.

BIORETENTION AREA

Bioretention areas are shallow, landscaped areas that receive and treat stormwater. Runoff is allowed to pond on the surface of the bioretention area, typically less than a foot deep, where it can then filter through a vegetative layer and engineered soil media to remove sediment and pollutants. In locations of well drained subsoils, the water may then infiltrate into the subgrade. At sites or locations that will not allow for infiltration, flow-through systems are required; underdrains are installed beneath the planting soil to drain the facility and release the treated water to a conveyance feature or storm drain system. Bioretention areas are very versatile facilities that can fit a wide range of settings.

Bioretention areas are among the most common LID techniques implemented, often in highly visible locations.

Retrofit Opportunities

Benefits

- Applicable to a wide range of sites and layout, easily integrated into urban retrofit projects
- Provides reliable water quality function
- Attenuates peak flows; reduces runoff volume and recharges groundwater when infiltration possible
- Provides greening and reduces heat island effect in urban areas
- Provides aesthetic amenity and creates habitat

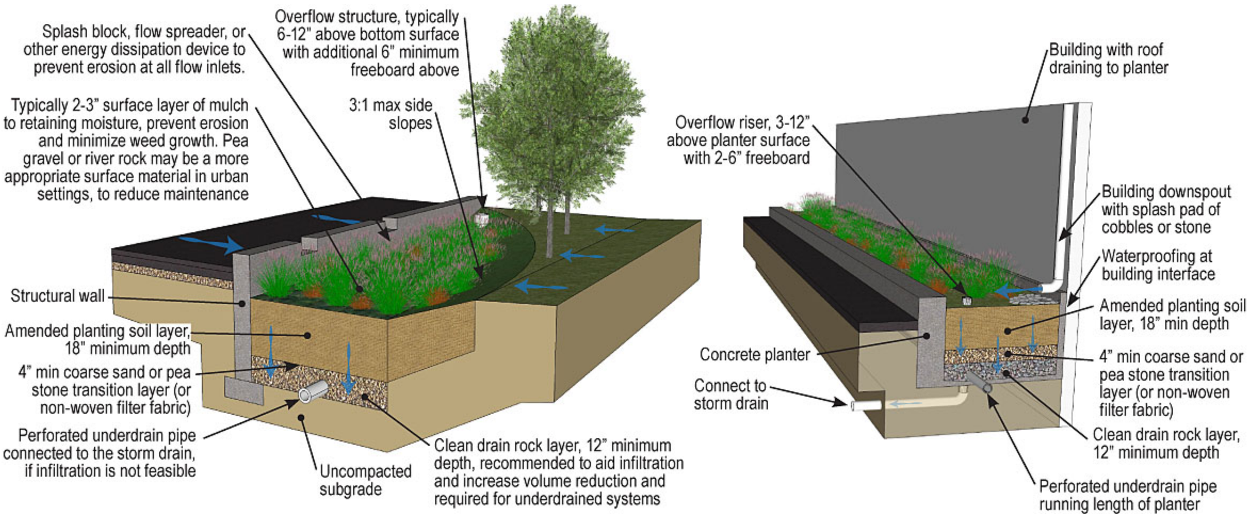
Potential Constraints

- Infiltration design requires sufficiently permeable soils, depth to groundwater/hardpan; underdrain system increases cost and infrastructure
- Vegetation requires maintenance
- Maintaining desired aesthetics may require dry season irrigation
- Should not receive more than about 1 acre of runoff; divide larger watersheds among dispersed cells

Siting Applications

- Residential yards
- Office and commercial storefronts
- Roadway medians, bulb-outs, and traffic circles
- Parking lot islands, cul-de-sacs
- Parks and other landscaped areas

Technical Information



Design & Sizing Criteria

- Bioretention areas can be sized as either volume-based or flow-based systems (or a combination).
- Volume-based systems are sized to capture the WQV within the surface ponding area and void space of the drain rock storage layer and should release all captured runoff within a maximum 48 hour drawdown time (either by subgrade infiltration or through an underdrain).
- Flow-based systems are sized to percolate the WQF through the bottom of the facility. The surface area of the system multiplied by the infiltration rate of the planting media (which should be considered as 5 in/hr for design) must equal or exceed the WQF. The subgrade infiltration rate must be high enough to process this flow as well, or an underdrain is necessary.
- Reliance on subgrade infiltration requires a minimum soil infiltration rate of 0.5 in/hr, in addition to the above requirements.
- If the separation from the bottom of the facility to the seasonally high groundwater elevation is less than 10 feet then an underdrain should be installed, with an impermeable liner placed beneath all system media.
- Infiltrating bioretention systems should be placed a minimum of 10 feet from building foundations and 100 feet from drinking water wells.
- Pre-treatment (e.g., vegetated buffer strip, swale, sediment forebay) can improve function and ease maintenance.
- Runoff from storms larger than the water quality event is ideally diverted to the storm drain system.

Plant Selection *(See Appendix A)*

Plants should be suitable for periods of inundation during the rainy season. Vegetation should be drought-tolerant, especially at the edges, but may require irrigation during initial establishment or dry periods. Trees require more intensive maintenance, and may show limited growth.

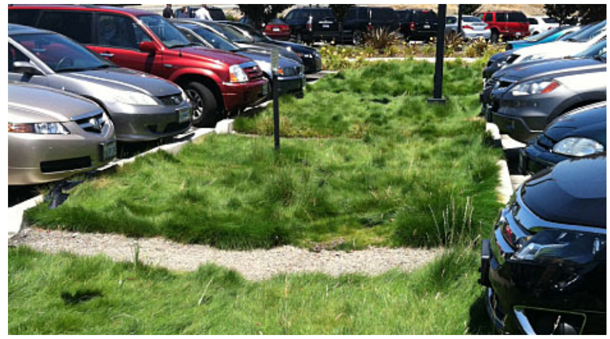

Blue eyed grass


Desert baccharis


California rose


San Diego sedge

Vegetated swales are shallow stormwater conveyance channels with vegetation covering the side slopes and bottom. Treatment occurs as runoff flows through the vegetation and infiltrates into the soil matrix. Swales can be designed as part of the stormwater conveyance system and can eliminate the need for some curbs, gutters and storm drains. They are also well suited to treat runoff from roads and highways because of their linear nature. The treatment effectiveness is correlated to the residence time of the runoff in the swale, and therefore, flow-based swales tend to be considerably longer than other types of treatment BMPs.



Vegetated swales, such as this installed in a parking lot, can both treat and convey runoff, eliminating the need for some catch basins and pipes.

Retrofit Opportunities

Benefits

- Can convey stormwater, including within street right-of-way
- Low installation and maintenances costs
- Reduces peak flows and velocity compared to concrete or piped conveyance
- Improves water quality, depending on site constraints, by removing sediment, suspended solids, and trace metals
- Vegetation provides aesthetic benefit and reduces the heat island effect in urban areas

Potential Constraints

- Larger space requirements than traditional conveyance methods
- Requires regular vegetative maintenance and trash removal
- Can be difficult to locate in retrofit applications
- Not suitable for areas with steep slopes or highly erodible soils
- Limited to relatively small drainage areas, generally less than 5 acres
- Limited volume reduction and peak flow attenuation, unless designed with check dams

Siting Applications

- Road shoulders and medians
- Parking lot islands
- Commercial, industrial, and residential developments
- Open space and parks

Technical Information

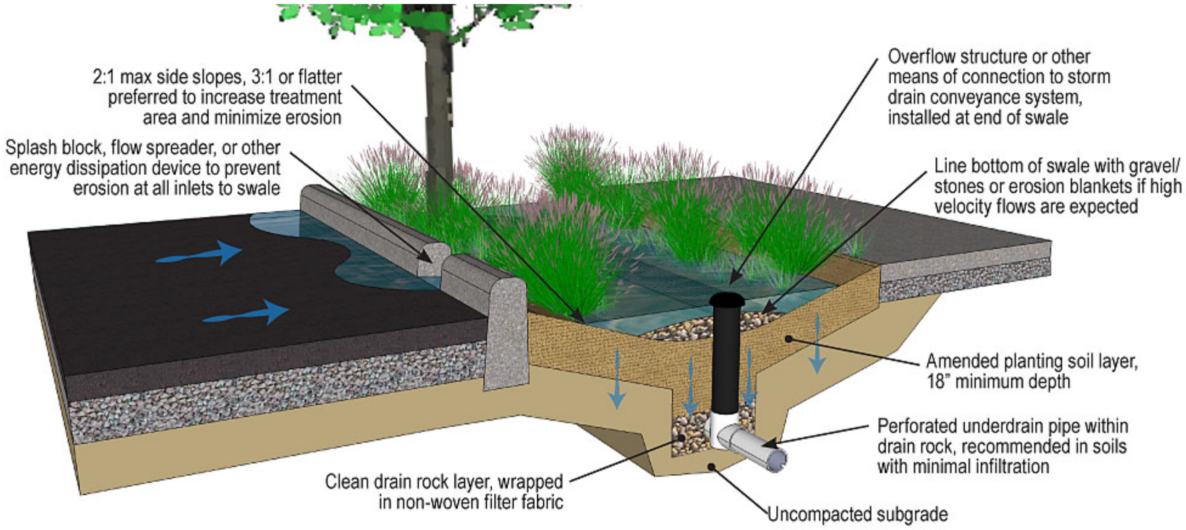


Figure: Vegetated swale typical detail

Design & Sizing Criteria

- Swales are flow-based systems sized to convey the WQF at a flow velocity not exceeding 1 foot per second and maximum water depth not exceeding the lesser of 6 inches or 2/3 of the vegetation height.
- Swales must provide a minimum of 10 minutes of stormwater residence time for pollutant removal, with a minimum length of 100 feet.
- The preferred longitudinal slope is 1-2% to limit flow velocity. Check dams placed across the flow path can promote additional infiltration and flow reduction, and should be used for longitudinal slopes exceeding 5%.
- Swales should generally have a trapezoidal or parabolic shape to promote even flow across the whole width of the swale. The bottom width should be between 2 and 10 feet.
- A dense and well maintained vegetative cover on the swale bottom and side slopes filters pollutants out of runoff and helps reduce flow velocities and protect the swale from erosion. Stones or gravel may also be used on the bottom to protect against erosion.
- Vegetated swales that are primarily designed to detain runoff (behind check dams or due to layout) should be considered bioretention facilities and designed accordingly.
- Most effective on soils that allow infiltration. In impermeable soils, installing well-drained planting media with an underdrain beneath is recommended.

Plant Selection *(See Appendix A)*

Hughson receives little precipitation and has a long dry period in the summer, so flow will be irregular and plants must be chosen accordingly. Periodically the swale will experience high flows and plants should be chosen with well established roots to protect against erosion, and the ability to withstand inundation

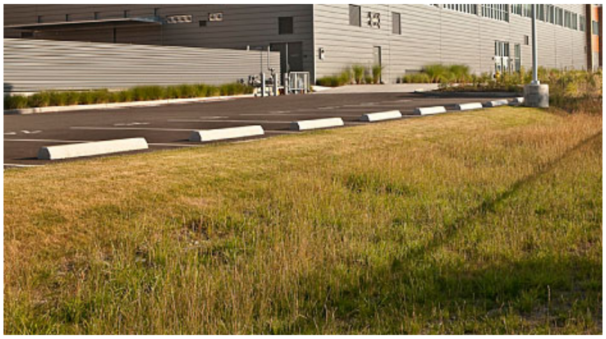
Purple needle grass

Hummingbird trumpet

Bush monkey flower

Western meadow sedge

Filter strips are vegetated surfaces that are designed to treat sheet flow from adjacent surfaces. Filter strips function by slowing runoff velocities and allowing sediment and other pollutants to settle and by providing some infiltration into underlying soils. Filter strips are most effective when runoff passes over the filter surface as shallow, uniform sheet flow. They can suffer erosion and lack of treatment if exposed to concentrated flows. They are well suited to treat runoff from adjacent roads or small parking areas and are good for use as vegetated buffers between developed areas and natural drainages.



Filter strips can be as simple as a gentle slope covered in grass that receives runoff from an adjacent strip of parking stalls.

Retrofit Opportunities

Benefits

- Low construction cost and minimal maintenance requirements (generally just erosion prevention and mowing)
- Can provide reliable water quality benefits if properly designed, vegetated, and maintained
- Good for roadside shoulders and landscape buffers when slope and length criteria are met
- Simple, aesthetically pleasing landscape feature
- Easy to customize to varying site conditions

Potential Constraints

- Not appropriate for industrial sites or locations where spills may occur
- Limited ability to treat large drainage areas
- Water quality benefits severely limited without adequate filter length and flow characteristics
- Does not provide significant stormwater volume reduction
- Only minor reduction in flow rate, especially during larger storms
- May require dry season irrigation

Siting Applications

- Roads and highway shoulders
- Small parking lots
- Residential, commercial, or institutional landscaping
- Pre-treatment component for subsequent BMP

Technical Information

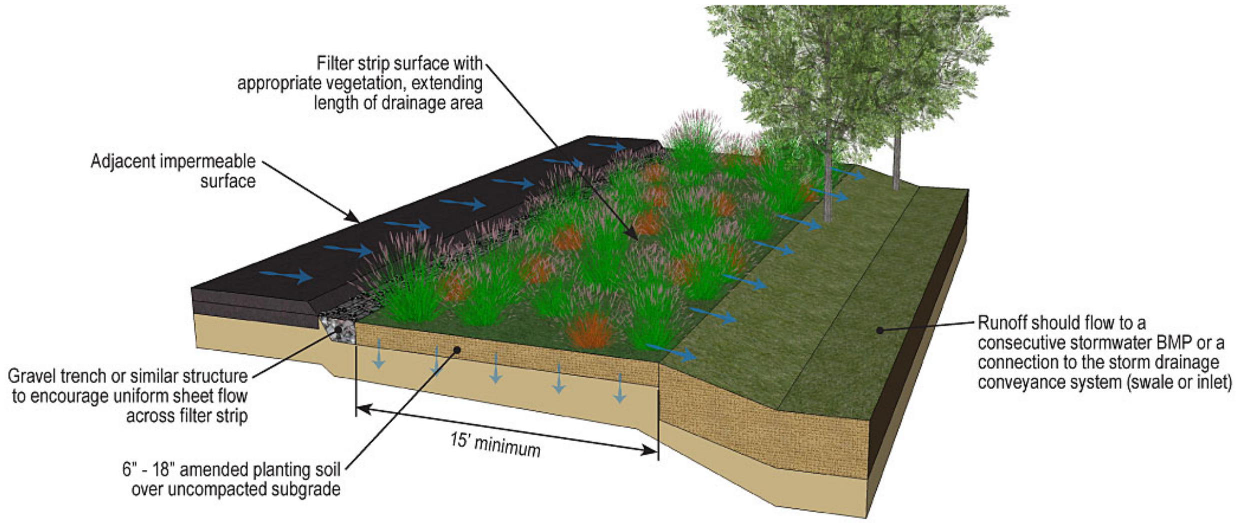


Figure: Filter strip typical detail

Design & Sizing Criteria

- Filter strips are flow-based systems designed to convey the WQF across the vegetated surface at a flow velocity not exceeding 1 foot per second and maximum water depth not exceeding 1 inch.
- Should be at least 15 feet wide and preferably 25 feet wide (in the direction of flow) to provide adequate water quality treatment.
- Filter strips are considered effective at treating contributing impervious surface widths up to twice the width of the vegetated strip. The maximum length (in the direction of flow towards the filter strip) of the contributing tributary area should be 60 feet.
- Should be immediately adjacent to, and extend the full length of, the contributing drainage area.
- Ideal cross-slope is between 2% and 6% to avoid ponding (at low slopes) and concentrated flows (at high slopes). Slopes up to 15% may be acceptable with proper design and careful maintenance, but are generally not recommended.
- If the cross-slope is less than 0.50%, or if the underlying soil infiltration rate is less than 0.5 in/hr, consider an underdrain system to facilitate drainage.
- Requires shallow, evenly-distributed sheet flow across the entire width of the strip. Level slopes perpendicular to the direction of flow are required to achieve sheet flow.

Plant Selection *(See Appendix A)*

The filter area should be densely vegetated with native grasses, shrubs, and trees that effectively bind the soil. The thicker and more uniform the plant cover, the greater the stormwater management benefits.

California encelia

Wild rye

California sagebrush

San Diego sedge

CONSTRUCTED WETLAND

Vegetated basins are temporary holding areas for stormwater that capture and detain flows from a water quality design storm for some minimum time (e.g. 48 hours) to allow particles and associated pollutants to settle. They are typically designed with an outlet structure that slowly releases the water requiring treatment via a small orifice and allows controlled routing of larger events. Water quality drawdown can be achieved through infiltration, if site conditions will allow. Stormwater collected in vegetated basins can be re-used for landscape irrigation, and basins can also be used to provide flood control by including additional flood detention storage.

Basins that are thoughtfully designed and planted can manage stormwater from a larger area, while still offering aesthetic appeal.

Retrofit Opportunities

Benefits

- Relatively low construction and maintenance costs
- Highly effective at attenuating peak flows, can reduce runoff volumes with infiltration or reuse
- Improves water quality by removing particulate matter, sediment, trash, and debris
- Suitable for sites where infiltration is poor or not an option
- Suitable for large drainage areas
- Multi-purpose detention ponds can provide open space, habitat, and aesthetic amenity

Potential Constraints

- Limitations of the release orifice may not allow use of detention in watersheds of less than 5 acres (would require an orifice with a diameter of less than 0.5 inches that would be prone to clogging)
- Only moderate pollutant removal, compared to some other BMPs and ineffective at removing soluble pollutants
- May exhibit undesirable aesthetics due to dry, bare areas and inlet and outlet structures
- Site must have no risk of land slippage if soils are saturated

Siting Applications

Parks, open spaces, and golf courses

- Commercial, industrial, or residential developments
- Regional detention & treatment

Design Variation

A basin designed with a permanent pool is commonly referred to as a wet pond; additional treatment and amenity benefits can be realized by the body of water, along with maintenance and the need for base flow or supplemental water.

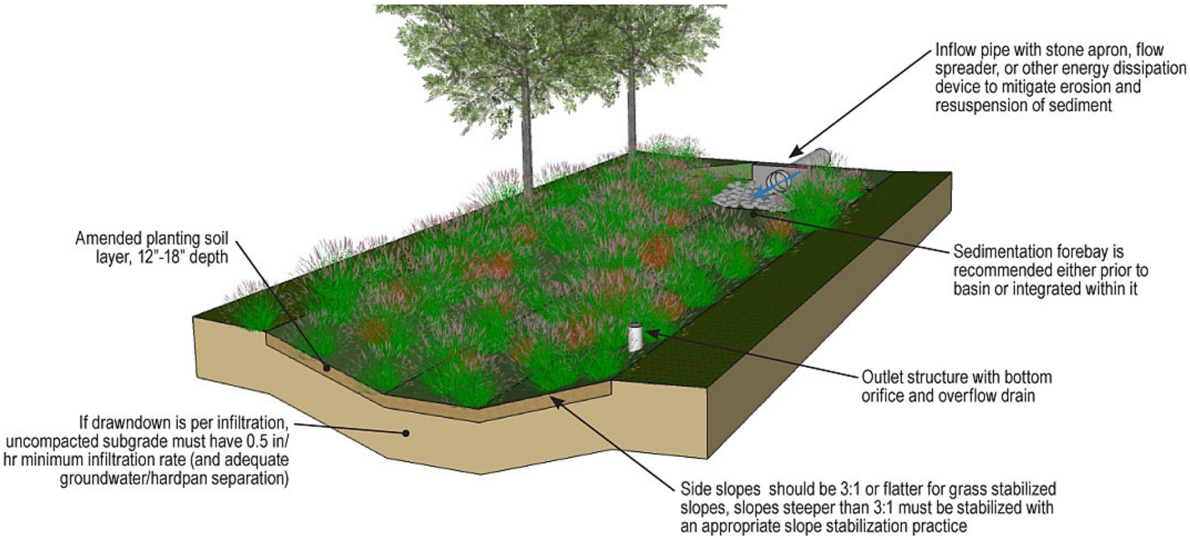


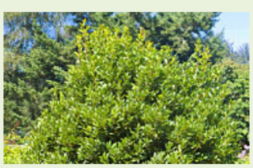
Figure: Vegetated basin typical detail

Design & Sizing Criteria

- Vegetated basins are volume-based systems sized to capture the WQV and discharge it within a typical 48 hour drawdown time, with no more than 50% of the total volume draining in the first 16 hours.
- Longer drawdown times may result in vector breeding, and should be used only after coordination with local vector control authorities. Shorter times should be limited to BMP drainage areas with coarse soils that readily settle or where infiltration is responsible for the majority of drawdown.
- A length to width ratio of at least 1.5:1 (and ideally 3:1) is recommended for greatest treatment capability (due to a longer flow path).
- A reinforced channel from inlet to outlet can be included to convey low flows through the basin.
- Maintenance can be reduced if runoff passes through upstream filtration BMPs or a sedimentation forebay prior to entering the basin.
- Outlet structure(s) include an orifice (and/or infiltration) for drawdown, an overflow drain for storms greater than the design storm, and an emergency spillway/drain for large flood events.
- If the separation from the bottom of the facility to the seasonally high groundwater elevation is less than 10 feet the facility should be lined with impermeable liner (compacted native clay or geomembrane).
- If sufficient space is available, a vegetated buffer around the pond can be used to slow overland runoff entering via the side slopes, help prevent access to the pond if desired, and provide an aesthetic and habitat amenity.

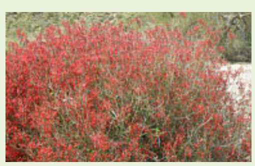
Plant Selection *(See Appendix A)*

Vegetation within the detention zone (up to the elevation of the design storm) increases pollutant removal and decrease resuspension of accumulated sediment. Vegetated detention basins have greater pollutant removal than concrete basins.



Sweet bay

Four wing saltbush



Chuparosa

Blue grama

Constructed wetlands are man-made systems that typically have multiple shallow permanent pools of water at varying depths, incorporating both emergent wetland plants and open water areas. Though possessing less biodiversity than natural wetlands, they still offer significant habitat enhancement and aesthetic value while being optimized for stormwater treatment. These facilities are among the most effective at removing pollutants from stormwater. Constructed wetlands provide water quality benefits through settling, microbial transformation, and plant uptake. Treatment primarily occurs in the root zone and soil media, where nutrients and dissolved pollutants are removed.

Though more technically complex, constructed wetlands have the potential to provide the most water quality improvements of any naturalized system.

Retrofit Opportunities

Benefits

- Effective at removing a broad spectrum of stormwater pollutants
- Reduces stormwater peak flows
- Provides substantial habitat
- Attractive landscape feature, well suited as an open-space amenity
- Good in areas unsuitable for infiltration or with high groundwater table
- Easily customizable to various sizes and dimensions, based on site, budget, and design intent

Potential Constraints

- Occupies relatively large area
- Standing water may represent safety concern
- Mosquito breeding is likely to occur, requiring vector control
- Cannot be placed on steep or unstable slopes
- Base flow or supplemental water source needed in dry season if water level is to be maintained
- Possible aesthetic concerns related to vegetation appearing dead or unkempt in winter and summer

Siting Applications

- Parks, open spaces, and golf courses
- Commercial, industrial, or residential developments
- Regional detention & treatment

Design Variation

A subsurface flow wetland has no open water and runoff is directed beneath the surface through a planted substrate. They generally require less surface area and have fewer vector issues, but may be more expensive to construct and maintain.

Technical Information

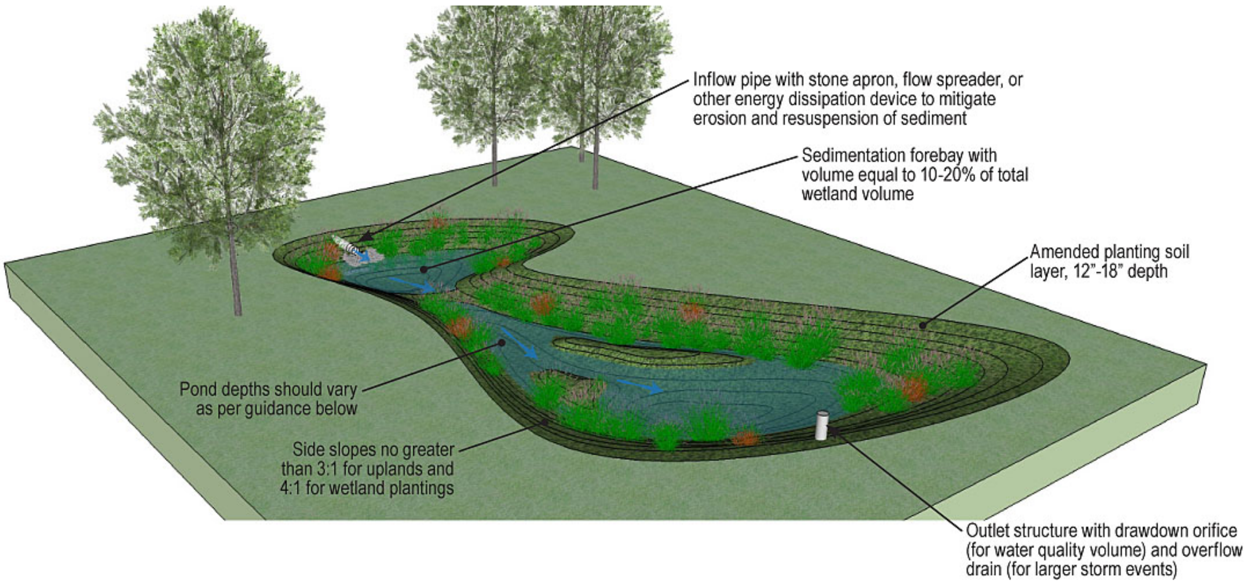
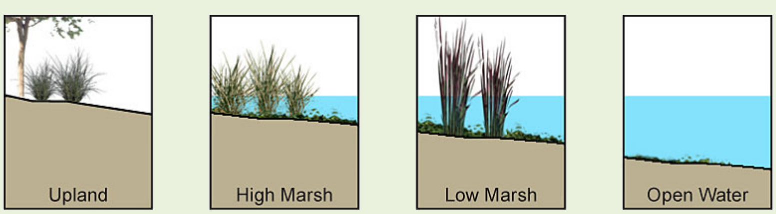


Figure: Constructed wetland typical detail

Design & Sizing Criteria

- Constructed wetlands are volume-based systems sized to capture the WQV and discharge it from the outlet within 24 hours.
- The health of wetland vegetation is integral to the ability of stormwater wetlands to improve water quality. Wetlands should have zones of both very shallow (less than 6 inches) and moderately shallow (6 to 18 inches) standing water to maintain both vegetated and open water areas, with maximum depths of about 5 feet.
- To enhance pollutant removal, wetlands should feature “complex microtopography” in which the underwater surface varies in elevation to increase the length of flow paths for runoff.
- The minimum length to width ratio should be 2:1 though 4:1 is preferred.
- Open water should be occupy 25-50% of the surface.
- Pre-treatment, which occurs via settling in a forebay, will greatly aid the function of constructed wetlands. Additional upstream BMPs may also be used to enhance treatment effectiveness.
- Stormwater wetlands require sufficient drainage to maintain a permanent pool, typically at least 5 acres.
- In areas with well draining soils (Type A or B) an impermeable liner may be necessary to maintain standing water.
- Wetlands may intersect the groundwater table, which will help maintain the permanent pool. This should be avoided in areas where stormwater or the groundwater may be contaminated. In these areas, an impermeable liner should be utilized.

Plant Selection *(See Appendix A)*



-Edge & small islands
-3:1 max side slope
-Inundated by runoff

-Water depth ≤6”
-4:1 max side slope
-May dry in summer

-Water depth 6”-18”
-5:1 max side slope
-Emergent plants

-Water depth ≤5’
-25-50% of total area

Plant Selection

Wetlands, with their variety of water depths and topography, will require a more diverse and extensive plant palette than other BMPs. Most locations will require plants suitable for prolonged standing water. Due to the permanent pool, it is acceptable to use plants with higher irrigation demand.

PERMEABLE PAVEMENT

Permeable pavement refers to any porous, load-bearing surface that allows runoff to pass through the surface layer and be temporarily stored in a drain rock layer. Ideally, site conditions will allow the subsurface storage layer to drain by infiltration into the subsoils. The permeable pavement system itself will provide some water quality benefits by filtering sediments and some other pollutants, but primarily will reduce peak flows due to detention in the rock layer. Infiltration functions as the primary mechanism for water treatment and volume reduction. Systems which use underdrains will not provide these benefits. When properly constructed, pervious pavements are durable, low maintenance, and have a low life-cycle cost.

Since they replace traditional hard surfaces, permeable pavement is easily integrated into developed areas. The wide variety of surface types provides diverse options for either matching or enhancing the character of an existing site.

Retrofit Opportunities

Benefits

- Assists in attenuating peak flows
- Reduces runoff volume and facilitates groundwater recharge (infiltration-based systems only)
- Easily integrated into existing infrastructure and retrofits
- Reduces the heat island effect
- Can be used as a design element to provide aesthetic benefits
- Construction costs can be equivalent to conventional paving
- Can reduce the need for curbing and storm sewers

Potential Constraints

- Not recommended for roads with high-speed traffic or frequent turning
- Maintenance costs are greater than for conventional paving
- Will require additional maintenance when exposed to regular high-volume traffic
- Storage and infiltration are only effective on relatively flat sites with slopes less than 5%, as level subgrade must be achieved
- Likely not effective as a treatment method if infiltration to the subgrade is not an option

Siting Applications

- Parking lots or parallel parking strips
- Driveways and low traffic roads
- Sidewalks and pathways
- Golf cart paths
- Park hardscape
- Plazas, patios, or terraces

Technical Information

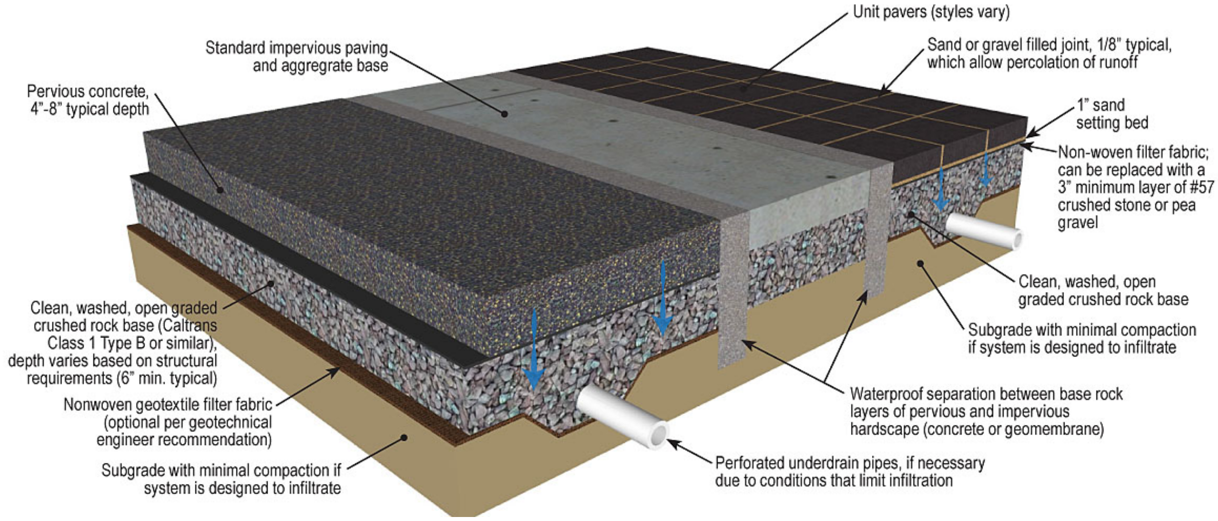


Figure: Pervious concrete and permeable pavers typical details

Design & Sizing Criteria

- Permeable pavements are volume-based systems sized to capture the WQV within the void space of the subsurface storage layer and should fully drain all stored runoff within a maximum 72 hour drawdown time.
- Infiltration-based systems (which provide treatment and volume reduction) must have a minimum subgrade soil infiltration rate of 0.5 in/hr; underdrains should be used in impermeable soils (Types C and D) that do not meet this standard. If infiltration exceeds 2.5 in/hr, runoff should be fully treated with upstream BMPs to protect groundwater quality.
- Infiltration requires a minimum 10-foot separation between the bottom of the drain rock layer and the seasonally high groundwater elevation. For areas with inadequate separation or where the groundwater is contaminated, an underdrain should be used with an impermeable liner placed beneath the rock.
- Infiltration-based systems should be placed a minimum of 10 feet from building foundations and a minimum of 100 feet from drinking water wells.
- Tributary areas should contribute runoff with low levels of sediment to avoid clogging the surface layer. If drainage will come from pervious or un-stabilized areas, appropriate pre-treatment measures should be implemented to filter the runoff before reaching the permeable pavement.
- To ensure proper system function, it is essential that permeable pavements (especially poured in place systems) are installed properly by a contractor with prior experience and certification.

Pavement Types

There are several styles of permeable pavement available, including those that are poured in place (such as pervious concrete and porous asphalt) and modular paving systems (such as interlocking concrete pavers, unit stone or brick pavers, or reinforced turf type systems).

Pervious Concrete

Porous Asphalt

Permeable Pavers

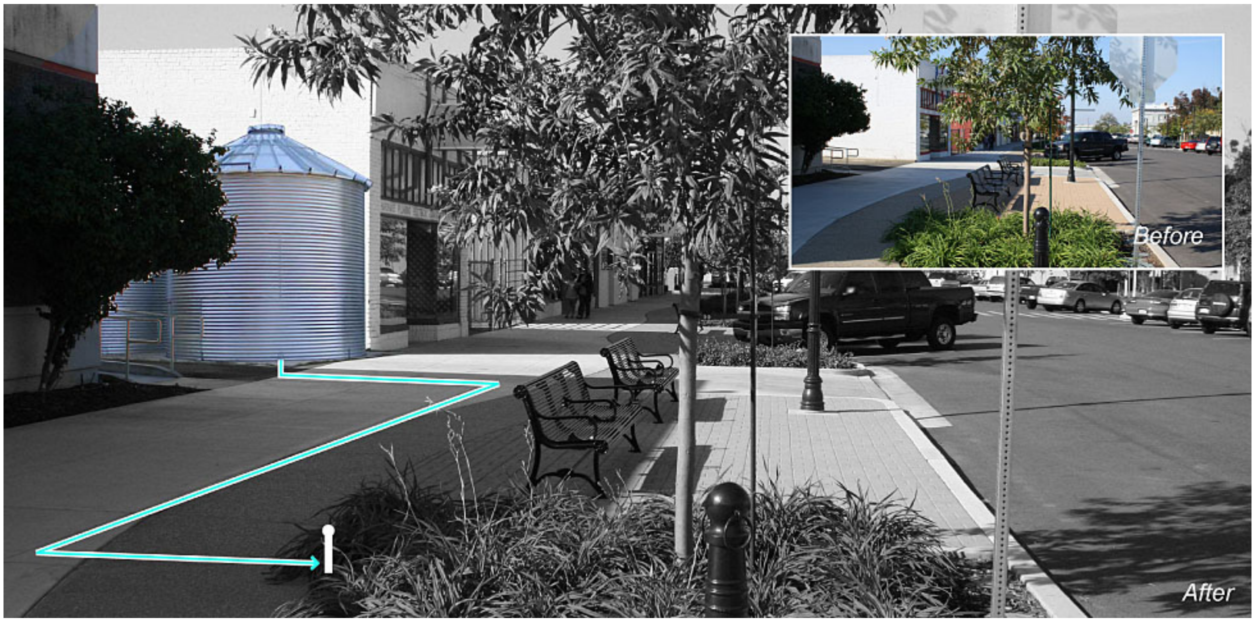
Reinforced Turf

RAINWATER HARVESTING

Rainwater harvesting involves capturing stormwater runoff and then using the stored water for a non-potable application, typically landscape irrigation. Captured runoff can be stored in anything from small rain barrels to large underground cisterns or retention ponds. A distribution system (a pump and/or valves) draws stored water and delivers it to the intended use, routing it through an appropriate treatment system, if necessary. With the right conditions, rainwater harvesting is a very effective stormwater control mechanism, as it provides substantial treatment and volume reduction while also satisfying a portion of the site's water demand.

Harvesting systems can incorporate sculptural or artistic rainwater conveyance components, which serve as aesthetic amenities in addition to making the practice more visible.

Retrofit Opportunities



Benefits

- Pollutant removal rates are nearly 100% for reused water
- Offsets a portion of the potable water required by a site
- Reduces the volume and peak flows of stormwater runoff
- Good for sites where infiltration is not an option
- Easy to apply to rooftop collection; both new buildings and retrofits on existing roofs
- Scalable to large drainage areas, provided demand is adequate

Potential Constraints

- Requires reliable reuse demand high enough to ensure availability of treatment volume in storage
- Lack of summer rainfall coincides with larger irrigation demands
- Often requires infrastructure (pumps or valves) to use stored water, increasing complexity
- Relatively frequent inspection and maintenance is necessary to ensure reliable system function
- Regulatory obstacles may limit reuse opportunities beyond irrigation

Siting Applications

- Collect rooftop runoff
- Golf courses and parks
- Any type of land use, provided adequate end use of water

Technical Information

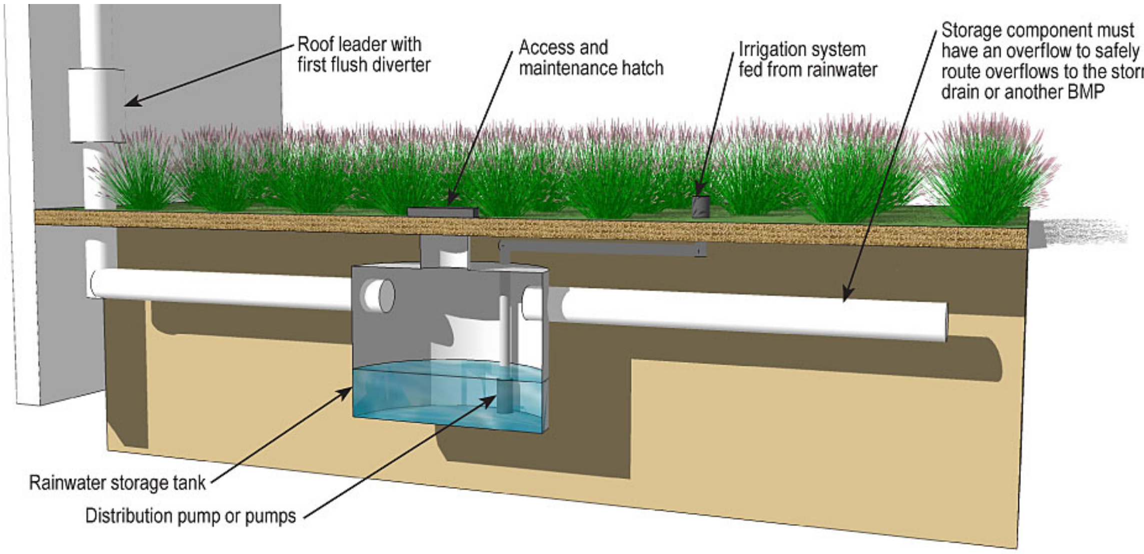


Figure: Rainwater harvesting system typical detail

Design & Sizing Criteria

- Rainwater harvesting systems are volume-based systems with adequate space available in the storage device to capture the WQV. In order to be used as a water quality treatment device, the demand on the system must sufficient to ensure that the system has available capacity to capture the WQV within 72 hours of any rain event.
- The seasonal rainfall patterns in Hughson present difficult circumstances for designing rainwater harvesting systems. Hughson receives approximately 13 inches of rain annually, with an average of less than an inch falling each month from April through October. This lack of rainfall coincides with the higher irrigation demand of the warmer summer months. It is this mismatch of supply and demand that will inhibit successful implementation of rainwater harvesting for many sites. To provide a noticeable offset to potable water demand will likely require enough storage to capture runoff from a large upstream watershed.
- Components of all rainwater harvesting systems include conveyance (to collect water), storage (to hold water), and distribution (to use water).
- In a typical pumped system, stormwater from a building's roof is conveyed through rainwater leaders into a storage tank. The storage tank is connected to a wet well or suction pump, which is linked to the irrigation system. When the pump receives a signal to deliver water, it will begin operation. When the pump receives a signal to stop (either because irrigation is complete or from a level sensor in the tank indicating that it is nearly empty), it will end operation.
- A supplemental method of supplying water is typically necessary, generally through a valved connection to the traditional water system to either refill the tank or supply irrigation water directly.
- All rainwater harvesting system pipes and fixtures should be labeled "NON-POTABLE WATER, DO NOT DRINK."
- Design of the stormwater storage component is flexible as long as the water quality volume and an appropriate distribution system can be accommodated.
- Enclosed tanks should have a hatch or manhole opening for maintenance access. Above-ground tanks should be sited in a stable area (ideally in a cool, shaded location to avoid algal growth) and may require seismic stabilization if greater than 5000 gallons.
- Any pumps and treatment components should be accessible for maintenance.

A pretreatment component is necessary to remove trash and sediment prior to storage to avoid clogging the distribution pump and to reduce maintenance. Pretreatment components may be:

- first flush diverter
- in-line filter
- upstream BMP

GREEN ROOF

A green roof is a vegetated system covering a building's roof that detains and filters incident rainfall. Stormwater is captured in the soil media and storage layers of the system, reducing peak storm flows and promoting evapotranspiration. A primary water quality benefit of green roofs is that they avoid the common pollutants associated with conventional roof runoff, instead releasing only rainwater that has been further filtered. Green roofs can be designed with minimal thickness to allow retrofit installation on existing buildings or with a mix of shrubs, trees, pathways, and benches to be a valuable amenity for building tenants and the public.

Green roofs are unique stormwater features which also provide a variety of diverse benefits to building systems as well as inhabitants and users.

Application Examples

Extensive green roof

Intensive green roof

Benefits

- Reduces the peak discharge rate by slowing down roof runoff
- Enhances site aesthetics and can provide a useable amenity or public space
- Creates habitat and increases vegetation, even in densely developed areas
- Can extend the life of the roof, compared to a conventional roof
- Reduces heat island effect and improves air quality
- Provides insulation, which reduces building energy use

Potential Constraints

- Not ideal for steep roofs (>20 degrees)
- Only manages rooftop runoff
- Greater roof weight may increase dead and live loads and increase structural support requirements
- Existing buildings may not be able to support increased load
- Will likely require irrigation during establishment (typically first 2 years) and dry seasons
- Requires increased maintenance compared to a conventional roof

Siting Applications

- Commercial, industrial, and large residential buildings
- Urban areas with limited space and/or minimal vegetation

Technical Information

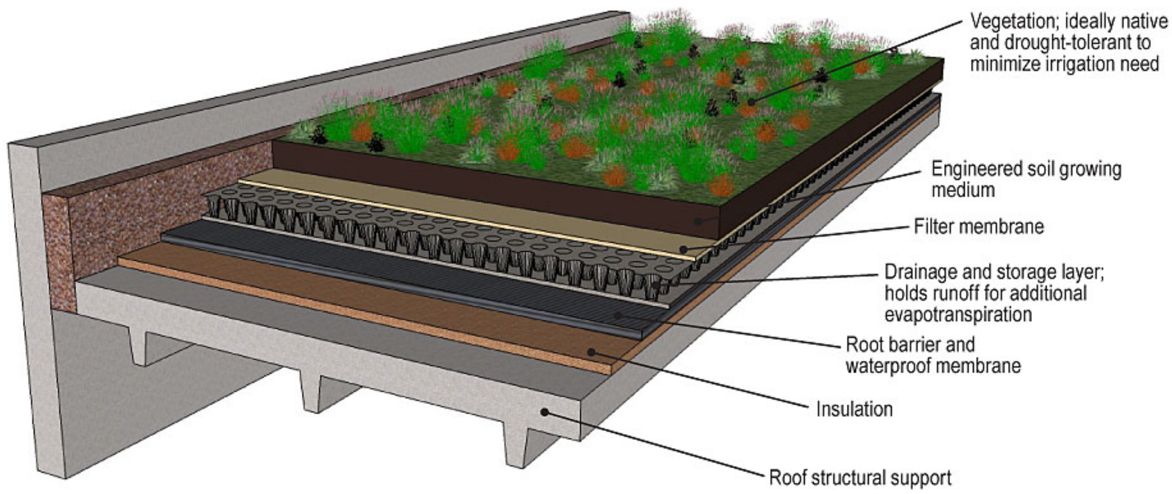


Figure: Green roof typical detail

Design & Sizing Criteria

- Green roofs are flow-based systems designed to treat the rainfall that falls directly onto the vegetated area.
- Runoff from rooftop areas that are not part of the vegetated system (such as spaces for mechanical or ventilation equipment) will likely need to be routed to treatment areas on the ground.
- Green roofs are generally classified as either extensive or intensive. Extensive green roofs generally have six inches or less of soil media, use smaller plants, are lower maintenance, and are typically not intended to be accessible. Intensive green roofs have greater than six inches of soil, larger plants, greater structural and maintenance requirements, and are often designed as rooftop gardens or park-like settings for use by people.
- They are most suitable for flat roofs or those with slopes less than 20 degrees. Extensive green roofs can be constructed on slopes up to 40 degrees with specialized designs.
- A new or retrofit building must be designed to support the weight of the green roof when all layers and vegetation are fully saturated. This wet weight can be up to 6 or 7 pounds per square foot per inch of soil depth.
- A waterproof membrane is needed to protect the roof structure and a root barrier can be installed to protect the membrane. Insulation, if included, can be installed either above or below the waterproof membrane.

Plant Selection *(See Appendix A)*

Vegetated roofs should feature drought tolerant plants that are well adapted to the local climate. Vegetation that is fire resistant is important considering the setting. Low maintenance plants that will create a healthy and appealing aesthetic are ideal candidates for vegetated roofs.

Coreopsis

Beard tongue

Lyme grass

Foothill penstemon

References

City of Hughson Storm Drain System Master Plan, prepared by Nolte Associates, Inc., June 2008.

City of Hughson Standard Specifications, 2007.

Storm Water Management Program for the Cities of Ceres, Oakdale, Patterson, Hughson, Report of Waste Discharge, March 10, 2003.

Bruinville Area Master Public Facilities Plan, Public Review Draft, September 2005.

New Development and Redevelopment, Stormwater Best Management Practice Handbook, California Stormwater Quality Association, January 2003.

EPA website(s)

LID Guidebooks

- City of Modesto Stormwater Management Program, 2010 Guidance Manual for Development Stormwater Quality Control Measures
- Stormwater Quality Design Manual for the Sacramento and South Placer Regions, May 2007
- San Joaquin County
- San Mateo County C.3 Guide
- SoCal LID Manual

Stanislaus County Department of Public Works, Standards and Specifications, 2007.

Storm Water Quality Handbook – Project Planning and Design Guide, California Department of Transportation, May 2007.

Start at the Source: Design Guidance Manual for Stormwater Quality Protection, Bay Area Stormwater Management Agencies Association (BASMAA), 1999

A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California, University of California Cooperative Extension, California Department of Water Resources, August 2000.

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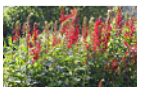
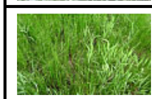
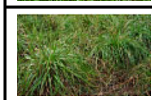
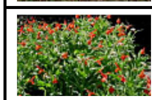
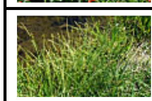
Appendix A - Plant List

The species listed below are intended to serve as a general guide for identifying plants likely to be suitable for use in LID within Central California climate zones. This list has been compiled of largely California native species and augmented with California friendly species to promote species diversity while avoiding monoculture. The list has been organized to group species likely to be compatible with the hydrozones found in the LID solutions in this manual and includes information for determining estimated water budgets. A qualified professional in LID site design should be consulted before construction and implementation.

Photo	Common Name	Latin Name	Form	Light Level	Irrigation Need	Height/ Spread
Suitable for long periods of inundation or permanent shallow water						
	Beaked Spikerush	*Eleocharis rostellata*	Grass	Sunny	High	3'-4' / 3'-4'
	Cardinal Flower	*Lobelia cardinalis*	Perennial	Sunny	Medium	1'-6' / 1'-3'
	Common Spikerush	*Eleocharis palustris*	Grass	Sunny	High	6"-18" / 6"-18"
	Gooding's Willow	*Salix gooddingii*	Tree	Sunny	High	10'-40'
	Long Leaf Rush	*Juncus macrophylla*	Grass	Sunny	High	2'-3' / 2'-3'
	Narrowleaf Willow	*Salix exigua*	Tree	Sunny	High	8'-16' / 8'-16'
	Needle Spikerush	*Eleocharis acicularis*	Grass	Sunny	High	6 "/ 6"
	Pacific Reed Grass	*Calamagrostis nutkaensis*	Grass	Sunny	Low	2' / 2'-3'
	Scarlet Monkey Flower	*Mimulus cardinalis*	Perennial	Sunny	Medium	3' / 2'
	Silvery Sedge	*Carex canescens*	Grass	Sunny	High	1'-2' / 1'-2'
	Soft Rush	*Juncus effuses*	Grass	Sunny	Medium	2'-3' / 2'-3'

Notes: Certain plants which prefer very wet environments will generally be suitable for use in locations which experience only short periods of inundation. Of the plants listed above, this would include Cardinal Flower, Pacific Reed Grass, and Scarlet Monkey Flower.

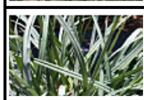
Photo	Common Name	Latin Name	Form	Light Level	Irrigation Need	Height/ Spread
Suitable for short periods of inundation (24-48 hours)						
	Blue eyed grass	*Sisyrichium bellum*	Grass	Sunny	Very Low	6”-18”
	Blue Oat Grass	*Helicotrichon sempervirens*	Grass	Sunny	Medium	24”-30” / 24”-30”
	California rose	*Rosa californica*	Shrub	Sunny	Low	3’-5’ / 8’-10’
	California wax myrtle	*Myrica californica*	Shrub	Sunny	Low	15’-20’ / 15’-20’
	Common Rush	*Juncus patens*	Grass	Sunny	Medium	18”-24” / 18”-24”
	Cottonwood	*Populus fremontii*	Tree	Sunny	Medium	40’-60’ / 25’
	Deer grass	*Muhlenbergia rigens*	Grass	Sunny	Low	2’-3’ / 2’-3’
	Desert Baccharis	*Baccharis sergiloides*	Shrub	Sunny	Low	4’-6’ / 4’-6’
	Desert willow	*Chilopsis linearis*	Tree / shrub	Sunny	Very Low	15’-20’ / 15’-20’
	Fourwing saltbush	*Atriplex canescens*	Shrub	Sunny	Very Low	4’-5’
	Narrow leaf milkweed	*Asclepias fascicularis*	Shrub/gound -cover	Sunny	Low	2’-3’ / 3’-4’
	San Diego sedge	*Carex spissa*	Grass	Sunny	Medium	3’-5’ / 4’-5’
	Sweet bay	*Laurus nobilis*	Tree / shrub	Sunny/Partial Shade	Low	15’-20’ / 15’-20’
	Western meadow sedge	*Carex praegracilis*	Grass	Sunny	Medium	12”-15”
	Western sycamore	*Platanus racemosa*	Tree	Sunny	Medium	40’-80’ / 30’-50’

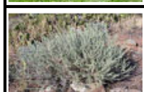
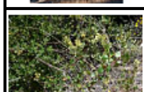
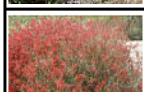
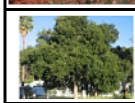
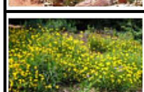
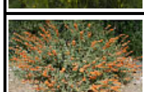
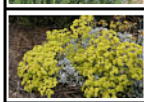
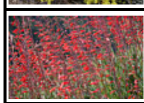
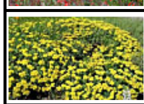
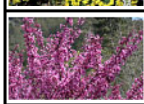
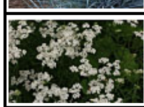
Photo	Common Name	Latin Name	Form	Light Level	Irrigation Need	Height/ Spread
Prefer upland / suitable for slope stability						
	Beard tongue	*Penstemon spectabilis*	Shrub / perennial	Sunny	Low	3'-5'
	Blue grama	*Bouteloua gracilis*	Grass	Sunny	Low	15"-24" / 12"
	Broom Baccharis	*Baccharis sarothroides*	Shrub	Sunny	Low	8'-10' / 8'-10'
	Bush anemone	*Carpenteria californica*	Shrub	Partial Shade	Low	6' / 6'
	Bush monkey flower	*Mimulus aurantiacus*	Shrub	Sunny	Low	2'-3' / 2'-3'
	California encelia	*Encelia californica*	Shrub	Sunny	Very Low	3'-5' / 3'-5'
	California Meadow Sedge	*Carex Pansa*	Grass	Sunny	Medium	12" / 18"
	California sagebrush	*Artemisia californica*	Shrub	Sunny	Low	3'-5' / 5'-7'
	Canyon live oak	*Quercus chrysolepis*	Tree	Sunny/Partial Shade	Low	60' / 40'
	Chaparral honeysuckle	*Lonicera subspicata*	Shrub / vine	Partial Shade	Medium	3'-4' / 8'-10'
	Chuparosa	*Justicia californica*	Shrub	Sunny	Low	4'-6' / 6'-8'
	Coast live oak	*Quercus agrifolia*	Tree	Sunny	Very Low	30'-60' / 40'-70'
	Common buckwheat	*Eriogonum fasciculatum*	Shrub	Sunny	Low	2'-3' / 2'-3'
	Coreopsis	*Coreopsis grandiflora*	Shrub / perennial	Sunny	Low	1'-2' / 2'-3 '
	Coreopsis - large	*Coreopsis gigantea*	Shrub / perennial	Sunny	Low	3'-5' / 3'-4'
	Desert mallow	*Sphaeralcea ambigua*	Shrub	Sunny	Low	2'-3' / 2'-3'
	English lavender	*Lavandula angustifolia*	Shrub	Sunny	Low	2'-3' / 2'-3'
	Ericameria	*Ericameria laricifolia*	Shrub	Sunny	Low	2'-4' / 2'-4'

Photo	Common Name	Latin Name	Form	Light Level	Irrigation Need	Height/ Spread
	Foothill needle grass	*Nassella lepida*	Grass	Sunny	Low	1’-2’ / 1’-2’
	Foothill penstemon	*Penstemon heterophyllus*	Shrub / perennial	Sunny	Low	1’-2’/ spreading
	Grape soda lupine	*Lupinus excubitus*	Shrub	Sunny	Very Low	3’ / 4’
	Honey mesquite	*Prosopis glandulosa*	Tree	Sunny	Low	25’-30’ / 25’-30’
	Hummingbird trumpet	*Epilobium canum*	Shrub	Sunny/Partial Shade	Low	varies
	Lyme grass	*Leymus arenarius*	Grass	Sunny	Very low	4’-5’ / clumping
	Nodding needle grass	*Nassella cernua*	Grass	Sunny	Low	3’ / 3’
	Parry’s penstemon	*Penstemon palmeri*	Shrub / perennial	Sunny	Low	4’-6’
	Pink muhly grass	*Muhlenbergia capillaris*	Grass	Sunny	Low	2’ / 2’-3’
	Purple needle grass	*Nassella pulchra*	Grass	Sunny	Low	18”-24” / 18”-24”
	Rosemary	*Rosmarinus officinalis*	Shrub	Sunny	Low	4’-6’ / 6’-10’
	Saffron buckwheat	*Eriogonum crocatum*	Shrub	Sunny	Low	1’-2’ / 2’-3’
	Scarlet bugler	*Penstemon centranthifolius*	Shrub / perennial	Sunny	Low	2’-3’ / 2’-3’
	Sulfur buckwheat	*Eriogonum unbellatum*	Shrub /ground-cover	Sunny	Low	6”-18” / 1’-3’
	Western redbud	*Cercis occidentalis*	Tree	Sunny/Partial Shade	Very Low	15’-20’ / 15’-20’
	Western serviceberry	*Amelanchier alnifolia*	Shrub / Tree	Sunny/Partial Shade	Low	3’-15’ / 6’
	Wild rye	*Leymus condensatus*	Grass	Sunny	Very Low	2’-3’ / 2’-3’
	Yarrow	*Achillea millefolium*	Ground-cover	Sunny	Low	18”-30” / clumping

Appendix B - BMP Pollutant Removal Efficiency

Different pollutants tend to be present in runoff depending on the land use. The table below provides general guidance as to which pollutants may be expected in higher concentrations, as well as the typical ability for different BMPs to remove the pollutants.

		Target Pollutant				
		Sediment	Nutrients	Metals	Bacteria	Oil & Grease
Land Use	Agriculture	×	×		×	
	Commercial	×		×		×
	Residential	×				
	Industrial	×		×		×
	Parks	×				
	Vacant/Barren Areas	×	×			
	Roads & Parking Lots	×		×		×

		Pollutant Removal Efficiency				
		Sediment	Nutrients	Metals	Bacteria	Oil & Grease
Best Management Practice	Underground	◉	●	●	●	●
	Bioretention Area[2]	●	◉	◉	●	●
	Vegetated Swale	◉	○	◉	○	◉
	Filter Strip	●	○	●	○	◉
	Vegetated Basin	◉	○	◉	◉	◉
	Constructed Wetland	●	◉	●	●	●
	Permeable Pavement[1]	●	●	◉	◉	◉
	Rainwater Harvesting[3]	●	●	●	●	●
	Green Roof[4]	●	●	●	●	●

Key to Symbols: ● High ◉ Medium ○ Low

[1] If underground infiltration and permeable pavement are unable to drain by infiltration, removal efficiency for all constituents is low.

[2] Assumes that bioretention area is drained by underdrains. If able to discharge via infiltration, efficiency will be increased.

[3] Rainwater harvesting effectively removes all pollutants from runoff since the water quality volume is never released downstream.

[4] Green roofs receive runoff which has not yet encountered pollutants, and eliminate the addition of pollutants typically found on roofs.

Appendix C - Planning Area Maps

Additional maps, two showing the entire Hughson Planning Area, are included for reference on the following pages.

- Opportunity Sites Map
- Soils Map
- Depth to Hardpan map

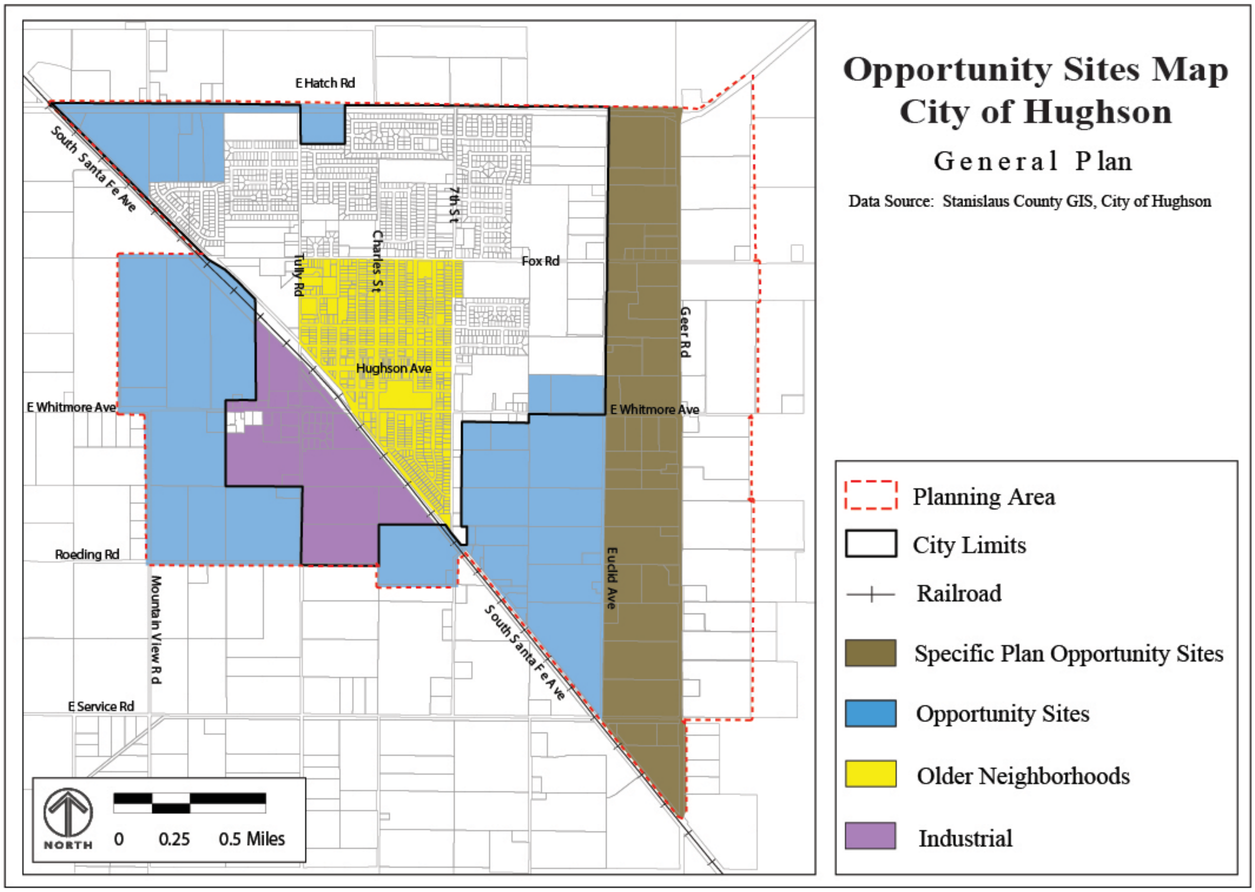


Figure C1: Opportunity Sites Map (Source: General Plan)

Hughson Arboretum and Gardens opportunity site. (Photo courtesy of Thom Clark)

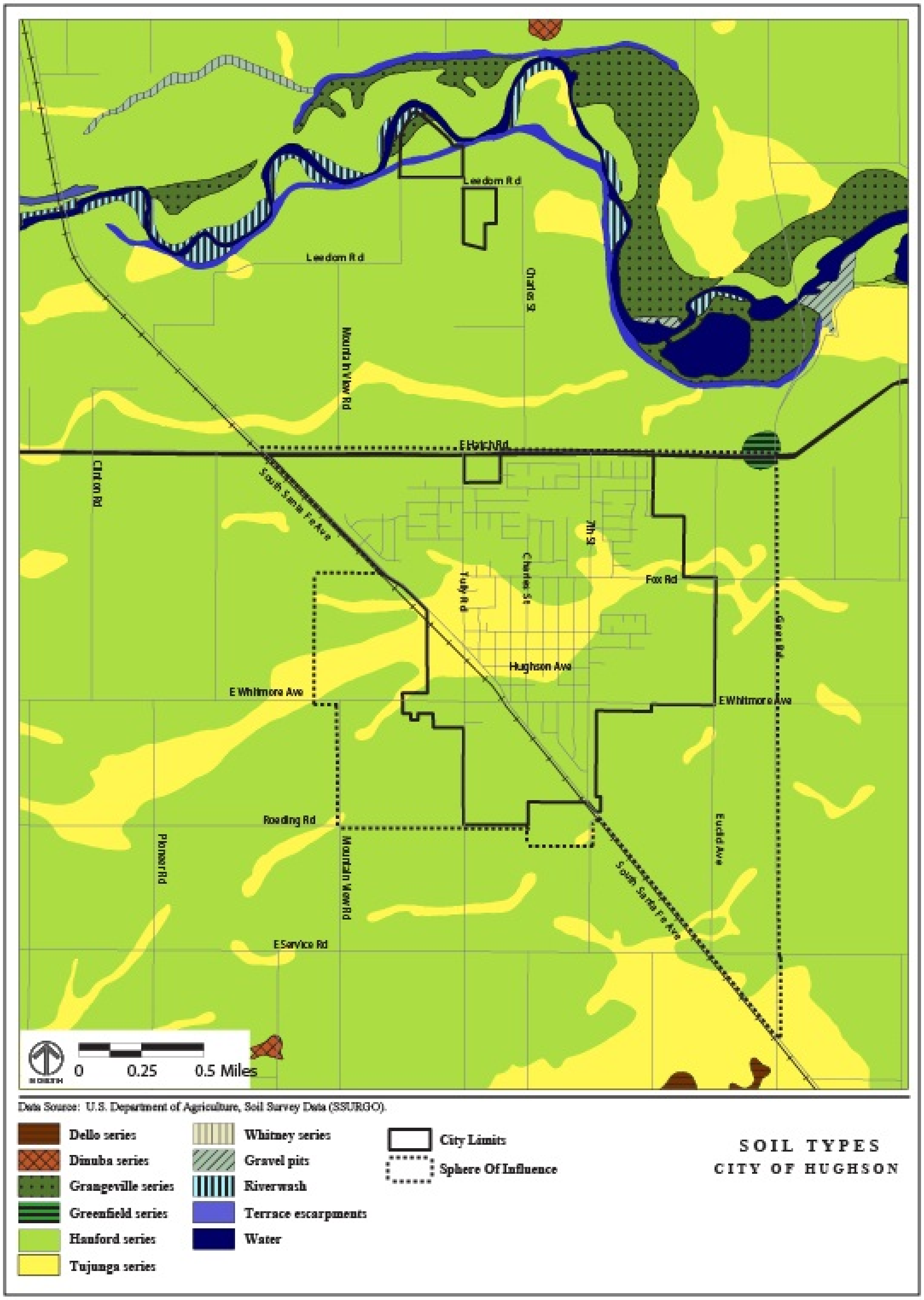
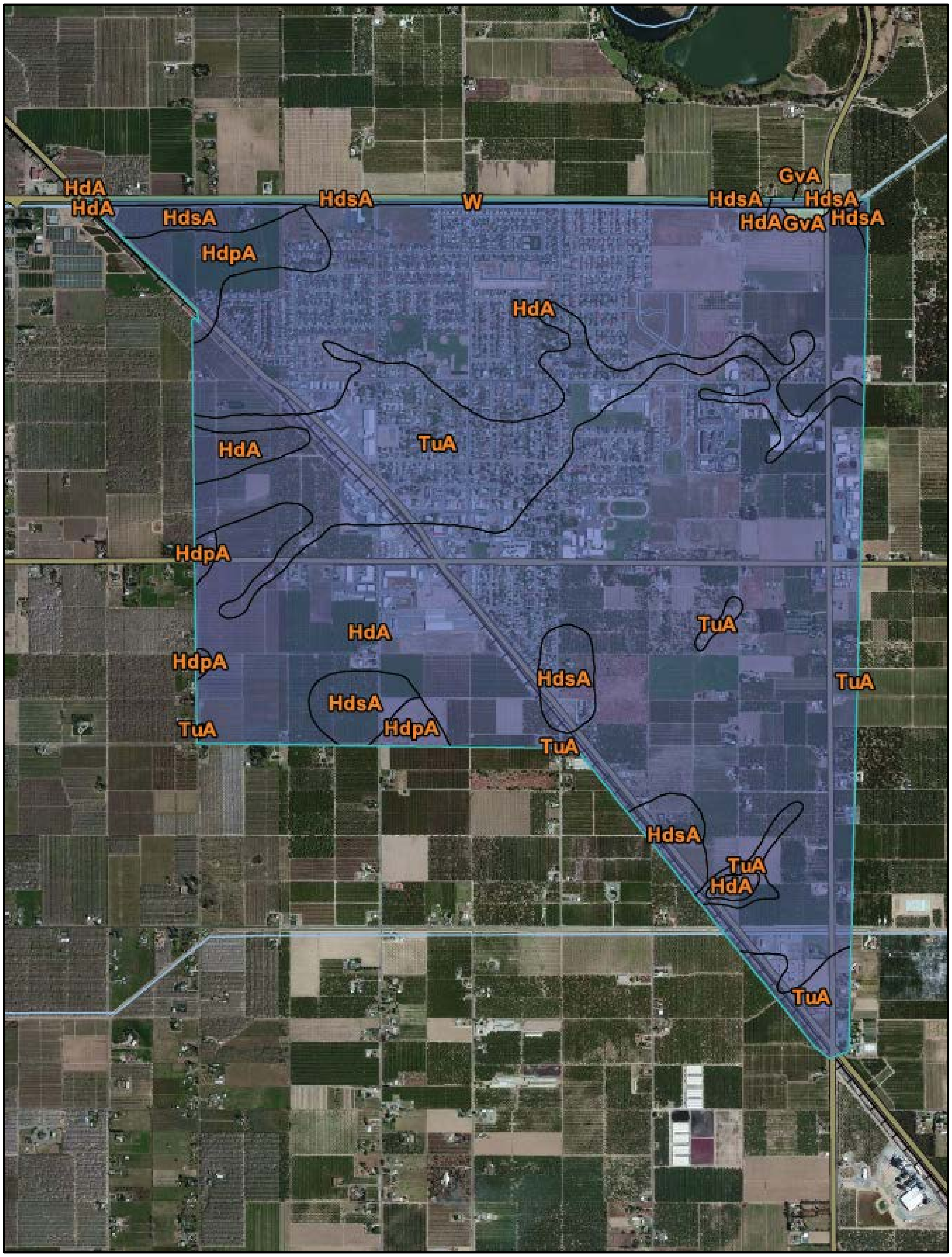


Figure C2: Soils Map (Source: NRCS 2011)



DEPTH TO HARDPAN

> 200 **(Centimeters)**

CITY OF HUGHSON

Figure C3: Depth to Hardpan Layer Map (Source: NRCS 2011)