Guidance for Stormwater and Dry Weather Runoff

CAPTURE

(California Practices To Use Runoff Effectively)

AT SCHOOLS

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at California State University, Sacramento

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2018

Acknowledgements

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Disclosure

The Guidance for Stormwater and Dry Weather Runoff CAPTURE at Schools is considered a living document that may be updated in response to evolving best design and use practices or regulations. It is recommended that public schools consider this guidance for voluntary implementation or in preparation for potential coverage under the National Pollutant Discharge Elimination System (NPDES) municipal separate storm sewer system (MS4) permit.

Contents

Sections

Appendices

ACRONYMS USED FREQUENTLY THROUGHOUT THIS GUIDANCE

BMPs	BEST MANAGEMENT PRACTICES
CASQA	CALIFORNIA STORMWATER QUALITY ASSOCIATION
CDE	CALIFORNIA DEPARTMENT OF EDUCATION
CGP	CONSTRUCTION GENERAL PERMIT
CWA	CLEAN WATER ACT
CWH	COUNCIL FOR WATERSHED HEALTH
DROPS	DROUGHT RESPONSE OUTREACH PROGRAM FOR SCHOOLS
DSA	DIVISION OF THE STATE ARCHITECT
DWR	DEPARTMENT OF WATER RESOURCES
IRWM	INTEGRATED REGIONAL WATER MANAGEMENT
IRWMP	INTEGRATED REGIONAL WATER MANAGEMENT PLAN
LID	LOW IMPACT DEVELOPMENT
MOA	MEMORANDUM OF AGREEMENT
MOU	MEMORANDUM OF UNDERSTANDING
MS4	MUNICIPAL SEPARATE STORM SEWER SYSTEM
NPDES	NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM
O&M	OPERATION AND MAINTENANCE
OWP	OFFICE OF WATER PROGRAMS
Phase II permit	NPDES PERMIT FOR SMALL MS4S
QSD	QUALIFIED SWPPP DEVELOPMENT
SCMs	STORMWATER CONTROL MEASURE
SFPUC	SAN FRANCISCO PUBLIC UTILITY COMMISSION
SFUSD	SAN FRANCISCO UNIFIED SCHOOL DISTRICT
SWPPP	STORMWATER POLLUTION PREVENTION PLAN
TMDLs	TOTAL MAXIMUM DAILY LOADS
TSS	TOTAL SUSPENDED SOLIDS
USEPA	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

I. Background

I. Background

Introduction

These guidelines provide insights for the selection, design, and implementation of practices that can reduce runoff and pollutants that flow from school properties. These practices include minimizing impervious surfaces, increasing green space, promoting infiltration, and treating runoff on site.

In using these guidelines, school districts can achieve benefits that apply directly to schools, such as creating school yards that promote natural play and improve student health and well being, developing educational opportunities related to sustainability, and reducing the heat island effects of asphalt. This guidance also provides strategies school districts can use to to help protect local watersheds, such as augmenting water supply, protecting against localized flooding, protecting and improving water quality, and reducing greenhouse gas emissions. In the face of climate change and the recent California drought, these concepts are particularly crucial to support sustainability— conserving current resources for future generations.

The guidelines are not requirements or standards. Instead, they provide background on and examples of stormwater management principles and common capture practices (Figure I-1). Notably, some information provided herein may become outdated as regulations, policies, and technologies evolve. Consequently, the guidelines direct the reader to other resources, such as the California Stormwater Quality Association (CASQA) and municipal stormwater programs and manuals, that will be updated to address these changes.

These guidelines provide school administrators, facility managers, and their design teams insight on the following elements related to runoff management and capture:

1. Background
2. Benefits
3. Practices
4. Planning and design
5. Construction
6. Maintenance
7. Costs
8. Regional collaboration
9. Codes and regulations
10. References

To better understand the context of the runoff prevention and capture material presented in this guidance, the remainder of this section summarizes why runoff is a concern and how it can be captured and used as a resource. Relevant regulations and examples of existing schools efforts are also provided.

A guide for runoff capture at schools

Chapter 811, Statute of 2017 (SB 541, Allen) requires the State Water Resources Control Board (State Water Board) to "recommend best design and use practices for stormwater and dry weather runoff capture practices that can generally be applied to all new, reconstructed, or altered public schools, including school grounds." The intent of such practices is: "…to control water pollutants, pollutant loads, and water runoff volume exiting a site to the maximum extent feasible by minimizing impervious surface area and controlling runoff from impervious surfaces through infiltration, evapotranspiration, bioretention, treatment, and rainfall harvest." (California SB 541 2017)

Figure I-1—Example of runoff capture implementation at a school in New York (San Francisco Public Utilities Commission)

Why Capture Runoff?

Urban development alters natural landscapes causing degradation of water resources.

Grasslands, forests, and other naturally occurring, pervious landscapes are replaced with impervious surfaces such as buildings, roads, and parking lots. The hardened surfaces reduce the amount of precipitation that can infiltrate into the soil, resulting in increased volumes and flow rates of runoff that are discharged to water bodies. This trend is referred to as **hydromodification** (Figure I-2).

Hydromodification

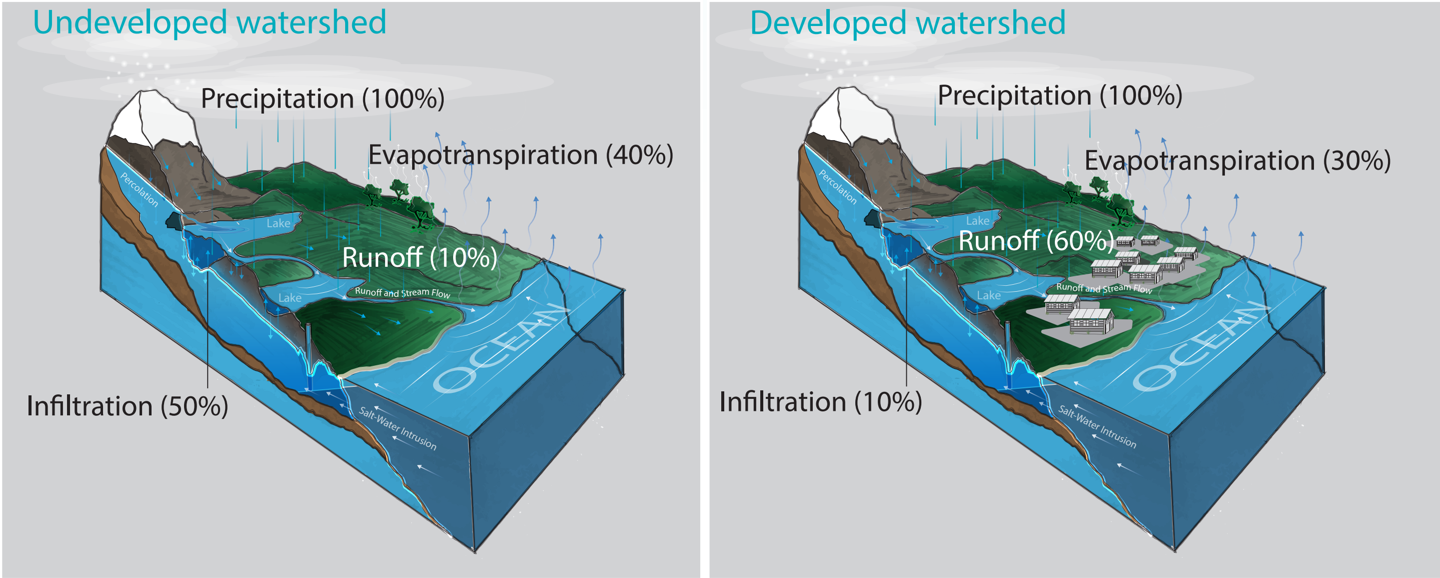


Figure I-2—Hydromodification: The alteration of flow characteristics through a landscape resulting in the degradation of water resources.

I. Background

Hydromodification exacerbates flooding and causes downstream erosion, which results in excess sediment transport into streams and disruption of natural drainage patterns, stream flows, and habitat (Figure 1-3).

Figure I-3—Impacts of hydromodification (Clockwise from upper left: Stillwater Sciences, Soil Science on Flickr, State Water Board, Flickinpicks on Flickr)

In addition, human activities have introduced pollutants, such as plastics, oils, greases, metals, and pesticides, which are transported across landscapes to downstream receiving waters (Figure I-4).

Figure I-4— Pollutant transport (left: Draper City UT; right: SW Washington Stormwater Partners)

These pollutants pose threats to a water body's beneficial uses. Such threats include damage to habitats and biotic integrity and degradation of water quality for consumption and recreation (Figure 1-5).

Figure I-5— Impacts from pollutant discharges (clockwise from upper left: eutrofication&hypoxia on Flickr, Heal the Bay, Pixabay, Wikipedia Commons)

Dry weather runoff—excess irrigation water that drains from properties—combines with the stormwater runoff, exacerbating these impacts (Figure I-6).

Figure I-6— Dry weather runoff from excess irrigation or outdoor water use (City of College Station, TX)

I. Background

To address these issues, runoff practices today emphasize designs that reduce runoff volumes, flow rates, and pollutants discharged to receiving waters (Figure I-7). Such practices not only reduce detrimental impacts, but capture and use runoff as a resource to supplement water supply. These practices can also reduce flooding, enhance communities, and support climate change resiliency and adaptation.

Figure I-7— Runoff capture (clockwise from upper left: BASMAA, OWP, fireballsedai on Flickr, City of San Diego)

"Stormwater is a resource and an asset and should not be treated as a waste product. Managing rainwater and stormwater at the source is a more effective and sustainable alternative to augmenting water supply, preventing impacts from flooding, mitigating stormwater pollution, creating green space, and enhancing fish and wildlife habitat. California encourages alternative, innovative, multi-objective solutions to help use and protect this valuable resource, while at the same time controlling pollution due to urban runoff."

—State Water Resources Control Board, 2013

Relevant Regulations

Discharging pollutants into surface waters is prohibited by the federal Clean Water Act (CWA), unless they are in compliance with a National Pollutant Discharge Elimination System (NPDES) permit. NPDES permits regulate discharges from several programs, including stormwater discharges from municipal separate storm sewer systems (MS4s) and combined sewer overflows (CSOs). Figure 1-8 shows many examples of entities subject to NPDES permits.

Figure I-8— Entities subject to NPDES permits. Sources: https://www.maxpixel.net, https://www.flickr.com, https://commons.wikimedia.org, https://pixabay.com, https://en.wikipedia.org, https://sfec.cfans.umn.edu, https://www.ang.af.mil, https://picryl.com

MS4 permits regulate runoff from an MS4—a conveyance or system of conveyances (e.g., roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains, 40 CFR 122.26(b)(8). The permits address runoff from stormwater as well as dry weather flows. Stormwater permits were first issued for large municipalities having populations of 100,000 or greater, and

I. Background

are referred to as "Phase I permits". In California, these permits are issued by the Regional Water Quality Control Boards. In 2003, the State Water Board issued the NPDES permit for small MS4s (the "Phase II permit"). The Phase II permit covers counties, cities, towns, etc., with populations of more than 10,000 but less than 100,000 people, as well as non-traditional facilities such as universities, colleges, state parks and beaches, transit authorities, prisons, and other state properties. The State Water Board also issues an NPDES permit to the California Department of Transportation (Caltrans) for stormwater discharges from their roadways and other facilities. The Phase I, Phase II, and Caltrans permits are updated and reissued every few years.

The NPDES permits include several minimum control measures for managing runoff.

- Education and outreach
- Public involvement and participation
- Illicit discharge detection and elimination
- Construction site stormwater runoff control
- Pollution prevention/good housekeeping
- Post-construction stormwater management for new and redevelopment
- Water quality monitoring
- Program effectiveness and assessment
- Total maximum daily load (TMDL) compliance

The guidance in this document mostly pertains to the post-construction stormwater management element of the permits. Post-construction requirements stipulate design practices and features that must be included in new development and redevelopment projects of a certain size to prevent and reduce runoff for the lifetime of the project. Section VIII (Regional Collaboration) offers suggestions for school districts to leverage expertise and support regional permittees in implementing some permit elements to support watershed health. A good example is the San Francisco Public Utility Commission's (SFPUC) Urban Watershed Stewardship Grants for Schools (Figure I-9). The SFPUC incentivizes schools to install green infrastructure, including runoff capture devices, which supports the city's permit compliance.

Figure I-9— Stewardship Grants For Schools

The State Water Board also issues a Construction General Permit (CGP) that specifies actions to be taken to prevent and reduce runoff and pollutant discharges generated during construction activities. These requirements are incorporated throughout this guidance document.

See Section VIII (Regional Collaboration) for how school districts can leverage expertise and potential resources from municipal permittees.

Existing School Efforts

Some school districts in California are actively engaged in managing runoff. They have done so for a variety of reasons. For example, school districts in San Diego and Los Angeles have worked with local communities to capture runoff and support regional water supply and water quality goals. Also, a few districts are named in NPDES permits for managing runoff and are actively managing runoff to address water quality issues. The Los Angeles Unified School District (LAUSD) is releasing a stormwater technical manual in 2019.

Some newly constructed or retrofitted schools in California have pursued certification through the Collaborative for High Performance Schools (CHPS) standards program, which incentivizes energy efficiency and green design practices, including runoff capture (Figure I-10). The LAUSD adopted CHPS standards for school designs in 2009.

Figure I-10— Opportunities through Collaboration for High Performance Schools (CHPS 2018)

Several school districts in Southern California have developed a Stormwater Pollution Prevention Plan (SWPPP) internship program, which was first funded by the State Water Board's Drought Response Outreach to Schools (DROPS) grants. The program gives students hands-on educational opportunities related to water quality sampling and analysis, site evaluations, stormwater infrastructure design and construction, and more.

There have been some unique efforts exemplifying the possibilities for regional collaboration between schools and their communities in supporting runoff catpure. Green Schoolyards America encourages and provides support to communities investing in school grounds to improve children's well-being, learning, and play while contributing to the ecological health and resilience of their cities (including incorporation of runoff capture practices). As another example, TreePeople collaborated with the Los Angeles Department of Water and Power (LADWP), the LA County Department of Public Works (LACDPW), the City's Bureau of Sanitation (LASAN), and other agencies to examine collaborative options that could allow for increased runoff capture projects on LAUSD campuses (TreePeople 2015).

I. Background

The SFPUC and the San Francisco Unified School District (SFUSD) completed a jointly funded "Stormwater Schoolyard" project at Robert Louis Stevenson Elementary School in October 2018 (Figure I-11). The project collects runoff from about one acre of impervious surface and diverts it to dry creek beds and a sunken amphitheater that uses permeable pavers for ground cover. Drought tolerant plants are incorporated throughout. The project prevents impacts from runoff, provides opportunities for outdoor education and play, and serves as a demonstration facility for other schools in the district. The SFPUC has also developed the Green Infrastructure Grant Program to further these types of runoff capture practices throughout San Francisco.

Beyond these examples, the majority of schools and school districts throughout the state do not have active runoff management programs. These guidelines will provide a foundational understanding of stormwater management strategies and a framework for developing projects on your own campus.

Figure I-11— Example of dry creek bed and signage installed at Robert Louis Stevenson Elementary School in San Francisco (SFUSD 2018)

II. Benefits

School Benefits

Regional Benefits

II. Benefits

School Benefits

Many runoff capture practices can be designed to incorporate features that enhance schoolyards beyond merely improving runoff management. This includes creating outdoor play, learning, and teaching spaces; increasing shade; increasing access to natural areas; and establishing drought tolerant habitat. By doing so, the schools can:

- Enhance educational opportunities
- Improve student health and well-being
- Create environmental benefits
- Leverage funding
- Share costs
- Reduce on-site flooding
- Engage communities
- Improve community reputation
- Support regional sustainability

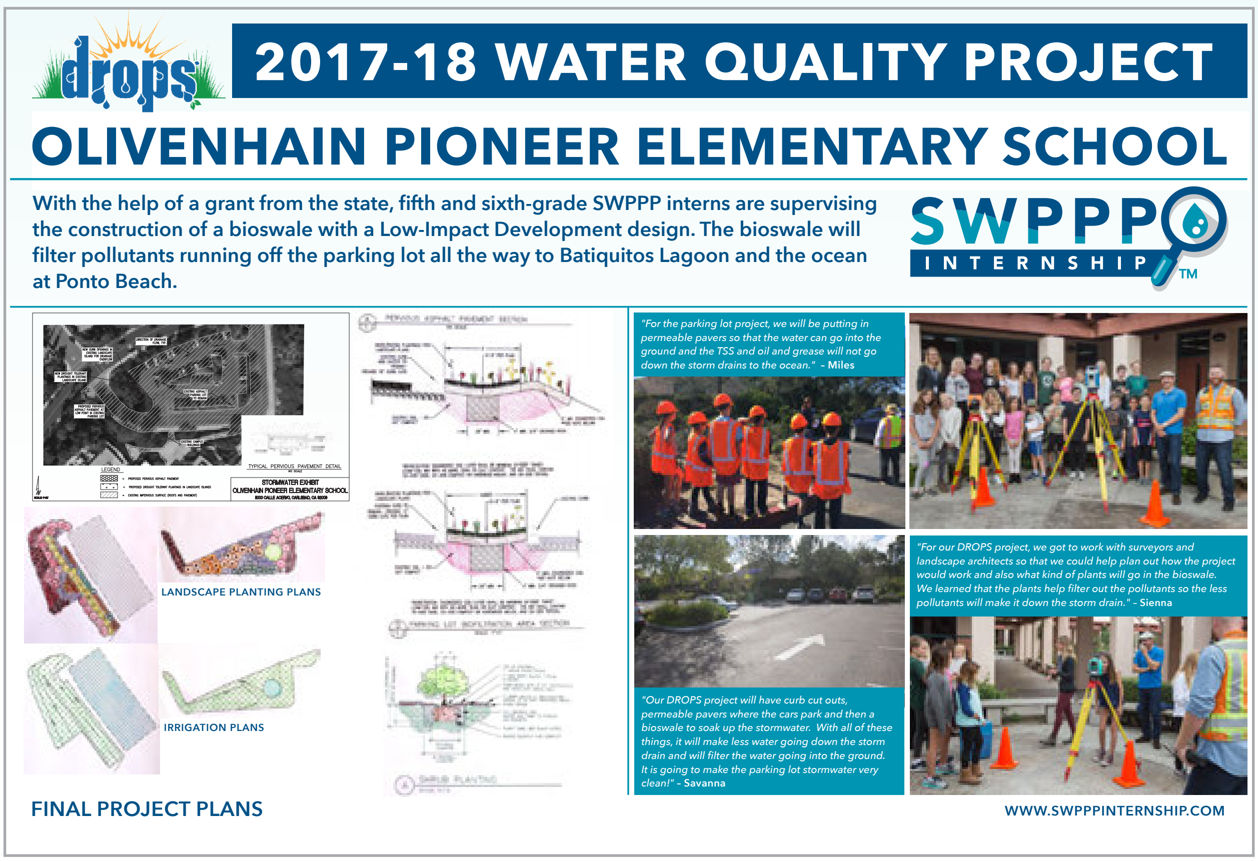


Figure II-1—An example of opportunities for education

Enhance Educational Opportunities: School districts that implement runoff minimizing practices can create projects that offer teachers and students opportunities in the science, technology, engineering, and mathematics (STEM) fields, and possibly other areas such as language arts, social studies, government, and arts. Projects can incorporate education regarding the beneficial uses of capturing runoff to sustain future supplies and reduce flood risks. A great example of an existing educational opportunity is the SWPPP internship program offered by some California school districts (Figure II-1). More broadly, schools that create green schoolyards (which can include runoff capture features) can be used to enhance educational opportunities across almost every subject at every grade level in a variety of ways.

Improve Student Health and Well-Being: Many runoff capture practices can be used to create green spaces that support the physical and mental well-being of students. Project designs where large non-permeable areas in the main schoolyards are replaced with living materials and trees increase student activity levels and create shade, which reduces playground temperatures, and provide opportunities for children to be more active, improving their physical fitness and motor coordination. In addition, research indicates that students with views and access to trees and nature recover faster from stress and mental fatigue (Daniel et al 2018, Liang et al 2014, Lovasi et al 2008, Taylor & Kuo 2011), and improve their ability to pay attention, along with measurably improved test scores (Li and Sullivan 2016). The Children and Nature Network provides visual summaries of these benefits (Figure II-2).

Figure II-2— Children and Nature Networks downloadable infographics regarding the benefits of green schoolyards

II. Benefits

Create Environmental Benefits: Potential environmental benefits that can be realized from implementing runoff prevention and capture practices include providing shade and reducing heat island effects, lowering building energy demands, reducing smog and air pollution, improving health and well-being, sequestering carbon, increasing wildlife habitat, and reducing pollutant discharges.

Leverage Funding: Because preventing and capturing runoff provides many benefits, several agencies provide grant and low-interest loan programs to assist in funding these projects. These can be tied into existing school enhancement projects.

Share Costs: Schools districts can work with neighboring municipalities and other agencies on stormwater management to spread costs among collaborators.

Reduce On-Site Flooding: Preventing and reducing the runoff volume and flow rates discharged from school properties helps reduce the risk, frequency, and consequences of on-site flooding, in turn reducing capital and maintenance costs of runoff infrastructure.

Engage Communities: Embracing sustainability practices can draw interest from the school community (parents, teachers, maintenance staff, students, etc.) interest, creating further support and involvement and extending benefit opportunities. School communities can participate in the design of stormwater management elements to ensure that multiple needs of the school are met. This can encourage buy-in and support from the greater local community.

Improve Community Standing: The school benefits previously discussed as well as the regional benefits described next all improve a community's reputation and draw residents to the neighborhood and students to schools. This increased public support and enrollment can accentuate the community's existing pride, extending and expanding the benefits that are possible.

Support Regional Sustainability: Beyond the benefits that apply directly to schools, preventing and reducing runoff from school properties can support regional goals for managing watershed health and achieving sustainability. Such practices can supplement regional benefits related to water quality, water supply, flood control, communities, and other environmental systems (e.g., air quality or habitat condition), as well as climate change adaptation and resilience. Specific examples are provided later in this section.

Regional Benefits

Preventing and reducing runoff can contribute to regional goals of sustainability, including those related to:

- Water quality
- Water supply
- Flood control
- Environmental systems
- Communities
- Climate change

Improve Water Quality: Runoff capture practices prevent and reduce runoff volumes, flow rates, and pollutants discharged from a property to protect the beneficial uses of local water ways.

Augment Water Supply: Many of the runoff practices presented in this guidance document involve capturing runoff and allowing it to infiltrate into underlying soils where it often percolates down, recharging groundwater basins for future water supply. Other practices in this document capture and store runoff for direct use (e.g., irrigation), which can increase water supply by reducing demand on local surface water sources.

Figure II-3—Example of a regional project that improves water quality, alleviates flooding, recharges groundwater, and enhances public recreation.

II. Benefits

Support Flood Prevention: Runoff prevention and capture practices can reduce and slow the discharge of runoff, reducing risks and mitigating flooding. Localized flooding can be remedied by incorporating features such as pervious pavement, dry wells, vegetated landscapes that promote infiltration, or even sunken sports field that can serve as temporary detention basins. These practices, when distributed copiously throughout an area, can support other regional flood practices as well.

Protect Environmental Systems: Runoff capture practices that prevent and reduce runoff volumes and flow rates can protect or enhance wetlands, riparian zones, and other aquatic habitats by reducing the potential for 1) excess sediment transport to streams; 2) downstream erosion and sedimentation; 3) flooding; 4) disruption of natural drainage patterns, stream flows, and riparian habitat; 5) elevated water temperatures; and 6) transport of pollutants to these habitats. In addition, runoff capture and prevention can reduce the need for pumping and, therefore, the use of electricity and greenhouse gas emissions. Some stormwater capture measures (SCMs) can even provide carbon sequestration.

Enhance Communities: Minimizing imperviousness and incorporating vegetated runoff capture at schools can enhance communities by expanding education, involvement, and recreation opportunities. It can also make communities more beautiful, sustainable, and friendly to wildlife. Such gathering places provide ideal locations for educating visitors about the impacts of urbanization on their environment. This can lead to modifications in behavior to support or improve watershed health. Developing brochures, websites, mobile applications, and signage and conducting public outreach events are a few ways to educate communities.

Climate Change Adaptation and Resilience: Climate research and modeling indicate that, in future decades, weather events in California will grow more extreme. This includes more extreme precipitation events and prolonged drought periods (Dettinger 2011, Diffenbaugh 2015, Swain 2017). Storms in particular will likely increase in intensity, straining current stormwater drainage systems, but presenting opportunities for more capture and infiltration. Runoff prevention and capture practices provide opportunities to adapt and develop resiliency in the face of climate change by:

- Addressing increased precipitation volumes and intensities by increasing infiltration, reducing runoff volumes, and delaying peak runoff. This will help prevent erosion, water quality and habitat degradation, and flood damage
- Preparing for more extreme and frequent drought conditions by capturing and using runoff to reduce demand on water supplies, as well as recharging groundwater to increase groundwater supplies
- Reducing heat island effects by promoting incorporation of vegetated landscapes to the extent feasible
- Providing redundancy through distributed, small-scale measures

III. Practices

Small-scale Landscape Features

Design Strategies

Stormwater Control Measures

Additional Runoff Management Practices

III. Practices

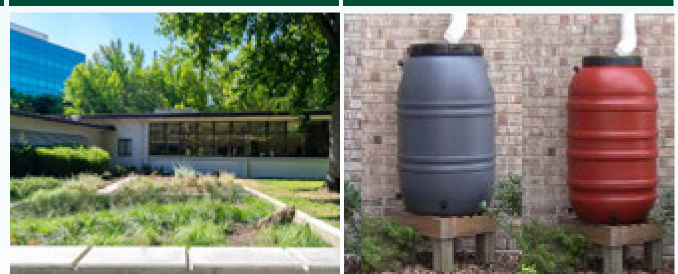
Small-Scale Landscape Features

There are several small-scale landscape features that can support runoff prevention and capture. These features involve fairly simple planning and modifications. The material needs for construction are often quite accessible, making them excellent candidates for low-cost features that offer educational opportunities for schools, such as engaging students in project designs, visualization of the rainfall-runoff process, or constructing new campus features. Figure III-1 shows some examples.

Water Wise Landscapes:

Using plants that require little water, especially native plants, can help reduce the water needs of revamped landscapes and promote more infiltration. Low-water plants often do not require spray irrigation, further reducing overwatering and dry weather runoff. California's Model Water Efficient Landscape Ordinance (MWELO) is a good resource for planning such landscapes. It specifies design, installation, and maintenance practices that meet an irrigation water budget based on climate parameters and site characteristics.

Water wise vegetation | *Curb cuts* | *Downspout disconnects*



Rain gardens | *Above ground storage*

Figure III-1—Small-scale landscape features (clockwise from left: OWP; OWP; CWH; Porter County, IN; OWP)

Curb Cuts:

These features allow runoff to flow from sidewalks or roads into swales, bioretention planters, and other infiltrating areas.

Downspout Disconnects: Disconnected downspouts direct roof runoff to cisterns, rain barrels, porous pavement, or other SCMs in lieu of discharging it untreated, to conveyance systems and ultimately receiving waters.

Rain Gardens: Rain gardens are depressed landscapes that capture runoff and allow it to pond and slowly infiltrate over time. Rain gardens are simple planters consisting of amended soils (to promote infiltration) and waterwise vegetation. Notably, rain gardens in California often require summer irrigation.

Rain barrels: Rain barrels are small containers that collect roof runoff for later use such as irrigation. They can be combined with down spout disconnects.

Many online tools and guidebooks exist for these features, such as CASQA's LID Portal as well as stormwater design manuals. The manuals can be identified by contacting MS4 permittees. See the CA Phase II LID Sizing Tool for a map of the permittees.

Design Strategies

Design strategies are tactics and principles incorporated during the planning and design stages of a project to help capture and prevent runoff. Such strategies are summarized in Figure III-2. Project designs should acheive multiple benefits.

Preserve, create, and enhance natural areas and features

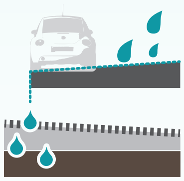
- Design around existing trees and vegetated landscapes to promote infiltration
- Design new and natural areas that allow infiltration

Minimize impervious surfaces

- Combine hardscape play areas with interactive green space if possible
- Design to replace impervious surfaces with pervious surfaces, such as porous pavement or green roofs
- Minimize building footprints with multi-story structures

Design with soils that promote infiltration

- Use compost and mulch to amend soils to both promote and enhance infiltration
- Minimize soil compaction in identified green spaces during construction

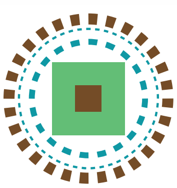


Arrange impervious surfaces to drain to permeable surfaces

- Drain runoff from impervious surfaces to pervious surfaces like vegetated landscapes to allow infiltration

Design areas to prevent irrigation runoff

- Select plants that require minimal watering
- Use non-spray systems, when possible
- Operate and maintain irrigation systems to minimize generation of runoff



Allocate space to stormwater control measures

- See the discussion on stormwater control measures on page 24 discussion later in this section

Incorporate visual stormwater features and learning oportunities

- Place SCMs in areas visible to students, staff, and visitors to increase awareness regarding runoff management
- Install signage, create brochures, offer tours, and create other oportunities to educate school communities on the need for, and function of, runoff capture features

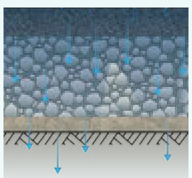
Figure III-2—Design strategies

III. Practices

Stormwater Control Measures (SCMs)

SCMs are structural devices that reduce runoff volumes, flow rates, and pollutant transport. SCMs are referred to as structural best management practices (BMPs), and some qualify as low impact development (LID) devices. Note that some of the SCMs can be combined in series to create a "treatment train" that provides cumulative performance. This is especially useful when site layout is limited, but also allows creativity in site aesthetics related to SCM features. SCMs address runoff volumes, flow rates, and pollutants through a number of mechanisms, as shown in Figure III-3.

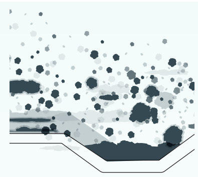
Capture and Treatment Mechanisms



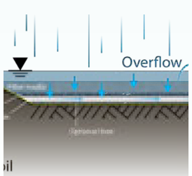
Infiltration (I): The movement of runoff downward from the ground surface through the unsaturated soils

Rainfall Harvest (RH): Collecting and storing rainfall for later use. Check local ordinances for treatment requirements

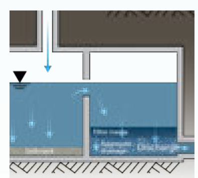
Trash Capture (T): Capturing trash in accordance with the State Water Board's definition of a Full Trash System (State Water Board 2018e)



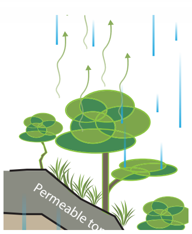
Sedimentation (S): Slowing the flow rate of runoff, allowing suspended particles to settle or deposit and be retained on a surface



Filtration and Adsorption (FA): Filtration involves passing runoff through a straining media (a filter) that traps and retains particulates but allows liquid and smaller suspended particles to pass through. Adsorption involves adherence of atoms, ions, or molecules in runoff to a solid

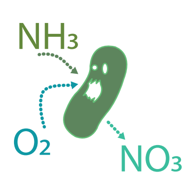


Flotation (F): Floating and trapping materials such as trash, oils, and grease, allowing heavier materials and fluids to flow through



Evapotranspiration (ET): A combination of processes by which water at or near the earth's surface becomes atmospheric water vapor. It includes evaporation of water from surface waters, bare soil, and vegetative surfaces; evaporation from within the leaves of plants (transpiration); and sublimation from ice and snow surfaces (Dingman 1994)

Plant Uptake (P): Root plants taking up nutrients and other chemicals from runoff

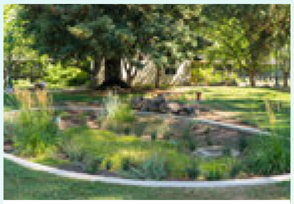


Biochemical Transformation (B): Biological and chemical processes, such as biological nitrification, that convert molecules into different forms

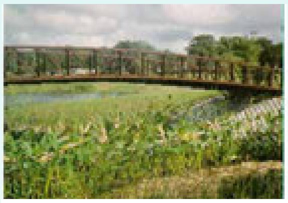
Figure III-3—Capture and treatment mechanisms

Common SCMs are shown in Figure III-4. Appendix A provides factsheets summarizing their functions, advantages, limitations, and more. Additional information is available from CASQA's BMP Handbooks.

Aboveground storage
(Porter County IN)



*Bioretention planter**
(OWP)



*Constructed wetland**
(EPA)

*Detention basin**
(Stormwater Partners SW Washington)

Dry well
(Torrent Resources)

Infiltration basin
(UC Santa Cruz)

Infiltration gallery
(Brentwood Industries)

Infiltration trench
(Richland Soil and Water Conservation District)

Porous pavement
(EPA)

Underground storage vault
(CSU Fort Collins)

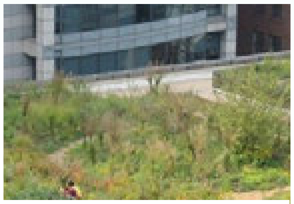
Vegetated buffer strip
(Caltrans)

Vegetated swale
(Sacramento Stormwater Quality Partnership)

*Wet pond**
(MN Pollution Control Agency)

*Media filter**
(City of Portland OR)

Drain inlet insert
(Grainger)



Green roof
(Center for Neighborhood Technology)

Hydrodynamic separator
(EPA)

Oil water separator
(Stormwater Partners SW Washington)

** Refer to factsheets in Appendix A for descriptions, relevant treatment mechanisms, and more*

Figure III-4—Common SCMs

III. Practices

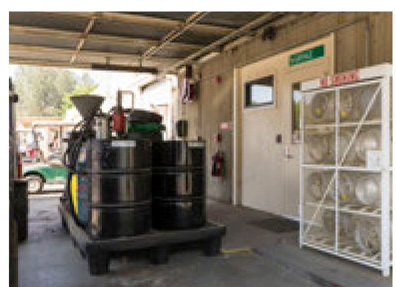
Additional Runoff Management Practices

In addition to the design strategies and SCMs presented in this guidance, there are several runoff management practices that prevent potential pollutants from coming into contact with runoff, as well as practices for evaluating and refining runoff management activities. Although not the focus of this document, these elements are crucial to preventing pollutants from entering waterways, and guidance on the related activities is provided from a variety of sources. The CASQA New and Redevelopment BMP Handbook is an excellent resource. Among publicly available material, EPA's National Management Measures to Control Nonpoint Source Pollution from Urban Areas is a highly regarded reference resource. Figure III-5 shows some examples.

Other Runoff Management Practices	
Education and outreach	
Public involvement and participation	
Illicit discharge detection and elimination	
Construction site runoff control	
Water quality monitoring	
Program effectiveness assessment and improvement	
Pollution prevention/good housekeeping related to: • Outdoor storage of liquids and raw materials • Parking/storage area maintenance • Vehicle/equipment fueling and maintenance • Outdoor loading and unloading of materials	• Sweeping and cleaning • Outdoor process equipment • Landscape maintenance • Trash storage • Evaluating irrigation system for intended operation

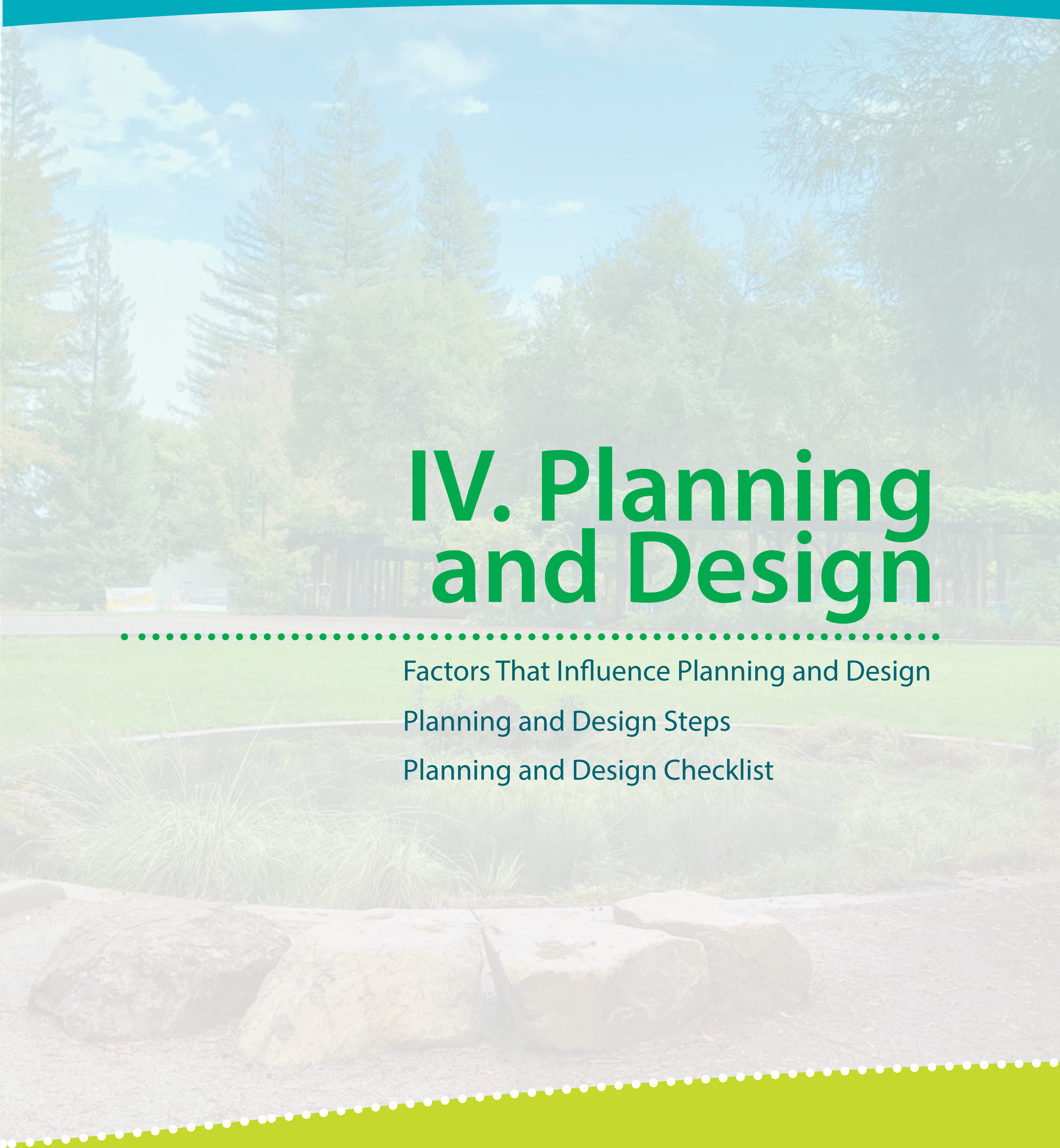
Interpretive signage

Straw waddles



Secondary containment

Figure III-5—Examples of other runoff management practices that help prevent degradation of water bodies.



IV. Planning and Design

Factors That Influence Planning and Design

Planning and Design Steps

Planning and Design Checklist

IV. Planning and Design

Factors That Influence Planning and Design

SCMs are designed to capture, retain, and treat a certain amount of runoff. In general, the amount of runoff to be captured is estimated using historic climate data, the area on which precipitation falls (drains from), and land cover characteristics that influence the amount of precipitation that becomes runoff. SCM selection and design also depend on the pollutants of concern, the desired performance (runoff volumes, flows, and pollutants discharged), the characteristics of existing soils, and the types of and proximity to surrounding infrastructure. Additional considerations for SCM design include vegetation, safety, maintenance, and permit requirements.

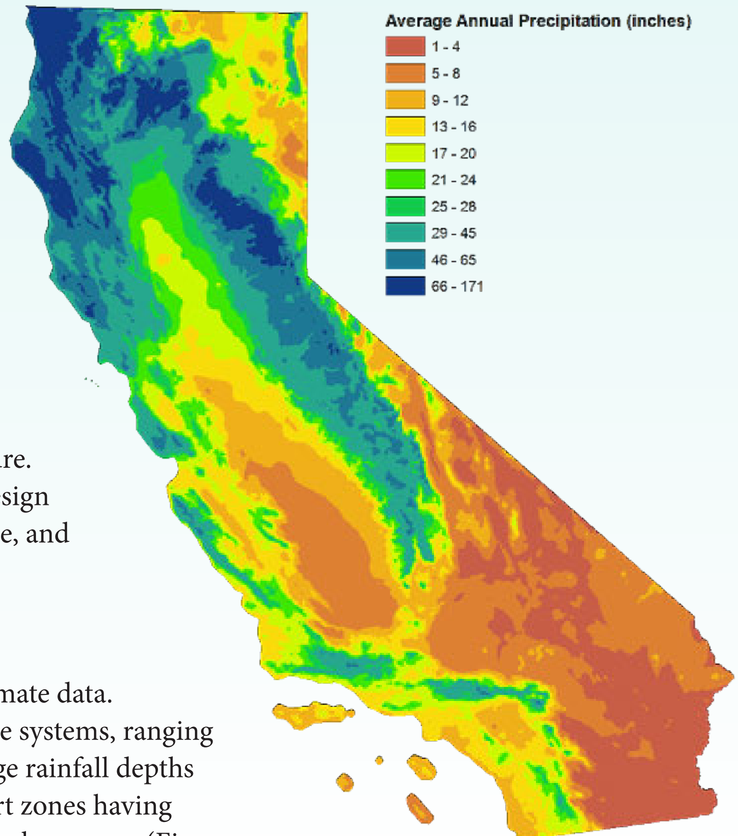


Figure IV–1. Annual average precipitation throughout California (USDA 2012)

Climate

SCM designs are based on historic climate data. California has uniquely diverse climate systems, ranging from rainforest conditions with average rainfall depths exceeding 170 inches per year to desert zones having average rainfall depths of less than 1 inch per year (Figure IV-1).

Hydrologic data is easily available from several sources. Both Basin Sizer from the California Department of Transportation (Caltrans) and the Phase II Sizing Tool from the Office of Water Programs (OWP) include databases of precipitation data throughout California. The Phase II Sizing Tool also provides a map of municipal stormwater programs, which have local precipitation data.

Drainage Area

The area, or catchment, on which precipitation falls significantly influences the volume and flow rate of runoff generated during a storm event. Catchments are delineated based on topography, with runoff flowing down slopes and accumulating according to the grading of a site. In planning, grading should be designed to delineate drainages that flow toward areas where SCMs can be used. Drainage areas can be determined from topographic surveys or satelite imagery.

Land Cover and Use

Land cover is the primary factor that determines the percentage of precipitation that becomes runoff. Areas with more impervious surfaces generally create more runoff because less precipitation is infiltrated and stored in soils, plants, and other pervious materials (Figure IV-2). Minimizing impervious surfaces and maintaining or increasing pervious surfaces can prevent the generation of runoff and reduce the discharge of runoff to water bodies. While all pervious surfaces can help promote infiltration and reduce runoff, their effectiveness varies. Surfaces with more and/or larger gaps between soil particles allow more infiltration. Many soils beneath developed properties are disturbed and have been compacted, reducing the space between soil particles, and therefore, infiltration. This increases the amount of precipitation that becomes runoff.

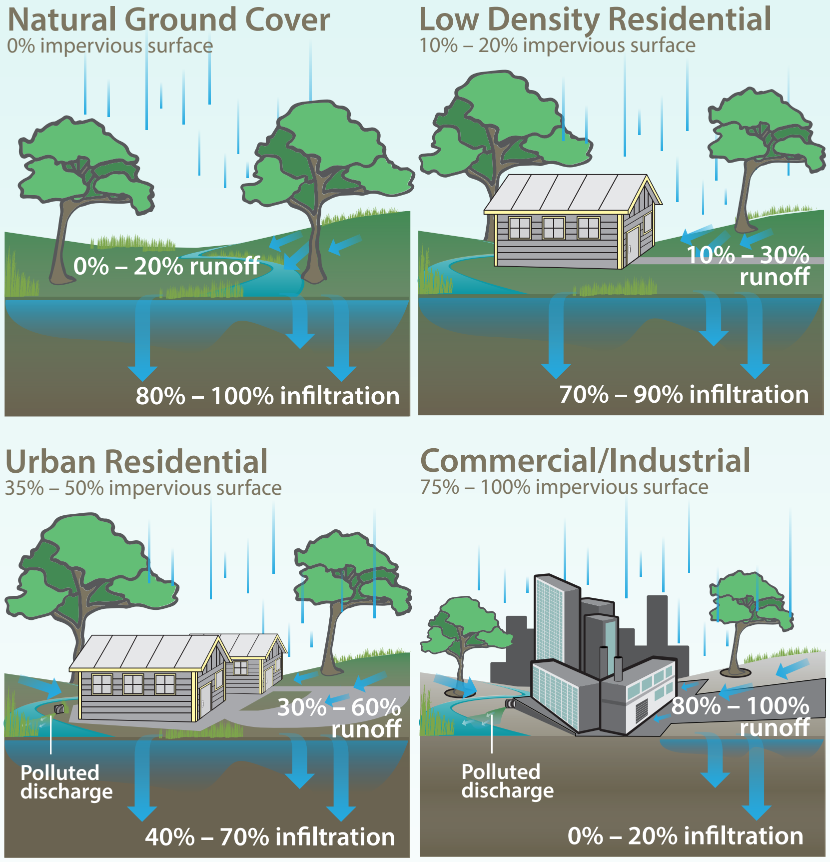


Figure IV–2. Changes in land cover and use impact runoff and infiltration

Additionally, different land uses affect the types of pollutants in runoff. Pollutants generated on school properties would include those typical for residential and commercial properties (sediments, nutrients, metals, pesticides, oil and grease, bacteria and pathogens, and trash) and possibly organic compounds and other hazardous chemicals if used on site for maintenance or industrial purposes. If off-site runoff is captured on or diverted through school grounds, additional pollutant types may be present according to the land cover and uses of the contributing drainage.

Soil Characteristics

For infiltrating capture devices, soil type is an important design consideration. Soils with significant amounts of sand and gravel have higher rates of infiltration, while less porous soils such as clay and silts have lower infiltration rates. The infiltration rates will influence the size and configuration of the device.

There are several ways to classify soils, but for runoff capture planning, the US Geological Survey (USGS) categorizations are most common, consisting of four different groupings (see tabulation on the next page). Infiltrating SCMs that are implemented in areas with better infiltrating soils (A and B hydrologic soil groups) can have smaller footprints than those implemented in areas with soils having poor infiltration rates (groups C and D). Different soil groups have different ranges of saturated hydraulic conductivity, which is often used to represent overall infiltrations.

IV. Planning and Design

USGS hydrologic soil groups

USGS Hydrologic Soil Groups	Description	Saturated Conductivity (in/hr)
A	Sandy and loamy soils with low runoff potential and high infiltration rates	>1.42
B	Silty and loamy soils with some infiltration potential but can reduce with saturation	0.57-1.42
C	Sandy clay loam soils that are less advantageous for infiltration	0.06-0.57
D	Clay loam, silty clay loam, sandy clay, or clay soils with limited infiltration capacity	<0.06

USDA NRCS 2007

Soil types vary across latitude, longitude, and depth, with any particular location comprised of many subsurface soil layers, each of varying composition. Figure IV-3 shows how soils and infiltration rates can vary within the subsurface. Often a soil type provided for a particular location represents a weighted-average of the multiple types of soils that exist within the subsurface. The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) hosts a web map, the Web Soil Survey, that depicts hydrologic soil groups throughout the country, using this weighted average representation. The NRCS also publishes its Soil Survey Geographic Database (SSURGO) dataset that shows soil groups at specific depths (Figure IV-4).

The Web Soil Survey and SSURGO are based on extrapolations of historical soil investigations. Given the spatial variability of soil types, these resources should be used for planning and preliminary design only. Final designs should be based on an on-site soil survey that involves collecting soil cores to characterize soil types and saturated conductivities laterally and vertically within the subsurface.

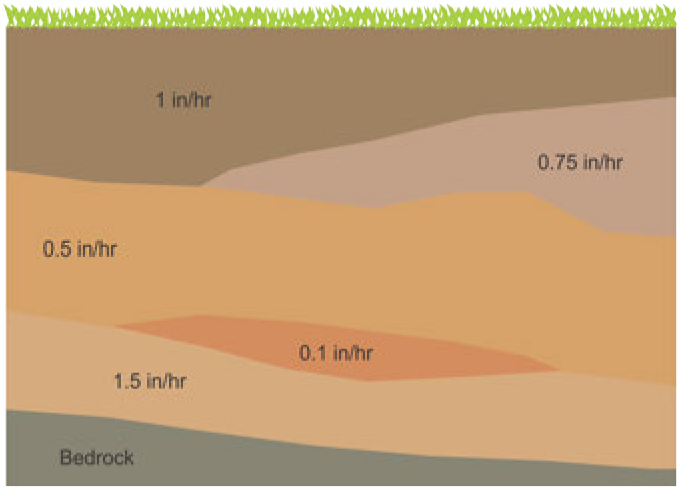


Figure IV–3. Example of how soil layers and infiltration rates can vary within the subsurface

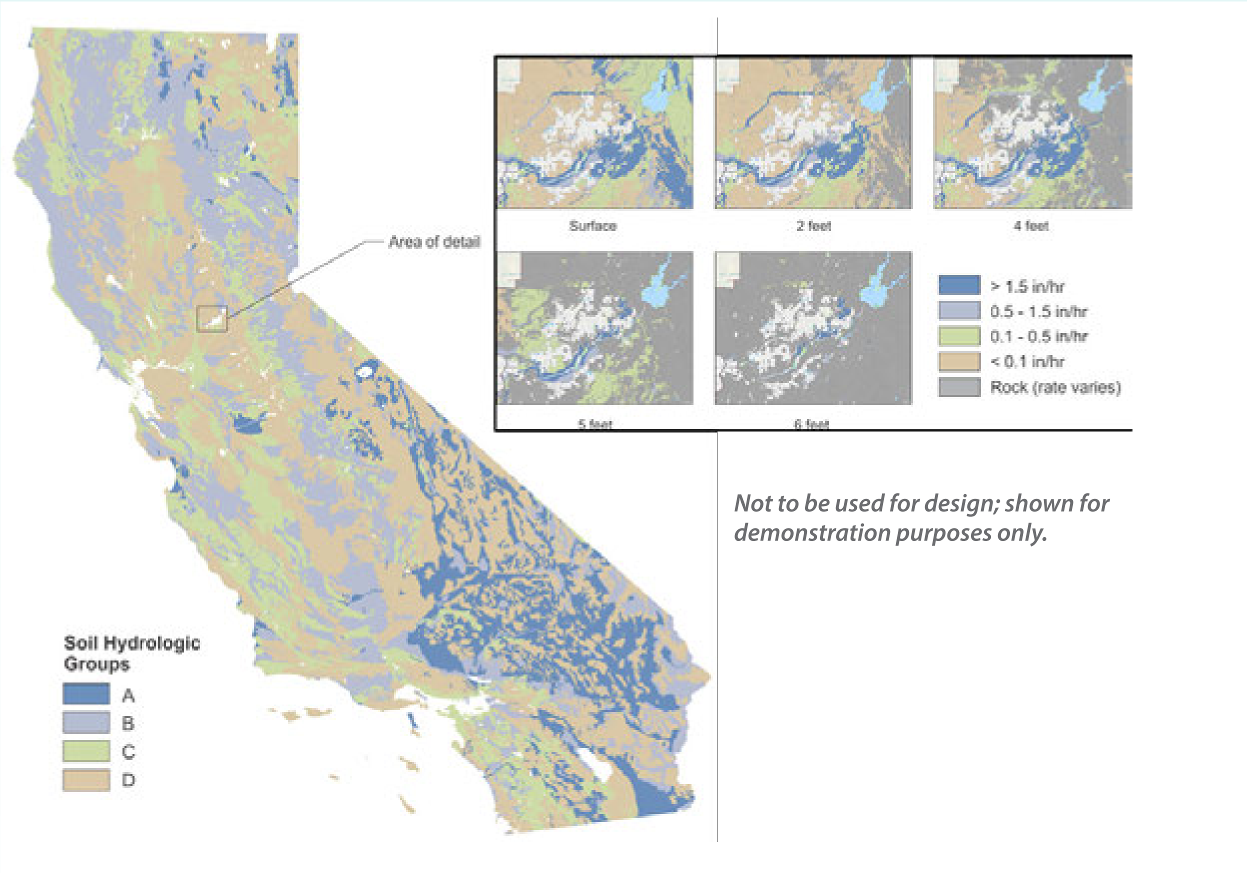


Figure IV–4. Hydrologic soil groups throughout California (left) and infiltration rate (represented by saturated hydraulic conductivity) variations with depth in Sacramento (right). (NRCS 2018)

Existing Standards

Many municipalities throughout California have been subject to runoff permit requirements for several years and have already established design standards for preventing and minimizing runoff. The standards provide specifications for the technical aspects of runoff management, including types of materials to be used; numerical retention, treatment, and hydromodification design criteria and tools; and required maintenance activities. These standards were developed with specific regional interests in mind, and can serve as resources for design specifications for schools in the interest of regional sustainability and consistency. When adopted into local drainage ordinances, compliance is required per Government Code §53097. The CA Phase II LID Sizing Tool includes a map of school properties and municipalities that can be used to identify permittees with existing stormwater design manuals and standards that may be useful for schools.

IV. Planning and Design

Pollutants of Concern

Pollutants of concern vary by water body, and are influenced by land cover and use as previously explained. These pollutants can be used to prioritize treatment of typical school runoff pollutants. Generally, the pollutants in runoff include sediment, nutrients, metals, pesticides, oil and grease, bacteria, pathogens, and trash (Figure IV-5). A list of typical pollutants, their sources, and impacts are tabulated by municipalities and other entities regulated by NPDES permits. They must also comply with regional and local water quality standards (WQS), such as United States Environmental Protection Agency's (USEPA's) 303(d) program. The program lists TMDLs, which stipulate the maximum amount of contaminant discharges to water bodies that are allowed. The 303(d) list, TMDLs, and other WQS may be used to identify pollutants of concern in water bodies receiving runoff from schools. An assessment of land cover and use helps indicate whether these pollutants can be targeted for reduction by SCMs. The 303(d) water bodies, pollutants, and TMDLs are posted on the State Water Board's **Impaired Water Bodies** website.

Typical pollutant concentrations in runoff from various land types can be estimated from either regional data (often available from local municipalities) or the **National Stormwater Quality Database**. The type and concentrations of pollutants generated can inform selection of SCMs.

Figure IV–5. An outfall below a neighborhood and golf course discharging multiple pollutants.

Typical pollutants of concern in urban runoff (adapted from CASQA 2003)

Pollutant Category	Example Constituents	Land Use Categories: Global/Regional Aerial Deposition	Agriculture	Commercial	Construction	Industrial	Residential	Transportation	Undeveloped	Example Sources	Impacts
Sediment	TSS Turbidity	X	X	X	X	X	X	X	X	Erosion Excavation	Habitat destruction Reservoir storage loss Increased water treatment costs
Nutrients	Nitrogen Phosphates		X	X	X	X	X	X		Fertilizers Farm animal waste Septic systems	Algae blooms Habitat destruction Fish kills
Bacteria and Pathogens	Fecal coliform *E. Coli*		X	X	X	X	X	X	X	Domestic sewage Pet waste Wildlife waste	Odors Toxicity Beach closures
Oils and greases	Total oil & grease Total petroleum Hydrocarbons			X		X		X		Vehicles Solvents & degreasers Crude oil	Visually unappealing Toxicity
Organic pollutants	PAHs[1] VOCs[2]			X		X		X		Illicit discharges Asphalt sealants Insecticides Varnishes & paints	Toxicity
Metals	Lead Zinc Copper	X		X	X	X	X	X	X	Industrial waste Mining Vehicles	Toxicity
Pesticides	Pyrethroids Chlorpyrifos Fipronil Diazinon		X	X	X	X	X	X	X	Residential landscape Agriculture Vegetated roadsides	Toxicity
Trash and particulates	Cigarette butts Paper bags Leaf litter			X	X	X	X	X	X	Schools Shopping centers Landscapes Fugitive trash[3] Vehicle accidents	Visually unappealing Habitat destruction Odors

[1]Polyaromatic hydrocarbons

[2]Volatile organic compounds

[3]Fugitive trash released from landfills, transfer stations, garbage trucks, personal vehicles, trash recepticals, and industries

IV. Planning and Design

SCM Performance

SCMs have varying performance capabilities, as shown on the following page. Some SCMs can reduce runoff volumes, flow rates, and pollutant loads; some do not reduce volumes (only flow rate and pollutants); and some merely remove pollutants. Some SCMs are better at removing particular pollutants of concern, and some provide more volume or flow rate reduction. Design variations within the same SCM type can also affect performance. For example, bioretention planters that include an elevated underdrain can have better nitrate removal than those without an elevated underdrain—storing water within the gravel allows time for denitrification.

Selecting SCMs that maximize infiltration or on-site use is often the best way to address the many pollutants common in runoff. SCMs that include infiltration (see the SCM factsheets) will provide water quality treatment and volume reduction, while most of those without infiltration will provide water quality treatment only. The International BMP Database provides data and assessments of SCM performance reported by others.

Individual School Needs

Each school will have needs that can be met by projects designed for multiple purposes. Schools that need new sports fields, practice fields, or interactive play areas can plan these projects to include capturing runoff as part of the recreation infrastructure.

School District Requirements

School districts have specific requirements related to many elements of runoff capture design, as dictated by the California Code of Regulations, the California Department of Education (CDE), and the Division of State Architect (DSA). Examples include compliance with the Americans with Disabilities Act (ADA), excavations near existing structures, and geotechnical design for infiltration and runoff capture. Section IX summarizes many of the regulatory codes that may impact the SCM design.

Safety and Access

SCM implementation cannot create a condition that violates safety and access requirements in the DSA code requirements. In particular, limitations on SCM selection or design and incorporation of safety features may be needed for the following conditions:

- SCMs with a grade drop of more than 4 inches
- SCMs with confined spaces or standing water
- SCMs near fire access or emergency egress from any building

> *"In spite of the high voids content, properly placed pervious concrete pavements can achieve flexural strengths of more than 500 psi … more than adequate for most low-volume pavement applications, including high axle loads for garbage trucks and emergency vehicles such as fire trucks."— Perviouspavement.org*

Environmental Compliance

There are several environmental regulatory compliance considerations for SCM installations, including the California Environmental Quality Act (CEQA) and the CGP. These are discussed further in Identify Relevant Regulations and Programs later in this section.

Maintenance Needs

SCMs are investments. To maximize these investments, operation and maintenance (O&M) needs must be considered and addressed during the project planning and design. Available funding and staffing, required equipment and materials, and aesthetics and function should be considered in SCM selection and design. Engaging maintenance staff in planning is particularly crucial to incorporate their insight and experience in easing future maintenance, and to address concerns regarding worker safety and changes to job descriptions or expectations. These and other O&M aspects are further discussed in Identify Long Term Maintenance Needs later in this section, and in Section VI (Maintenance).

Pollutants addressed by various SCMs | [1] Assumes runoff is fully retained, [2] Total metals only (does not address dissolved metals), [3] SCM comes in lined or unlined variations. Volume is retained only in unlined SCMs that allow infiltration

SCM	Parameter Addressed								
	Sediments	Nutrients	Pathogens & Bacteria	Oils & Grease	Organic Pollutants	Metals	Pesticides	Trash	Volume
Aboveground Storage[1]	X	X	X	X	X	X	X	X	X
Bioretention Planter	X		X		X	X	X	X	X[3]
Constructed Wetland	X		X			X	X	X	X[3]
Detention Basin	X					X[2]	X	X	X[3]
Drain Inlet Insert	X					X[2]		X	
Dry Well[1]	X	X	X	X	X	X	X	X	X
Green Roof	X	X			X	X	X	X	
Hydrodynamic Separator	X	X	X	X	X	X	X	X	
Infiltration Basin[1]	X	X	X	X	X	X	X	X	X
Infiltration Gallery[1]	X	X	X	X	X	X	X	X	X
Infiltration Trench[1]	X	X	X	X	X	X	X	X	X
Media Filter	X					X	X	X	X[3]
Oil Water Separator	X			X		X[2]		X	
Porous Pavement	X	X	X	X	X	X	X	X	X[3]
Underground Storage[1]	X	X	X	X	X	X	X	X	X
Vegetated Buffer Strip	X	X			X	X	X	X	X
Vegetated Swale	X	X			X	X	X	X	X
Wet Pond	X					X	X	X	X[3]

IV. Planning and Design

Surrounding Infrastructure

Surrounding infrastructure is an important component of SCM design.

Proximity to buildings is important for SCMs that infiltrate, because moisture can damage foundations and basements. Guidance for SCMs often specifies a separation of 10 feet between buildings and infiltrating devices (Figure IV-6). Alternatively, a geotechnical engineer can be consulted. Additional measures, such as the use of a vertical moisture barrier, underdrains, or trench drains, can help route water away from buildings and structures.

Figure IV–6. A lined bioretention planter prevents infiltration impacts to building foundation

The location of existing underground utilities also affects SCM siting and construction. Subsurface electric, gas, phone, and cable infrastructure must all be identified to prevent damage from excavations or long-term corrosion from habitual saturation. Upon request, public utilities staff will come to the site to delineate utility lines. Property owners should also be contacted to locate privately installed utilities, such as underground wiring for parking lot lights.

For redevelopment or retrofit projects, and even some new development projects, tapping into existing drainage infrastructure can be a good cost-savings approach. SCMs could be connected to or built around existing drain inlets, grading, surface conveyance (e.g., valley gutters), and subsurface conveyance piping to either direct runoff to the SCM or provide a means of discharge for excess runoff (i.e., overflows). Figure IV-7 shows an example.

Figure IV–7. Tying a bioretention planter into existing drainage infrastructure

Vegetative Health

Erosion control and irrigation needs, weed suppression, sun exposure, saturated soils, drought conditions, and maintenance requirements all affect vegetation selection. Several documents guide the selection and siting of plants within green infrastructure. Most contemporary landscape guidance documents emphasize the use of native plants for their drought adaptive traits and contributions to local habitat such as supporting pollinators. The County of San Diego's LID handbook includes detailed, species-specific information on plant water needs, sun requirements, climate zones, and, uniquely, ideal locations within SCM landscapes where inundation varies. Some plants are suitable for areas of sustained inundation such as lower areas within an SCM, while others do better in drier areas of SCMs, such as the upper slope of a rain garden. Similar considerations should govern the species of trees that are chosen for planting. Smaller trees may establish faster and be hardier, easing landscaping and maintenance needs.

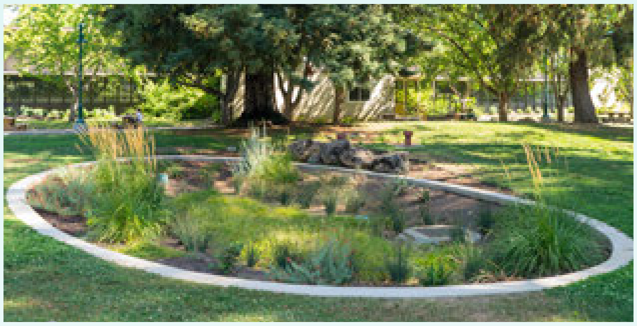


Figure IV–8. Use of hardier drought resistant plant species is appropriate for SMCs

Input from the School Community

To maximize the benefits from a capture project, teachers, parents, maintenance staff, and even students can provide unique insight and ideas related to how their school grounds could better serve their curriculum as well as their recreational, educational, and environmental needs.

In California's climate, plants located in SCMs may need seasonal irrigation during vegetation establishment—even native plants located in a bioretention planter or similar feature—especially when not protected by tree canopy cover. In regions of the state with hot summer months, new plantings are best done in the fall or early winter to provide plants time to establish root systems, which is critical for drought tolerance. Most newly planted vegetation, even native species, benefit from watering during the first several months as they become established. Figure IV-9 shows some varieties of plants used in bioretention planters in Sacramento.

Figure IV–9. Left to right: Feather Reed Grass, Sticky Monkey Flower, Douglas Iris, Deer Grass, Blue-Eyed Grass, Spreading Rush, California Coffee Berry, Sawleaf Zelkova (Images acquired through Wikimedia Commons, https://commons.wikimedia.org; Sticky Monkey Flower, Mimulus aurantiacus: Image by Curtis Clark, Creative Commons Attribution-Share Alike 2.5 Generic, Douglas Iris: Image by Curtis Clark, Creative Commons Attribution-Share Alike 2.5 Generic)

IV. Planning and Design

Planning and Design Steps

Planning and design activities are essential to implementing a project that meets its intended objectives and is sensitive to cost and other feasibility constraints. The following activities should be integrated into the planning activities for any project adding or replacing impervious surfaces. They can also be useful in planning stand-alone projects for SCM implementation. Planning and design activities can be categorized as follows:

- Step 1—Conduct a site reconnaisance
- Step 2—Establish the Project Team
- Step 3—Identify Relevant Regulations and Programs
- Step 4—Develop the Project Concept
- Step 5—Plan the Implementation Components
- Step 6—Finalize the Design and Cost Estimate

The Guidance for Design and Construction of Vegetated Low Impact Development Projects (Figure IV-10), developed as part of the State Water Board's DROPS effort, provides many additional planning and design suggestions that supplement the information provided in this document.

Figure IV–10. Guidance for Design and Construction of Vegetated Low Impact Development Projects (CWH 2016)

Step 1: Conduct a Site Reconnaisance

Identify existing issues at the site, such as flooding that needs to be addressed, natural play and learning areas that are desired, and increased shade and greening. From this information, identify the project's objectives, which should be multifaceted to maximize the potential benefits, as described in Section II.

Step 2: Establish a Project Team

A good project starts with a good team, and a good team can assist in identifying and understanding critical planning and design factors. When soliciting an architectural and engineering firm, consider requesting particular expertise as identified in the DROPS Guidance (Appendix B). The project team should consist of appropriate personnel. Design staff, maintenance staff, teachers, and parents can serve as key proponents and provide brainstorming ideas (Figure IV-11). This will ensure that district and school site needs and requirements (budgetary limits, ADA access, fire lanes, etc.) will be addressed. Plumbing and landscape staff should also be consulted regularly to ensure they will approve any proposed additions or modifications that will require code approvals as well as maintenance.

Figure IV-11—Teachers and parents participated in a brainstorming event for the Robert Lewis Stevenson Elementary School stormwater schoolyard project in San Francisco SFPUC

Step 3: Identify Relevant Regulations and Programs

Identify regulatory requirements that may need to be addressed, including:

California Environmental Quality Act (CEQA): All projects in California that propose new development and structures are subject to the requirement to prepare an environmental impact report (EIR) before construction of projects. A certified environmental planner will review the project and determine EIR requirements. The California Natural Resources Agency provides introductory material for understanding basic guidelines and procedures related to CEQA requirements.

Capital Improvement Programs: Runoff prevention and capture practices can easily be incorporated into capital improvement program (CIP) projects, as most CIP projects will involve site grading and runoff management. Verify that drainage for school CIP projects incorporate runoff prevention and capture practices covered in this document.

IV. Planning and Design

Construction General Permit (CGP): For any construction project that disturbs more than one acre of soil, coverage under the CGP from the State Water Board is required to mitigate the effects of construction site runoff (State Water Board 2018b). To fulfill the requirements, a SWPPP must be developed that outlines measures to prevent debris, trash, and sediment from entering runoff. The plan must be written by a Qualified SWPPP Developer (QSD). The CGP also contains post-construction runoff management requirements, which can be addressed by use of SCMs that promote infiltration.

CWA Sections 401 and CA Porter Cologne Water Quality Control Act: CWA Section 401 and California's Porter Cologne Act protect wetlands from development. The State Water Board's CWA Section 401 program regulates discharges of fill and dredged material to all waters of the state (including wetlands) through protection of special-status species and control of hydromodification impacts. Actively managed runoff detention facilities are generally not subject to these development and permitting requirements, as they are not naturally-occurring wetlands. Active management must include record keeping that details regular trash removal, inspections, erosion control, and mowing and weeding. For sites that contain endangered species, much stricter management and protection requirements apply (WRA 2015).

DSA approval: Plans meeting certain minimum thresholds for scope and cost must also be reviewed by DSA. Section IX summarizes many regulatory codes that relate to runoff capture practices. Examples of features requiring approval are tabulated below.

CCR Title 24 Part 2 (CBC) §1803A.1	Water retention basins and/or vaults anywhere on a school site that will regenerate (percolate) localized ground water will require DSA approval. A geotechnical report from a CA-registered geotechnical engineer evaluating the effect of the water level on the soil bearing and lateral resisting capacity of any nearby structures will be required.
	Any basin or vault located close to an existing structure will require a geotechnical report and DSA approval. The bearing capacity of the structure's foundations may be affected, and open trenches may result in settlement of the structure during installation.
CAC Part 1 §4-302 CCR Title 24 Part 2 (CBC) §1601A, 1604A, & 1803A.1	Basins, vaults, culverts, and porous pavement must be designed to support heavy vehicle traffic (fire-fighting trucks and equipment) and will require DSA approval. A geotechnical report may be required to determine the effect on bearing .
	Surface structural elements, including but not limited to site walls, fences, covered walkways, pedestrian bridges, solar or shade structures, covered parking, retaining walls, planters, and retention ponds will require DSA approval.
CAC Part 1 §4-302 & §4-314	New and/or rerouted plumbing and electrical utility lines and systems will require DSA approval.
EDC § 17280 – 17317 CCR Title 24, Part 1 (CAC) (Chapter 4, Groups 1 - 3)	Plans, specifications, and/or calculations shall be prepared by CA-licensed architects or professional engineers registered for their scope of work and will require approval by DSA prior to contracts being let to contractors and the start of any construction. Project inspection and material testing will be required during construction.

CCR: CA Code of Regulations; CBC: CA Building Code; CAC: CA Administrative Code; EDC: Education Code;

Incentive Programs and Grants: Runoff capture projects can often qualify for funding through grants, loans, or regional collaboration. Refer to Section VII (Costs and Funding) for more detailed descriptions of these opportunities. Runoff capture projects can also be used to develop education programs on sustainability, such as the SWPPP internship program implemented by several school districts in southern California. Informing teachers, principals, and even parents and guardians of plans for runoff capture may help create incentives.

Monitoring and reporting requirements: Any of the above regulations may require monitoring and/or reporting. In addition, monitoring or reporting may be required by Sections 13267 or 13383 of the CA water code, which allows the State Water Board and Regional Water Boards to establish monitoring, inspection, entry, reporting, and recordkeeping requirements. Check with the State Water Board and Regional Water Boards to inquire if monitoring would be required. The State Water Board hosts the Stormwater Multiple Application and Report Tracking System (SMARTS), a platform for submitting and storing relevant runoff monitoring and reporting information.

National Pollutant Discharge Elimination System (NPDES) Permits: Some locations may be subject to NPDES permits for MS4s. Such permits could be applicable through local drainage ordinances or a statewide MS4 permit. These permits contain SCM performance criteria and monitoring and reporting requirements.

Other Requirements: Additional requirements could include zone variances and local drainage ordinances (See Title 5 §53097).

Step 4: Develop the Project Concept

Step 4a: Create a Preliminary Site Plan

Using input from the stakeholders engagement (Step 1), identify general ideas of what project elements are needed and where they can be placed. This involves determining where small-scale landscape and SCM features can be used to acheive the multiple objectives and benefits identified in Step 1.

Step 4b: Estimate Existing Metrics

Estimate the runoff volumes and flow rates that will be generated from the post-construction project site and identify the pollutants of concern. Various methods and models for estimating runoff volumes and flow rates are available as discussed in Step 4e and Appendix B. Types and concentrations of pollutants can be determined using the resources described previously in Pollutants of Concern.

Step 4c: Select SCM Type(s)

Select the SCM type(s) based on the the requirements from Step 3, the estimated metrics from Step 4, the on-site soil characteristics, available space, slope, and other considerations that are described in the SCM factsheets (Appendix A).

Step 4d: Conduct Preliminary Sizing

Determine a rough estimate of the dimensions of the selected SCMs. This is needed to perform subsequent planning tasks such as permitting, site layout, and traffic routing. The practices presented in SCM Sizing Methods can be used for preliminary sizing, but with a less rigorous estimation of the variables.

Site selection should consider the area available, funding constraints, and site hydrology. Constraints such as endangered species habitat, protected vegetation, archaeological resources, and maintenance and access needs and concerns should be assessed during site selection. Low areas, oddly configured areas, or otherwise unbuildable locations might present opportunities for siting SCMs.

This step, like many, may be an iterative process. If appropriate space is not available, grading or facility location adjustments can be used to increase sustainability.

Step 4e: Estimate the Expected Performance

Quantify the expected performance of the SCM in terms of volume and/or pollutants. Performance can be established as:

- Percent retained, for example:
  - 90% volume retained annually
  - 90% total suspended solids (TSS) retained annually
- Difference retained, for example:
  - 9 acre-feet of runoff retained annually
  - 1,200 kg of TSS reduced annually
- Amount discharged, for example:
  - 1 acre-foot of runoff discharged annually
  - 100 kg of TSS discharged annually

There are many models and tools, as well as simple hand calculation methods, that can be used to estimate volume and pollutant reductions and discharges based on specified SCM design elements. Some may have been used during preliminary sizing. Some tools evaluate volume reduction performance, such as the USEPA National Stormwater Calculator (Figure IV-12) and the CA Phase II LID Sizing Tool (Figure IV-13). These volume reductions can be combined with water quality treatment performance data from local municipalities or the International Stormwater BMP Database to estimate pollutant load reductions. These tools provide estimations for individual catchments. Separate simulations are required to evaluate overall performance for a particular site or region consisting of many catchments. Other models such as GreenPlanIT or the Tool to Estimate Load Reductions (TELR) are available for regional planning and include pollutant load reduction estimates.

Step 4f: Compare the Expected Performance to the Desired Performance

Comparing expected performance to the desired performance helps check whether the conceptual design of the SCM meets the target objectives. The desired performance may come from NPDES permit criteria or other regulations mentioned in the Step 3. If the expected performance does not meet the desired performance, the SCM may need to be resized, or additional or alternative SCMs may be needed.

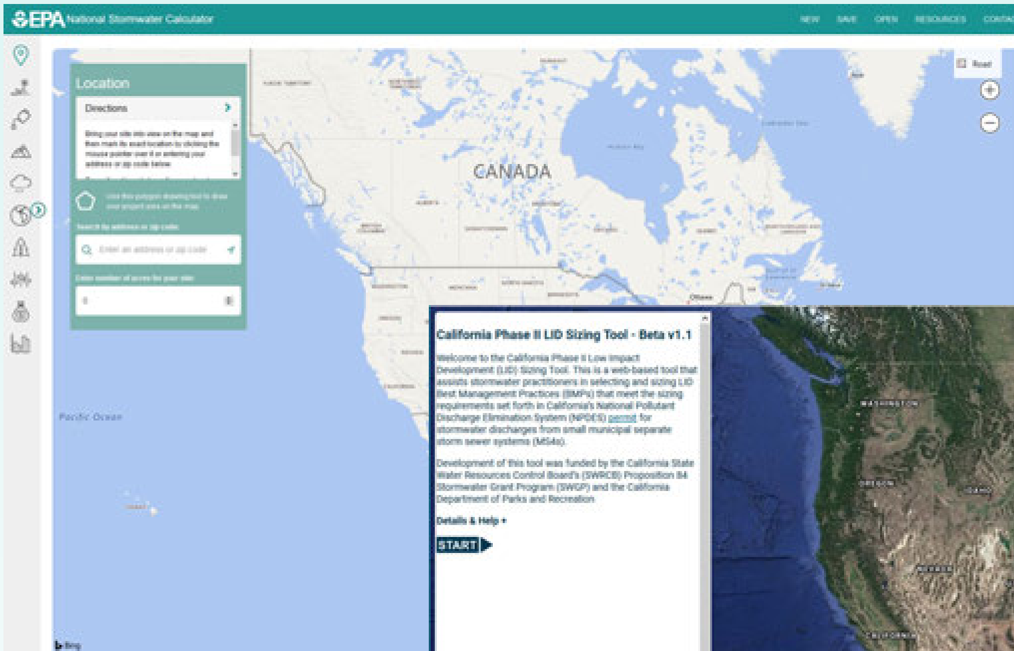


Figure IV-12— USEPA National Stormwater Calculator

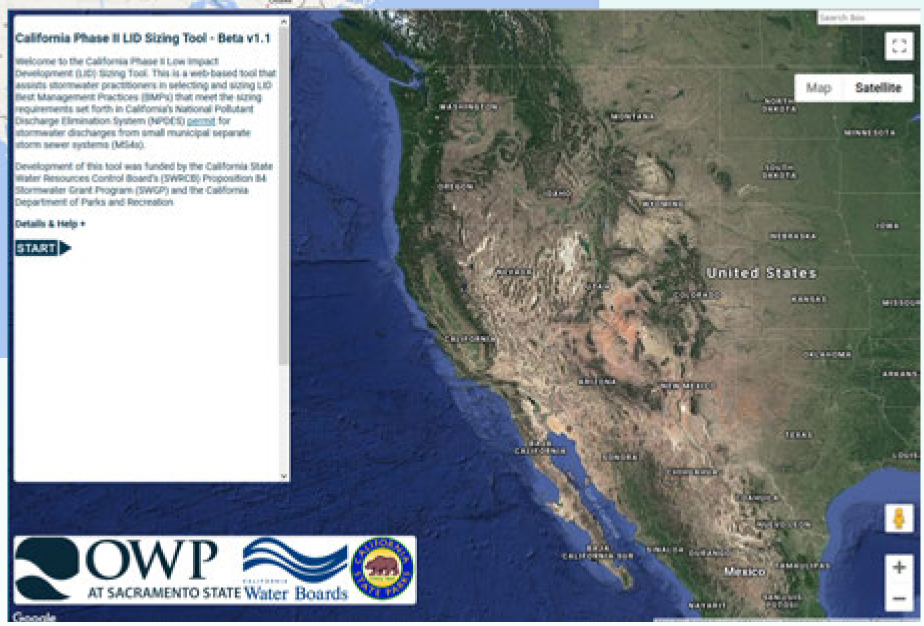


Figure IV-13— CA Phase II LID Sizing Tool

Step 4g: Identify Long-Term Maintenance Needs

Determine O&M activities that will be required after construction and throughout the expected life of the SCMs. "Design with maintenance in mind" is a valuable strategy for managing costs and feasibility of a project. Fortunately, guidance already exists. For instance, DeepRoot Green Infrastructure posted an insightful blog breaking down maintenance aspects to be considered during project design and planning (DeepRoot 2018). In many cases, incorporating features that reduce long-term maintenance efforts and costs may be well worth any additional capital cost investments.

Maintenance staff should be engaged early in the planning and design process to incorporate their insight and experience as well as address any concerns regarding potential changes in job descriptions or expectations. See Section VI (Maintenance) for details.

If maintenance will be handled by an external entity, maintenance agreements should be developed. An O&M plan should be created to document responsibilities, activities, and schedules, and then included in the maintenance agreement. See Section VI (Maintenance) for information regarding maintenance activities, including a template for an O&M plan.

Design with maintenance in mind

Maintenance Considerations
Funding: Establish a maintenance budget specific to the selected SCMs. Section VII (Costs and Funding) provides resources for estimating these costs and acquiring funding.
Equipment: Identify what equipment is needed and available for O&M. Examples include commonly-owned equipment (leaf blowers and power washers) and specialty items (weed burners or vacuum sweepers). Exclude SCMs for which proper maintenance equipment is not or will not be available. Design SCM elements to "fit" the equipment. For example, curb cut openings should be sized to fit a shovel or allow street sweeping.
Materials: Verify that materials needed for maintenance will be available. Example materials include familiar supplies (bark or mulch) or specialty materials (bioretention soil or pervious concrete). Ensure there will be means for maintaining an inventory and condition schedule, as well as communicating where equipment can be procured and accessed.
Appropriate Staff: Determine which personnel have the authority and capability to maintain the SCMs as needed and whether training or addition of staff is needed.
Aesthetic vs Function: Establish the desired aesthetics and relevant level of effort and maintenance required to maintain that aesthetic.

(adapted from DeepRoot 2018)

Step 4h: Document Final Concept

Documentation of the final concept facilitates its use to gather input from stakeholders, develop cost estimates, and inform final design and funding. The document can also be offered to teachers, providing them a resource for learning opportunities.

Developing the SCM project concept is an iterative process. As information is developed and evaluated throughout the planning period, the concept may be adjusted to meet project constraints. Advantages and constraints that were identified to develop the final concept should be recorded, along with preliminary details and schematics with respect to SCM type, siting, dimensions, and infrastructure proximity or tie-ins. Share the conceptual plan with the stakeholders identified in Step 1 for potential additional ideas or limitations.

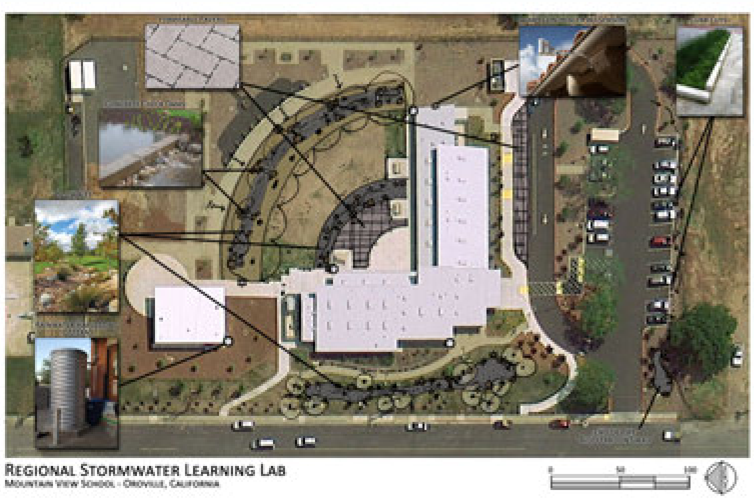


Figure IV–14. Example of a conceptual plan for SCM installations at a school (provided by DROPS program)

Step 5: Plan the Implementation Components

Step 5a: Develop a Vegetation Plan

A number of runoff capture practices (e.g., tree planting, bioswales, bioretention planters, and wetlands) include vegetation. Maintaining vegetation health throughout the life of the SCM is essential for adequate performance. Upfront planning will identify resources needed to successfully establish vegetation and long-term maintenance. This includes staff responsible for and committed to the establishment and maintenance of vegetation, and access to water (and nutrients, if needed). If possible, allow for plant establishment prior to letting children access areas where there is significant investment in plant materials. Council for Watershed Health (CWH) DROPS Guidance provides good tips for using appropriate plants and landscaping materials and determining an irrigation approach. The county of San Diego's LID Handbook also provides good information

Step 5b: Evaluate Pedestrian and Traffic Routing

Implementing SCM projects may disrupt pedestrian traffic patterns if the footprint impinges on walkways, bike lanes, roads, or other transportation corridors on the school campus. Therefore, site SCMs to ensure that foot, bike, and car traffic patterns can be maintained after construction. This could involve rerouting traffic or development of alternative routes to maintain traffic flow. If porous pavement is an element of a proposed SCM, the porous pavement needs to be constructed to manage the vehicle traffic loads. Avoid designs that re-route foot traffic and try to keep existing pathways in place. Pathways that are replaced by vegetation may continue to be used, risking damage to the new installations. CWH's DROPS Guidance provides further insight regarding pedestrian circulation and use (Figure IV-15).

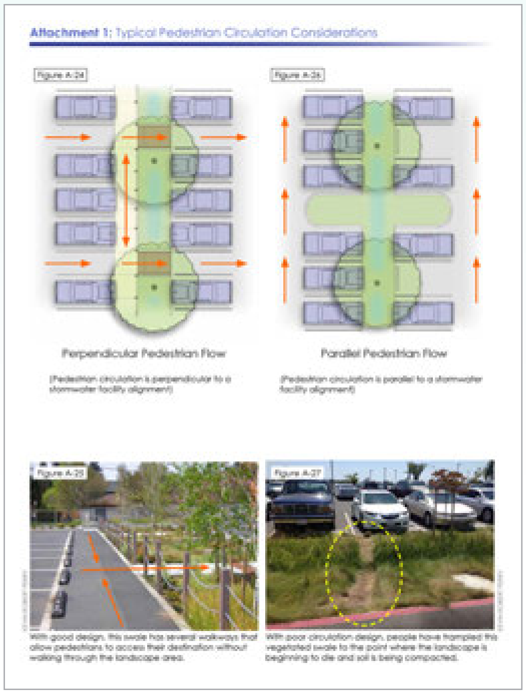


Figure IV–15. Pedestrian circulation considerations from DROPS (CWH 2016)

Step 5c: Coordinate Construction Staging

When scheduling construction activities, consider both the school's daily and seasonal schedules. It may be less disruptive if construction activities occur in the summer or at other times when school is not in session. Also, if the project involves excavations (e.g., detention basins or bioretention planters), work will be more difficult in the rainy season, when run-on to the construction site must be managed. If the SCM involves planting of vegetation, the planting schedule should consider weather to ensure that plants have an optimal chance for establishing healthy growth, as discussed previously in Step 5a.

Step 5d: Develop a Plan for Waste Disposal

Installation and maintenance of some SCMs may generate waste materials that require disposal. For example, plant material may need to be periodically removed from some SCMs, such as biostrips, bioswales, and bioretention planters. Additionally, dry wells, infiltration basins, and detention basins must be periodically cleaned of soils and settled solids. Grates and drains must be cleaned of debris and material that can impact optimum performance. These waste materials will generally be inert and non-hazardous, but plans should be put in place to characterize any waste streams that could possibly be defined as hazardous under California regulations. Hazardous wastes require more stringent storage and disposal procedures. A plan for waste disposal should be put in place before SCM construction.

Step 5e: Develop a Monitoring Plan

Once the SCM is constructed, monitoring (if required) may be performed to assess its performance. Monitoring may also help demonstrate compliance with regulatory requirements, if applicable (see monitoring and reporting requirements in the Identify Relevant Regulations and Programs step). This monitoring can take the form of visual inspections, runoff sampling, flow measurements, or water quality analysis and evaluation.

Step 5f: Estimate Costs and Secure Funding

Estimate the costs and identify sources of funding for initial planning, design, and construction activities as well as for future O&M. Section VII (Costs and Funding) describes several resources for estimating SCM capital and O&M costs as well as funding sources.

Step 5g: Document the Implementation Details

For simpler projects with fewer stakeholders and planning tasks, the activities discussed above can be documented through informal communication among the project team. For more complex projects, it may be useful to prepare a written document describing all activities and selected strategies. This can be used to inform stakeholders and allow them to understand the project elements and decision process, as well as provide input.

Step 6: Finalize the Design and Cost Estimate

Step 6a: Refine and Finalize the Design

Refine the design plans and specifications. A few versions of the plans and specifications should be developed prior to finalization, with each progressively more detailed and accurate. The conceptual plan conceived during the Develop the Project Concept step can be considered a preliminary draft design, as it includes simple elements such as what SCMs are to be installed, where they are to be located, and their approximate dimensions. Multiple drafts may be needed before finalizing the design. Each draft should incorporate and adjust the components considered during the implementation planning step, namely the vegetation plan, traffic routing, construction staging, and waste disposal.

The DROPS guidance (CWH 2016) serves as an excellent resource for design, particularly for ensuring that runoff can enter and exit the project, protecting adjacent structures, using ponding depth and check dams to enhance infiltration, and avoiding sediment and erosion problems. It also has extensive appendices with pictures of good design practices, as well as poorly implemented SCMs. The DROPS guidance includes a discussion on sizing aspects of design, focusing on a simple method, although there are other methods that may reduce the required SCM size and, therefore, costs. To supplement the DROPS guidance, common design (sizing) methods are presented in SCM Sizing Methods (Appendix B).

SCM design tips from DROPS (CWH 2016)

Design Topics
Ensure runoff can enter and exit the project
Protect adjacent structures from runoff intrusion
Use ponding depth and check dams to enhance infiltration
Avoid sediment and erosion problems

Step 6b: Update the Cost Estimate

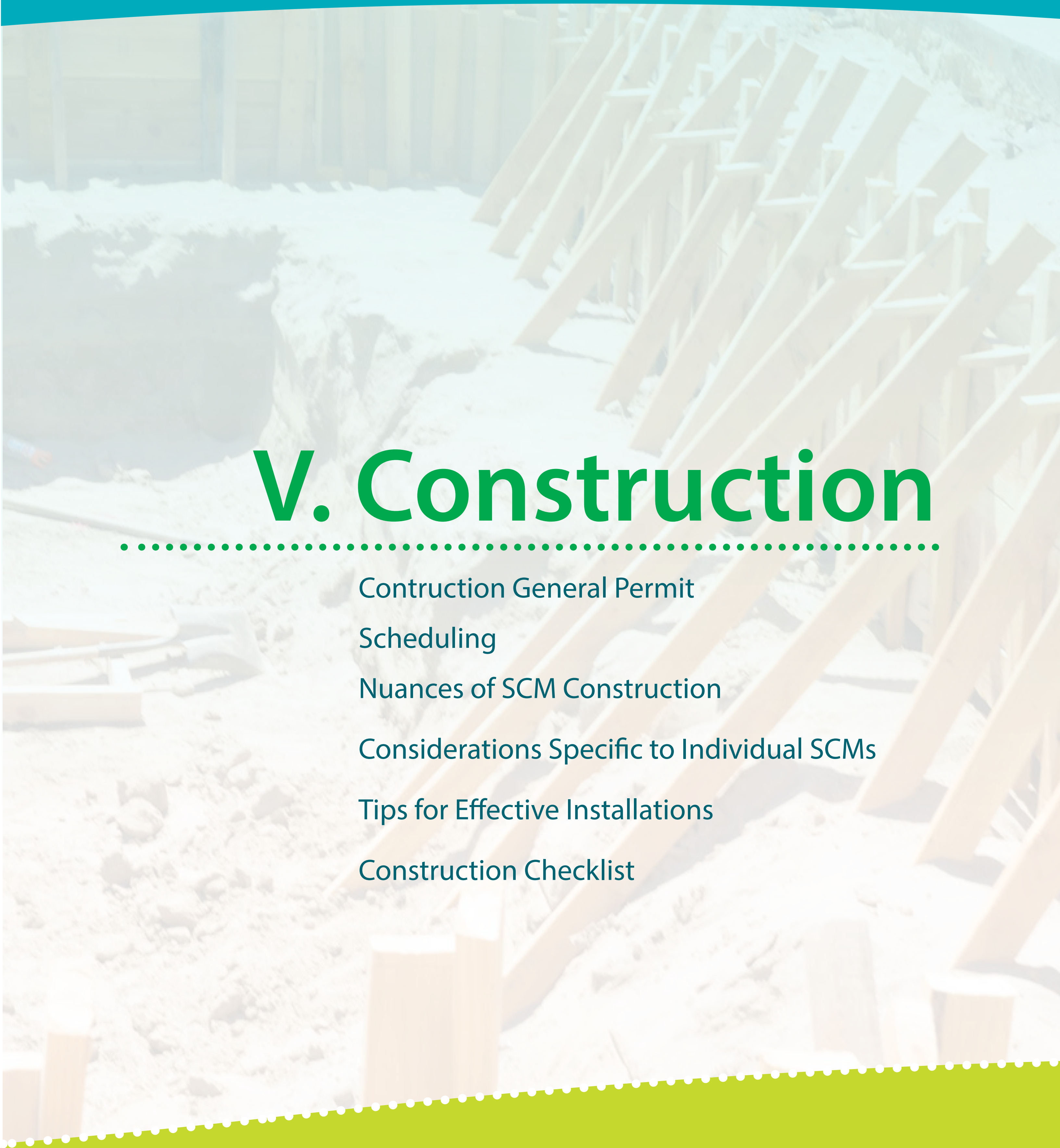
Update the cost estimate to reflect the final design plans and specifications. Refer to Section VII (Costs and Funding) for relevant resources.

Planning and design checklist

The table below can be used to ensure that appropriate objectives of each planning and design step have been addressed.

Step	Question	Y/N
1	Has a site reconnaisance been conducted to identify the site needs, project objectives, and ways multiple benefits can be acheived?	
2	Has the project team been established, with members having appropriate knowledge of and experience with the project objectives?	
3	Have relevant regulations and programs that may limit or support various project elements been identified?	
4a	Has a preliminary site plan been developed that identifies where improvments are needed and where infrastructure can be placed to meet the project objectives?	
4b	Have the pre-project metrics been estimated, including runoff volumes, flow rates, and pollutant loads?	
4c	Have SCMs and design strategies been selected based on the relevant regulations and programs, existing metrics, on-site soils, available space, slope, and other considerations?	
4d	Have the SCMs been sized appropriately based on relevant regulations, available space, funding constraints, site hydrology, etc?	
4e	Has the expected performance for the project been estimated in terms of a percent retained, a difference retained, or an amount discharged?	
4f	Does the expected performance meet the desired performance?	
4g	Have long-term maintenance needs been identified, including maintenance staff concerns, specialty equipment needs, funding, scheduling, and an O&M plan?	
4h	Has the conceptual design been documented and shared with relevant stakeholders?	
5a	Has a vegetation plan been developed, with selection of plants that are drought and inundation tolerant, along with an irrigation plan for vegetation establishment and long-term maintenance?	
5b	Has pedestrian and traffic routing been evaluated to ensure patterns and flow will meet required needs after construction?	
5c	Has a general construction schedule been developed, taking into consideration school functions and how seasons impact certain construction aspects (e.g., avoid rainy season for deep excavations, avoid planting in hot weather)?	
5d	Has a plan for disposal of waste materials such as excavated soils, vegetation, and underground infrastructure components been developed?	
5e	Has the project team determined if monitoring is required for the project, and if so has a monitoring plan been developed?	
5f	Have costs and funding sources for planning, design, construction activities, and future O&M been estimated and identified?	
5g	Have the implementation details addressing all items of this checklist been documented for future reference?	
6a	Has the design been refined and finalized to meet the project objectives and constraints?	
6b	Has the cost estimate been updated to reflect the final design plans and specifications?	

**Adapted from* DROPS Guidance (CWH 2016, Appendix B)



V. Construction

V. Construction

Construction General Permit

Construction activities that disturb a specified area of land (i.e., clearing, grading, excavating, and stockpiling—including installation of SCMs) are subject to requirements in the California CGP. The requirements include development of a SWPPP. The SWPPP must be created by a QSD and implemented by a qualified SWPPP practitioner (QSP). The SWPPP must include potential pollutant sources; pollution prevention/good housekeeping practices; construction BMPs (e.g., swaddles, drain inlet covers); inspections, maintenance, and repair of pollution prevention equipment; spill response; and other elements.

Scheduling

As cornerstones of communities, schools are busy places that often host a variety of activities during non-classroom hours, ranging from after-school camps and scout meetings to parent-teacher conferences, festivals, and recreational sports. Scheduling when and where various construction activities can occur to minimize activity disruptions is challenging. For some schools, summer may be an ideal time for construction, although the long, dry summers typical of much of California can be difficult for plant establishment, even if irrigation is provided. So, the sequencing and staging of construction activities should be considered during the planning stages of the project and confirmed during design and at the start of construction.

Nuances of SCM Construction

Compared to conventional drainage infrastructure, the runoff management practices featured in this document focus on capture, retention, and treatment of small storms. This is a relatively new concept to many contractors and developers. The Central Coast LID Initiative developed a useful and concise Technical Assistance Memo (TAM) that informs practitioners on the nuances of LID implementation, such as avoiding compaction of soils to allow runoff to infiltrate (Figures V-1 and V-2). The Water Environment Federation's National Career Infrastructure Certification Program also provides training on the special details needed for green infrastructure installations.

Figure V–1. Keep heavy equipment off areas intended for infiltration

Low Impact Development (LID) For Contractors and Developers

LIDI Technical Assistance Memo (TAM)

Low Impact Development, or LID, is required for many new and redevelopment projects, including public projects. It is an approach to managing stormwater by mimicking natural landscapes. LID integrates design features (e.g., specially designed landscapes, permeable hardscapes, and rainwater catchment systems) on-site to meet post-construction stormwater controls. In contrast to post-construction flood control infrastructure (e.g., vaults and detention ponds) LID focuses on infiltration of small storm events to meet water quality requirements for watershed protection and to support water supply objectives. Although projects with LID features may look like conventional development projects, there are key differences for contractors and developers to understand as part of bidding or cost estimating, construction, and maintenance. The goal of this TAM is to give contractors and developers who are new to LID pointers to help identify aspects of LID implementation that impact cost, affect project schedule, or require special construction procedures.

UNDERSTANDING PROJECT DESIGN

It is important to carefully review construction documents (CDs) and specifications for design elements, construction methods, special phasing, and new materials related to LID features that may impact implementation or cost. Subcontractors should also review CDs with this in mind. For public projects, contractors and subcontractors should attend the pre-bid meeting, which is an opportunity to obtain valuable information for bidding the LID features. Additional considerations to better understand the LID project include:

- LID features typically involve excavation. Ensure that potholing is included in the cost estimate where utilities are expected to be present.
- Account for protection of LID features from compaction as identified in CDs and specifications.
- Account for additional sediment and erosion control effort. LID features are designed to intercept stormwater and are often at low points. However, during construction stormwater should be diverted away from LID features until the site is stabilized.
- LID features often require special construction, such as deepened curbs that cannot be built as extruded.
- Verify that suppliers can meet the specifications for LID materials. Substitutions may be limited, or in some cases not allowed.

CONSTRUCTION
Sequencing and Schedule

- Understand the unique needs for construction sequencing of LID features. LID features need protection from compaction, erosion, sedimentation, and construction runoff. Plan to sequence construction of LID features for the least amount of conflict with other aspects of construction.
- Avoid excavation and other work in LID features during wet or saturated conditions.
- Consider lead times and associated submittals on specialized LID materials (e.g., impermeable liner, bioretention aggregate, bioretention soil mix, plants for ponded area of bioretention facility, mulch).

Source: Cannon

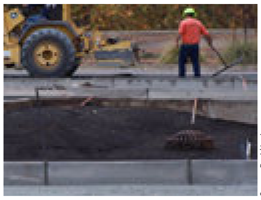
CONSTRUCTION
Excavation and Infrastructure

- Excavations for LID features may create utility conflicts. Pothole first. Is there still adequate cover? Are there conflicts? Do utilities need temporary relocation or protection from equipment and compaction?
- Provide clear signs/barriers to prevent entrance and compaction of LID features.
- Meet and walk the property with equipment operators regularly to clarify construction boundaries.
- Machinery performing excavation should be adjacent to, not inside of, the LID facility whenever possible.
- When machinery must operate in the LID facility due to size or location, consult the soils engineer for strategies to minimize compaction, and re-scarification requirements.
- Grading of LID features is non-traditional and assumptions and changes to grades shown on plans should not be made without consulting the designer. Ask questions if grading design is not clear.

LID For Contractors and Developers — page 2

Excavation and Infrastructure (continued)

- Curbs and gutters may have unique details for the purpose of directing stormwater to LID features. Don't overlook these details. Ask questions if a detail is unclear or not provided.
- Do you understand the functional intent of the LID feature? What is the stormwater ponding depth and where is the overflow location?
- Drainage overflow structures (e.g., catch basins and raised area drains), their locations in the facility, and inlet elevations are intentional for stormwater ponding. Do not make field adjustments to overflow structures; clarify the design intent if an elevation looks wrong.



Source: David Innis

- Understand where infiltration is desired and where it is not. Road base, utilities trenches, and building foundations must be protected as noted per plans and specifications. Deep curbs, underdrains, impermeable liners, and trench dams keep infiltration away from these undesired locations.
- Filter fabric is not recommended in LID infiltration features. It can clog with sediment and cause the system to fail. Do not substitute or install filter fabric without consulting the designer.
- When underdrains are used, their placement and the orientation of their pipe holes are intentional, and may vary for facilities on the same site. Underdrains at the lowest elevation of the LID facility drain the maximum amount of water. Underdrains installed at a higher elevation allow retention and infiltration of stormwater into underlying soils.

Technical Resources
More information, including standard details and technical specifications for LID design is available on LIDI's website at: **centralcoastlidi.org/technical**

Soil and Landscape

- Are plans and specifications clear on soil placement and compaction for LID features? Compaction for LID is not like traditional compaction. Systems are designed to infiltrate. Over compaction of underlying or engineered soils inhibits infiltration. Over-compacted soils must be rescarified to a depth identified by the soils engineer to return soils to their desired infiltration rates.
- Are plans and specifications clear on plant locations and spacing? Installation must accurately match landscape plans because special plants are selected to tolerate the ponding areas.
- The contractor should coordinate with the landscape contractor to ensure that final grades are maintained upon completion of plant and mulch installation.
- LID landscapes can receive erosive stormwater flows; inlets should be blocked or otherwise protected until plants establish enough to withstand stormwater flows. Look for direction in the plans and specifications.

Source: Cannon

VERIFICATION

- The Regional Water Board may require field verifications of LID features by the municipality or a third party during construction. Coordinate with the inspector at appropriate construction phases to ensure compliance and avoid re-excavation.
- Obtain approval for submittals/substitutions from the designer or owner's representative before ordering.

MAINTENANCE/WARRANTY

- LID features often require additional maintenance (e.g., sediment and debris removal from inlets and overflows, periodic vacuuming of void spaces within permeable hardscapes). Be sure to clarify what is required for projects that include a maintenance and/or warranty period.

Legal Disclaimer: This Technical Assistance Memo (TAM) is intended as guidance only and should not be used as a substitute for design and engineering. Applicants are responsible for compliance with all code and rule requirements whether or not described in this TAM.

Figure V–2. LID for Contractors and Developers Technical Assistance Memo (LIDI 2018)

Considerations Specific to Individual SCMs

The SCM factsheets in Appendix A note construction considerations specific to each SCM. Examples include:

- Following proper confined space entry practices
- Conducting leak detection
- Preventing sediment from entering SCM
- Scheduling vegetation establishment to minimize irrigation needs and plant loss/damage
- Mitigating plant damage
- Field verifying soil characteristics
- Following manufacturer guidelines

V. Construction

Pitfalls of SCM Construction

- **Installing overflow risers flush to the ground rather than raising them**
- **Swapping specified bioretention soil mix with a mix not designed for water quality treatment**
- **Allowing heavy equipment and compaction on areas intended for infiltration**
- **Actual on-site soils having lower infiltration potential than intended design**
- **Sloping curb cuts away from SCMs**
- **Planting when weather is too hot**

Tips for Effective Installations

SCM installation activities include those typical for many construction projects: staging, surface preparation, excavation, infrastructure placement, regrading, planting, and vegetation. But, designs may differ slightly from those that contractors typically follow. The DROPS guidance effort provides many details for effective installations:

- Reviewing the project design with the construction team
- Preparing for different construction techniques and material requirements
- Ensuring that proper protections are in place and checking the native soil conditions
- Excavating sites, placing materials, and setting elevations

Construction Checklist

Items to be checked to help support successful SCM construction are tabulated below

#	Question	Y/N
1	Has a SWPPP been developed by a QSD? Does it include measures and practices intended to address requirements of the CGP?	
2	Is the contractor prepared to implement devices and practices outlined in the SWPPP?	
3	Has a project team member been delegated to provide continuity and support during construction?	
4	Has the project team met with the contractor and reviewed the project, including the nuances of SCM construction and considerations specific to each SCM?	
5	Is the correct planting, bioretention, media mix, or other fill material being used and placed correctly?	
6	Is the infrastructure being installed at the proper depths and alignment, including underdrains, raised inlets, and conveyance piping?	
7	Have all final grades all been checked, reviewed, and set correctly?	
8	Are the materials, systems, and practices needed for vegetation establishment in place, particularly plant placements, irrigation schedule, and maintenance plans?	
9	Has an O&M plan been developed and reviewed with maintenance staff, with their concerns properly addressed?	

VI. Maintenance

The Value of Maintenance

Types of Maintenance Activities

Engaging Maintenance Staff

Developing an O&M Plan

VI. Maintenance

The Value of Maintenance

SCMs require investments in planning, design, and construction. Maintenance can maximize these investments. Installations have an effective life of 20 or more years, if properly maintained.

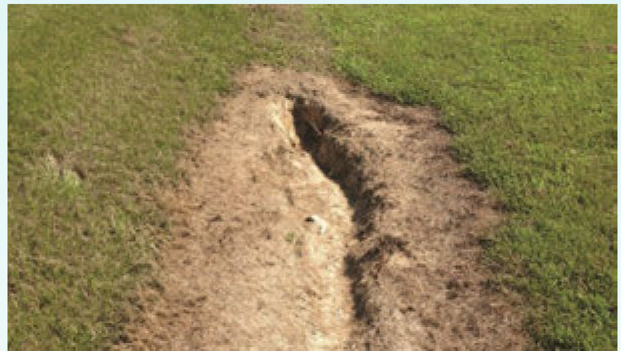
Most maintenance activities involve simple inspections or preventive measures, with occasional corrective actions, to reduce the risk of premature failures. The consequences of ineffective maintenance or neglect can include clogging or short circuiting of the systems, often well before they reach their intended effective life. Engaging with maintenance crews during planning, design, and construction and developing an O&M plan can ensure that maintenance activities and any follow-up actions are completed.

Types of Maintenance Activities

Typical maintenance activities include those listed below. Refer to the O&M template for descriptions of the activities and the SCMs they apply to.

- Inspect adjacent landscaping and pavement
- Inspect for erosion
- Inspect inlet conveyance infrastructure
- Inspect irrigation system
- Inspect outlet conveyance infrastructure
- Inspect overflow system
- Inspect for permanent pool
- Inspect for ponding
- Inspect porous/pervious pavement structure
- Inspect pumps
- Inspect SCM structure
- Inspect vegetative health
- Clean/vactor sediment
- Perform integrated pest management
- Prune vegetation
- Remove accumulated debris
- Replace fill material
- Replace mulch
- Weed

Flooding Due to Broken Sprinkler Head



Erosion in Vegetated Swale (EPA 2016)

Porous/Pervious Pavement in Need of Maintenance vs. Clean

Leaves Clogging Inlet Pipe

Leaf Debris Covering Overflow

Sand and Sediment Entering SCM Drainage Area

Figure VI–1. Examples of SCM maintenance needs

VI. Maintenance

Engaging Maintenance Staff

Maintenance staff should be engaged during planning and design activities to incorporate their insights and experiences in easing future maintenance, as well as to address concerns regarding any changes to job descriptions or expectations. Most maintenance activities are straight-forward and similar to those typical for landscaped areas, but maintenance staff may have concerns about issues like:

- Extra training required for integrated pest management, porous pavement cleaning, and other activities
- More weeding (especially during vegetation establishment) due to restrictions on herbicide use
- Seasonal hand pruning instead of using powered shears
- Concerns of exposure to potential pollutants

Throughout SCM planning, design, and construction, project planners must engage maintenance crews, and perhaps any associated unions, to discuss and resolve potential concerns, including changes to job descriptions.

In addition to obtaining maintenance staff insight and addressing any concerns, training crews on the particulars of SCM maintenance can be valuable. The lack of proper and regular maintenance can result in loss of performance and aesthetics, and ultimately expensive repairs. For example, tasks such as weeding and irrigating can often be postponed or forgotten, resulting in the need to replace vegetation. Purchasing plants, directing repairs, and conducting mitigation can be costly. A good training program for maintenance of green infrastructure is available from the **Water Environment Federation's National Green Infrastructure Certification Program** (NGICP).

Developing an O&M Plan

O&M plans must describe the SCMs to be maintained, specific maintenance activities and schedules, training, recordkeeping, and safety considerations.

The State Water Board website offers an [O&M plan template] with standard language. Recommended activities, including the frequency for each activity, are provided for common SCMs. Any SCMs that are not applicable can simply be deleted. The template uses a color highlighting system to indicate fields where information needs to be added or deleted or to give other instructions.

Inspection form templates are provided for each SCM as attachments to the O&M plan template. The template also allows for attaching vegetation plans, preferred species lists, and/or material specifications used for SCM design and construction. The intent of attaching this information is to provide a starting point for making decisions regarding what is an intended plant versus a weed, and what type of fill material could be used for replacements, if needed.

Example of maintenance frequency table for a specific SCM

Frequency	Activity
Monthly	Inspect Inlet Conveyance Infrastructure[1]
Semi-Annually	Inspect Adjacent Landscaping and Pavement
	Inspect Outlet Conveyance Infrastructure
	Clean/Vactor Sediment
	Remove Accumulated Debris
Annually	Inspect SCM Structure

[1] Inspect monthly during leaf fall season and once outside of leaf fall season

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VII. Costs and Funding

VII. Costs and Funding

Costs

While runoff prevention and capture practices have numerous benefits, there is a monetary expense associated with planning, design, construction, and O&M. These costs vary according to region, types of practices, design features, and industry demand.

Balancing Capital and Maintenance Expenses

The "design with maintenance in mind" concept presented in Section IV (Planning and Design) can help manage the costs of O&M activities during the planning and design stages. Project details should be evaluated in the interest of minimizing maintenance and repair costs. Given the ongoing limitations of funding for schools, investing in higher, upfront costs for more sustainable capital infrastructure and features that reduce the maintenance burden may be more cost-effective over the life of the SCM.

Cost-Benefit Considerations

The SCMs presented in this document, as a subset of green infrastructure practices, are often identified as cost-effective in comparison to traditional gray infrastructure alternatives. A number of studies comparing the costs of green and gray infrastructure are tallied in USEPA's Green Infrastructure Cost-Benefit Resources. However, evaluating cost alone does not fully represent economic feasibility or potential for a project. Cost analyses alone "… ignore the differences in performance between green infrastructure and gray infrastructure. As a result, they provide an incomplete basis for decision-making," according to the USEPA (2018a). As an alternative, cost-benefit analysis "…provides a more complete basis for decision-making. It considers costs as well as environmental, social, and public health outcomes of alternative management approaches. The result is more complete information on the benefits associated with different stormwater control options." (USEPA 2018). The webpage above cites and describes cost-benefit studies, as well as tools for gathering information to initiate conversations with stakeholders regarding the benefits and costs of green infrastructure, including SCMs.

Cost-benefit analysis "…provides a more complete basis for decision-making. It considers costs as well as environmental, social, and public health outcomes of alternative management approaches. The result is more complete information on the benefits associated with different stormwater control options." (USEPA 2018)

Another forthcoming resource for cost-benefit analysis is the Water Research Foundation's Community Enabled Lifecycle Analysis of Stormwater Infrastructure Costs (CLASIC). This project is currently developing a life-cycle analysis framework and publically accessible tool to assist in selection of green and gray infrastructure.

Cost Resources

Summaries of costs for various runoff projects are well documented, although local social, economic, political, and other conditions will drive actual contracted rates. In addition, project scale can impact costs. For example, implementing projects at many schools within a district can have an economy of scale benefit.

Some resources include CASQA's New Development and Redevelopment BMP Handbook, which provides capital and O&M costs for many SCMs. Literature on the cost of runoff capture practices thoughout the U.S. are provided in Appendix C.

The best resource may be local municipalities that are subject to NPDES permits and have likely implemented similar projects. Permittees within the vicinity of schools and school districts can be identified through the CA Phase II LID Sizing Tool. Other resources include cost books and online data centers that provide line-item cost estimates. Examples include RSMeans and Sierra West Group, the latter of which is used by the Office of Public School Construction to verify costs for their state-wide grant program, which funds new construction and modernization (but not necessarily stormwater features—see the funding discussion later in this section). Such materials are updated annually or every few years.

In 2019, the Sacramento State Environmental Finance Center (EFC) will begin hosting a stormwater cost estimating tool, developed using existing literature and data, along with statewide surveys of capital and O&M costs for green and gray infrastructure. The tool will also provide suggested methods for best practices in stormwater management accounting.

Tips for Estimating Costs

- A design engineer typically develops a cost estimate based on the quantities specified in the final plans and local pricing, so having the project design team on board early is helpful for cost planning.
- Resources such as costing books and on-line data centers can help estimate line-item cost estimates. Such materials are updated annually or every few years. Searching "construction cost estimate resources" through an internet browser will provide multiple such projects. Examples include RSMeans and Sierra West Group.
- Estimates will need to include a contingency amount intended to account for unknown occurrences, such as increased labor rates, material expenses, or unexpected field conditions requiring design alternations.
- Design with maintenance in mind to balance capital and long-term maintenance costs. In many cases, incorporating features that reduce long-term maintenance efforts and costs may be well worth additional capital cost investments.

VII. Costs and Funding

Funding

Grants and Loans

There are a number of federal, state, and local grants and loans available for SCM projects, some directly targeting stormwater management practices and green infrastructure and others encouraging one or multiple goals for ecosystem protection, air quality, water supply, flood control, and community enhancement.

The State Water Board's **Stormwater Grant Program** promotes the beneficial use of stormwater and dry weather runoff through multiple-benefit projects. Runoff capture projects must be part of a **regional stormwater resource plan** (SWRP) to be eligible for this funding. The Board's **Division of Financial Assistance** (DFA) administers these and several other grant and loan programs.

DWR's **Integrated Regional Water Management (IRWM) Grant program** offers grants for planning and implementation of projects developed in collaboration with other projects and programs related to water resources in a region. Projects that support disadvantaged communities are highly encouraged. To receive funds, schools can collaborate with their regional IRWM group and municipalities to develop multi-benefit projects.

The California Natural Resources Agency's **Urban Greening Grant Program** also provides opportunities for funding runoff capture projects. To be eligible, projects must achieve multiple benefits and be part of a SWRP.

The **Office of Public School Construction** administers a $42 billion voter-approved school facilities construction program. The funds support new school construction and modernization. In some cases, runoff management features may be eligible.

The USEPA hosts the **Water Finance Clearinghouse** with a repository of qualitative and quantitative information on funding water infrastructure in the U.S. Additionally, CASQA hosts the **Stormwater Funding Resource Portal** that includes current grant and loan funding opportunities.

Regional Collaboration

Because many municipalities in California are subject to NPDES permits for runoff discharges, they are motivated to collaborate with other regional entities in developing and implementing runoff capture projects. Section VIII (Regional Collaboration) of this document provides background on the types of projects schools might partner on as well as tips for optimizing school and school district benefits.

VIII. Regional Collaboration

Existing Regional Efforts

Incentives for Collaboration

Types of Collaboration

Maximizing Benefits for Schools

Potential Barriers

Developing Cooperative Agreements

VIII. Regional Collaboration

Existing Regional Efforts

Spurred by existing regulations, there are many ongoing regional activities underway for managing runoff. For example, most municipalities in the U.S. are subject to NPDES permits that regulate runoff discharges from stormwater as well as dry weather flows. In response to these requirements, most NPDES permittees have fairly well-established runoff management programs. The programs address permit elements such as education and outreach, illicit discharge detection and elimination, water quality monitoring, and TMDL compliance. TMDL compliance often involves development of projects intended to reduce pollutants and discharge volumes through large regional SCMs, many distributed site-scale SCMs, or both. As part of their programs, permittees have developed stormwater design manuals that provide SCM standards and specifications.

Many permittees are also collaborating with water purveyors, wastewater facilities, and environmental stewardship groups through integrated regional watershed management plans (IRWMPs), supported by grants from the Department of Water Resources (DWR). The plans outline processes for meeting regional watershed goals related to water supply, water quality, flood control, environmental and community health, and climate change adaptation and resiliency. A subset of IRWMPs are stormwater resource plans (SWRPs, Figure VIII-1) that focus on regional efforts for capturing runoff to achieve multiple benefits. Projects that are part of a SWRP may be eligible for grants from the State Water Board. School districts can coordinate with these local and regional entities to capitalize on expertise, sharing the resources needed to manage runoff contributing to sustainable regional development efforts.

Incentives for Collaboration

With over 130,000 acres throughout California being managed by school districts, incentives exist for school districts to engage in jointly managing runoff with other local entities, particularly NPDES permittees. MS4 permittees often consider these properties ideal for implementing SCMs, as part of a vision of regional runoff capture facilities distributed throughout an urban area. Such coverage can go a long way in achieving permit compliance. Given this motivation, permittees may be willing to support runoff capture practices at schools through funding and resources. Schools and their districts, then, can benefit from this assistance. In addition to the advantages described in Section II (Benefits), further incentives for schools to participate in regional efforts include leveraging resources and expertise, sharing costs, and delegating efforts, as described in this section.

Figure VIII-1. Example of a regional project from the San Mateo SWRP.

Leveraging resources and expertise—Schools can leverage the expertise and existing resources of local permittees with ongoing program activities and trained personnel. Current school and district staff could learn from these professionals through joint workshops and planning or directly engage local runoff managers to help scope and plan projects and relevant activities. Additionally, local municipal permittees have existing stormwater management design manuals, which specify local development regulations for new and existing properties. These include runoff management requirements, hydrologic design approaches, best practices, LID requirements, and others.

Sharing costs—Rather than starting a new program, schools could work with a local permittee to streamline resources needed for planning, design, construction, and other activities like outreach, administration, and monitoring. If a school property drains to a large-scale, existing (or planned) municipal SCM, diverting runoff to that SCM could be cheaper than building multiple SCMs. Alternatively, school districts could partner with local permittees and land owners to build new infrastructure that manages runoff from multiple contributing areas. This would also reduce costs to the school district.

Delegating activities—Schools can benefit from working with local permittees by entering into agreements that delegate activities needed for managing runoff. The organization to which responsibilities are delegated is referred to as a separate implementing entity (SIE). In this arrangement, a school district that designates a local municipality as an SIE would devise an arrangement to compensate the local entity for managing runoff, perhaps through monetary payments or in-kind services.

Types of Collaboration

School districts can work with local agencies in several ways:

Joint use projects—School districts and other entities can implement runoff capture projects together. It may involve collecting runoff from several sites in a single project or moving runoff across jurisdictional boundaries (e.g., municipal property to school grounds).

Joint program activities—Local entities and school districts can merge or delegate responsibilities for necessary program activities such as maintenance, education and outreach, or publishing design and procedural manuals through cooperative agreements. For example, school districts might assign responsibilities to a local government permittee with a current runoff program. Cooperative agreements for joint use projects and joint program activities take many forms. They can be formalized through memorandums of understanding (MOUs), maintenance agreements, and memorandums of agreement (MOAs). While MOUs are typically non-binding, maintenance agreements and MOAs can be used to formally delineate responsibilities between partner organizations. The document contents might include descriptions and examples of activities, which are described in more detail in the Developing Cooperative Agreements section.

VIII. Regional Collaboration

Joint Use Projects

There are generally two configurations for joint use projects. First, schools could accept runoff from offsite areas. The municipality benefits by demonstrating compliance with runoff mitigation requirements, while the school district benefits by receiving new infrastructure or compensation, among the other benefits cited in Section II (Benefits) and the Incentives for Collaboration identified previously. Second, schools can send runoff generated on school property to an offsite SCM. In these arrangements, the school benefits by demonstrating that its runoff is mitigated at a downstream site, while other agencies benefit by lowering unit costs of infrastructure or supporting enhanced groundwater recharge.

Regional projects that involve multiple agencies tend to capture and retain or treat runoff from larger catchment areas. No clear classifications of project sizes exist, but regional projects generally involve capturing runoff from catchments larger than a property or site, which could translate to catchment areas larger than an acre. However, projects could comprise thousands of acres.

Projects Accepting Regional Runoff on School Properties

A variety of project designs can fit requirements for regional projects. For larger projects, detention basins, infiltration galleries, and subsurface cisterns can be good options within or beneath parking lots or sports fields. Figure VIII-2 shows an example of a sunken soccer field used as a detention basin at Leonardo Da Vinci Elementary School in Sacramento, CA. For this project, the city contracted with the local school district to divert municipal runoff to the basin. In exchange, the city paid for several school improvements (see list below.)

Improvements provided by the City of Sacramento as part of a joint use project at a local elementary school

- New soccer field (improved grading)
- New baseball diamond
- New irrigation systems
- Amphitheater-style seating
- New pathways
- Improved site drainage

This proposed project directs runoff to two recharge basins beneath sports fields for groundwater recharge.

Figure VIII–2. Regional detention basin built with a soccer field at Leonardo Da Vinci Elementary School, Sacramento

Projects Diverting School Runoff to Other Sites

Alternatively, rather than moving off-site runoff to school grounds, runoff from schools can be diverted to other sites. For example, as part of its Green Solutions Project, Los Angeles-based Community Conservation Solutions created conceptual plans (Figure VIII-3) to redevelop a regional park with wetlands that infiltrate runoff from the neighboring area, including from an adjacent charter school. The wetlands remove trash and pollutants, and bioswales address runoff that would otherwise flow untreated to the Los Angeles River.

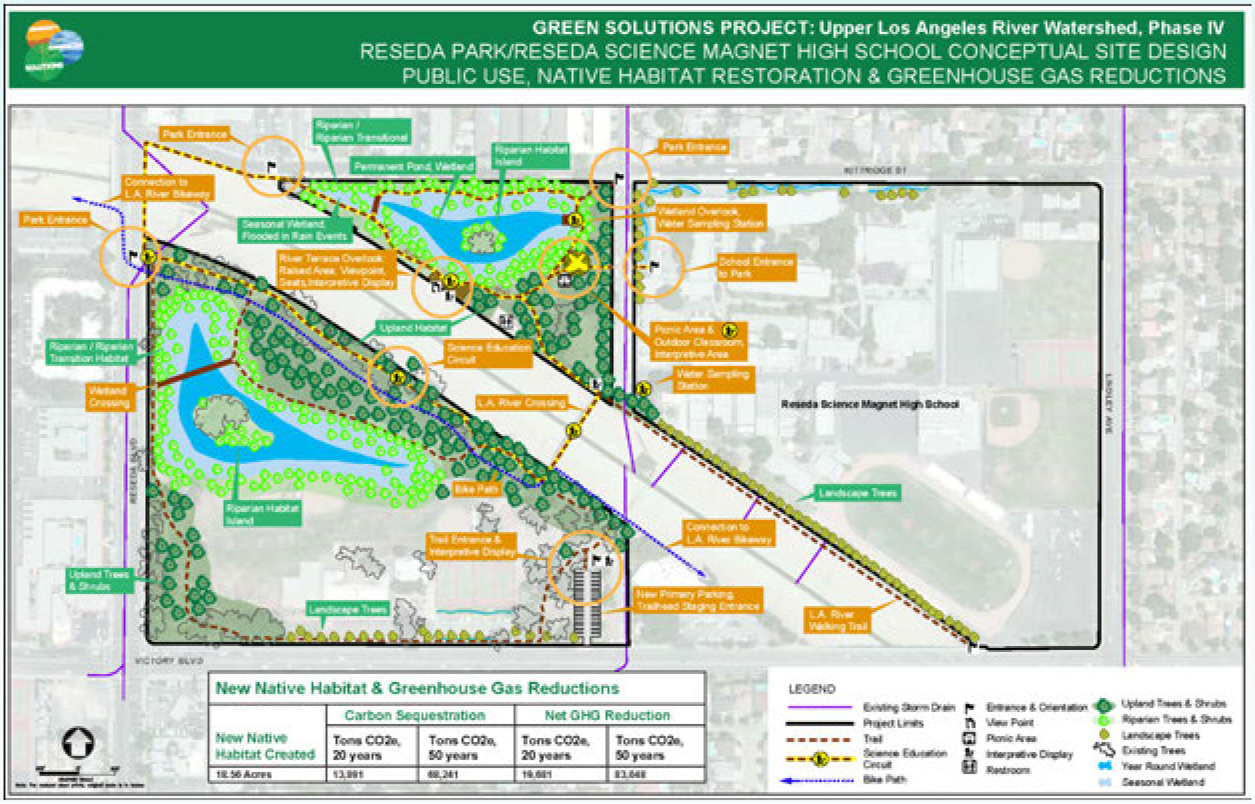


Figure VIII–3. Conceptual design for a regional project diverting runoff from a school site to offsite green infrastructure (Source: Community Conservation Solutions, 2016. Reprinted with Permission).

Joint Program Activities

Beyond collaborating on implementation of projects, school districts can coordinate with regional groups for other programmatic activities related to runoff management, including:

- Education and outreach
- Public involvement and participation
- Illicit discharge detection and elimination
- Construction site stormwater runoff control
- Pollution prevention/good housekeeping
- Post-construction stormwater management for new and redevelopment
- Water quality monitoring
- Program effectiveness and assessment
- TMDL compliance

A good example is an education and outreach program that the Sacramento Stormwater Quality Partnership funds. The program provides classroom presentations to 3rd through 6th grade students. During the presentations, the students are taught about water quality, stormwater pollution, and creek stewardship (Figure VIII-4).

Figure VIII-4. Students participating in stormwater workshops sponsored by the Sacramento Stormwater Quality Partnership (SSQP)

There are a variety of possible joint efforts between school districts and municipalities. For example, municipalities could develop and execute plans and inspections required by the CGP for projects that benefit both entities. Municipalities could also conduct illicit discharge inspections and identify mitigations on school sites, if required by an NPDES permit, and will be good resources for practices that prevent pollutants from coming into contact with rainwater and runoff, including standard plans and specifications for SCM design. Finally, municipal programs have monitoring and program effectiveness protocols and experience that schools could use.

Maximizing Benefits for Schools

Schools and schools districts that work with local agencies on joint programs and projects must identify benefits that will accrue from the partnerships. Collaborative activities are most likely when all parties realize benefits, and outlining expectations as part of the planning process offers a greater likelihood of long-term success for multi-agency regional projects.

VIII. Regional Collaboration

For such efforts, school district administrators, utility managers, and planning department staff will likely be working with local municipalities, consultants, and regulators. School district staff will need to assess the potential value of proposed collaborative projects, as well as promote school district interests, as part of any agreement.

The discussions below provide information that school district staff should be aware of in regards to large-scale watershed projects and regional collaboration, beyond the planning, design, construction, maintenance, and cost/funding resources presented in Sections IV through VII.

Design Approaches

In designing joint use projects, many of the same considerations described in Section IV (Planning and Design) apply, but in the context of multiple contributing catchments, which collectively comprise a watershed that will drain to the regional SCM to be constructed. In particular, methods for establishing the amount and quality of runoff generated will differ slightly from the catchment-scale methods discussed in Section IV.

As runoff moves and collects through a watershed (consisting of several catchments), its volume and flow rates increase. These metrics are driven by the intensity and duration of precipitation, as well as the characteristics of the watershed (soil type, land cover and use, etc.). Several methods are used to estimate the flow of runoff at various locations within the watershed at points in time, such as the rational method and the modified rational method. The methods estimate flow over surfaces and in pipes, gutters, and channels at particular locations and times, which are plotted as a hydrograph (Figure VIII-5). Municipal runoff design manuals often provide guidance and templates for performing hydrograph and routing calculations, as well as flows through pipes to design downstream flooding and water quality mitigation systems, including SCMs.

Common runoff pollutants from schools include sediment, trash, and others as described in Section IV. Runoff from off-site sources will likely have all these pollutants, but in greater amounts. Off-site runoff may also contain other pollutants such as oils and organic pollutants. As such, understanding the characteristics of the contributing watershed is an important step for ensuring an SCM project is properly designed to protect school interests. Land use characteristics influence the types and toxicity of runoff. Common land use types include single- and multi-family residential, commercial, light and heavy industrial, government, and institutions. Within these general categories, some land uses are of greater concern for managing risks associated with runoff pollutants. Ideally, each contributing catchment within the watershed should be assessed individually for potential pollutant contributions, although some guidelines exist to generally associate land uses and runoff pollutants (see the following table).

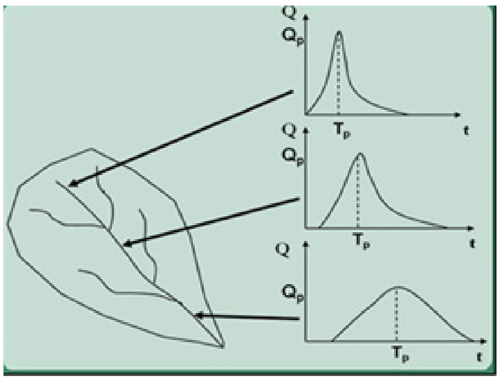


Figure VIII-5. How flow (Qp) and its time of occurrance (Tp) change as runoff moves downstream through a watershed.

General runoff pollution risk categories associated with land use types

Risk Category	Description	Example Land Uses
Insignificant	Little to no risk of contaminated runoff that would not be mitigated through normal treatment measures.	Residential rooftops
Low	Low risk of contaminated runoff that would not be mitigated through normal treatment measures. Sites should be assessed for any specific sources of contamination that would increase risk.	Residential properties Office parks Small retail shops with limited parking Streets with <15,000 AADT[1]
Medium	Increased risk of some contaminants, such as higher concentrations of trash, fertilizers, oils, greases, and metals from automobiles, and increased sediment associated with greater impervious surfaces.	Medium- and high-density residential Institutional and commercial land uses Major retail and offices Large parking lots Streets with 15,000 – 30,000 AADT[1]
High	High risk of contaminated runoff that would not be mitigated through normal treatment measures.	Industrial land uses Gas stations, plant nurseries, car washes, automobile repair stations and shops Streets with >30,000 AADT[1]

OWP 2018a

[1] annual average daily traffic (AADT)

In addition to these general categories, some properties require special considerations. Brownfields and properties with hazardous contaminants from past activities should have special mitigation plans in place for runoff management. Searchable databases of identified brownfield sites are available through the State Water Board's Geotracker website (State Water Board 2018d), along with the California Department of Toxic Substances Control EnviroStor website (DTSC 2018). These databases can be used to identify any potential properties of concern in the contributing watershed for a joint use project.

VIII. Regional Collaboration

Funding Considerations

A critical part of the planning process for joint use projects is identifying funding responsibilities. In particular, how will the new infrastructure be paid for and by whom? Will parties share costs equally through an agreed-upon arrangement, or will one party provide the majority of funding? How will various parties alternatively support capital and long-term maintenance costs?

In joint use projects to date, various financing options have been proposed, including:

- Joint grant applications—All project participants apply together. These grants can pay for some or all of the project costs. Funding programs through the California Department of Transportation, along with statewide General Obligation Bonds, are potential sources for joint grants.
- Catchment-based funding allocations—The percentages of funding contributions closely match the assessed runoff contributions of all parties to the device. For instance, if a new joint use project will capture runoff from a 100-acre catchment and the participating parties own 75 and 25 acres, respectively, a 75/25 funding scheme may be appropriate. Alternatively, funding amounts could be adjusted if some land uses in the catchment are higher risk.
- Mutually-agreed upon allocations—Each of the parties agrees to contribute according to the value it expects to gain. In many cases, local and regional runoff quality control agencies may contribute a large percentage of the capital costs, while school districts agree to fund long-term maintenance and upkeep as part of regular activities.

Funding arrangements can include the monetary value of cash contributions for design and construction together with the assessed value of land in determining cost-sharing. One strategy is to compare municipal and school district capital improvement project plans, looking for projects that help meet both. These will have funding streams readily available. Ultimately, the proper funding scheme for a project will involve detailed negotiations among parties and could be part of broader capital improvement projects on school grounds. Refer to Section VII of this guidance document for specific funding resources.

Operations and Maintenance

One of the most important benefits of joint use stormwater projects for schools is capitalizing on the expertise and resources of partners for operations and maintenance. School districts will benefit from partner agencies that have existing maintenance plans and perform regular staff training. An implemented maintenance program will help lengthen the life of any investments made by school districts and partner agencies in SCMs.

Like all SCMs, joint use projects need maintenance plans. Guidelines and templates for maintenance plans for joint use projects relevant to schools are presented in Section VI (Maintenance). In addition to the information provided in these resources, joint use project maintenance plans must allocate maintenance responsibilities among participating parties, specifically identifying the responsible party for each activity.

Municipalities regularly use maintenance agreements to assign maintenance responsibilities to parties other than the named stormwater permittee. For instance, a municipality might develop a standard maintenance agreement for private landowners who agree to build and maintain SCMs as part of a new or redevelopment project. Maintenance agreements would outline:

- Routine performance activities
- Maintenance schedules
- Inspection requirements
- Personnel access to SCMs for maintenance
- Consequences of failing to maintain SCMs
- Recordkeeping requirements for operations and maintenance

In addition, maintenance agreements should include a description of the system and a map of assets so that all involved parties understand what needs to be maintained or inspected. Developing Cooperative Agreements, presented later in this section, provides some example agreements.

VIII. Regional Collaboration

Potential Barriers

A number of potential barriers to joint use projects have been identified through existing partnerships and processes. Such barriers can be overcome through teamwork and creativity in the planning process. In 2015, the non-profit TreePeople published a summary of a collaborative fact-finding workshop that identified barriers for school districts in working with regional agencies on joint use projects. TreePeople then worked with regional experts to explore these barriers and identify potential solutions. The barriers and solutions are summarized below.

Potential barriers and solutions for implementing joint use projects

Potential Barrier	Description	Potential Solution
Health risks	Accepting off-site runoff could expose students and faculty to health risks from contaminates	Use monitoring to demonstrate risk exposure and work with local public health officials to assess potential exposure risks.
Regulatory issues	Schools may not be allowed to accept off-site runoff due to environmental and water quality standards	While California state agencies (e.g., Department of Toxic Substance Control) could prohibit such transfers, no current regulations exist that prohibit the transfer of runoff to schools from another site.
Land-use limitations	Developing runoff facilities, such as subsurface infiltration, could inhibit future development of those areas	Runoff planning and design processes on school sites should include school district and site-specific master plans to ensure that SCMs do not conflict with long-term infrastructure upgrades.
Training and labor agreements	Implementing and managing green infrastructure on public school grounds will require additional training for facilities personnel and faculty, and may conflict with existing labor agreements if personnel from other municipal agencies or water districts are engaged to maintain SCMs	Existing programs in LA, supported through the DROPS program, have devised training programs on runoff management with separate components for faculty, students, facility managers, and the broader community. Agreements can be organized to allocate duties for maintenance among school district staff and other personnel.
Additional maintenance requirements	Green infrastructure for managing runoff requires more maintenance than existing ground cover, such as asphalt	Long-term funding and worker training should incorporate the requirements of maintenance plans. State and local funding streams that promote green infrastructure should be adapted to allow for such expenses as well as long-term, life-cycle considerations. Emerging research indicates the benefits of more diverse school grounds that are not just hardscape. School maintenance activities, and associated funding, must be adjusted to promote better student experiences.
Liability	School districts could be vulnerable to lawsuits concerning the risks of health exposure, personal injury, subsidence from saturated soils, soil contamination, or other long-term environmental consequences of infiltrating runoff on-site	Liability considerations can be discussed as part of negotiations. Mechanisms such as indemnification agreements exist that could protect schools from such lawsuits. Notably, in surveying stakeholders and existing research for this report, liability concerns arose in examples of larger school districts, but were not raised in discussions about site-level projects. Statewide legislation could alleviate such concerns, which would support the regulatory efforts to include school districts in the Phase II MS4 permits by offering an avenue for schools to meet permit requirements through regional collaboration.

Adapted and augmented from a study in Los Angeles by TreePeople (2015).

Notably, for all these challenges, smart designs can alleviate concerns. For instance, at a school site, off-site runoff could be captured, retained, and infiltrated and/or released only on peripheral areas where students and faculty are not exposed. This would pose exposure similar to any retention and infiltration-based SCM implemented within a municipality, which is increasingly common. Additionally, designs can emphasize subsurface SCMs, where no captured runoff is exposed at the surface. While more expensive, such projects have been proposed in California with no associated safety or liability risks raised during design discussions.

Developing Cooperative Agreements

Any agreements among schools, school districts, and other local agencies should be codified in writing. Several types exist, ranging in formality and commitments:

1. **Maintenance agreements** specify a commitment by a party, such as a private landowner, to operate and maintain stormwater infrastructure. Municipalities use maintenance agreements with partner agencies and private parties to delegate the responsibilities of long-term SCM upkeep for meeting local drainage and development codes. The agreements among parties are binding, and municipalities may be expected to undertake regular inspections to verify compliance.
2. **Memorandums of understanding (MOUs)** specify the agreed-upon terms for entities to collaborate; share; or exchange goods, services, data, or other resources. While MOUs are not binding agreements and do not have legal standing, they can serve as the basis for continued collaboration.
3. **Memorandums of agreement (MOAs)** specify agreed-upon terms for entities to work together in some capacity. Unlike MOUs, MOAs are binding and used to formalize arrangements, similar to contracts. The MOAs will specify relevant stipulations (sometimes called “recitals”), such as relevant regulatory requirements or consent decrees of participating parties, and the terms (for instance, “mutual covenants”) by which both parties agree to participate for the term of the MOA.

Each of these arrangements may be relevant for a joint use project among school entities and local agencies, though MOAs would be a likely mechanism to formalize long-term arrangements and contingencies for the parties to share resources and duties on a project.

Schools throughout California work with local municipalities on a variety of joint use activities. For instance, many schools have agreements to open school grounds to community groups or municipal departments after school hours. These recreational facilities are the school’s asset that it is agreeing to share in return for use, payment, safety and security precautions, maintenance, liability, and any other terms. These agreements stipulate the permitted uses of school property and identify the terms of the agreement.

VIII. Regional Collaboration

Example Agreements

A number of example agreements are available for easy reference. Cities such as Philadelphia, Boston, and San Francisco have developed model agreements to work with many types of parties on joint stormwater-related activities. In addition, joint use agreements were developed by an Oakland non-profit, Public Health Law & Policy, as a template for schools and local groups to facilitate use of school grounds after school hours. These templates (Figure VIII-6), available at the website of ChangeLab Solutions, can be usefully adapted for joint use stormwater management projects, drawing on the other stormwater-specific examples to identify key terms that should be included.

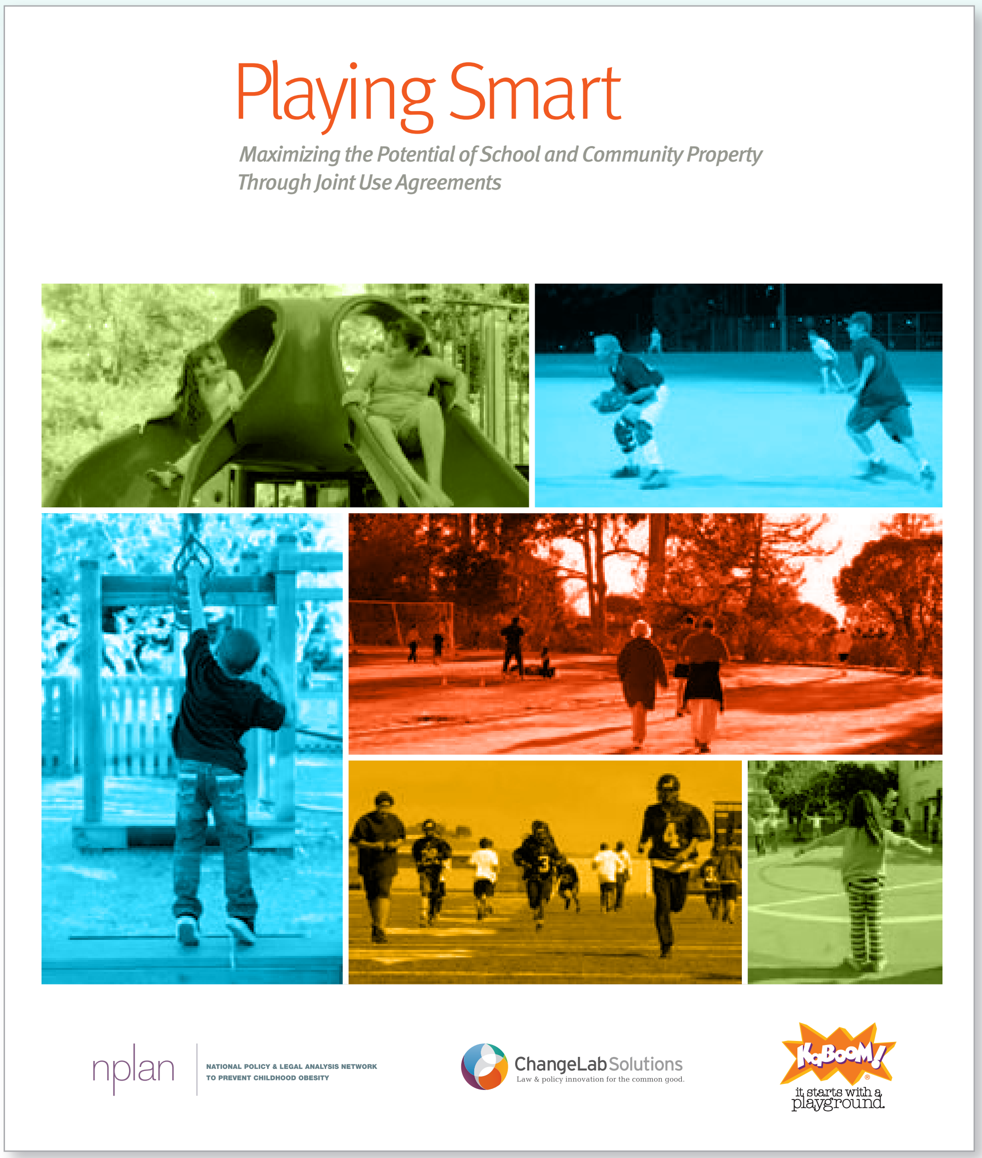
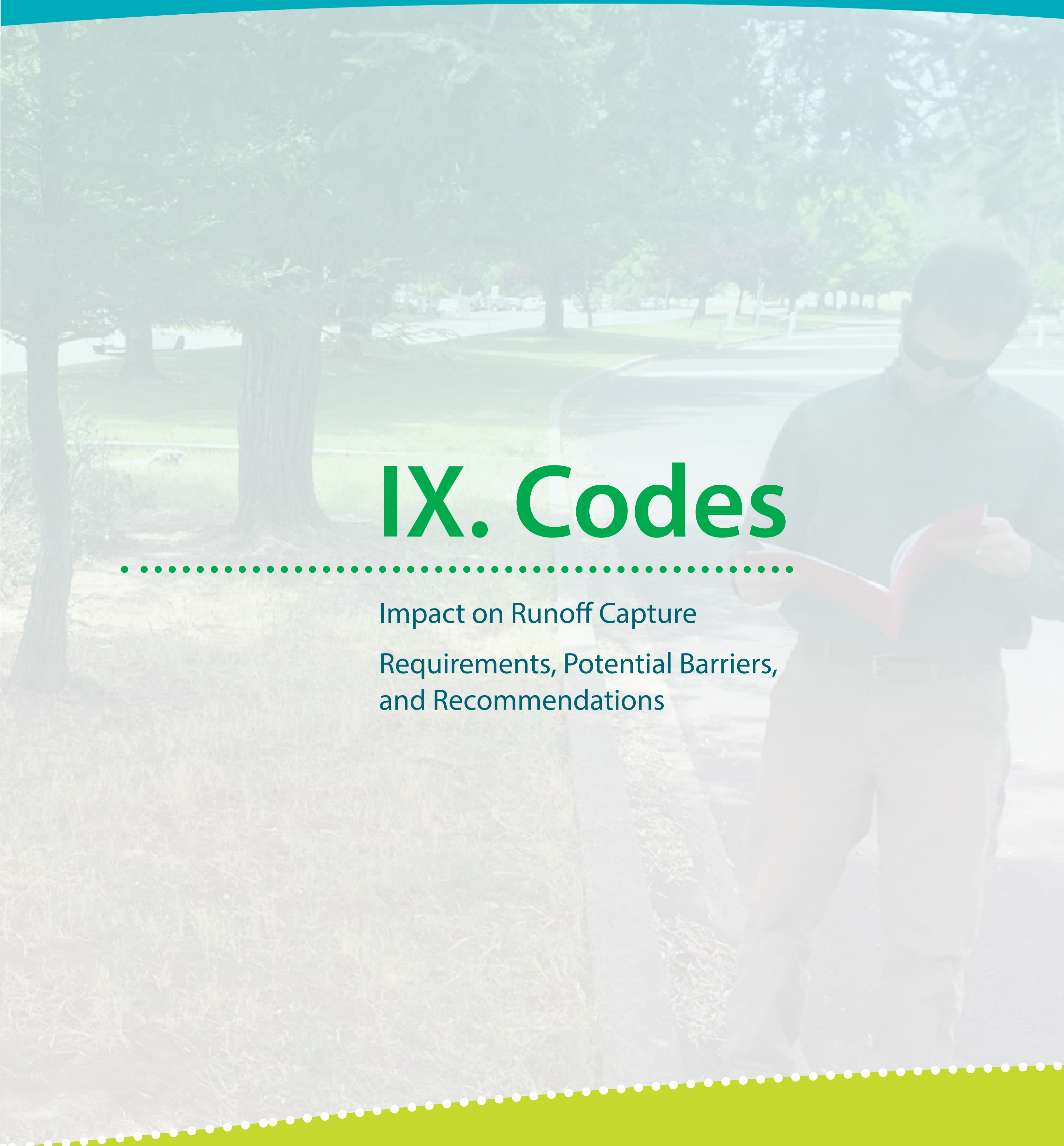


Figure VIII–6. Joint use agreement guidance by ChangeLab Solutions (2018)



IX. Codes

Impact on Runoff Capture

Requirements, Potential Barriers, and Recommendations

IX. Codes

Impact on Runoff Capture

California law, originating from the legislature as statute or by promulgation by a state agency through regulation, influences whether runoff minimization and runoff capture measures are feasible for a site.

Location, design, construction, and rehabilitation of school district infrastructure can fall under the jurisdiction of several entities, including CDE, DSA, State and Regional Water Boards (CCR), and local drainage authorities, and the requirements of those entities should be considered early in the planning process to successfully integrate stormwater measures. Some affect drainage directly, while others specify minimum infrastructure requirements that can affect how much impervious surface is used. The key requirements and the roles and authority for these agencies are:

- All school districts must meet the standards in California Code of Regulations, Title 5, section 14001 et seq. in selecting new school sites and in designing new schools. Those requesting state capital funding assistance must submit projects for review by CDE. CDE has an early role in advising districts on proposed school locations and site programming and design. New schools are to be located consistent with the district's adopted facility master plan and local land use planning, although a district's governing board has statutory authority to exempt a project from certain local standards. CDE convenes regional meetings to inform districts of policy updates.

- As authorized in sections 17280 and 81130 of the California Education Code, DSA has an active role in the design and construction of K–12 public schools, community colleges, and essential services buildings. As the enforcement entity, DSA provides plan review and construction oversight of new construction and alterations to buildings and facilities for conformance to Title 24 California Building Standards Code. To ensure compliance, DSA certifies project inspectors who are hired by the school district to oversee construction projects. The division also reviews California State University and University of California projects and state-funded construction for accessibility compliance. DSA has the authority, in the state of California, to promulgate regulations related to public school construction, and accessibility regulations for public accommodations, commercial buildings, public buildings, and public housing.

- State and Regional Water Boards have designation authority for stormwater permit enrollment, a delegated federal authority. Regardless of permit designation, the Water Boards have broader authority via sections 13267 and 13383 in the California Water Code to investigate pollutant sources and require landowners to report on those occurrences.

- Local drainage authorities can set local drainage standards via ordinance, and according to CCR Title 5 (section 53097), school districts must conform to local ordinances.

One example of codes that must be considered during design is the California statutes and regulations that impact the placement of vehicle-bearing surfaces. However, they do not always specify that impervious surfaces must be used. These requirements, and how they impact runoff prevention and capture practices, are presented in this section, along with a discussion of whether the requirements are a significant barrier to runoff prevention and capture measures, or merely a design consideration. This section also recommends improvements or changes to existing requirements or policy to improve use of the design strategies and SCMs presented in this document. Guidelines that could be improved for better stormwater planning are also listed.

Requirements, Barriers, and Recommendations

Requirements and Barriers

The following pages tabulate regulations relevant to minimizing impervious surfaces through runoff capture practices. No modifications to support compliance with runoff regulations, without compromising safety or learning objectives, were identified.

The following areas were thought to have regulations affecting runoff capture implementation. However, during investigations as part of the development of this document no impact was found.

- Minimum shade
- Covered lunch areas
- Security or barriers around standing water

Finally, some policies support consideration of SCMs and regional projects. For example, California Education Code, section 35275 requires meeting with appropriate local government, recreation, and park authorities to consider possible joint use of the grounds and buildings and to coordinate the design to benefit the intended users. Such collaboration could also provide a platform for regional urban runoff projects.

Recommended Changes in Policy or Regulation

Recommendations for modifying policies, laws, regulations, and guidance to better promote implementation of the design strategies and SCMs at school properties, as described in the guidelines, are included in the table in this section. In addition to this list, the CDE Blueprint for Environmental Literacy supports environmental protection efforts, and serves as a useful resource for incorporating sustainable runoff management into school district curriculums and activities.

IX. Codes

Relevant regulations

Authority/ Regulation[1]	Requirement	Imperviousness Required	Recommended Change[2]
CCR Title 5 §14001 (& forward)	Overall minimum facility size: • For kindergarten and grades one through six: 59 square feet (sq ft) per pupil • For grades seven and eight: 80 sq ft per pupil • For grades nine through twelve: varies from 91.5 sq ft per pupil for an enrollment of 2,400 to 127 sq ft per pupil for an enrollment of 400	Yes	None[1]
CCR Title 5 §14030	Site layout: parking, loading, drop off	No[3]	None
	Playground & field areas: adequate physical education stations (includes hardcourts)	Yes[4]	None[1]
	Classroom size: grades one through twelve may not be less than 960 sq ft	Yes	None[1]
	Kindergarten classroom size for permanent structures may not be less than 1350 sq ft	Yes	None[1]
	New school speech and language program: at least 200 sq ft.	Yes	None[1]
	Science and home economic labs: at least 1300 sq ft	Yes	None[1]
	Library space proportional to maximum planned school enrollment: at least 960 sq ft	Yes	None[1]
	Computer laboratory: at least 960 sq ft	Yes	None[1]
CCR Title 5 §14030 EDC §17747(a)[1]	New school resource specialist program: at least 240 sq ft	Yes	None[1]
CCR Title 24, Part 2 (CBC) Chapt 11B[1]	Americans with Disabilities Act (ADA) as incorporated into Title 24 CBC for sidewalk widths and parking stall widths	No[5]	None
CCR Title 19 (PS) §3.05(a)[1]	Fire access: all-weather hard-surfaced at least 20 feet in width	No	None
CCR Title 24, Part 9 (CFC) §503.4 CCR Title 19 (PS) §3.05(a)[1]	All parking: faculty, staff, students, visitors	No	None
CCR Title 24, Part 11 (CalGreen) §5.106.12[9]	Shade trees: plant in parking lots, landscaped areas, and landscaped areas at percentages specified in code	No	None

Authority/ Regulation[1]	Requirement	Imperviousness Required	Recommended Change[2]
CCR Title 24, Part 9 (CFC) §503.4 CCR Title 19 (PS) §3.05(a) VEH §22500 (i), 22500.1, and 22500.5[1]	Bus drive aisles serving as the required fire apparatus emergency vehicle access must be maintained free and clear of obstruction at all times. Stopping for short periods for the purposes of unloading, where the bus driver remains in the vehicle would be permitted. Stopping/parking where the driver shuts the bus off and leaves the vehicle would not be permitted (additional area would be required to accommodate bus parking).	No	None
DSA Policy PL 07-03	Minimum 30-foot width when student drop-off/loading zones are incorporated with required fire apparatus access roadways (fire lanes)	No	None
CCR Title 24, Part 2 (CBC) §1015[1]	Requires 42" high guards[6] along open-sided walking surfaces that are located more than 30 inches (measured vertically) to the grade below at any point within 36 inches horizontally to the edge of the open side	No[7]	None
CCR Title 19 (PS)[1]	Shade material	No[8]	None

[1] EDC: Education Code; CCR: CA Code of Regulations; CBC: CA Building Standards Code (2016); PS: Public Safety; CFC: CA Fire VEH: Vehicle Code;

[2] Assumes modifications to regulations that require minimum impervious surface areas but would compromise safety or learning objectives; so no modifications are recommended.

[3] Could impact SCM placement

[4] Hardcourt minimums vary by grade and number of pupils

[5] Impacts minimum widths and turning radii, but allows pervious surfaces if compliant with Title 24, Part 9 and with approval from the local fire authority

[6] Design detail: Guards shall not have openings which allow passage of a sphere 4 inches in diameter from the walking surface to the required guard height

[7] Does impact SCM design feature

[8] Not specific restriction on use of pervious materials, but other restrictions apply for fire safety

[9] Proposed for adoption in January 2019, with effective date of Jan 1, 2020

IX. Codes

Potential actions to promote runoff capture at school properties[1]

Entity to Take Action	Recommendation
CDE	Include runoff capture as an objectives for strengthening relationships between schools and communities with those previously identified in CDE's Re-Visioning School Facility Planning and Design for the 21st Century Roundtable Report (CDE 2008).
Legislature/DSA	DSA project review thresholds per Education Code §17280 (K-12) and 81133 (post-secondary) are currently based on project cost estimate greater than $100,000. Add additional thresholds based on amounts of impervious surface created or replaced as cited in the Phase II MS4 Permit for post-construction measures
CDE	Expand Education Code §35275 to require consultation specifically on local water capture projects that could be colocated with joint recreation facilities.
CDE	Update the Schools of the Future Report (CDE 2011) to include green infrastructure for stormwater runoff management.
CDE	Update Item 9 in Vision for California School Facilities (CDE 2015) to include "limit runoff".
CDE	Update CDE Sample Form 1.02b - Plot Plan of Site and Buildings (from Guide to Development of Long Range Facilities Plan, CDE 1986) to include SCMs.
DSA	Add stormwater management information to the DSA's Water Resources page for Sustainable Schools (DSA 2018) or where appropriate.
CDE	Update the Guide for Planning Educational Facilities (COEFP 1991) to include runoff capture information. Although this document states to consult state and local "Water Pollution Control" codes, Phase II stormwater regulations were only promulgated in 1990, so detailed information should not be expected. Consequently, the guidance needs updating or this document could also be listed within CCR Title 5, §14034 (Planning Guides).
CDE	CCR Title 5, §14031, Plan Approval Procedures for State-Funded School Districts, Part b states, "Each state-funded school district shall submit final plans including grading, site utilization, elevation, floor, lighting, and mechanical working drawings and any alterations to the educational specifications to the California Department of Education for approval." The regulation could be updated so that grading plans are required to include post-construction SCMs (compliant with current CGP and future Phase II requirements).
CDE	Update Healthy Children Ready to Learn: Facilities Best Practices (CDE 2006) to reference these SB 541 guidelines.
CDE	Update Guide to School Site Analysis and Development (CDE 2000) to incorporate SCM footprint requirements for impervious roofs, hardcourts, and other impervious surfaces (that do not use pervious alternatives).
USEPA	Update School Siting Guidelines (EPA 2011) to address concerns with colocation of regional stormwater projects that would manage offsite urban runoff. Also, expand list of tools for water quality mitigation provided on page 51 of those guidelines.

[1]These potential actions may not be the only solution and the identified agencies may require time and resources to explore the most efficient solution

X. References

X. References

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Appendix A

SCM Fact Sheets

Runoff Capture Practices

Aboveground Storage Factsheet

1.0 General Description

Figure 1. Aboveground storage (Porter County IN)

Potential Treatment Mechanisms								
I	ET	FA	B	RH	S	F	P	T
				✓	✓			

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Aboveground storage can consist of rain barrels, cisterns, or other containers—usually made of either metal or plastic—that receive roof stormwater runoff from a downspout for temporary storage. These containers can have either an open outlet or a valve from which the water can more slowly infiltrate the ground below or be used as a non-potable water source. Some may also have a bypass valve or other form of filtration to help filter out grit and other contaminants. In addition, most have either a screen and/or tight seals to keep out mosquitos or other vectors and pests. A schematic of one type of container is shown in Figure 2.

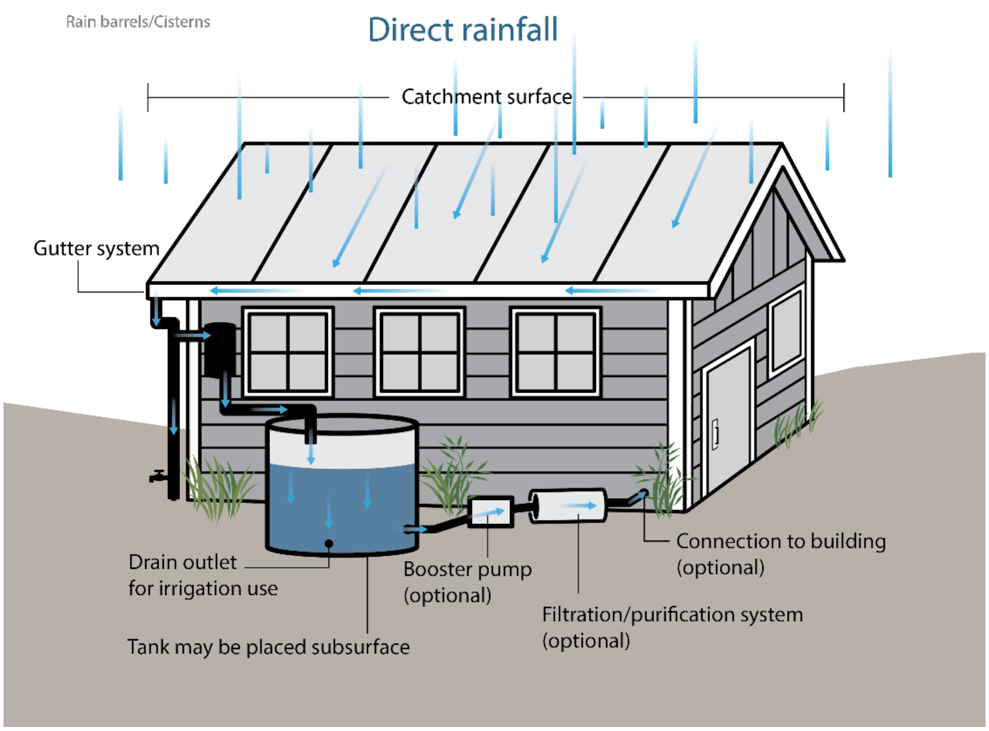

Figure 2. Basic schematic of aboveground storage

1.1 Variations and Alternative Names

- Harvest and (Re)Use (Practices)
- Aboveground cisterns
- Rain barrels

2.0 Advantages & Limitations

2.1 Advantages

✓ Can be used in areas where space is limited

- ✓ Provides an alternative non-potable water source
- ✓ Can easily be added to existing buildings

2.2 Limitations

- ✗ Limited storage capacity
- ✗ If not properly installed or maintained, odors and mosquito habitat may develop
- ✗ May require permitting or be subject to plumbing code regulations
- ✗ May require pumps

3.0 Siting

Aboveground storage should be located in a shaded area to help limit algal growth and on stable flat ground or pavement for stability.

4.0 Design Considerations

When adding aboveground storage, the following design parameters should be considered:

- ❑ Volume
- ❑ Space available
- ❑ Existing gutters
- ❑ Tank opacity
- ❑ Piping
- ❑ Screening
- ❑ Overflow
- ❑ Pump size (optional)

5.0 Construction Considerations

- ❑ Level area where the aboveground storage is to be placed

6.0 Maintenance

- ❑ Checks of seals and screens to prevent entry by mosquitos and other pests
- ❑ Inspections of all components for leaks
- ❑ Pump maintenance, if required
- ❑ Removal of sediment, if required

7.0 References

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

County of Placer, City of Roseville, City of Auburn, City of Lincoln, and Town of Loomis (County of Placer et al. 2016). *West Placer Storm Water Quality Design Manual*. April 2016.

Bioretention Planter Factsheet

1.0 General Description

Figure 1. Bioretention planter

Potential Treatment Mechanisms								
I	ET	FA	B	RH	S	F	P	T
✓*	✓	✓	✓		✓		✓	✓

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

*For unlined systems

Bioretention planters are depressed landscapes into which runoff is directed and allowed to collect, filter, and sometimes infiltrate. These planters come in a variety of configurations. All include a few inches of ponding depth (often 4 to 6 inches). A raised inlet allows a means of bypass in case of overflows. Under the ponding zone is the planting zone. The planting zone is constructed using various media blends that support growth and filter and retain pollutants. Mulch is sometimes applied over the planting zone for plant health and weed management. The ponding zone temporarily stores runoff and promotes percolation into the planting mix and bioretention mix below. In addition to storing the runoff in its pore structure, the bioretention mix filters and biotreats the runoff. In some configurations, water drains into a subsurface storage layer (typically gravel or porous road base) below the bioretention mix. These systems are preferably unlined to allow infiltration into the underlying native soils. A perforated underdrain can be located at the top of the storage component to reduce the amount of untreated overflows that can occur where the soil type or available area limit infiltration. A schematic of this configuration is shown in Figure 2.

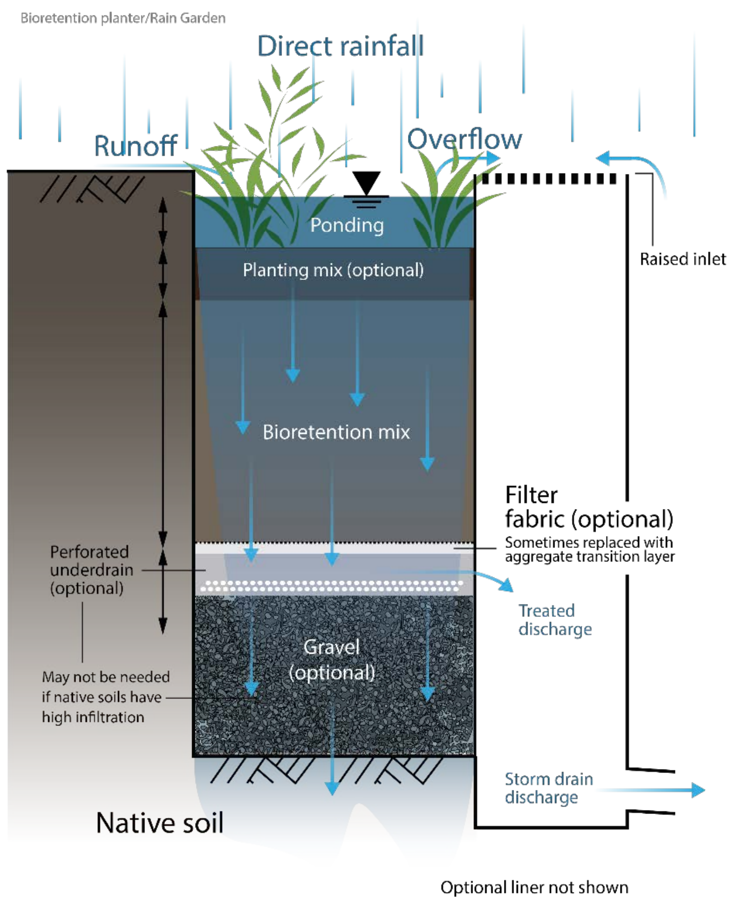

Figure 2. Schematic of a basic bioretention planter

Topsoil may or may not be used within the planters. Some practitioners argue topsoil is necessary for plant growth in some climates, while others believe it is not needed and hinders infiltration. Some use a geotextile fabric placed below the bioretention mix in configurations with gravel storage to prevent the smaller-sized bioretention mix particles from migrating into the storage zone and possibly escaping via the underdrain. Alternatively, to avoid possible fabric clogging, some practitioners use a transitional-sized aggregate or a porous base with smaller pore spaces than gravel.

Bioretention Planter Factsheet

1.1 Variations and Alternative Names

- Rain gardens
- Lined bioretention planters
- Infiltrating stormwater planters
- Bioretention cells
- Vegetated filters
- Biotreatment

2.0 ADVANTAGES & LIMITATIONS

2.1 Advantages

- ✓ When done well, rain gardens can be both inexpensive and add aesthetic appeal
- ✓ Can create habitat
- ✓ Can be used in areas with limited space
- ✓ Can optimize load reduction by allowing both infiltration and filtration (treat and discharge) components

2.2 Limitations

- × Requires terracing for steeper slopes
- × Limited to a small contributing drainage area

3.0 SITING

The site should be relatively flat and, in some climates, irrigation should be available during the dry season.

4.0 DESIGN CONSIDERATIONS

When designing a bioretention planter or rain garden, the following parameters should be considered:

- ❑ Contributing drainage area
- ❑ Flat layers (no slope)
- ❑ Design volume
- ❑ Drawdown time
- ❑ Transitional side slopes
- ❑ Surcharge depth
- ❑ Soil types and media
- ❑ Layer depths (ponding, planting, and subsurface storage)
- ❑ Area
- ❑ Underdrain
- ❑ Overflow
- ❑ Containment curb/curb cuts (optional)
- ❑ Precise inlet, overflow, and media depth elevations
- ❑ Hydraulic soil group of existing subsurface material at final excavation depth
- ❑ Planting mix design
- ❑ Storage layer:
    - o Usually when underdrain is used
    - o Media type
    - o Media depth
- ❑ Liners for high groundwater or contaminated soils
- ❑ Soils testing of delivered fill material

5.0 CONSTRUCTION CONSIDERATIONS

- ❑ Stabilize drainage area or divert any flows to prevent sediment loading and/or erosion during construction

- ❑ Replace plants damaged during construction
- ❑ Provide temporary irrigation until plants are established
- ❑ Ensure correct elevation before and during concrete work

6.0 MAINTENANCE

- ❑ Plant management
  - o Identification and promotion of desired species
  - o Removal of unwanted species (not all volunteer species are undesirable)
  - o Increased plant density can decrease weeds
- ❑ Litter removal (for areas prone to litter)
- ❑ Inspections for standing water to prevent mosquitos and other vector breeding
  - o Top layer of the planter may need to be replaced if standing water becomes a chronic issue

7.0 REFERENCES

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

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Constructed Wetland Factsheet

1.0 General Description

Figure 1. Constructed wetland (EPA)

Potential Treatment Mechanisms								
I[1]	ET	FA	B	RH	S	F	P	T
✓	✓	✓	✓		✓		✓	

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

[1] *For unlined systems only; these systems are sometimes constructed with a liner*

Constructed wetlands are vegetated basins with shallow pools of water that allow stormwater to slowly infiltrate and receive treatment from the plant roots. The shallow pool may only exist through the wet season though some exist year-round, depending on location and climate. The wetland may or may not discharge back into a downstream water body. A schematic of a wetland is shown in Figure 2.

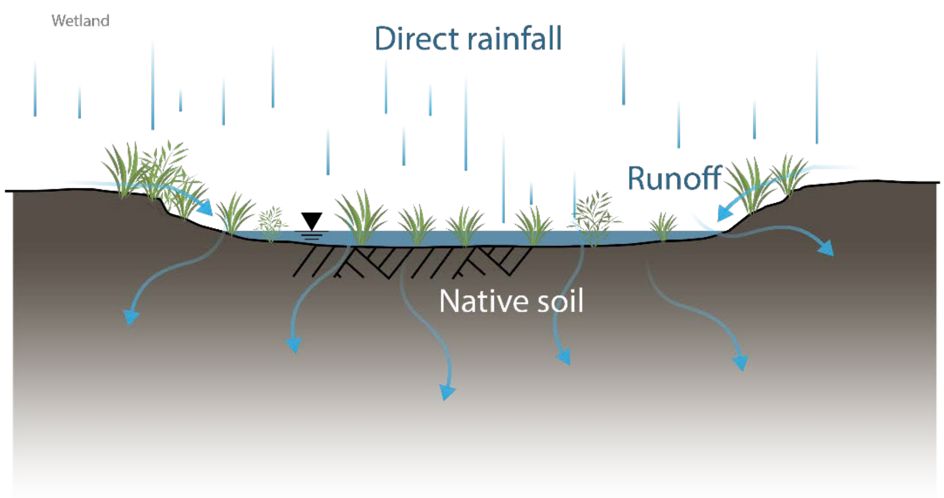


Figure 2. Schematic of a basic constructed wetland

2.0 Advantages & Limitations

2.1 Advantages

- ✓ Can provide habitat for wetland wildlife and add aesthetic appeal
- ✓ If designed and constructed well, constructed wetlands can provide significant reduction in contaminants/pollutants

2.2 Limitations

- × Typically take years to establish
- × Will require irrigation/supplemental water at first
- × Public access safety concerns may require security fencing around the area
- × Requires a significant amount of land

Constructed Wetland Factsheet

3.0 Siting

Constructed wetlands are not suitable for areas with steep/unstable slopes. They are also not suited for cold water systems because the relatively deep still water in the pool will be much warmer than the cold water stream and so may warm the stream if it is discharged.

If the site has significantly porous soil, an impermeable liner along the bottom may be required.

4.0 Design Considerations

When designing a constructed wetland, the following parameters should be considered:

- ❑ Contributing drainage area
- ❑ Design volume
- ❑ Drawdown time
- ❑ Permanent pool volume/depth
- ❑ Liner (optional)
- ❑ Inlet/outlet erosion control
- ❑ Forebay
- ❑ Open-water, wetland, and outlet zones
- ❑ Surcharge depth
- ❑ Length to width ratio
- ❑ Freeboard
- ❑ Bottom slope
- ❑ Embankment slope
- ❑ Side slopes
- ❑ Maintenance access ramp
- ❑ Vegetation
- ❑ Vector control animals (e.g., mosquito fish)

5.0 Construction Considerations

- ❑ Do not allow heavy machinery, vehicles, and other traffic to enter the basin
- ❑ Stabilize drainage area or divert any flows to prevent sediment loading and/or erosion during construction
- ❑ Ensure that the bottom is graded to be level and relatively flat
- ❑ Install seepage collars on outlet piping to prevent water from seeping out and causing damage

6.0 Maintenance

- ❑ Maintain permanent pool of water (if designed to)
  - o may require water to be pumped in
- ❑ Replace plants damaged during construction as well as any that do not establish
- ❑ Inspections for:
  - o leaks in the outlet
  - o trash and debris accumulation
- ❑ Inspections and treatment for mosquitos and other vectors

7.0 References

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

California Stormwater Quality Association (CASQA 2017). *Draft Stormwater Best Management Practice Handbook: New Development and Redevelopment*. April 2017.

Sacramento Stormwater Quality Partnership (SSQP 2018). *Stormwater Quality Design Manual*. July 2018.

Detention Basin Factsheet

1.0 GENERAL DESCRIPTION

Figure 1. Detention basin (Stormwater Partners SW Washington)

Potential Treatment Mechanisms								
I[1]	ET	FA	B	RH	S	F	P	T
✓					✓			✓

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

[1] For unlined systems only; these systems are sometimes constructed with a liner

Detention basins are designed to capture rainfall and runoff and hold it for a maximum time (e.g., up to 72 hours), after which the basin fully drains and returns to being a dry basin. The maximum drain time (via orifice drain and infiltration) is specified to prevent mosquito breeding and to restore capacity for subsequent storm events. A minimum drain time is sometimes specified to encourage quiescent conditions for particle sedimentation. An orifice on the outlet riser typically meters out treated water. A riser or overflow weir is typically provided to route flood flows. A schematic of a basic detention basin is shown in Figure 2.

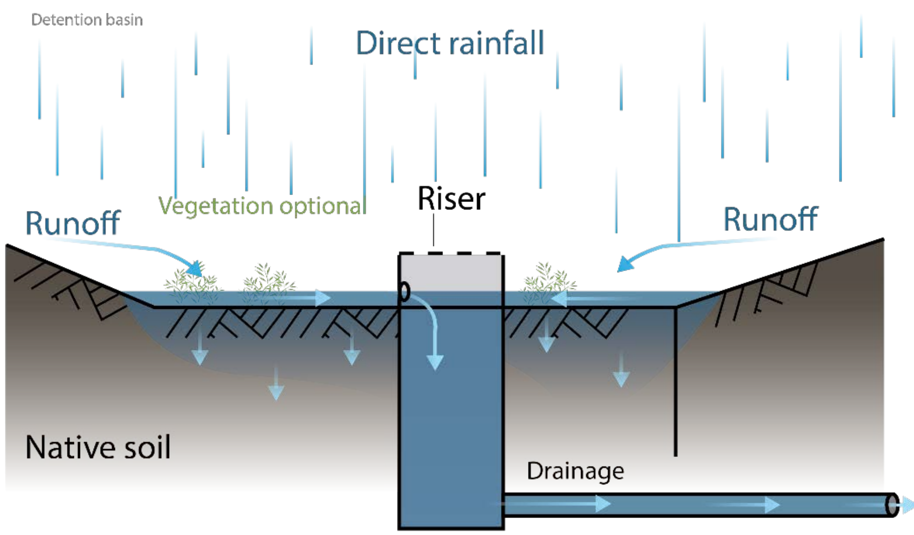


Figure 2. Schematic of a basic detention baisn

1.1 Variations and Alternative Names

- Detention ponds
- Extended detention basins
- Dry extended detention basins or ponds
- Dry ponds

2.0 ADVANTAGES & LIMITATIONS

2.1 Advantages

- ✓ Provides flood control as well as stormwater runoff treatment, in some cases
- ✓ Can be inexpensive
- ✓ Can have relatively low maintenance

- ✓ Can be integrated into an aesthetically appealing landscape design, though access restriction may be required for public safety

2.2 Limitations

- × Moderate pollutant removal
- × May not be suited for areas where the water table is close to the ground surface
- × Requires elevation change between inlet and outlet

3.0 Siting

To avoid direct connection to groundwater, reduce mosquito breeding habitat, and avoid wetland habitat conditions, the bottom of the basin should be located sufficiently above the wet season water table. If the water table is high, an impermeable liner may be required.

According to the California Stormwater Quality Association, detention basins should not be used for contributing drainage areas (CDA) of less than 5 acres because such a small CDA may require an orifice size so small that it will clog easily (CASQA 2003).

4.0 Design Considerations

When designing a detention basin, the following parameters should be considered:

- ❑ Contributing drainage area
- ❑ Design volume
- ❑ Drawdown time
- ❑ Side slopes
- ❑ Length to width ratio (distance between inlet and outlet)
- ❑ Orifice diameter
- ❑ Slope stability
- ❑ Energy dissipation at inlet
- ❑ Maintenance and inspection areas
- ❑ Basin area and infiltration capacity
- ❑ Seepage collar (to prevent piping/internal erosion on bermed systems)
- ❑ Utility conflicts
- ❑ Buried manmade materials and past disposal practices

5.0 Construction Considerations

- ❑ Potholing is recommended to verify locations of buried infrastructure.

6.0 Maintenance

- ❑ Identify and remediate clogging issues at the orifice or outlet screens (may require special training)
- ❑ Plant management
- ❑ Litter removal (for areas prone to litter)
- ❑ Inspect for standing water to prevent mosquitos and other vector breeding

7.0 References

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

California Stormwater Quality Association (CASQA 2017). *Draft Stormwater Best Management Practice Handbook: New Development and Redevelopment*. April 2017.

Sacramento Stormwater Quality Partnership (SSQP 2018). *Stormwater Quality Design Manual*. July 2018.

Drain Inlet Insert Factsheet

1.0 General Description

Figure 1. Drain inlet insert (Grainger)

Potential Treatment Mechanisms

I	ET	FA	B	RH	S	F	P	T
		✓						

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Drain inlet inserts are placed into drop inlets to provide sediment and debris removal. Most inserts employ a fabric or media filter. Some also use baffles to enhance sedimentation or isolate coalesced oil droplets. Others are constructed with coarse screens to target trash removal. The inlet typically requires little to no modification. Inlets are generally easily removed, although excessive sediment accumulation may increase the difficulty of removal. Removal mechanisms vary. Figure 2 shows a schematic of a basic drain inlet insert.

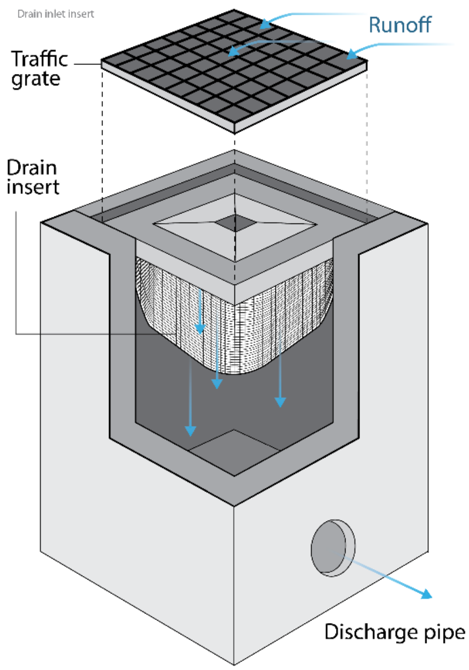


Figure 2. Schematic of a basic drain inlet insert

2.0 Advantages & Limitations

2.1 Advantages

- ✓ Does not require additional space/land
- ✓ Can be relatively inexpensive
- ✓ Easy to install and maintain

2.2 Limitations

- × Less effective than other stormwater control measures
- × Many models clog easily, especially if leafy debris is present

Drain Inlet Insert Factsheet

3.0 Siting

The California Stormwater Quality Association recommends that "inserts be used only for retrofit situations or as pretreatment where other treatment BMPs … are used" (CASQA 2003, 2018).

4.0 Design Considerations

When designing a drain inlet insert, the following parameters should be considered:

- ❑ Contributing drainage area
- ❑ Filter media type
- ❑ Pretreatment needs of downstream stormwater control measures (e.g., trash removal)
- ❑ Litter/debris loading and storage capacity

5.0 Construction Considerations

- ❑ Careful installation of insert to ensure there are no areas around the insert where stormwater may leak and bypass the filter

6.0 Maintenance

- ❑ Removal of trash and debris to avoid clogging of the inlet

7.0 References

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

California Stormwater Quality Association (CASQA 2017). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. April 2017.

Dry Well Factsheet

1.0 GENERAL DESCRIPTION

Figure 1. Dry well (Torrent Resources)

Potential Treatment Mechanisms								
I	ET	FA	B	RH	S	F	P	T
✓		✓			✓	✓		

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Dry wells are stormwater infiltration devices typically constructed with a vertical pipe that extends deep into the subsurface without contacting the groundwater table. A typical installation has a 3-foot diameter with a depth of 20–50 feet. The EPA defines dry wells as infiltration facilities that are deeper than they are wide. Perforations are located along the length of the pipe and/or at the bottom to permit stormwater to flow from various parts of the well into the surrounding soils (Figure 2). There are many varieties in construction and design practices that affect the placement of perforations, use of geotextiles, and use of internal gravel or rocks. Dry wells can be used in a variety of situations, but have unique advantages in areas with shallow clay or hardpan soils because they facilitate the movement of stormwater runoff below these types of constricting layers to facilitate infiltration. Multiple dry wells can be installed to create treatment trains for large drainage areas.

Typically, runoff is initially directed to a pretreatment facility—such as a bioretention planter, biostrip, bioswale, proprietary device, or sedimentation chamber (sometimes with screens or hydrophobic sponges or pillows)—to remove sediment and other pollutants that could clog the well or subsurface soils, or pose risks to groundwater. Pretreatment can also accommodate spill response. After pretreatment, a conveyance pipe directs treated runoff into the system's primary chamber, the dry well. The dry well may be constructed of concrete or other material. The lower section includes a pervious shaft which may be an open shaft with or within aggregate backfill or it may be comprised of perforations within the casing material. Before reaching groundwater, it is beneficial for runoff to pass through layers of silt or clay to help sequester contaminants before they reach groundwater (OWP et al 2018).

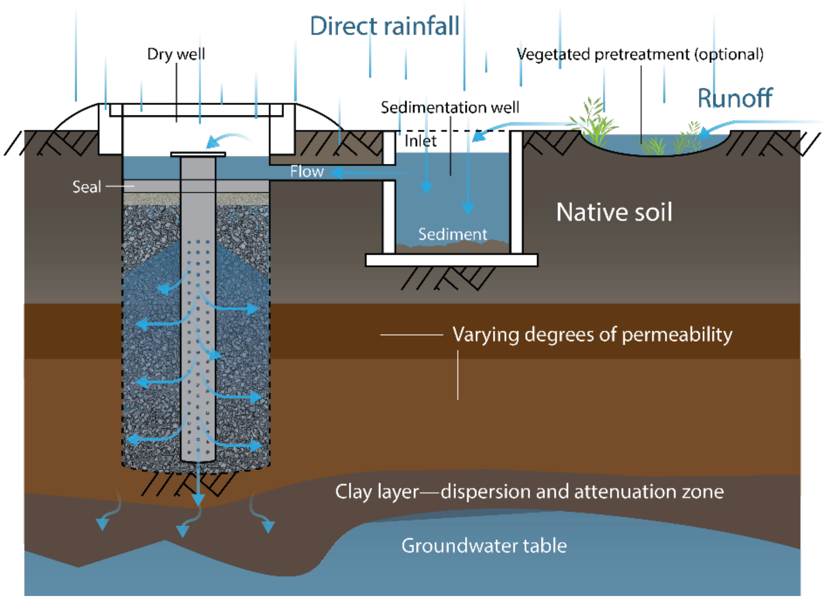


Figure 2. Basic schematic of a dry well

Dry Well Factsheet

1.1 Variations and Alternative Names

- Underground injection control (UIC)

2.0 Advantages & Limitations

2.1 Advantages

- ✓ Well suited for areas where near-surface infiltration is restricted
- ✓ Minimal area requirements
- ✓ Can be used for groundwater recharge
- ✓ Reduces runoff flow rates and volumes
- ✓ Can be relatively easy to maintain

2.2 Limitations

- ✗ Not yet efficient at treating some water soluble contaminants and non-aqueous phase liquids that may be present in stormwater
- ✗ Not suitable for areas with steep slopes, a water table that is near the ground surface, or soil or groundwater that has been contaminated
- ✗ Unclear local regulations in some areas

3.0 Siting

Dry wells should not be installed too close to drinking water wells to minimize the risk of contamination or in areas where soil or groundwater has been contaminated to avoid flushing contamination into groundwater. They should also not be installed in or near sites where contamination by dissolved pollutants is likely (e.g., auto repair shops).

The soil composition should be inspected prior to installation to ensure that the dry well is well past any impermeable layers or layers in which the water will not infiltrate adequately.

Dry wells should be set back from buildings and other foundations and should not be installed in areas with steep slopes.

All dry well locations should be registered with USEPA.

4.0 Design Considerations

When designing a dry well, the following parameters should be considered:

- ❑ Contributing drainage area
- ❑ Depth
- ❑ Volume
- ❑ Sedimentation chamber/well
- ❑ Pretreatment (may be necessary in some areas)

5.0 Construction Considerations

- ❑ Erosion control around the hole to prevent contamination and clogging during installation
- ❑ Watch for any unexpected fluid, colors, or odors coming from the drill site to avoid installing the dry well in an unknown contaminated area

6.0 Maintenance

- ❑ Inspections and cleaning of sedimentation chamber to prevent buildup and/or clogging
- ❑ Inspections of dry well for clogged filter screens or other issues that may arise
- ❑ Street sweeping for dry wells that are set into a roadway to prevent excess loading of sediment and debris

7.0 REFERENCES

Office of Water Programs at California State University, Sacramento; Booth D.; Ellison-Lloyd D.; Washburn B.; Werder C. (OWP et al. 2018). *The American River Basin Stormwater Resource Plan, Appendix L - Design Guidance for Drywell Implementation in the ARB Region*. 2018.

Green Roof Factsheet

1.0 General Description

Figure 1. Green roof (Center for Neighborhood Technology)

Potential Treatment Mechanisms								
I	ET	FA	B	RH	S	F	P	T
	✓	✓	✓		✓		✓	

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Green roofs are layered stormwater management systems with a well-insulated and structurally sound roof for the first layer. On top of the roof is a waterproof layer and root barrier. Next is a drainage layer made of varying materials, such as a drainage mat or rock aggregate, to convey excess water off of the roof. Above this layer is a filter layer, which can also be made of varying materials (e.g., filter fleece), that assists in filtering out pollutants and some sediment. The top and final layers are the growing medium and plants that reduce runoff by storing and using the incidental stormwater. A schematic showing these layers is given in Figure 2.

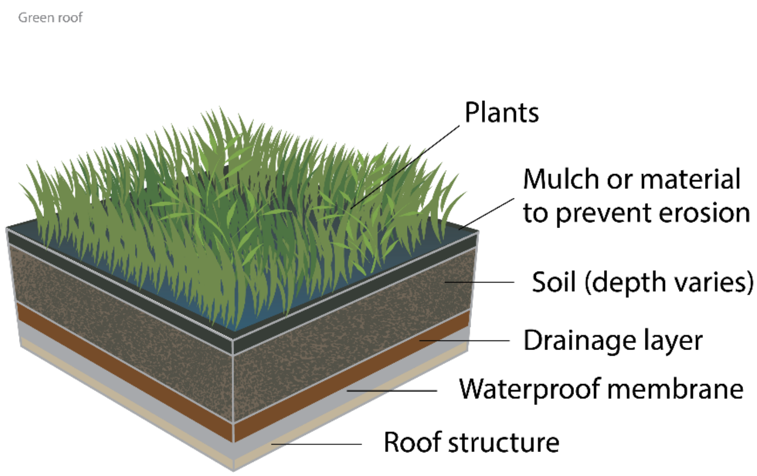


Figure 2. Schematic of basic green roof

1.1 Variations and Alternative Names

- Rooftop garden
- Eco-roof

2.0 Advantages & Limitations

2.1 Advantages

- ✓ Does not need any additional land
- ✓ Decreases runoff temperature (SSWP 2018)
- ✓ Can provide usable green space as well as wildlife habitat

2.2 Limitations

- × Requires specific structural support
- × Requires irrigation which can lead to structural issues if the roof is not properly protected
- × Not suitable for wooden structures

3.0 Siting

Due to the moisture and load, installing green roofs on wooden structures may be infeasible.

4.0 Design Considerations

When designing a green roof, the following parameters should be considered:

- Roof structure materials and design
- Building load capacity, including seismic loads during saturated conditions
- Vegetation
  - planting material and water holding capacity
  - mulch
- Drawdown time
- Roof slope
- Access
- Irrigation
- Lining
- Outlet drainage
- Overflow drainage

5.0 Construction Considerations

- Highly specialized construction may require a specialist to oversee the construction process
- Protection of vegetation during establishment from
  - construction damage
  - public access
  - heat exposure
- Covering the area with mulch or another erosion control method before vegetation is added can help prevent erosion, especially during vegetation establishment.

6.0 Maintenance

- Plant management
  - mowing of grass
  - pruning of non-grasses
  - weed removal
  - identification and promotion of desired species (may require special training)
- Inspections for standing water after major rainfall events to prevent vector breeding

7.0 References

Sacramento Stormwater Quality Partnership (SSQP 2018). *Stormwater Quality Design Manual*. July 2018.

Hydrodynamic Separator Factsheet

1.0 General Description

Figure 1. Hydrodynamic separator (EPA)

Potential Treatment Mechanisms								
I	ET	FA	B	RH	S	F	P	T
					✓	✓		

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Hydrodynamic separators are underground systems located in wet vaults designed to remove large sediment by gravity settling. Some use screens to remove trash. Screens or baffles can also be designed to enhance settling. A schematic of one type of hydrodynamic separator is shown in Figure 2.

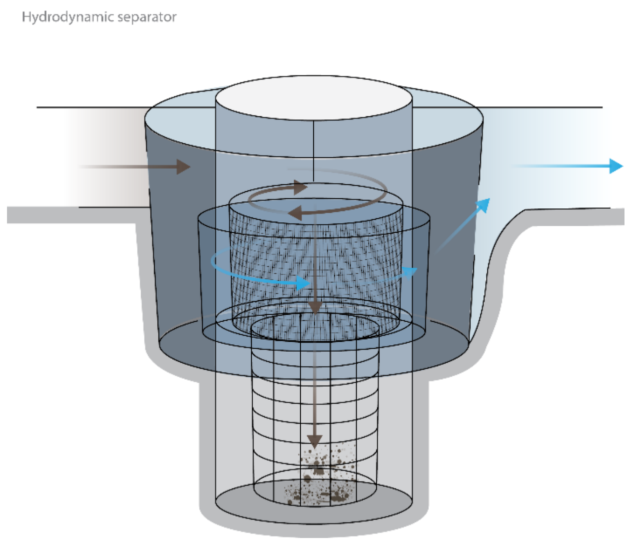


Figure 2. Schematic of a basic hydrodynamic separator

1.1 Variations and Alternative Names

- Vortex separators
- Swirl separators
- Gravity separators
- Flow-through separators

2.0 Advantages & Limitations

2.1 Advantages

- ✓ Located underground
- ✓ May be used for spill containment
- ✓ Works for a large range of flow velocities
- ✓ Can be inexpensive to install

2.2 Limitations

- Due to permanent pools or stagnant water, regular treatment for mosquito control may be necessary
- Moderate pollutant removal
- May not be able to remove fine sediments
- Does not remove dissolved pollutants (CASQA 2003, 2018)
- Some models store vegetation debris in standing water, which can increase nutrient and sediment loading by decomposition

3.0 Siting

Because wet vaults are sealed underground systems, underground utilities must first be located to avoid utility conflicts.

4.0 Design Considerations

When designing a hydrodynamic separator, the following parameters should be considered:

- ❑ Contributing drainage area
- ❑ Design volume
- ❑ Maintenance access
- ❑ Flow rate
- ❑ Hydraulic residence time

5.0 Construction Considerations

The usual construction considerations apply.

6.0 Maintenance

- ❑ Mosquito breeding abatement (if standing water)
- ❑ Removal of trash and debris
- ❑ Sediment control

7.0 References

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

California Stormwater Quality Association (CASQA 2017). *Draft Stormwater Best Management Practice Handbook: New Development and Redevelopment*. April 2017.

Infiltration Basin Factsheet

1.0 General Description

Figure 1. Infiltration basin (UC Santa Cruz)

Potential Treatment Mechanisms								
I	ET	FA	B	RH	S	F	P	T
✓	✓	✓			✓			✓

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Infiltration basins are shallow basins designed to infiltrate stormwater runoff into the underlying soil. These basins are typically sized to infiltrate collected water within 48 hours. The maximum drain time (via infiltration) is specified to prevent mosquito breeding and to restore capacity for subsequent storm events. A minimum drain time is sometimes specified to encourage quiescent conditions for particle sedimentation. A riser or overflow weir is typically provided to route flood flows. A schematic of a basic infiltration basin is shown in Figure 2.

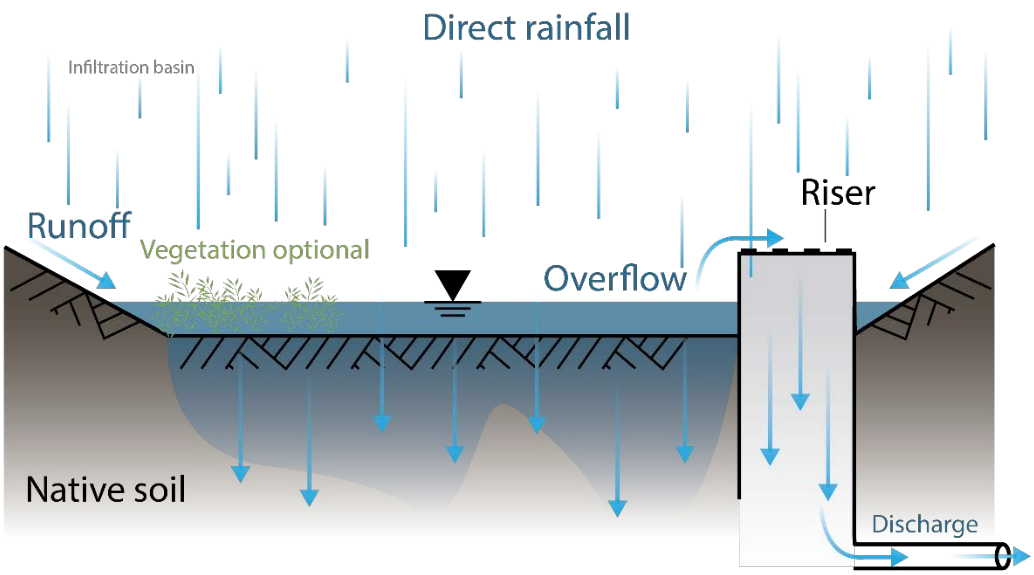


Figure 2. Schematic of a basic infiltration baisn (not to scale)

1.1 Variations and Alternative Names

- Retention basins
- Spreading grounds

2.0 Advantages & Limitations

2.1 Advantages

- ✓ Provides substantial reduction of pollutant load discharged to surface waters
- ✓ Infiltration basins can be integrated into an aesthetically appealing landscape design, though access restriction may be required for public safety

2.2 Limitations

- × Not suitable for:
  - areas where the water table is near the ground surface

  - areas where the groundwater is already contaminated
  - areas with low infiltration rates (slowly permeable soils)
  - industrial sites where spills of dissolved pollutants are likely to occur and escape pretreatment infrastructure
- ✗ If the basin ever becomes clogged with sediment, heavy equipment may be required to restore infiltration rates to an acceptable level

3.0 Siting

The site should not have the potential for spills nor can the groundwater level be too high or have previous contamination. The site also should not have soils throughout the vadose zone that infiltrate too quickly (i.e. have little pollutant removal capacity). However, if the infiltration rate is too fast, pretreatment (e.g., soil amendments or filter layers) may be used to protect groundwater.

Infiltration basins must be set back from buildings, slopes, highway pavement, and bridges that are not designed for sustained soil saturation.

4.0 Design Considerations

When designing an infiltration basin, the following parameters should be considered:

- ❑ Contributing drainage area
- ❑ Soil type/infiltration rate
- ❑ Location in relation to foundations/pavement
- ❑ Base flow
- ❑ Drawdown time
- ❑ Groundwater depth
- ❑ Freeboard
- ❑ Setbacks
- ❑ Inlet and overflow spillway (if existing) erosion control
- ❑ Side slope
- ❑ Access ramp
- ❑ Maintenance drain (optional)
- ❑ Vegetation type
- ❑ Seepage collar (to prevent piping/internal erosion on bermed systems)

5.0 Construction Considerations

- ❑ Stabilize the drainage area before establishment of final grade
  - If stabilization is not possible, flows should be diverted from the basin
- ❑ Completely remove excavated material from the site to avoid any soil washing back into the basin
- ❑ Prohibit any non-tracked heavy equipment from driving over the infiltrating surface to avoid excess compaction

6.0 Maintenance

- ❑ Measure the drawdown time
- ❑ Check for sediment & particulate buildup
- ❑ Plant maintenance
  - Removal of woody vegetation
  - Vegetation managed to aesthetic standards

7.0 References

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

California Stormwater Quality Association (CASQA 2017). *Draft Stormwater Best Management Practice Handbook: New Development and Redevelopment*. April 2017.

Sacramento Stormwater Quality Partnership (SSQP 2018). *Stormwater Quality Design Manual*. July 2018.

Infiltration Gallery Factsheet

1.0 General Description

Potential Treatment Mechanisms								
I	ET	FA	B	RH	S	F	P	T
✓				✓	✓			

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Figure 1. Infiltration gallery (Brentwood Industries)

Infiltration galleries are underground void spaces consisting of one or more perforated containers such as large pipes, vaults, or archways. Galleries are engineered to support cover and aboveground land use. A schematic of a basic infiltration gallery is shown in Figure 2.

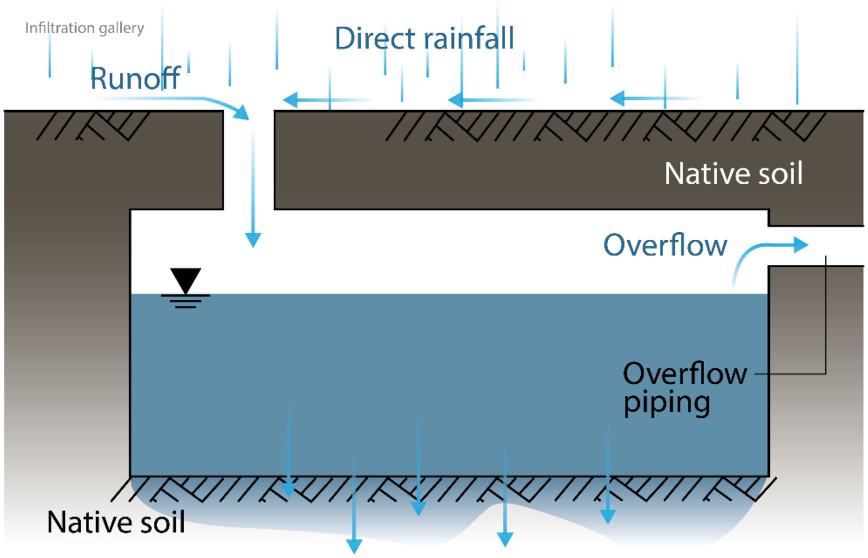


Figure 2. Basic schematic of an infiltration gallery

2.0 Advantages & Limitations

2.1 Advantages

- ✓ Recharge groundwater
- ✓ Located underground
- ✓ Provides substantial reduction of pollutant load discharged to surface water

2.2 Limitations

- × Not suitable for:
  - areas where the water table is near the ground surface
  - areas where the groundwater is already contaminated
  - areas with low infiltration rates (slowly permeable soils)
  - industrial sites where spills of dissolved pollutants are likely to occur and escape pretreatment infrastructure
- × If the basin ever becomes clogged with sediment, heavy equipment may be required to restore infiltration rates to an acceptable level

Infiltration Gallery Factsheet

3.0 Siting

The site should not have the potential for spills nor can the groundwater level be too high or have previous contamination. The site also should not have soils throughout the vadose zone that infiltrate too quickly (i.e. have little pollutant removal capacity). However, if the infiltration rate is too fast, pretreatment (e.g., soil amendments or filter layers) may be used to protect groundwater.

Infiltration basins must be set back from buildings, slopes, highway pavement, and bridges that are not designed for sustained soil saturation.

4.0 Design Considerations

When designing an infiltration gallery, the following parameters should be considered:

- ❑ Minimum cover
- ❑ Contributing drainage area (CDA)
- ❑ Volume
- ❑ Drawdown time
- ❑ Dead and live loading
- ❑ Maintenance access
- ❑ Setbacks

5.0 Construction Considerations

- ❑ Stabilization of the CDA or diversion of flows during construction to prevent sediment loading

6.0 Maintenance

- ❑ Inspections for trash and debris removal

Infiltration Trench Factsheet

1.0 GENERAL DESCRIPTION

Potential Treatment Mechanisms								
I	ET	FA	B	RH	S	F	P	T
✓		✓		✓				✓

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Figure 1. Infiltration trench (Richland Soil and Water Conservation)

Infiltration trenches are long, narrow trenches typically filled with sand, rocks, and gravel into which stormwater runoff collects in pore spaces and infiltrates into surrounding soils. Their primary function is to provide infiltration within a smaller, more flexible footprint than infiltration basins. The depth or bottom surface area must be sufficiently large enough to allow the trench to drain within 72 hours. A schematic of a basic infiltration trench is shown in Figure 2.

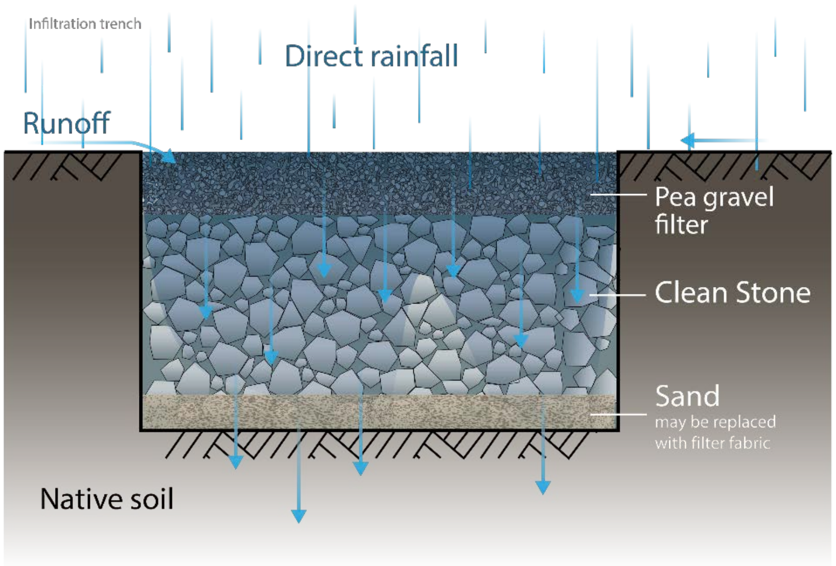


Figure 2. Basic schematic of an infiltration trench

1.1 Variations and Alternative Names

- Rock swales

2.0 ADVANTAGES & LIMITATIONS

2.1 Advantages

✓ Infiltration trenches can be integrated into an aesthetically appealing landscape design
✓ Provides substantial reduction of pollutant load discharged to surface waters

2.2 Limitations

✗ May not be suitable for:
  - areas with low infiltration rates (slowly permeable soils)
  - areas with steep slopes

- areas where the water table is near the ground surface and/or there is existing groundwater contamination
- industrial sites where spills may occur

- If the trench becomes clogged with sediment, reconstruction will likely be required to restore infiltration rates to an acceptable level

3.0 Siting

The site should not have the potential for spills nor can the groundwater level be too high or have previous contamination. The site also should not have soils throughout the vadose zone that infiltrate too quickly (i.e. have little pollutant removal capacity). However, if the infiltration rate is too fast, pretreatment (e.g., soil amendments or filter layers) may be used to protect groundwater.

Infiltration trenches must be set back from buildings, slopes, highway pavement, and bridges that are not designed for sustained soil saturation, as well as septic fields and water supply wells.

4.0 Design Considerations

When designing an infiltration trench, the following parameters should be considered:

- Contributing drainage area (CDA)
- Groundwater depth
- Soil type/infiltration rate
- Drawdown time
- Trench depth
- Trench lining
- Trench media
- Observation well size
- Underdrain (optional)
- Setbacks

5.0 Construction Considerations

- Stabilization of the CDA or diversion of flows during construction to prevent sediment loading

6.0 Maintenance

- Inspections for ponding that is not draining adequately
  - If trench becomes clogged, the rock will need to be removed and replaced

7.0 References

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

California Stormwater Quality Association (CASQA 2017). *Draft Stormwater Best Management Practice Handbook: New Development and Redevelopment*. April 2017.

Sacramento Stormwater Quality Partnership (SSQP 2018). *Stormwater Quality Design Manual*. July 2018.

Media Filters Factsheet

1.0 GENERAL DESCRIPTION

Figure 1. Media filter (City of Portland OR)

Potential Treatment Mechanisms									
S	I	ET	FA	B	RH	S	F	P	T
			✓						✓

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Media filters are usually in open bed or vault arrangements. Open bed filters generally have a settling area followed by the filter bed. The filter area typically has one or multiple perforated underdrains. Media filters can be made with one or multiple filtering media including, but not limited to, some mixture of two or more of the following: limestone, activated alumina, perlite, zeolites, sand, peat, biochar, and granular activated carbon. A schematic of a basic open bed, surface media filter is shown in Figure 2 and a schematic of a subsurface media filter is shown in Figure 3.

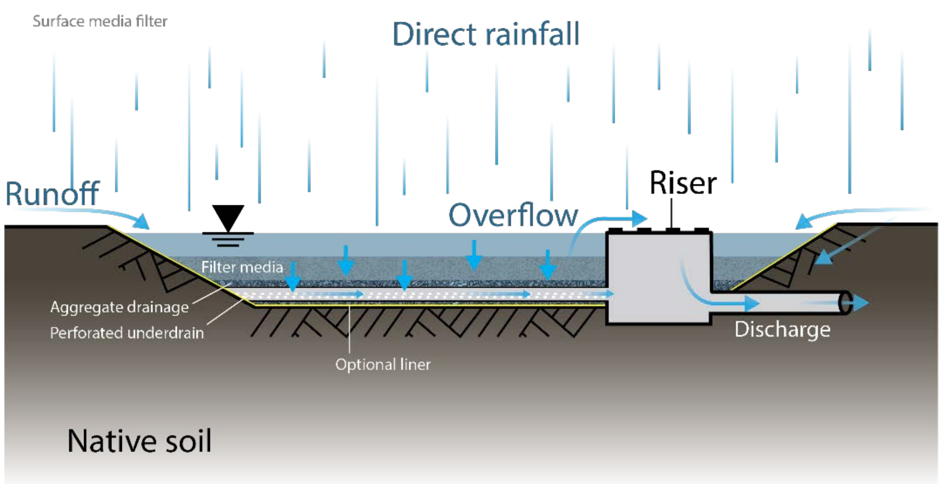


Figure 2. General schematic of a surface media filter

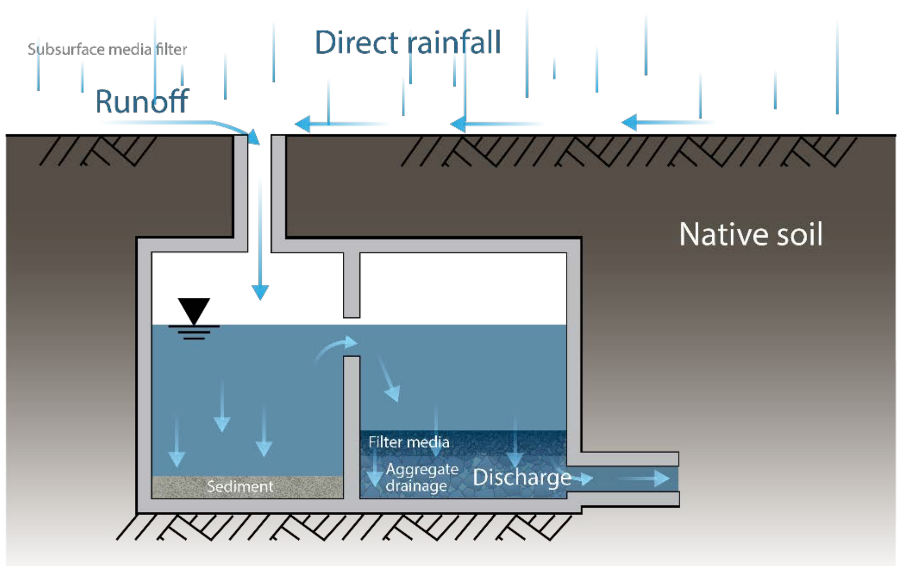


Figure 3. Schematic of a basic subsurface media filter

Media Filters Factsheet

1.1 Variations and Alternative Names

- Sand filters
- Austin sand filters
- Delaware sand filters
- DC sand filters
- Canister filters
- Alternative media filters

2.0 ADVANTAGES & LIMITATIONS

2.1 Advantages

- ✓ Typically provide high solids removal
- ✓ Can be used where space is limited
- ✓ Can be used where the water table is high
- ✓ Does not require vegetation management/irrigation
- ✓ Can be augmented with absorptive media to increase pollutant removal

2.2 Limitations

- × If the design includes a constant pool of water (e.g., Delaware sand filter), vector issues may arise.

3.0 SITING

Media filters require maintenance access and an elevation change from drainage surface to storm drainage systems.

4.0 DESIGN CONSIDERATIONS

When designing a media filter, the following parameters should be considered:

- ❑ Contributing drainage area (CDA)
- ❑ Filter media
- ❑ Filter bed size
- ❑ Hydraulic residence time (for sorptive media)
- ❑ Unlined underdrain (optional, to allow infiltration)

5.0 CONSTRUCTION CONSIDERATIONS

- ❑ Stabilization of the CDA or diversion of flows during construction to prevent sediment loading

6.0 MAINTENANCE

- ❑ Inspections for adequate drainage to avoid vector breeding
- ❑ Removal of sediment and debris

7.0 REFERENCES

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

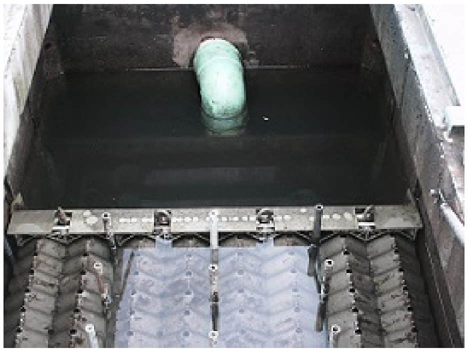
California Stormwater Quality Association (CASQA 2017). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. April 2017.

Sacramento Stormwater Quality Partnership (SSQP 2018). *Stormwater Quality Design Manual*. July 2018.

County of Placer, City of Roseville, City of Auburn, City of Lincoln, and Town of Loomis (County of Placer et al. 2016). *West Placer Storm Water Quality Design Manual*. April 2016.

Oil-Water Separator Factsheet

1.0 General Description



Potential Treatment Mechanisms								
I	ET	FA	B	RH	S	F	P	T
					✓	✓		

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Figure 1. Oil-water separator (Stormwater Partners SW Washington)

Sediment-oil-water separators are typically made up of three chambers. Sediment settles out in the first chamber while the rest flows through an outlet toward the middle or top of the separating wall. The second chamber allows the free oils (oils that are not emulsified or dissolved) to separate to the top of the water and a pipe at the bottom of the chamber conveys the now separated water out. A schematic of a basic sediment-oil-water separator is shown in Figure 2.

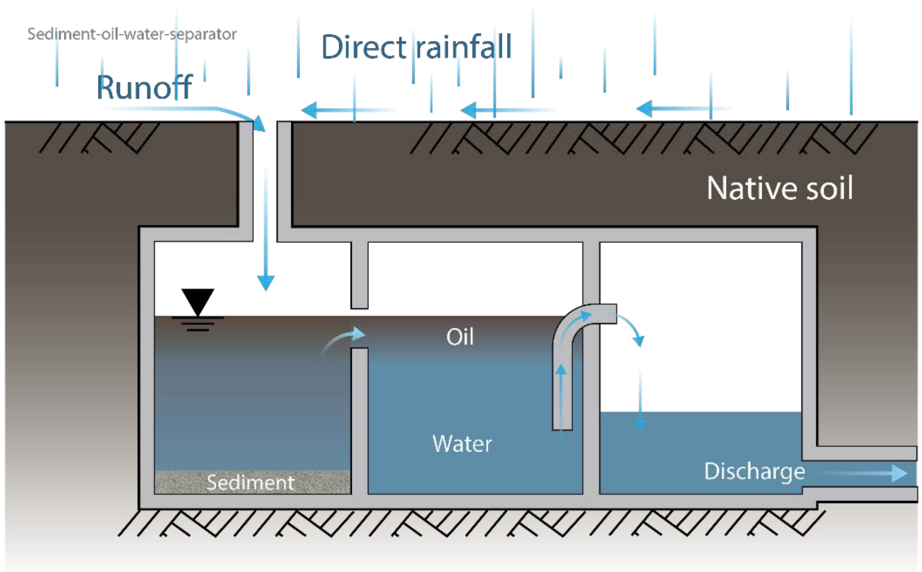


Figure 2. Schematic of an basic oil-water separator

1.1 Variations and Alternative Names

- Water quality inlets
- Trapping catch basins
- Oil-grit separators
- Flow-through separators

2.0 Advantages & Limitations

2.1 Advantages

✓ Suitable for industrial areas and/or areas where spills may occur

2.2 Limitations

× Moderate pollutant removal due to low hydraulic residence time

× Due to permanent pools or long standing water, regular treatment for mosquito control may be necessary

Oil-Water Separator Factsheet

3.0 SITING

Oil-water separators are well suited for industrial sites or areas where spills may occur.

4.0 DESIGN CONSIDERATIONS

When designing a sediment-oil-water separator, the following parameters should be considered:

- ❑ Design volume or rate
- ❑ Maintenance access

5.0 CONSTRUCTION CONSIDERATIONS

There are no unusual considerations for construction.

6.0 MAINTENANCE

- ❑ Mosquito breeding abatement (if standing water)
- ❑ Removal of trash and debris
- ❑ Sediment control

7.0 REFERENCES

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

California Stormwater Quality Association (CASQA 2017). *Draft Stormwater Best Management Practice Handbook: New Development and Redevelopment*. April 2017.

Porous/Pervious Pavement Factsheet

1.0 General Description

Figure 1. Porous pavement (EPA)

Potential Treatment Mechanisms								
I	ET	FA	B	RH	S	F	P	T
✓	✓	✓						

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Porous or pervious pavement refers to trafficked or parking surfaces in which the top layer is comprised either entirely of a permeable material (e.g., gravel or porous concrete) or impermeable material broken up with permeable seams, spaces, or joints (e.g., pavers). Underneath the top layer is a layer (or layers) of porous material that holds water while it infiltrates into surrounding soils. An example schematic of a porous pavement is shown in Figure 2.

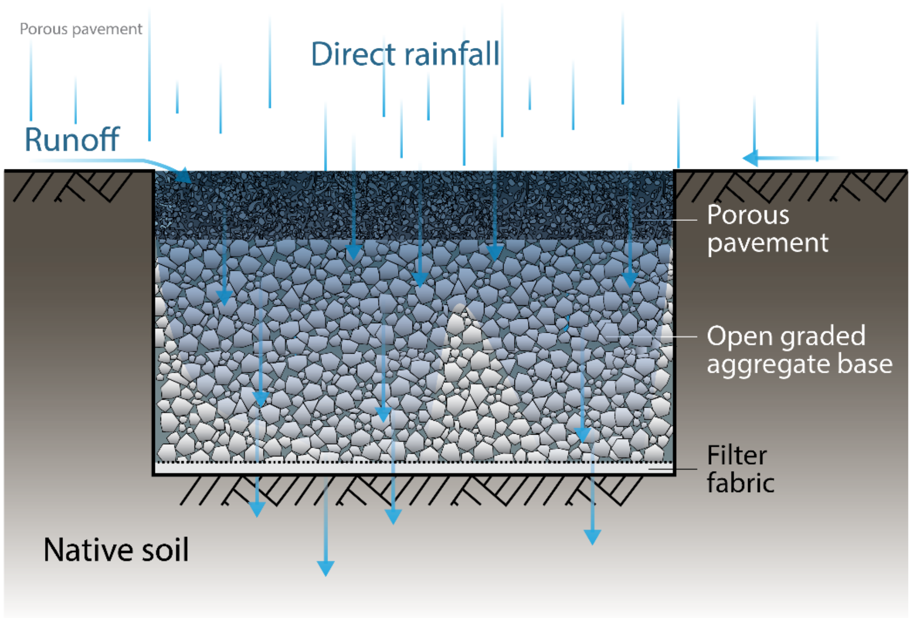


Figure 2. Basic schematic of porous pavement

1.1 Variations and Alternative Names

- Permeable pavers
- Porous pavers
- Porous/permeable asphalt
- Porous/permeable concrete

2.0 Advantages & Limitations

2.1 Advantages

- ✓ Does not require any additional land/space and can be a more aesthetically appealing option than the pavement it replaces
- ✓ Can enhance driving safety by reducing the amount of water pooling on the pavement surface

2.2 Limitations

- If not properly installed or regularly maintained/cleaned, the pavement/pavers can become clogged with sediment and debris
- Not suitable for areas with:
    - heavy traffic
    - high speeds
    - unstable slopes
    - possibility of spills
    - heavy vegetation debris

3.0 SITING

The area should be flat or only have a slight slope and be set back from buildings.

The site should not have heavy traffic, heavy debris loading, or the possibility of spills (e.g., industrial sites).

4.0 DESIGN CONSIDERATIONS

When planning to install an area of pervious pavement, the following design parameters should be considered:

- Contributing drainage area
- Potential traffic load, speed, and volume
- Location/setback from buildings
- Existing soil type
- Existing slope
- Pavement type
- Underdrain (optional)

5.0 CONSTRUCTION CONSIDERATIONS

- Care must be taken to lay the storage layer as level as possible and terrace or berm it to keep water from flowing out through the top of downstream pavement section
- If pavers are used, sufficient space must be left so that the joints do not clog easily

6.0 MAINTENANCE

.

- No storage of equipment on the pavement.
- Many types of porous pavement require cleaning in some way to avoid becoming clogged with sediment and debris

7.0 REFERENCES

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

California Stormwater Quality Association (CASQA 2017). *Draft Stormwater Best Management Practice Handbook: New Development and Redevelopment*. April 2017.

County of Placer, City of Roseville, City of Auburn, City of Lincoln, and Town of Loomis (County of Placer et al. 2016). *West Placer Storm Water Quality Design Manual*. April 2016.

Sacramento Stormwater Quality Partnership (SSQP 2018). *Stormwater Quality Design Manual*. July 2018.

Underground Storage Vault Factsheet

1.0 GENERAL DESCRIPTION

Potential Treatment Mechanisms								
I	ET	FA	B	RH	S	F	P	T
				✓	✓			

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Figure 1. Underground Storage Vault (Colorado State University, Fort Collins)

Underground storage vaults are engineered, subsurface void spaces consisting of one or more containers, such as large pipes or concrete vaults, with a permanent pool of water. Stormwater enters a vault through a surface inlet and is temporarily stored, allowing sediments and particles to settle. If the water level reaches a certain height, it is discharges as overflow. A schematic of an underground storage vault is shown in Figure 2.

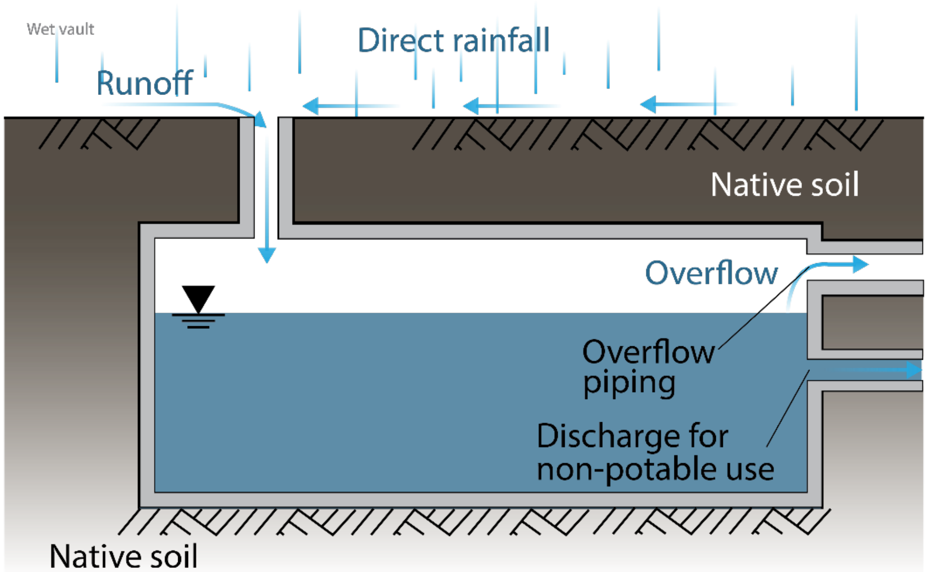


Figure 2. Schematic of a basic underground storage vault

1.1 Variations and Alternative Names

- Wet vault
- Underground cistern

2.0 ADVANTAGES & LIMITATIONS

2.1 Advantages

- ✓ Located underground
- ✓ Can be used where the water table is high

2.2 Limitations

- ✗ Due to the designed permanent pool of water or stagnant water, vector breeding can become an issue

Underground Storage Vault Factsheet

3.0 Siting

Because underground storage vaults are sealed underground systems, subsurface utilities must first be located to avoid utility conflicts.

4.0 Design Considerations

When designing an underground storage vault, the following parameters should be considered:

- ❑ Contributing drainage area
- ❑ Vault volume
- ❑ Dead and live loading capacity
- ❑ Maintenance drain
- ❑ Mosquito access prevention

5.0 Construction Considerations

Each manufacturer will have construction guidelines for each specific vault (CASQA 2003, 2018).

6.0 Maintenance

- ❑ Inspections for trash and debris removal

7.0 References

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

California Stormwater Quality Association (CASQA 2017). *Draft Stormwater Best Management Practice Handbook: New Development and Redevelopment*. April 2017.

Vegetated Buffer Strip Factsheet

1.0 General Description

Figure 1. Vegetated Buffer Strip (Caltrans)

Potential Treatment Mechanisms								
I	ET	FA	B	RH	S	F	P	T
✓	✓	✓	✓		✓		✓	

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Vegetated buffer strips are gently sloped, relatively flat vegetated surfaces over which runoff is treated as sheet flow. In conventional vegetated buffer strips, the plants slow the flow, which enhances sedimentation, filtration, and infiltration. In some cases, the soil underlying the strip is amended with compost or replaced with a permeable soil/compost mix. This allows more runoff to infiltrate into the ground, thus reducing runoff volumes. A schematic of a basic vegetated buffer strip is shown in Figure 2.

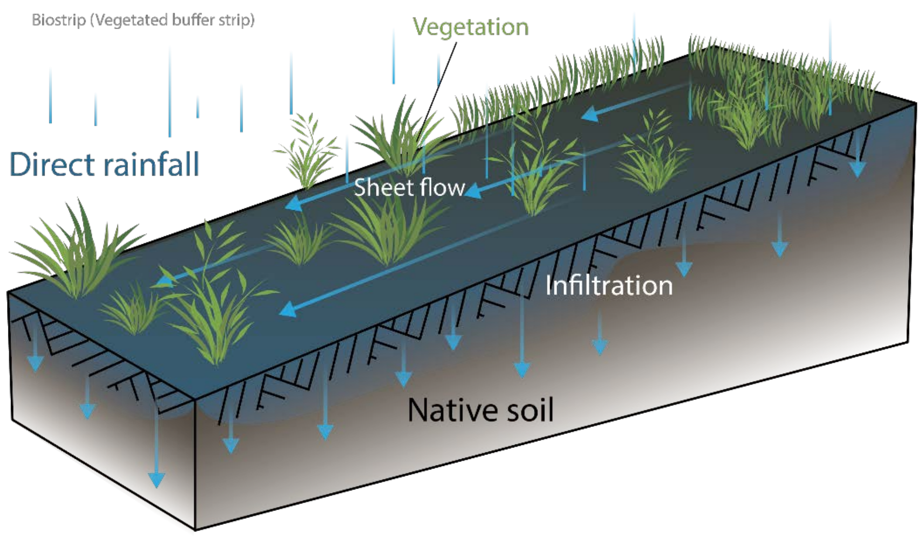


Figure 2. Schematic of a basic vegetated buffer strip

1.1 Variations and Alternative Names

- Strips
- Buffers
- Buffer strips
- Biostrips

2.0 Advantages & Limitations

2.1 Advantages

- ✓ Usually vegetated with grasses or other low maintenance plants, these strips often require little maintenance.
- ✓ When done well, strips can be both inexpensive and add aesthetic appeal.
- ✓ If sized correctly, strips provide adequate drainage and removal of particulate pollutants.

2.2 Limitations

- ✗ Prone to erosion and channelization if vegetative cover is not properly established.
- ✗ One strip is not suitable for large treatment areas or areas with concentrated runoff.

3.0 Siting

According to the California Stormwater Quality Association and the Sacramento Stormwater Quality Partnership, one strip is limited to treating only a few acres of contributing drainage area (CASQA 2003, SSQP 2018).

4.0 Design Considerations

When designing a vegetated buffer strip, the following parameters should be considered:

- ❑ Contributing drainage area
- ❑ Hydraulic residence time
- ❑ Slope in flow direction (longitudinal slope)
- ❑ Flat perpendicular to flow direction (no lateral slope)
- ❑ Flow depth (less than plant height)
- ❑ Length and width of strip (for estimating infiltration)
- ❑ Vegetation type and height (cool season grasses can reduce dry season watering needs)

5.0 Construction Considerations

- ❑ Install during a time of year when it is likely that the vegetation will receive sufficient watering from rainfall to become established without irrigation
  - o Irrigation should only be applied if incidental rainfall is insufficient for plant establishment
- ❑ Divert runoff until plants are established

6.0 Maintenance

- ❑ Plant management
  - o mowing grass
  - o pruning non-grasses
  - o removing woody vegetation
  - o removing weeds (if desired for aesthetics)
- ❑ Inspections for erosion with additional inspections after major rainfall events
- ❑ Litter removal (for areas prone to litter)
- ❑ Inspections for standing water to prevent mosquitos and other vector breeding

7.0 References

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

California Stormwater Quality Association (CASQA 2017). *Draft Stormwater Best Management Practice Handbook: New Development and Redevelopment*. April 2017.

County of Placer, City of Roseville, City of Auburn, City of Lincoln, and Town of Loomis (County of Placer et al. 2016). *West Placer Storm Water Quality Design Manual*. April 2016.

Sacramento Stormwater Quality Partnership (SSQP 2018). *Stormwater Quality Design Manual*. July 2018.

Vegetated Swale Factsheet

1.0 General Description

Figure 1. Vegetated swale (SSQP 2018)

Potential Treatment Mechanisms								
I	ET	FA	B	RH	S	F	P	T
✓	✓	✓	✓		✓		✓	

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

Vegetated swales are gently sloped vegetated channels. Plants slow the flow, which enhances settling, filtration, and infiltration. In some cases, the soil underlying the swale is amended with compost or replaced with a permeable soil/compost mix. This allows more runoff to infiltrate into the ground, thus reducing runoff volumes. An example schematic of a vegetated swale is shown in Figure 2.

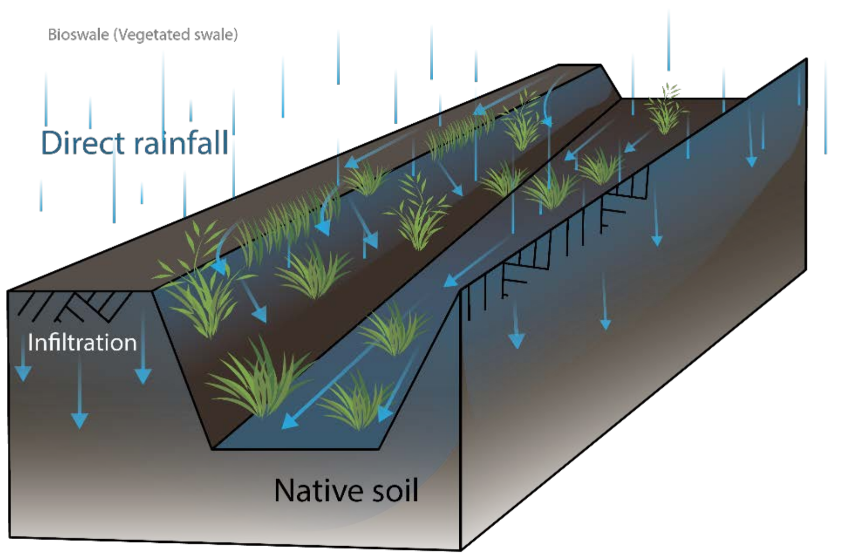


Figure 2. Schematic of an example vegetated swale

1.1 Variations and Alternative Names

- Swales
- Bioswales

2.0 Advantages & Limitations

2.1 Advantages

- ✓ Usually vegetated with grasses or other low maintenance plants, swales often require little maintenance.
- ✓ When done well, swales can both be inexpensive and add an aesthetic appeal.
- ✓ If sized correctly, provides adequate drainage and removal of particulate pollutants.
- ✓ Requires minimal elevation change

2.2 Limitations

- × Prone to erosion and channelization if vegetative cover is not properly maintained.
- × One swale is not suitable for large treatment areas or areas with high velocity flows.

3.0 Siting

According to the California Stormwater Quality Association and the Sacramento Stormwater Quality Partnership, one vegetated swale is limited to treating up to 10 acres of contributing drainage area (CASQA 2003, SSQP 2018).

4.0 Design Considerations

When designing a vegetated swale, the following parameters should be considered:

- ❑ Contributing drainage area
- ❑ Total inundated area (for estimating infiltration)
- ❑ Hydraulic residence time
- ❑ Bottom width
- ❑ Slope in flow direction (longitudinal slope)
- ❑ Side slopes
- ❑ Slope of invert perpendicular to flow
- ❑ Flow depth
- ❑ Vegetation type and height
- ❑ Underdrains
- ❑ Design volume (depth)
- ❑ Design rate (intensity)

5.0 Construction Considerations

- ❑ Install when vegetation will receive sufficient watering from rainfall to become established without irrigation. Only apply irrigation when incidental rainfall is insufficient for vegetation establishment.
- ❑ Divert runoff until plants are established

6.0 Maintenance

- ❑ Plant management
  - o mowing grass
  - o pruning non-grasses
  - o removing woody vegetation
  - o removing weeds (if desired for aesthetics)
- ❑ Inspections for erosion
- ❑ Litter removal (for areas prone to litter)
- ❑ Inspections for standing water to prevent mosquitos and other vector breeding

7.0 References

California Department of Transportation (Caltrans 2017). *Project Planning and Design Guide* (PPDG). July 2017.

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

California Stormwater Quality Association (CASQA 2017). *Draft Stormwater Best Management Practice Handbook: New Development and Redevelopment*. April 2017.

County of Placer, City of Roseville, City of Auburn, City of Lincoln, and Town of Loomis (County of Placer et al. 2016). *West Placer Storm Water Quality Design Manual*. April 2016.

Sacramento Stormwater Quality Partnership (SSQP 2018). *Stormwater Quality Design Manual*. July 2018.

Wet Pond Factsheet

1.0 General Description

Figure 1. Wet pond (MN Pollution Control Agency)

Potential Treatment Mechanisms								
I[1]	ET	FA	B	RH	S	F	P	T
✓	✓				✓		✓	

Legend: I = Infiltration; ET = Evapotranspiration; FA = Filtration and/or Adsorption; B = Biochemical Transformation; RH = Rainfall and Runoff Harvest; S = Sedimentation; F = Floatation; P = Plant Uptake; T = Trash Capture

[1] For unlined systems only; these systems are sometimes constructed with a liner

Wet ponds are similar to constructed wetlands in that they are vegetated basins with a pool of water year-round or, depending on location/climate, at least during the wet season, but they differ in that wet ponds are much deeper than wetlands. The constant pool of water allows stormwater to slowly infiltrate and receive treatment from the plant roots. A schematic of a basic wet pond is shown in Figure 2.

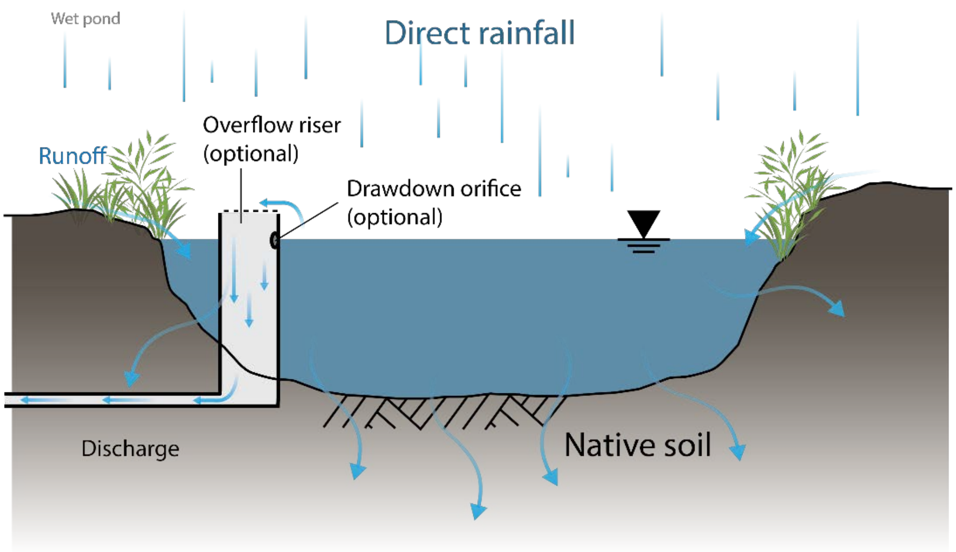


Figure 2. Schematic of a basic wet pond

1.1 Variations and Alternative Names

- Stormwater ponds
- Retention ponds
- Wet extended detention ponds
- Detention ponds

2.0 Advantages & Limitations

2.1 Advantages

- ✓ Can provide habitat for wetland wildlife and add aesthetic appeal
- ✓ Can provide significant reduction in contaminants/pollutants

2.2 Limitations

- × Vector breeding often becomes an issue
- × Public access safety concerns may require security fencing around the area

- ✘ Relatively high land area requirement

3.0 Siting

Wet ponds are not suitable for areas with steep/unstable slopes. Also, they may not be appropriate for discharges into cold water streams due to warm water from the pond possibly increasing stream temperatures.

If the site has significantly porous soil, an impermeable liner along the bottom may be required to maintain the permanent pool.

4.0 Design Considerations

When designing a wet pond, the following parameters should be considered:

- ❑ Design volume
- ❑ Drawdown time
- ❑ Permanent pool volume/depth
- ❑ Liner (optional)
- ❑ Inlet/outlet erosion control
- ❑ Forebay
- ❑ Surcharge depth
- ❑ Side slopes
- ❑ Seepage collar (to prevent piping/internal erosion on bermed systems)
- ❑ Vegetation
- ❑ Vector control animals (e.g., mosquito fish)

5.0 Construction Considerations

- ❑ Install seepage collars on outlet piping to prevent water from seeping out and causing damage

6.0 Maintenance

- ❑ Maintain permanent pool of water
  - o may require water to be pumped in during dry weather
- ❑ Inspections:
  - o of vegetation while pond is establishing, replanting vegetation as needed
  - o of outlet
  - o for trash and debris accumulation
  - o for mosquitos and other vectors
- ❑ Vegetation and fish management may be required

7.0 References

California Stormwater Quality Association (CASQA 2003). *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. January 2003.

California Stormwater Quality Association (CASQA 2017). *Draft Stormwater Best Management Practice Handbook: New Development and Redevelopment*. April 2017.

Sacramento Stormwater Quality Partnership (SSQP 2018). *Stormwater Quality Design Manual*. July 2018.

Appendix B

SCM Sizing Methods

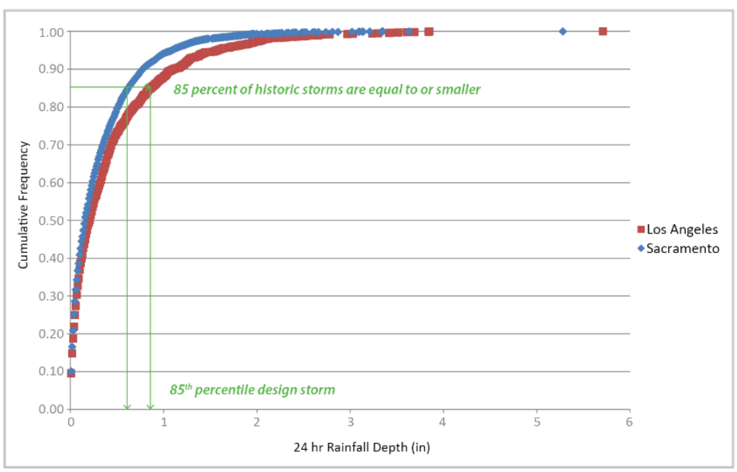
Capture Guidance for Schools
SCM Sizing Methods

1.0 RETENTION AND TREATMENT DESIGN METHODS

Retention and treatment design evaluates the required size and dimensions for a device to prevent or reduce discharges of runoff volumes and pollutants, while recognizing cost and other feasibility limitations. To balance water quality and costs, practitioners have generally accepted a handful of sizing methods, which fall into either volume-based or flow-based categories. The more common methods are summarized below. Complete descriptions, including calculations, are provided in the CA Phase II Sizing Tool documentation manual.

1.1 Volumetric Design Storm Method

The volumetric design storm method is an algebraic water balance in which the device must be able to capture the volume of runoff generated from a specific rain depth that falls onto a defined area. The depth is approximated by ranking several years of 24-hour rainfall data and calculating the depth at which a certain percent of the storms are smaller. The 85th percentile design storm (the depth at which 85% of the daily or 24-hour storms on record are equal to or smaller) is a common a rule of thumb based on research showing that more frequent, smaller storms have the greatest amount of pollutants. The design storm depth is multiplied by the drainage area and a runoff coefficient, the latter of which represents a fraction of the rainfall that becomes runoff (often 0.9 for impervious surfaces). The storage within the SCM— including within the void space of the media, ponding zone, or open space—must be large enough to hold this design storm volume. This method is documented in detail in many existing municipal design manuals, the CA Phase II LID Sizing Tool, and the CASQA New and Redevelopment BMP Handbook.



Design Storm Calculation

$V_{scm} = RF_{DS} \times R_V \times A_{IMP}$

Where:

V_{SCM} = required capture volume for SCM

RF_{DS} = depth of design storm

R_V = volumetric runoff coefficient

A_{IMP} = area of impervious surface draining to SCM

Figure IV–10. How a design storm is determined

1.2 Volumetric Percent Capture Method

The volumetric percent capture method models many rain events and the resulting runoff from a drainage area, as well as the infiltration, evapotranspiration, storage, and discharge from SCMs. The models use many years of historic rainfall and evaporation data (often in hourly time-steps), runoff coefficients appropriate for the drainage area land cover (representing the fraction of rainfall that becomes runoff), on-site soil properties (for infiltration estimates), and capture device characteristics (such as depths and media porosities) to calculate and record volumes of runoff that are generated and then evapotranspirated, infiltrated, and discharged from SCMs across each time step. The difference between the cumulative runoff volumes generated and that discharged is then divided by the total simulation period to determine an annual average volume retained. This average retained volume is divided by the annual average runoff generated to quantify the percent capture. Percent capture for various SCM sizes can be plotted to identify the point of diminishing returns—when higher percent captures start to require a much higher SCM size. Commonly diminishing returns affect cost-effectiveness around 80%.

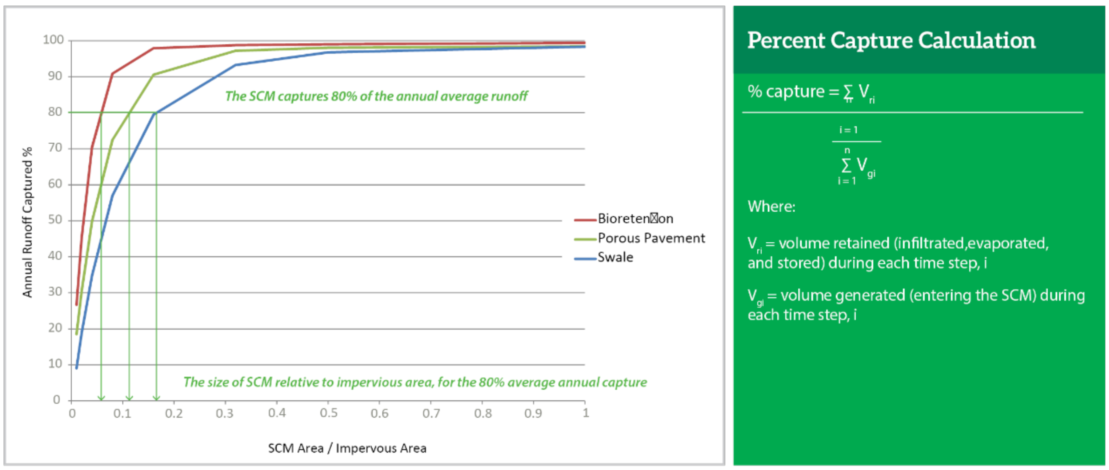


Figure IV–11. Sizing an SCM based on the percent capture method

1.3 Volumetric Baseline Bioretention Method

For the baseline bioretention method, a modification of the percent capture method, the size and other characteristics of a bioretention planter are pre-established without regard to local precipitation data. A common example is a planter that is 4% of the drainage area, with 18 inches of bioretention soil mix, 12 inches of gravel storage, an elevated underdrain, and other specified components. The percent capture for this bioretention SCM is determined, and sizing of other SCMs is based on this percent capture.

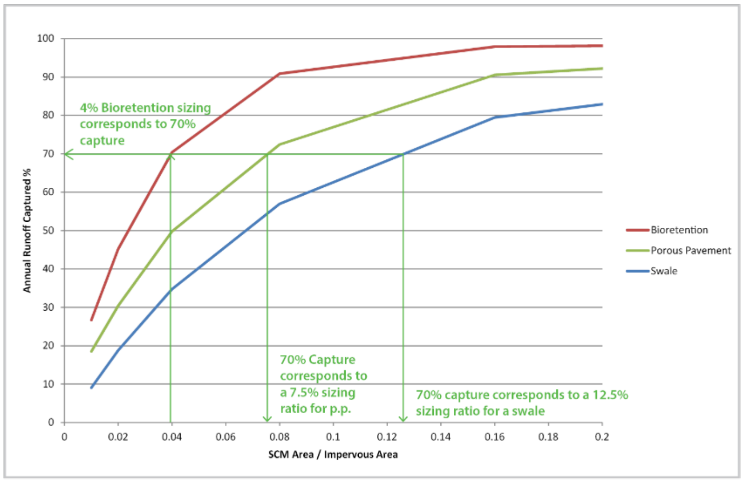


Figure IV–12. Sizing an SCM using the Volumetric Baseline Bioretention Method

1.4 Flow-Based Method

The flow-based method sizes an SCM to retain and treat the flow of runoff produced from a rain event of a specified intensity. Common intensities are 0.02 inches per hour or two times the 85th percentile rainfall intensity based on historic rainfall data. For flow-based design, a runoff model will simulate routing of flows through a single catchment (site-scale design) or multiple catchments (watershed-scale). As runoff moves through a site or watershed, it increases in volume and velocity. The time runoff takes to travel can be estimated through a number of methods. For instance, the rational method and modified rational method are typical, straightforward ways of estimating the travel time. While estimating large-scale flows across watersheds requires significant data, estimating flows and routing in a small catchment is usually less intensive.

1.5 Trash Sizing

Consult with the State Water Board's [Trash Implementation Program] for the latest guidelines on designing SCMs for trash policy compliance.

2.0 HYDROMODIFICATION DESIGN METHODS

Hydromodification design is intended to minimize impacts from higher runoff volumes and flow rates. The objective is to closely match post-construction flow rate discharge to that which occurred pre-construction. For this design, models are run to simulate pre-construction flow rates for a specified return interval such as the 2-year or 10-year storm; it is generally accepted that the greatest effects of hydromodification occur from these (or between these) recurrence intervals. The 2-year, storm represents the intensity of rainfall at which 50% (1/2) of the other historic rainfall intensities are equal to or greater than. This equates to a 50% probability that any storm in a given year will exceed that intensity. The 10-year storm is then the rainfall intensity at which 10% (1/10) of historical rainfall intensities are equal to or greater than, with a 10% likelihood of any storm in one year exceeding that intensity. The post-construction discharge rates cannot exceed these pre-project rates and durations by more than a specified percent. Other methods are more sophisticated, using statistical analysis to evaluate the probability of exceedance for the post-construction condition.

Appendix C

Cost Estimating Resources

CAPTURE Guidance for Schools
Cost Estimating Resources

There is much literature that summarizes costs for various types of runoff management projects, although local social, economic, political, and other conditions will drive actual rates. As part of the One Water Initiative in the City of Los Angeles, capital cost information was compiled for many of the more commonly used SCMs. The results are shown in Table 1.

Table 1. City of Los Angeles SCM Costs Survey Results (Source: "Los Angeles Sustainable Water Project: Ballona Creek Watershed", UCLA, November 2015).

SCM	Count	Present 2014 Value ($/unit)			Unit
		Average	Minimum	Maximum	
Bioretention	5	$ 15.97	$ 3.83	$ 27.13	vol (cf)
Detention Basin	5	$ 14.29	$ 4.57	$ 34.74	vol (cf)
Infiltration Trench	14	$ 12.40	$ 3.15	$ 43.16	vol (cf)
Vegetated Swale	4	$ 18.67	$ 5.58	$ 44.26	vol (cf)
Porous Pavement	8	$ 15.48	$ 7.63	$ 19.90	area (sf)

Other literature resources are summarized below in Table 2. An annotated description of each follows.

Table 2. Resources for SCM Cost Estimating

Resource	Type of Cost		SCMs Evaluated	Cost Information Type	Associated References
	Capital	O&M			
USEPA National Stormwater Calculator[1]	X	X	• Bioretention/Rain Garden • Cistern/Rain Barrel • Downspout Disconnect • Green Roof • Infiltration Basin • Porous Pavement • Street Planter	• Regression Equations • Software Application	• Rossman and Bernagros (2014) • Clary and Piza (2017)
University of Minnesota/Weiss BMP Cost Estimation Algorithm[1]	X	X	• Bioretention/Rain Garden • Constructed Wetland • Detention Basin • Infiltration Trench • Sand Filter • Wet Basin	• Literature Review • Regression Equations	• Weiss et al. (2007) • USEPA (1999) • Clary and Piza (2017)
University of New Hampshire Maintenance Expenditure Study [1]		X	• Bioretention/Rain Garden • Porous Pavement • Sand Filter • Subsurface Wetland • Swale • Wet/Dry Pond	• Physical models at field facility	• Houle et al. (2013) • Clary and Piza (2017)
WE&RF-AWWA-UKWIR Whole-Life Costs Tool[1]	X	X	• Bioretention/Rain Garden • Detention Basin • Green Roof • Infiltration Practices Porous Pavement • Retention Pond • Vegetated Swale	• Surveys/Site Visits • Spreadsheet Tool	• Andrews and Lampe (2005) • Clary and Piza (2017)
The National Cooperative Research Program (NCHRP) Whole-Life Cost Models[1]		X	• Bioretention • Swale	• Literature Review • Surveys	• Taylor (2014)

Cost Estimating Resources

Resource	Type of Cost		SCMs Evaluated	Cost Information Type	Associated References
	Capital	O&M			
ASCE EWRI Survey of BMP O&M Costs[1]	X	X	• Bioretention/Rain Garden • Infiltration Basins/Trench • Permeable Pavement • Rainwater Harvesting	• National Survey • Tabular Data Tool	• USEPA (1999) • Clary and Piza (2017)
Urban Drainage and Flood Control District's BMP-REALCOST Tool[1]	X	X	• Bioretention • Constructed Wetland • Detention Basin • Permeable Concrete Paver • Retention Pond • Sand Filter Basin	• Informational Interviews • Engineering Judgment • Spreadsheet Tool	• Clary and Piza (2017) • Urban Drainage and Flood Control District (2018)
Wossink and Hunt (2003) Empirical Cost Evaluation of SCMs in North Carolina	X	X	• Bioretention • Sand Filter • Wetlands • Wet Pond	• Phone Surveys • Site Contacts • Regression Equations	• Wossink and Hunt (2003) • Clary and Piza (2017)
USEPA Water Financing Clearinghouse LID and GI Case Study Inventory	X	X	• Varies by Study	• Varies by Study	• USEPA (2013)
Green Values National (GVN) Stormwater Management Calculator	X	X	• Cisterns/Rain Barrel • Disconnect Downspout • Green Roof • Swale • Vegetated Filter Strip	• Literature Review • Regression Equations • Online Assessment Tool	• Center for Neighborhood Technology (2009)
SCM Databases for Generating Capital and O&M Cost Equations	X	X	• Biofiltration • Bioretention • Dry Pond/Detention Basin • Gravel Wetland System Infiltration Basin • Infiltration Trench • Porous Pavement • Sand Filter	• Databases • Regression Equations • Tabular Data Tool	• Urbonas (2002) • Brown and Schueler (1997) • SWRPC (1991) • Torno (1984) • Knight et al. (1994) • RS Means Company (2018)

USEPA National Stormwater Calculator

The USEPA developed a user-friendly tool to calculate stormwater runoff at small sites anywhere in the United States. Computation of stormwater runoff is conducted by the USEPA's Stormwater Management Model (SWMM, v. 5.1.012; Rossman & Bernagros 2014). The model uses local soil conditions, meteorology, and land cover to assess the amount of stormwater runoff produced by historical rainfall trends at sites with varying development and stormwater control measures (SCMs).

The updated tool includes definitive estimates of construction and maintenance costs including but not limited to: impervious area disconnection, rainwater harvesting, permeable pavement, and infiltration basins. They are calculated using regression equations that are a function of fixed cost components and variable cost components linked to SCM size. Simple, typical, and complex cost curves were developed using previous cost curves and SCM costing data from a literature review. Capital and maintenance cost estimates for green infrastructure (GI) controls are accessible at Rossman and Bernagros (2014) and Clary and Piza (2017).

University of Minnesota/Weiss BMP Cost Estimation Algorithm

The best management practice (BMP; i.e., SCM) cost estimation algorithm is a product of collaborative research between the University of Minnesota (UM) and Peter Weiss at Valparaiso University. Initially, the algorithm generated expected costs of annual operation and maintenance (O&M) as a percentage of total construction costs (Weiss et al. 2007). Following the compilation of a 20-year record of SCM construction costs and annual O&M costs by UM researchers, the algorithm is now able to calculate the total present cost of SCMs in 2005 dollar terms (Clary & Piza 2017). Total present cost is defined as the current worth of a project in addition to the current worth of 20 years of annual O&M costs (Weiss et al. 2007).

The equation calculates total present cost by converting the 20-year-old annual SCM costs to present values using municipal bond yield rates and inflation values. Total present cost is a function of the SCM size (e.g., water quality volume, swale top width). According to Weiss et al. (2007), with the exception of infiltration trenches, annual SCM O&M costs (as a percentage of construction costs) decrease as construction costs increase.

Supporting information on the cost estimation algorithm can be found in Clary and Piza (2017), Weiss et al. (2007), and USEPA (1999).

University of New Hampshire Maintenance Expenditure Study

Houle et al. (2013) at the University of New Hampshire's Stormwater Center characterized and quantified the maintenance costs of low impact development (LID; i.e., SCMs) in the first two to four years of their operation. Physical models at a field facility—a 4.5-ha commuter parking lot with a series of uniformly sized, isolated, and parallel treatment systems—were used to examine the maintenance demands of seven different SCMs, including vegetated swales, dry/wet ponds, porous asphalt, and bioretention. System maintenance demands including materials, labor, and maintenance type and complexity were tracked and documented monthly using NYSDEC (2003) to help develop a framework for annual maintenance strategies and expenditures. Details on the tracking and calculation of maintenance costs are available in Houle et al. (2013).

Overall, analysis of annual maintenance demands of the SCMs compared to conventional pond systems indicates that they seldom have higher annual maintenance costs and normally have lower annual maintenance costs, and have higher water quality treatment capabilities due to elevated pollutant removal performance (Houle et al. 2013). Normalized installation and maintenance cost data can be found in Clary and Piza (2017). Key findings also provide insight into the structure of the maintenance regimes required by SCMs and their impact on maintenance costs. For example, vegetated filtration systems display lower cost and invested personnel hours than conventional pond systems. Also, maintenance approaches are frequently progressive. Initial maintenance activities are reactive (emergency- and/or complaince-driven) and, therefore, expensive. As maintenance programs evolve to include routine, periodic, and proactive inspections, they can reduce costs.

Houle et al. (2013) provides a platform to experiment with future maintenance expenditure studies that address additional factors impacting maintenance costs such as scalability and sensitivity to temporal variation and different land uses.

WE&RF-AWWA-UKWIR Whole-Life Costs Tool

Andrews and Lampe (2005) developed a whole-life cost model for the Water Environment and Reuse Foundation (WE&RF), the American Water Works Association (AWWA), and the United Kingdom Water Industry Research (UKWIR) to characterize the performance and whole-life costs of the following BMPs: retention ponds, extended detention basins, vegetated swales, bioretention, porous pavements, and various infiltration practices.

The whole-life cost tool was implemented in spreadsheet format and constructed using maintenance costs collected from extensive surveys of the experiences of U.S. agencies with BMPs. Surveys were also supplemented with site visits to seven cities across the United States to determine and document differences in design elements and the factors driving variations in BMP design.

In 2009, WE&RF developed an updated 2.0 version of the whole-life cost model to calculate whole-life costs of different green infrastructure measures as a function of design and maintenance options and capital and O&M costs. Outputs from the whole-life cost model indicate that differences in geography (climate, topography), aesthetic design considerations, and economics (availability and desirability of financial resources) drive the decision-making on selecting a wide array of SCMs and the maintenance costs associated with them. The size and complexity of SCMs and adequate inspection programs determine long-term maintenance expenses (Clary & Piza 2017). Average annual SCM maintenance costs for the United States—including labor, equipment, materials, replacement and/or additional planting, and disposal—can be found in Clary and Piza (2017).

The National Cooperative Research Program (NCHRP) Whole-Life Cost Models

Taylor (2014) and the National Cooperative Highway Research Program (NCHRP) developed a comprehensive list of SCM whole-life cost models in spreadsheet format. The spreadsheet was compiled using a literature review that was supported by surveys of 50 state departments of transportation on SCM's cost, performance, and operation and maintenance information (Taylor, 2014). Green infrastructure SCMs include swales and bioretention facilities.

The California Department of Transportation (Caltrans) is progressively engaging in true, real-time collection of the costs of maintaining stormwater controls. The data collection process involves assigning maintenance codes to roadside SCMs and locating the SCMs using GPS or automatic vehicle location technology. The process creates necessary data systems that enable fine-scale calculation of long-term life-cycle costs of post-construction of stormwater controls (Taylor, 2014). Actual construction and annual maintenance costs for Caltrans BMP retrofit programs can be found in Taylor (2014).

Urban Drainage and Flood Control District's BMP-REALCOST Tool

BMP-REALCOST is an Excel-based life cycle costing model developed by the Urban Drainage and Flood Control District in Denver, Colorado (Urban Drainage and Flood Control District 2018). BMP-REALCOST determines life-cycle costs of structural stormwater SCMs in urban and suburban settings. Informal interviews with persons with SCM experience and the engineering judgement of the authors were used to inform the model's structure (i.e., the type of maintenance activities for each SCM) and assumptions (i.e., assuming a proactive and predictive maintenance regime). The model's SCM costing is a function of two factors: (1) watershed physical properties that influence runoff quality and quantity, such as contributing areas and land use; and (2) the specification of the SCMs applied to the watershed/development. The model provides the user default cost and effectiveness values, or they can input their own custom values. The entered data is then analyzed to calculate life cycle costs based on the number, size, and type of SCMs required to treat average annual runoff quality and quantity for a designated watershed.

BMP-REALCOST's maintenance cost equation includes an SCM size-independent lump-sum component (e.g., annual inspection) and size-dependent component (expressed as storage volume or design flow-rate). Average annual costs are determined by various inputs including maintenance frequency, type, and equipment and labor costs. Annual maintenance costs according to BMP-REALCOST can be found in (Clary & Piza 2017).

Wossink and Hunt Empirical Cost Evaluation of SCMs in North Carolina

Wossink and Hunt (2003) developed empirical cost equations from data collected on O&M costs of 40 SCM facilities in North Carolina. Their statistical analysis indicates that in addition to watershed size, SCM construction costs are affected by factors such as watershed composition and other engineering considerations (e.g., required excavation depth). For bioretention devices, maintenance costs were highly dependent on the composition of the used soil (clayey versus sandy soils). Overall, except for bioretention devices in non-sandy soils, the construction and maintenance costs per acre decreased as the size of the watersheds increased (Wossink & Hunt, 2003).

A summary of the construction and maintenance cost curves per acre treated in North Carolina are available in Clary and Piza (2017) and Wossink and Hunt (2003).

ASCE EWRI Survey of BMP O&M Costs

In 2016, the American Society of Civil Engineers (ASCE) Environment and Water Resources Institute's (EWRI's) Municipal Water Infrastructure Committee (MWIC) conducted a national survey with contacts identified by the MWIC task committees to gather data on SCM O&M costs. The survey included a wide range of questions from inquiries on maintenance procedures and equipment and labor costs to stormwater program information. A comprehensive list of questions developed to guide phone interviews is found in Clary and Piza (2017).

The intended outcome of the survey was to generate a populated spreadsheet with itemized cost data on SCM installations; however, due to the lack of available data, the survey shifted its focus to collecting O&M cost data on bioretention devices for which national data was readily available. The median annual maintenance cost of bioretention devices was estimated at $0.687/sq ft with lower and higher costs of $0.13/sq ft and $2.30/sq ft, respectively. The survey also provides average annual reported maintenance costs, which range from $250 to $3880 with a median of $850. A tabular summary of bioretention O&M cost data is available in Clary and Piza (2017). According to several bioretention facilities that reported construction cost, annual maintenance costs averaged 6% of their capital costs, which falls within the estimated 5-7 percent range of maintenance cost as a percentage of capital cost (USEPA, 1999).

USEPA Water Financing Clearinghouse LID and GI Case Study Inventory

The USEPA's Water Financing Clearinghouse compiled a comprehensive list of LID and GI studies to analyze and promote the economic benefits of alternative stormwater infrastructure approaches. The list provides a compilation of study cases that track and analyze SCM capital and O&M costs (USEPA 2013). The studies include a wide array of methodological approaches that range from simple assessments of capital costs to comprehensive evaluations of infrastructure whole-life or life-cycle costs.

Many of the case studies support the cost-saving arguments of SCM-based alternatives (compared to conventional stormwater infrastructure). For example, the Capital Region Watershed District in Minnesota found considerable capital cost savings—estimated at $0.5 million—in adopting GI infiltration practices compared to traditional sewer conveyance systems. Similarly, a study in Western Union, Iowa, concluded that the O&M costs of permeable pavement would result in long-term cost saving, which begin accruing after 15 years and accumulate to an estimated $2.5 million in savings over a 57 year period.

Green Values National (GVN) Stormwater Management Calculator

The Center for Neighborhood Technnology (2009) collaborated with USEPA to develop a free online assessment tool to calculate and compare the costs of SCMs to conventional stormwater practices on single sites. The GVN calculator uses input precipitation data, runoff reduction goals, and choice of BMPs to calculate the life-cycle costs of green and grey stormwater infrastructure over 5 to 100 years. Data on lifespan data and construction and maintenance costs were gathered from available literature on green and grey stormwater infrastructure. The life cycle equation is a function of construction costs, annual maintenance costs, the number of times SCM components require replacement, annual benefits and the service age of the SCM (Center for Neighborhood Technnology 2009).

An expansive list of the definitive construction costs, maintenance costs, and component lifespan data for SCM and conventional stormwater systems are available in the Center for Neighborhood Technnology (2018).

SCM Databases for Generating Capital and O&M Cost Equations

According to Urbonas (2002), of the many databases that collect and store SCM cost information, only few are sufficiently comprehensive to provide the capital and O&M cost data required to generate cost equations. These databases include: BMP Cost Effectiveness Database (Brown & Schueler 1997), Southeastern Wisconsin Regional Planning Commission Database (SWRPC 1991), Cost Data Format for the Nationwide Urban Runoff Program (NURP) Projects (Torno 1984), USEPA's Design Manual for Wetlands (USEPA 1988), and North American Wetland Database (Knight et al. 1994). Also, the RS Means Company annually publishes a construction cost database collected by cost engineers. The 2018 construction database includes more than 85,000 unit line items of material, labor, and equipment cost at more than 970 locations (RS Means Company 2018b). Access to SCM cost data can be obtained by purchasing RS Means Company (2018a) in print or online.

The databases include study cases that provide SCM costs at different SCM facilities. Using regression analysis to quantify the relationship between SCM cost and facility characteristics (e.g., volume of the drainage area), these databases allow practitioners to formulate O&M cost equations.

CAPTURE Guidance for Schools
Cost Estimating Resources

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