San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook

First Edition ~ January 2009

SAN MATEO COUNTYWIDE
Water Pollution Prevention Program
Clean Water. Healthy Community.

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<< *El Camino Real*
Green Street Concept Sketch
San Mateo County, California

Executive Statement

In 2007, the City/County Association of Governments of San Mateo County (C/CAG) enthusiastically supported the recommendation from its San Mateo Countywide Water Pollution Prevention Program Technical Advisory Committee to develop this Sustainable Green Streets and Parking Lots Design Guidebook (guidebook).

The guidebook provides designers, builders, municipal staff, and other interested groups practical and state-of-the-art information on creating low-impact development roadways and parking lots within San Mateo County. Roads and parking lots provide important opportunities for managing stormwater because they constitute as much as 70 percent of the total impervious cover in ultra-urban landscapes.

Small amounts of rain throughout a watershed incrementally add up to large volumes of water downstream. Similarly, small changes to stormwater runoff treatment in a watershed can cumulatively result in significant improvements to overall watershed health. For this reason, the site-scale stormwater management strategies described in the guidebook are at the core of creating balanced watershed systems.

The guidebook encourages the use of low-impact development for new and retrofitted road and parking lot projects. Supporting use of low-impact development for stormwater management is an objective shared by the C/CAG, local communities, and the San Francisco Bay Regional Water Quality Control Board/State Water Resources Control Board, which has adopted low-impact development as one of its core values.

Funding for this guidebook and demonstration projects came from vehicle registration fees collected in San Mateo County for congestion and stormwater management. These fees were authorized by California Assembly Bill 1546, which was sponsored by Joseph Simitian and adopted in 2004. A continuation of this vehicle registration fee program for an additional four-year period starting in January 2009 was authorized by California Senate Bill 348 (also sponsored by Simitian and adopted in 2008).

SOURCE: WWW.PANORAMIO.COM/PHOTOS/ORIGINAL/9869089.JPG

The Pacific Ocean at the Fitzgerald Marine Reserve >>
Moss Beach, California

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CHAPTER 1

INTRODUCTION TO THE GUIDEBOOK

Project Summary

In 2004 the California State Legislature approved and the Governor enacted Assembly Bill 1546 that authorized the City/County Association of Governments of San Mateo County to impose a vehicle registration fee on motor vehicles registered in the county for the management of traffic congestion and stormwater pollution. A portion of the funds raised by this fee are earmarked for projects that help mitigate the environmental impact of automobiles on the environment, particularly stormwater runoff from roadways and parking lots.

SOURCE: HTTP://WEB.NESTUCCA.K12.OR.US/TEC/TEC.HTM

Figure 1-1: *Site-level design begins with the first drops of rain.*

The San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) initiated two measures to address the detrimental impacts of stormwater runoff from transportation infrastructure on County waters. The first measure involved creating a grant program using vehicle registration fees to fund the construction of demonstration projects in the County. The demonstration projects showcase the use of Best Management Practices (BMPs) to reduce, capture and treat runoff from roadways and parking lots. In 2008, C/CAG awarded demonstration project grant funds to five San Mateo County municipalities and approved a second call for projects in FY 2008/09 to fund additional demonstration projects. It is intended that these demonstration projects provide inspiration for future sustainable stormwater projects in the San Mateo County region.

The second phase was the production of this guidebook in order to provide the immediate need in assisting San Mateo County municipalities with designing green street and parking lot demonstration projects. This guidebook is intended to inspire small but widespread changes that will improve San Mateo County's watershed health. Conceptual design examples from some of the FY 2008 grant-funded demonstration projects are also included in the guidebook.

The Sustainable Green Streets and Parking Lots Guidebook is to be used in conjunction with the SMCWPPP's *C.3 Stormwater Technical Guidance: A Handbook for Developers, Builders and Project Applicants* (C.3 Technical Guidance). As the name suggests, that document is focused on providing step-by-step technical guidance on how to design, permit, and maintain post-construction stormwater controls in order to meet the current stormwater management requirements mandated in Provision C.3 of the countywide municipal stormwater permit. The primary purpose of this guidebook is to help the user identify and realize green street and parking lot site design opportunities, provide solutions to common implementation barriers, and provide guidance on how to best design, construct, and maintain successful projects. Any technical information provided herein is superceded by equivalent information in the C.3 Technical Guidance.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 1-2: *The conventional approach to stormwater management is treating rainfall runoff as a waste rather than a resource.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 1-3: *Sustainable stormwater design strives for a more natural, cost effective, and visible approach to managing runoff.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 1-4: *The Sustainable Stormwater Design Model. A balance of economy, ecology, and society.*

For much of the last century, drainage systems have been engineered to quickly collect runoff in underground pipes and carry it away using an "out of sight, out of mind" approach. This design philosophy treats rainfall runoff as a waste, and many people are unaware of the stormwater flowing in pipes underneath city streets when it rains.

Sustainable stormwater design treats rainfall runoff as a valuable resource. It is based on balancing urban development while preserving natural hydrological functions. Furthermore, sustainable stormwater design achieves the multiple goals of being cost effective, improving water quality, and addressing community concerns. Mimicking the natural hydrologic function of healthy ecosystems in street and parking lot landscapes can dramatically reduce pollution, decrease runoff volume, reduce runoff temperature, protect aquatic habitat, and create more interesting places to live.

The following pages illustrate how the natural environment functions prior to urban development, the overall effects of creating impervious area, and methods of redesigning urban landscapes to help bring healthy hydrological functions back into our neighborhoods.

SUSTAINABLE STORMWATER DESIGN PRINCIPLES

1. Manage stormwater at the source and on the surface. As soon as rainfall lands on a street or parking lot, allow it to infiltrate into the ground or provide surface flow to nearby landscaping.

2. Use plants and soil to absorb, slow, filter, and cleanse runoff. Let nature do its work.

3. Design stormwater facilities that are simple, cost-effective and enhance community aesthetics. Stormwater facilities can be beautiful!

A healthy, undisturbed landscape acts like a sponge by capturing, absorbing, and slowing the flow of water from the moment a raindrop lands on the ground. Urban development, though, has dramatically impacted natural hydrologic systems by reducing the landscape's absorptive capacity and introducing pollutants.

SOURCE: WWW.FLICKR.COM - DBARON

Figure 1-5: *A thick layer of trees, shrubs, groundcovers, and grasses absorbs water before it reaches the soil surface or flows downstream.*

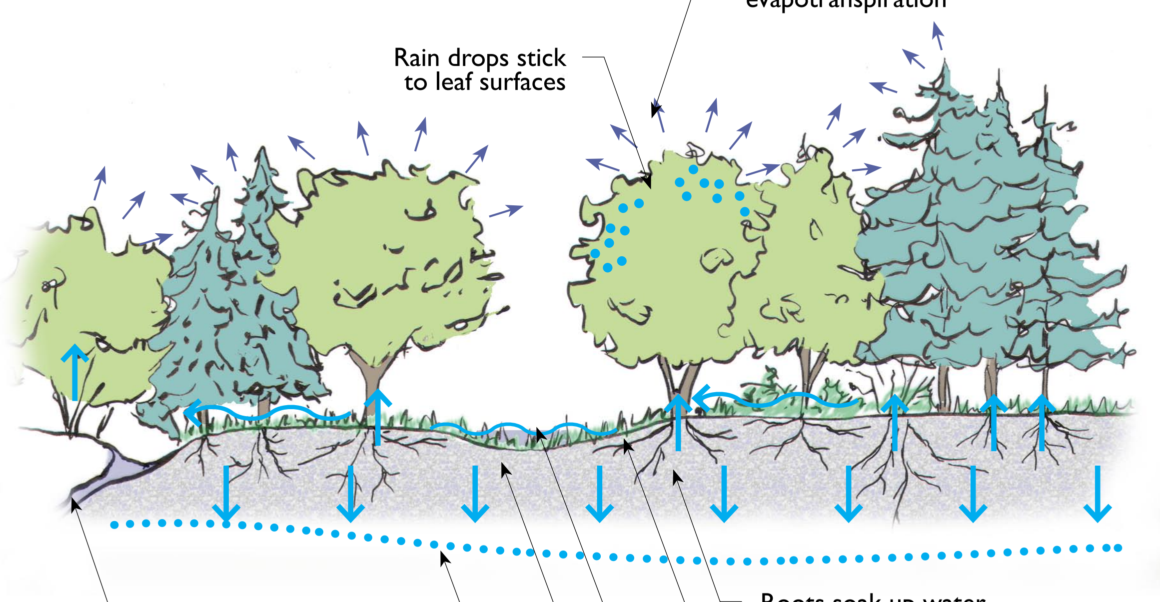
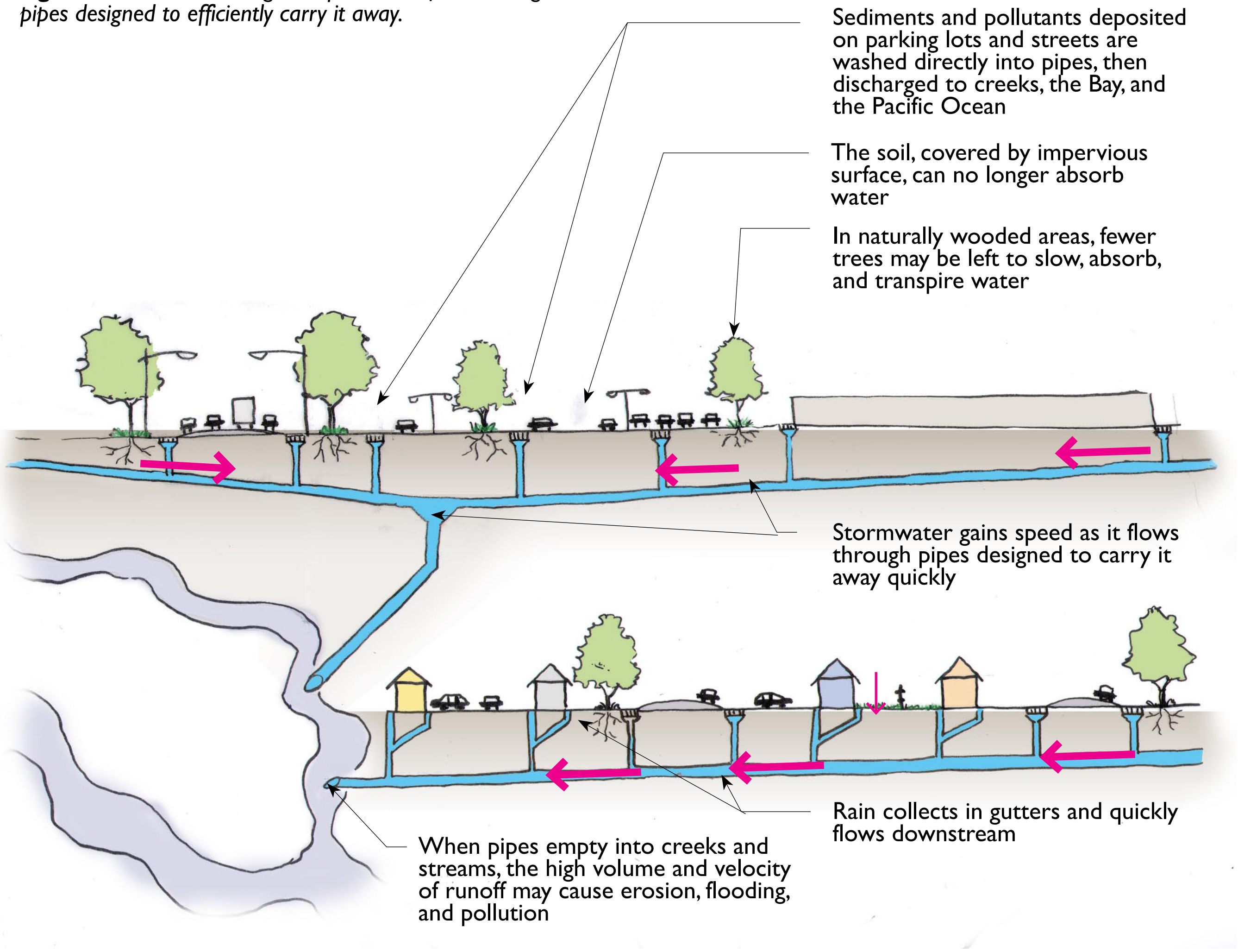


Figure 1-6: *Stormwater gains speed as it flows through pipes designed to efficiently carry it away.*

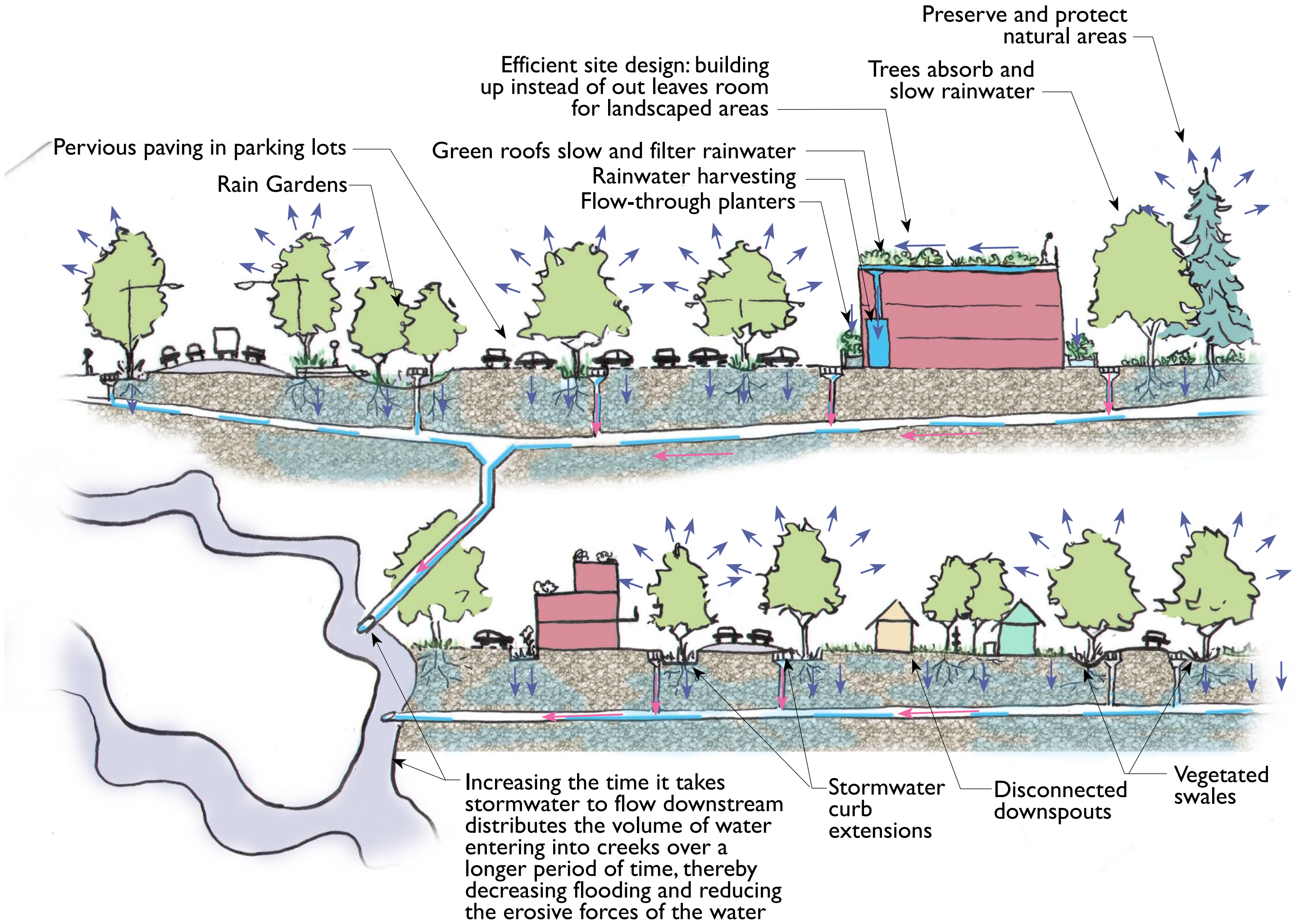
When the natural landscape is urbanized, impervious surface is created that prevents water from being absorbed at the source. Sediments and pollutants from streets, parking lots, homes, yards, and other sources are washed into pipes and water bodies. Stormwater runoff increases as more and more impervious surface is created. The high volume and velocity of stormwater runoff emptying into creeks and streams may cause flooding and erosion, destroying natural habitat. There is a better approach.



Infrastructure can be designed to minimize its impact on natural drainage systems. Our infrastructure can help maintain the balance of natural drainage systems by capturing, slowing, and absorbing stormwater, as well as filtering the pollutants that urban development introduces.

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

***Figure 1-7:** Infrastructure can help protect creeks and streams by capturing, slowing, and absorbing stormwater and filtering pollutants.*



SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 1-8: *Stormwater facilities filter sediments and other pollutants in runoff; which results in improved water quality.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 1-9: *Stormwater facilities slow the flow of stormwater runoff through the interaction of the water with plants and soil.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 1-10: *Stormwater facilities collect and absorb stormwater to reduce the overall volume of runoff.*

The Three Stormwater Management Goals

Sustainable stormwater design should achieve the following three goals to the greatest extent possible:

Water Quality Goal

Stormwater facilities should filter and **remove** excess sediments and other pollutants from runoff. By allowing water to interact with plants and soil, water quality improvements are achieved through a variety of natural physical and chemical processes. Even if soils are not conducive to infiltration, or if there is a high water table, water quality is still enhanced through pollutant settling, absorption into the soil, and uptake by plants.

Flow Reduction Goal

Stormwater facilities should **slow** the velocity of runoff by detaining stormwater in the landscape. Flow rate reduction can often be achieved by integrating design strategies (such as pervious paving, planter boxes, swales, and rain gardens) that provide stormwater detention. By detaining and delaying runoff, peak flow rates are attenuated and downstream creeks are protected from erosive flows. Conveying runoff through a system of naturalized surface features mimics the natural hydrological cycle and minimizes the need for underground drainage infrastructure.

Volume Reduction Goal

Whenever possible, facilities should collect and **absorb** stormwater to reduce the overall volume of runoff. Retention facilities offer long-term stormwater collection and storage for reuse or groundwater recharge. Plants contribute to retention capacity by intercepting rainfall, taking up water from the soil, and assisting infiltration by maintaining soil porosity. Volume reduction does not require stormwater facilities to be extremely deep. In fact, it is usually best to employ a highly integrated and interconnected system of shallow stormwater facilities.

There is a lot of variability in how a "green street" or "green parking lot" is defined. For the purposes of this guidebook, they include streets and parking lots designed with a landscape and/or paving system that captures, slows, filters, and potentially infiltrates stormwater runoff. Green streets and parking lots provide stormwater reduction and water quality benefits to runoff before discharging to local creeks. Specific design strategies are discussed in detail in Chapter 2.

Figure 1-11 below describes different levels of green design based on how aggressively a particular site manages runoff. For example, a street or parking lot with substantial landscape areas and a system of broad canopy trees to capture rainfall is a Level 2 design, even though it has no dedicated stormwater treatment measures. On days with minimal rainfall, a majority of the rainfall may be captured within the tree structure and ground landscaping.

However, green streets and parking lots are most commonly thought of as introducing some type of stormwater treatment measure (e.g., vegetated swale, planter, rain garden, etc.) to actively capture and manage surface runoff at its source. This is a Level 3 design and represents the most common perception of a green street or parking lot. But green streets can move beyond a Level 3 design.

The concepts of livability and stormwater management are intertwined for Level 4 and 5 designs and are primarily related to green streets rather than parking lots. A Level 4 green street not only encompasses the attributes of Levels 1, 2, and 3, but also provides a direct emphasis

Green Streets and Parking Lots are designed with a landscape element and/or pervious pavement system that captures, slows, filters, and potentially infiltrates stormwater runoff into the ground.

Figure 1-11:

GREEN STREETS AND PARKING LOTS CAN BE "MULTIPLE SHADES OF GREEN"

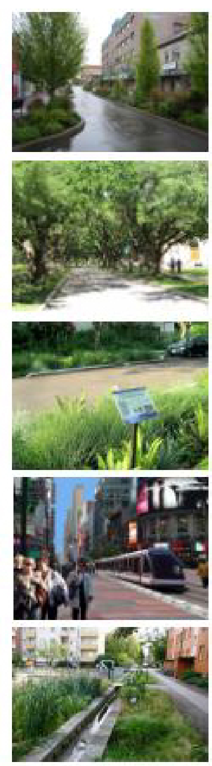
Level 1 Maximizes landscape areas along the street and minimizes overall impervious areas of the land. Some runoff from sidewalks may be managed in landscape areas.

Level 2 Significant tree canopy is added to the urban streetscape.

Level 3 Fully manages street, sidewalk, and driveway runoff by using a landscape system. Design solutions are cost effective, provide direct environmental benefits, and are aesthetically pleasing.

Level 4 Green street provides direct focus on alternative modes of transportation including mass transit, biking, and walking.

Level 5 Green street frontage manages both public and private stormwater runoff. Building, site, and street frontage become one integrated space designed for stormwater management.



SOURCE: NEVUE NGAN ASSOCIATES

on alternative transportation options, such as walking, biking, and/or using mass transit. More people using alternative transportation lessens the number of vehicles generating pollution. Furthermore, incorporating mass transit stops, bike lanes and racks, carpool drop off areas, or other similar site design measures can reduce the overall impervious area required.

The "greenest," and most difficult level to achieve, is a Level 5 design. This comprehensive approach allows stormwater to be managed within the entire street "envelope," which blurs the line between public and private space. Stormwater from private driveways and buildings could be managed within the public right-of-way. Conversely, stormwater from the street could utilize available landscape space within private property. This is currently not a widely-accepted condition here in the United States; however, in many European cities, this type of a green street is becoming more common.

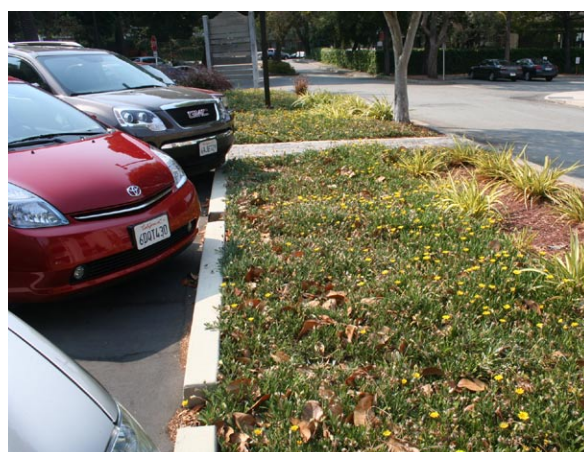
New and redevelopment projects offer more opportunities to achieve a Level 4 or 5 design. Other projects (especially retrofits), due to a multitude of site constraints, might only be able to achieve a Level 3 design. Regardless, the most important consideration is to always strive to reach the highest level of green design possible. When a high level of green design is applied to street and parking lot sites throughout the County, the overall health of the watershed, the San Francisco Bay, and the Pacific Ocean will improve.

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 1-12: *Green streets can be urban in form.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 1-13: *Green infrastructure can also be very free-form and artistic.*



SOURCE: NEVUE NGAN ASSOCIATES

Figure 1-14: *A vegetated swale within a green parking lot in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 1-15:** When it rains on our streets, pollutants are washed directly into pipes and then into creeks, the Bay, or the Pacific Ocean.*

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 1-16:** Even small parking lots contribute to the larger problem of increased stormwater runoff.*

SOURCE: CITYWIDE FACILITIES IMPROVEMENTS: STORM DRAIN IMPROVEMENTS REPORT, CITY OF BURLINGAME, 2004

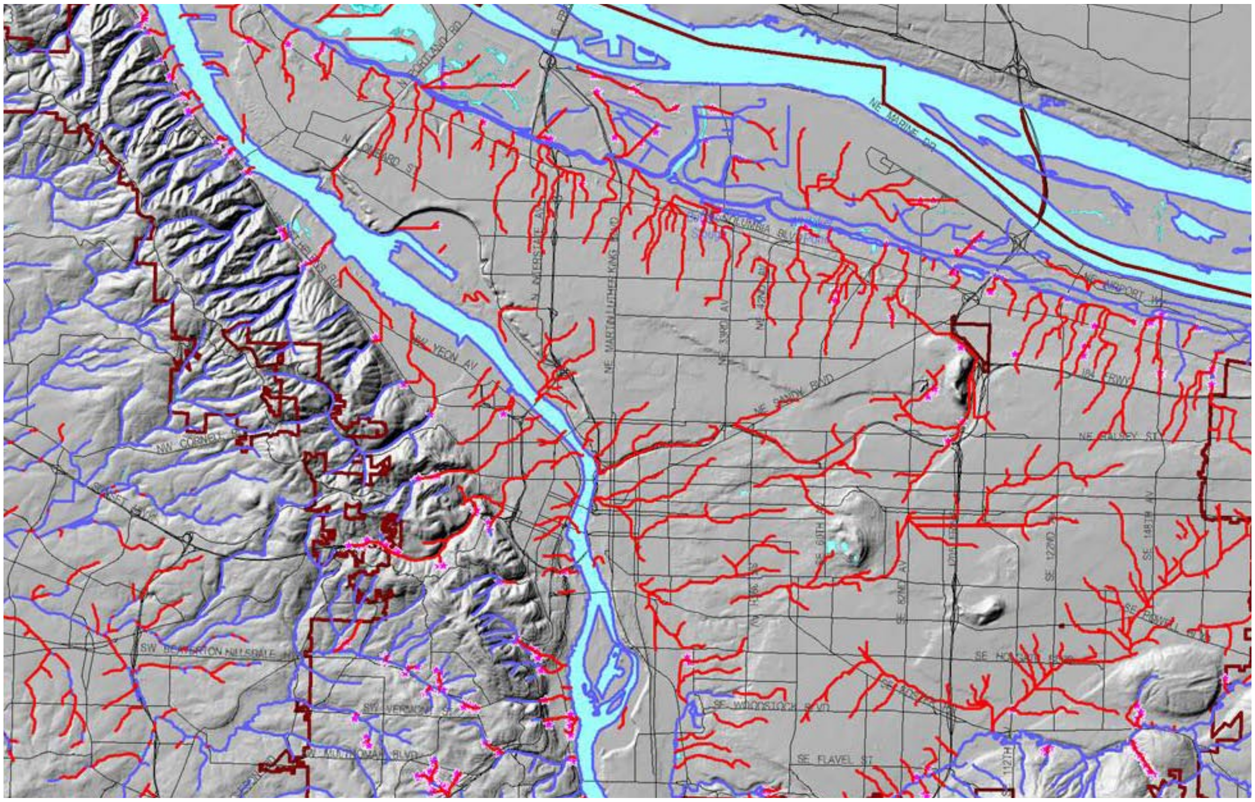
***Figure 1-17:** There is only so much that the existing storm drain infrastructure can take. Green streets and parking lots can help relieve over-taxed systems.*

Inadequate Existing Stormwater Infrastructure

Urban development leads to an increase in impervious surfaces and a corresponding increase in surface runoff and pollutants from vehicles and other urban sources. The problem is exacerbated when increased stormwater runoff reaches a creek channel that is not capable of handling increased flows without significant erosion and degradation. Creeks with tributary areas having greater than 10% impervious surfaces are likely to have degraded water quality and habitat.

In San Mateo County, many of the regional storm drain systems were designed to outdated standards and lower service populations. Steady growth and urbanization over recent decades has left some local storm drain systems unable to handle the quantity of runoff produced by larger storm events, resulting in local flooding and associated damage. Besides being under-designed, other storm drain system inadequacies exist for a variety of reasons, including:

- Existing storm drain infrastructure has deteriorated
- Local neighborhood catch basins are inadequate
- Culverts have reduced capacity due to siltation
- Culverts are too low to drain by gravity during tidal conditions



SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 1-18: *The red lines indicate creeks and small streams in urban areas that have been replaced by decades of built underground pipe infrastructure. This scenario is all too common in communities throughout the United States.*

Flooding from an overwhelmed storm drain system results in a myriad of problems, such as:

- Storm drain backups and localized flooding
- Property damage
- Creek bank and bed erosion and downstream sedimentation
- Settled creek levees
- Restricted vehicular access
- Damaged roads
- Damaged or deteriorated bridge structural members

Water Pollution from Streets and Parking Lots

San Mateo County's storm drain system was designed to prevent local flooding by channeling stormwater runoff ultimately into the San Francisco Bay or the Pacific Ocean. This system provides no inherent water quality treatment. Stormwater runoff accounts for a majority of the pollutants entering local creeks and the San Francisco Bay. Potential pollutants include:

- Oil, grease, antifreeze, heavy metals from leaking and deteriorating cars and trucks, and brake pad and tire wear
- Pesticides, herbicides, and fertilizers from our residential and commercial landscapes
- Solvents and household chemicals (e.g., paint thinner, detergents, and paint)

• Animal waste, litter, decomposing vegetation, and sewage from leaks

• Construction debris, such as fresh concrete or mortar

Certain creeks, coastlines, and water bodies in San Mateo County have been identified under the Clean Water Act's section 303(d) as impaired by specific types of pollutants, such as sediment (see Appendix C). Sediment impairment of creeks is often caused by non-point sources associated with past and current land use practices. Conventional development practices may degrade the environment at a substantial cost to the larger community.

The Multiple Benefits of Using Green Streets and Parking Lots

Implementing landscape-based stormwater management facilities as part of green streets and parking lots in San Mateo County has the potential to minimize pollution, stream degradation, and localized flooding. Reintroducing bioretention into the hydrologic cycle reduces peak runoff rates and volumes by holding back and slowing down the water that would otherwise flow quickly into the storm drain system. By increasing natural storage and infiltration of rainwater, municipalities can slow peak flows and ease the burden of overwhelmed storm drain infrastructure. However, the benefits of using green streets and parking lots go beyond the obvious and include many ancillary environmental and community benefits.

Trash Removal

The effects of trash is another important water quality issue in San Mateo County. Improperly discarded trash is often washed into drainage systems during rains and finds its way into local creeks and the San Francisco Bay. In addition to physical pollution, trash can contribute chemical pollutants when it includes batteries, fluorescent tubes, and other such toxic waste. While there is no substitute for keeping trash out of the drainage system, green streets and parking lots can serve as localized collectors. Trash that would otherwise end up in San Mateo County's waterways can be regularly removed, recycled, or discarded in an environmentally appropriate way.

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 1-19:** An example of the type of trash that often is conveyed into water bodies.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

***Figure 1-20:** Landscape-based stormwater facilities, such as this stormwater curb extension, can capture urban debris before it gets into creeks and other waterways.*

Community and Neighborhood Benefits

Green streets are not just about better stormwater management, but they are also about creating more beautiful and livable neighborhoods and communities in San Mateo County. Effectively "greening" the urban fabric helps provide a unique quality of life that increases the desirability of living in a particular community. Furthermore, incorporating green streets and parking lots offers people a very tangible way to learn about environmental sustainability. These types of projects can be built where we live, work, shop, learn, and play, and are constant reminders that rainwater is a resource, not a waste.

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 1-21: *Neighborhood green streets are commonly seen as a community asset.*

Air Quality Benefits

Significant tree plantings throughout a parking lot or along a street site help mitigate local air quality issues. Trees help settle out particulate matter, reduce low-level ozone, and help mitigate the urban heat island effect. Light-colored permeable pavement further mitigates the heat island effect, since it increases the albedo, or diffuse reflectivity, of the paved area.

SOURCE: WWW.IA.NRCS.USDA.GOV

Figure 1-22: *Light-colored pervious paving within a parking lot helps reflect heat rather than absorb it.*

Economic Benefits

Providing more landscaping in the urban environment makes good economic sense. *Project Evergreen* (2008) states the following:

• *Smart Money* magazine indicated that consumers value a landscaped home up to 11.3% higher than its base price

• Studies by the University of Washington showed that drivers found it easier to locate businesses on a street when they were framed by trees and landscaping, rather than having this green material removed

• A recent study has also found that consumers are willing to pay, on average, a 12% premium for goods purchased in retail establishments that are accompanied by quality landscaping

SOURCE: NEVUE NGAN ASSOCIATES

Figure 1-23: *This downtown residential street in Chicago, Illinois illustrates how ample landscaping can increase the appeal of a street.*

Potential Constraints for Green Street and Parking Lot Projects.

There are many constraints, both perceived and real, in implementing green street and parking lot projects. In an effort to fully understand the constraints specific to San Mateo County, a survey was developed and distributed to municipal public works staff in February 2008. This survey asked for direct input on potential constraints in four areas:

- Policy and Communication Constraints
- Site Characteristic Constraints
- Design-Related Constraints
- Construction/Long-Term Maintenance Constraints

The results of this survey is found in Appendix B of this guidebook. In addition, many of the "design-related" constraints are addressed in specific chapters of this guidebook.

Soil Conditions and Hydrology

Soil conditions and hydrology vary considerably in San Mateo County. In some cases, infiltration may be difficult due to steep hillsides or non-permeable soils (see Appendix C). However, there are ways to incorporate landscape-based stormwater facilities on streets and parking lots in steep conditions and poor infiltration soils. Chapter 5 discusses various methods for designing stormwater facilities in these difficult conditions.

Existing Impervious Area

Most of the impervious area in San Mateo County is concentrated in areas with flat topography (see Appendix C). An exception to this is with certain residential development areas that have occurred in moderately steep hillside conditions. Unfortunately, the areas of dense urban development also correspond with soil conditions that are typically unfavorable for infiltration. This represents a special challenge if a development project is subject to C.3 stormwater management requirements.

Current Stormwater Management Requirements

Current development or redevelopment projects that result in the addition or replacement of 10,000 square feet or more of impervious surface are subject to the C.3 requirements and are required to mitigate for water quality. In addition, all projects that create or replace one acre or more of impervious surface may be subject to flow and volume reduction requirements (see the C.3 Technical Guidance). Furthermore, there is a tremendous opportunity to significantly improve watershed health in the County by retrofitting existing streets and parking lots that are not slated for redevelopment and are not subject to C.3 stormwater requirements. There are many instances where stormwater facilities can be retrofitted in urban conditions that don't increase impervious area at all, but do increase landscape areas.In these conditions, the overall stormwater management goals are more flexible than what would be needed to comply with C.3 stormwater requirements for new and redevelopment projects.

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 1-24:** This green street retrofit project in Portland, Oregon was built not out of a requirement, rather it was built simply because it could be done.*

This chapter has described the principles of sustainable stormwater design, highlighted why better site-scale stormwater strategies are needed in San Mateo County, defined a green street and green parking lot, and described the unique conditions found in San Mateo County as they relate to stormwater management. The following provides a brief synopsis of what is included in the remaining chapters of the guidbook:

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

***Figure 1-25:** A residential green street example in Portland, Oregon.*

Chapter 2 introduces the stormwater design "toolbox" for San Mateo County. The toolbox contains a variety of site layout strategies and stormwater facility options that would be appropriate for San Mateo County. This chapter also highlights a three-step process for working through a site's stormwater design. The strategies found in Chapter 2 can be implemented in both new development and retrofit sites.

Chapter 3 describes the varying street and parking lot conditions found in San Mateo County and how these differing conditions affect the opportunities for green street and parking lot projects.

Chapter 4 illustrates how these different site strategies are applied to actual conditions within San Mateo County. Several example "before and after" sketches illustrate how sustainable stormwater design would look within the region.

Chapter 5 of this guidebook offers more specific design details for green streets and provides practical advice on how to design and construct green street and parking lot projects.

Chapter 6 provides key considerations in implementing green street and parking lot projects/programs. This chapter also showcases the conceptual designs of several grant-funded green street and parking lot projects in San Mateo County. These projects will illustrate many of the strategies found within this guidebook and give the reader an opportunity to see real projects that will be built in the near future.

CHAPTER 2

DESIGN STRATEGIES FOR GREEN STREETS AND PARKING LOTS

Within the last decade, a new interest has developed in using stormwater design strategies that mimic the hydrology of healthy watersheds. These stormwater strategies have been referred to by a variety of names, such as Low Impact Development (LID) facilities, rain gardens, swales, etc. These various forms of "green infrastructure" all manage stormwater runoff within the landscape.

Before choosing and designing a stormwater facility, there are certain site design strategies that should be first explored in order to maximize a site's full potential as a green street or parking lot.

This chapter looks at the full "toolbox" of stormwater design strategies that are most applicable to conditions in San Mateo County. Figure 2-1 illustrates how this toolbox is comprised of "Site Layout Strategies" and "Stormwater Facility Strategies."

Site layout strategies describe ways that a site can be designed more efficiently in order to create additional landscape space and ways to help mimic natural hydrologic processes. In some respects, site layout strategies are considered "passive" stormwater management.

Stormwater facility strategies showcase ways that stormwater can be "actively" managed. Examples include using pervious paving, vegetated swales, planters, rain gardens, and other landscape-based strategies.

In terms of design process, Figure 2-2 illustrates a simple three-step design process when working on green street and parking lot projects. Using this process will help designers think of ways to comprehensively "green" a project site without jumping ahead and merely selecting a stormwater facility.

Figure 2-1:
THE STORMWATER MANAGEMENT STRATEGY "TOOLBOX"

Site Layout Strategies	Stormwater Facility Strategies
Provide Efficient Site Design	Pervious Paving
Balance Parking Spaces with Landscape Space	Vegetated Swales
Utilize Surface Conveyance of Stormwater	Infiltration and Flow-Through Planters
Add Significant Tree Canopy	Rain Gardens
Provide Alternative Transportation Options	Stormwater Curb Extensions
	Green Gutters

Figure 2-2:

Step 1:

Address Site Layout

Emphasize efficient site design in order to maximize potential landscape area and minimize impervious surface. Design the site to drain stormwater runoff on the landscape's surface and minimize underground piped infrastructure. Green the street or parking lot by adding new trees and preserving any existing mature trees.

↓

Step 2:

Incorporate Alternative Transportation Options

Green streets and parking lots are not just about managing water, they should also provide and promote options for alternative transportation. Whenever possible, incorporate pedestrian walkways, bike lanes, and mass transit infrastructure.

↓

Step 3:

Choose Stormwater Facilities

Implement stormwater facilities that actively capture and treat runoff from impervious surfaces. Design vegetated swales, planters, rain gardens, and other stormwater facilities based on a site's contextual land use and the various constraints each site presents.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-3: *This narrow residential street maximizes the amount of landscape space and minimizes the amount of impervious area that generates stormwater runoff.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-4: *This arterial street emphasizes multiple transit options. The center median has a street car line, bike lanes flank both sides of the street, buses share travel lanes with autos, and pedestrians can safely cross street intersections.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-5: *Selecting stormwater facilities, such as this rain garden, is the final step in the 3-step design process.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-6: *This narrow residential street allows for adequate traffic flow and generates less stormwater runoff than conventionally wider streets.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-7: *This typical urban street is almost 100% impervious and designed primarily for auto flow. This combination creates a bleak streetscape environment that also generates large quantities of stormwater runoff.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-8: *By utilizing a more efficient site design, the wasted space in the street example above can easily be converted into conventional landscaping or be used for stormwater facilities. This retrofit opportunity also includes space for a bike lane.*

One of the first questions a designer or builder should ask themselves about their project is: Has the impervious area from streets, parking lots, and/or buildings been minimized? From a design perspective, there are several effective strategies to minimize these areas. However, what makes sense from a design perspective may conflict with prevailing policy. Design and policy must work together in order to achieve site-specific stormwater goals. A carefully thought out site plan will often yield the space for a stormwater facility(s) that fits seamlessly with the other site uses. This holds true for new streets, parking lots, and buildings, but is especially evident when designing street and parking lot retrofit projects. The following describes possibilities for gaining additional landscape space for streets, parking lots, and building envelopes.

Streets

•Narrow travel lanes from 12 feet to 10 feet (or less depending on street type). This helps to reduce impervious area, reduces new development infrastructure costs, calms traffic in pedestrian-oriented areas, and helps create room for stormwater facilities.

•Consolidate travel lanes/on-street parking. Can a travel lane on multi-lane streets be eliminated altogether? Can the size or number of parking spaces be reduced in order to increase landscape area along a street? Exploring a "yes" answer to these questions can often yield landscape space for stormwater facilities, as well as create space for bike lanes, wider sidewalks, and a more balanced and vibrant streetscape.

•Convert unused asphalt space next to travel lanes into landscape areas that can be used for stormwater management.

Parking Lots

•Shorten parking stall lengths to 15 feet and/or shorten the drive/back-up aisles to 22 feet (this will most likely require revisions in municipal code). The shorter stalls can still accommodate SUVs, and the drive aisles can still allow cars to comfortably back up and travel within the parking lot. Portland, Oregon and other cities have allowed even smaller parking lot dimensions within their city codes. These strategies are especially effective for creating landscape space in parking lot retrofits.

•When looking at parking lots, it is important to ask the question of how much parking is needed on an "average day." Parking lots often have many empty parking stalls for most of the year. This is especially true with shopping mall and "big box" store parking lots. As municipal requirements allow, parking lots can provide for the average day (as opposed to peak) condition, or at least can provide peak overflow parking zones with pervious paving.

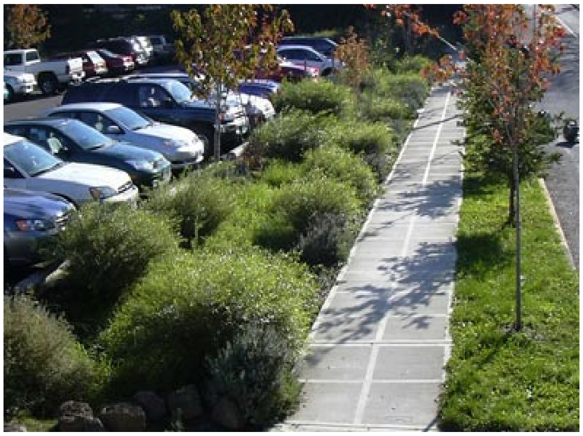
Building Envelopes

•Buildings and their adjacent surroundings can also be designed to use space efficiently, which can affect how surrounding streets and parking lots will be designed. For example, in new construction, buildings can be designed to allow for parking stalls to be tucked under the second floor podium. Using this design strategy can greatly reduce or possibly eliminate the need for additional site parking.

•Many buildings already have conventional landscaping around the building envelope that functions only as screening or aesthetics. Depending on site conditions, these landscape areas can be converted into stormwater facilities and thus maximize the use of the space.

SOURCE: KEVIN ROBERT PERRY- CITY OF PORTLAND

***Figure 2-9:** An existing, inefficiently designed parking lot with little landscaping.*



SOURCE: KEVIN ROBERT PERRY- CITY OF PORTLAND

***Figure 2-10:** The same parking lot redesigned to efficiently use space yielded a vegetated swale, sidewalk, and landscape zone for street trees.*

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 2-11:** This apartment complex allows for cars to park underneath the building's second floor. This allows for a more efficient site plan.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-12: *A typical commercial main street in San Mateo County that uses angled on-street parking.*

Street Example: Angled Parking

Many commercial main streets in San Mateo County use angled on-street parking rather than parallel parking stalls. The angled parking configuration yields more parking spaces along the street frontage compared to parallel parking. However, angled parking requires much of the street's right-of-way to be dominated by parking at the expense of sidewalk, landscape, and stormwater management space. This is especially true along streets with active outdoor storefronts, such as restaurants and boutique shops. Figures 2-14 and 2-15 compare the existing condition of using 30 degree angled on-street parking with that of a redesigned condition using parallel parking. By switching from an angled to parallel parking configuration, considerable space can be made available for wider sidewalks, more landscaping, and stormwater management.

SOURCE: GOOGLE EARTH

Figure 2-13: *An aerial view of a commercial main street using 30 degree angled on-street parking. Notice how much space is wasted at the back end of each oversized parking stall. Also notice the narrow the sidewalk zone.*

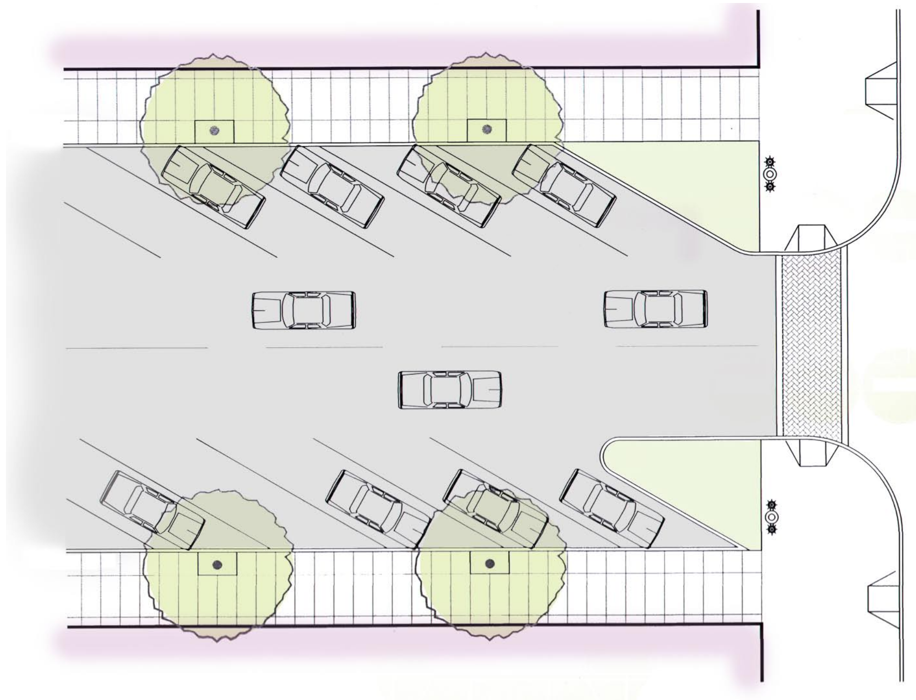


Figure 2-14: *A typical commercial main street in San Mateo County that uses angled on-street parking.*

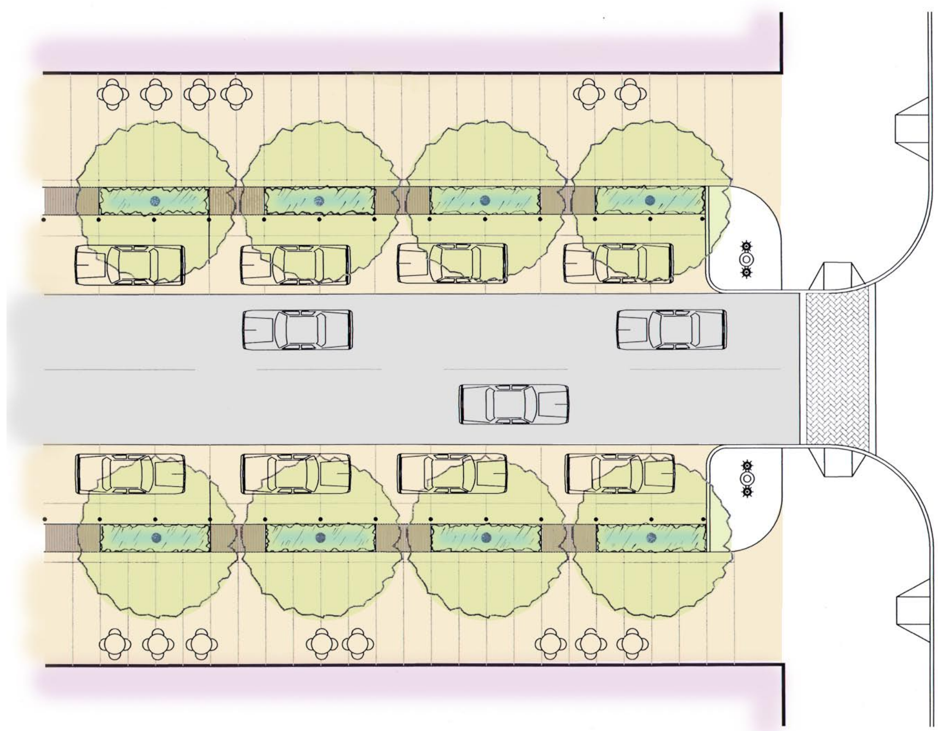


Figure 2-15: *When redesigned with parallel parking, this street gains significantly wider sidewalks, more green space, and better opportunities for stormwater management.*

Parking Lot Example: Reducing Parking Stall and Travel Aisle Dimensions

Sometimes local planning and design codes require more surface parking than is actually necessary for a particular business or use to thrive. Furthermore, parking lots are also often designed with oversized parking stalls and travel/back-up aisles. By fully utilizing the amount of space for parking and reducing the oversized dimensions, a considerable amount of space can be created for landscape-based stormwater management The hypothetical parking lot conditions illustrated in Figures 2-16 through 2-19 show how a conventional parking lot with oversized parking stalls and travel aisle dimensions compares with a more efficient parking lot design. Both scenarios have the same amount of parked cars. However, the more efficient parking lot design yields far more potential green space.

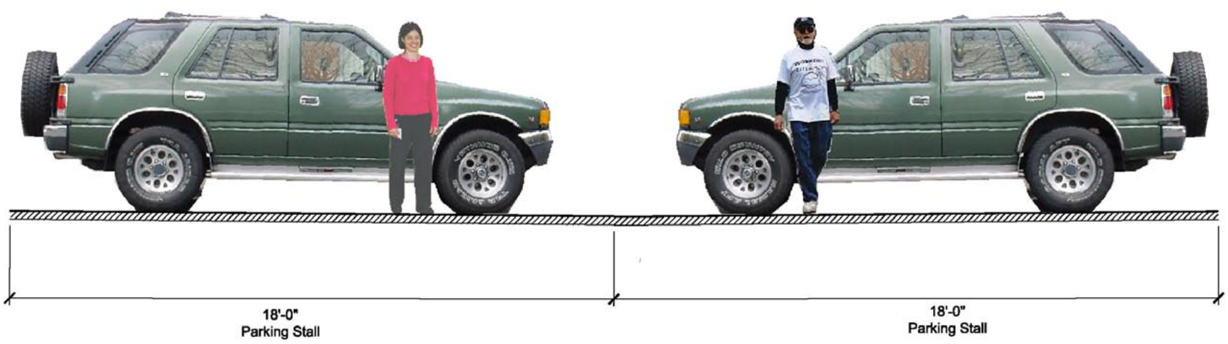


Figure 2-16: *This typical cross section illustrates a conventional parking lot condition with 18 feet long parking stalls.*

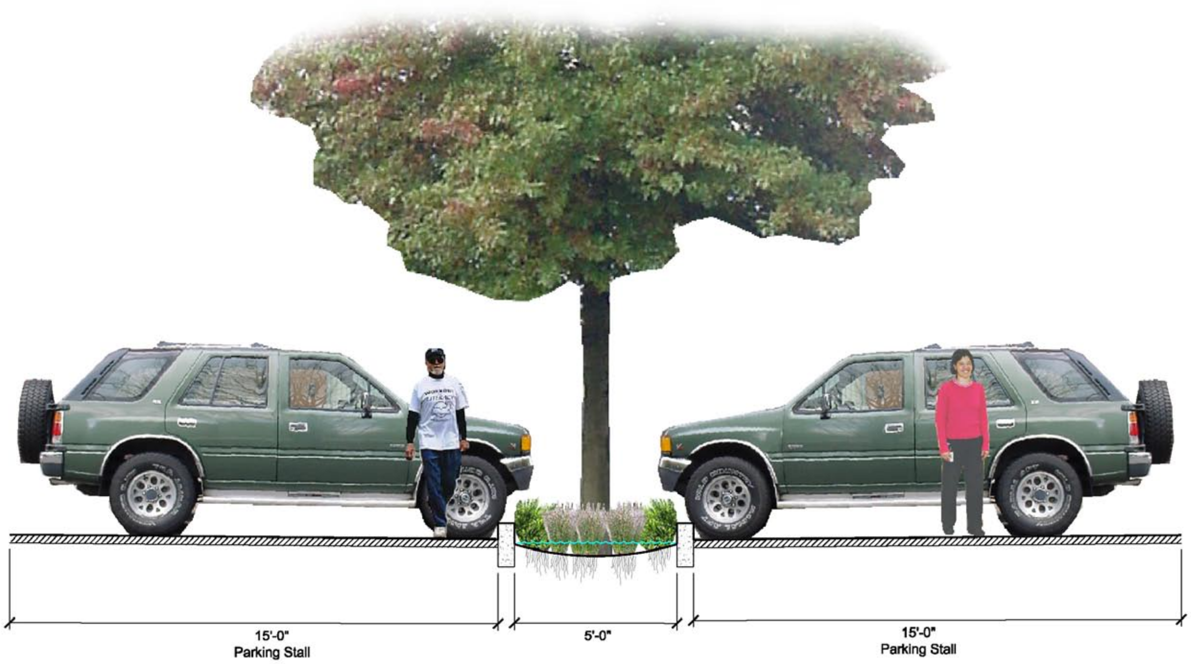


Figure 2-17: *This cross section shows how a 15 feet parking stall can help create room for landscaping used for stormwater management. Note that the parked cars in both scenarios are placed in the same place and fit within reduced length the parking stalls.*

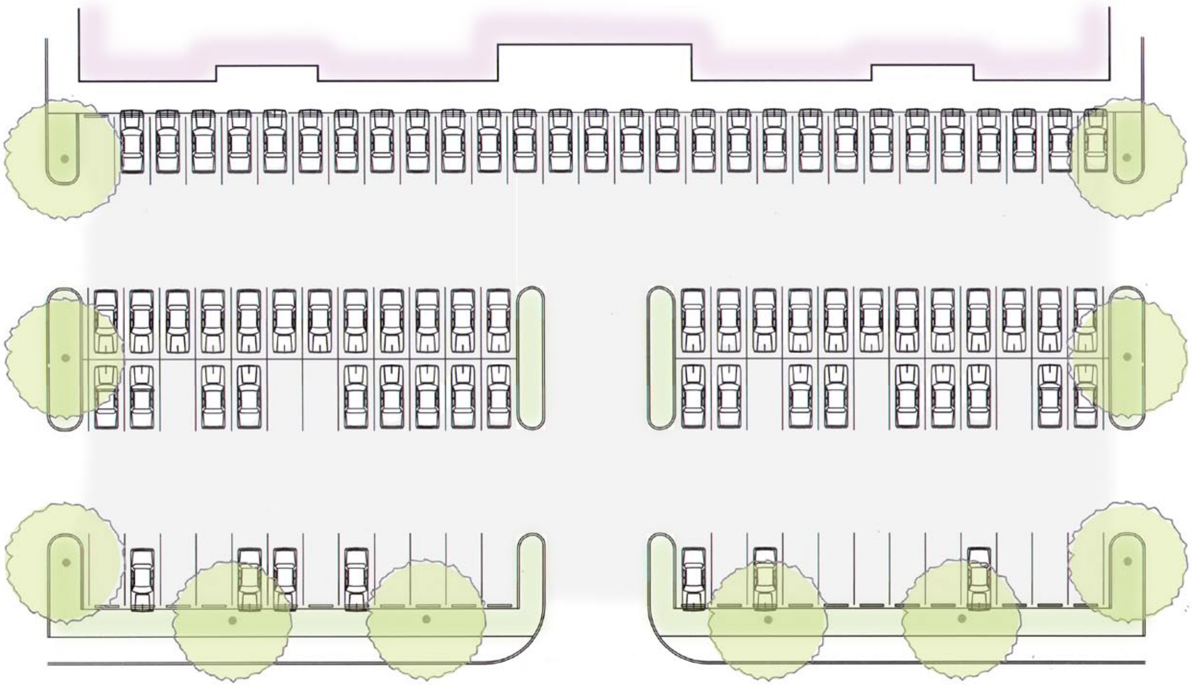


Figure 2-18: *This is a hypothetical parking lot example with both oversized parking stalls and vehicle travel aisles.*

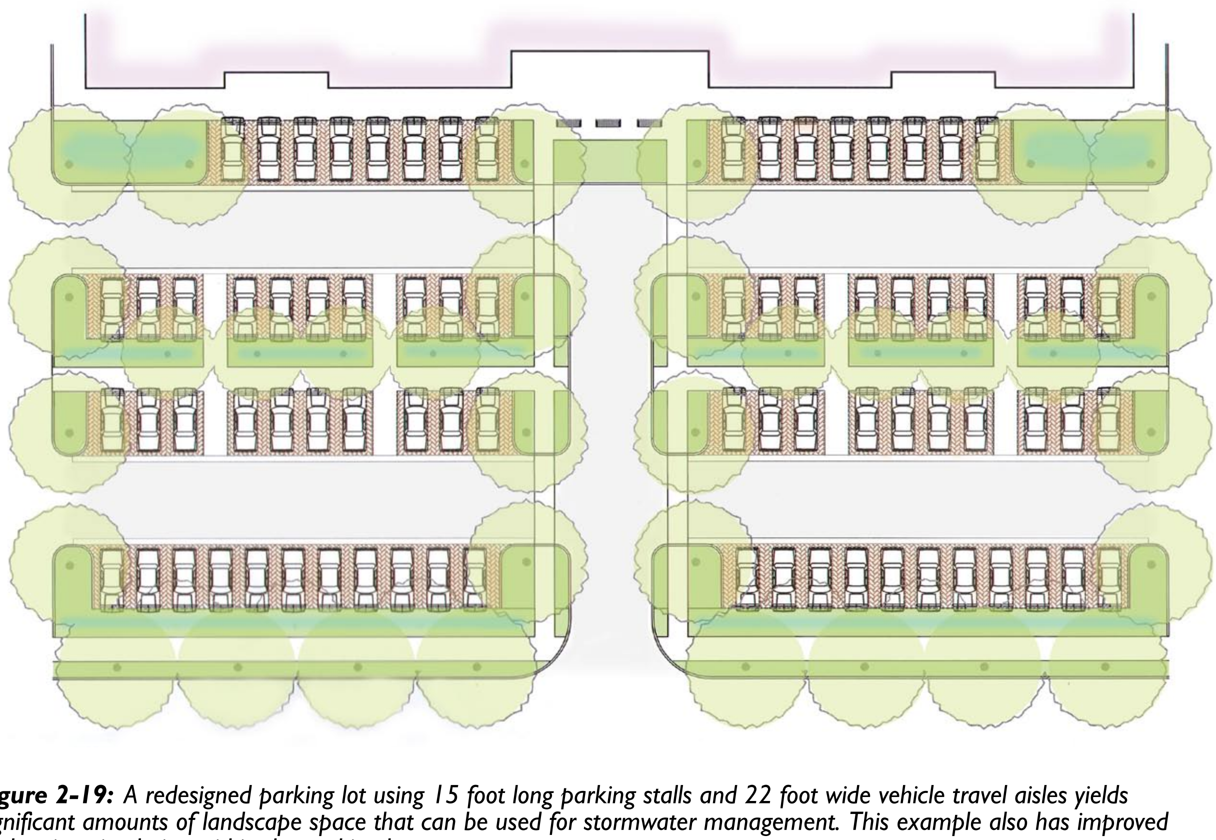


Figure 2-19: *A redesigned parking lot using 15 foot long parking stalls and 22 foot wide vehicle travel aisles yields significant amounts of landscape space that can be used for stormwater management. This example also has improved pedestrian circulation within the parking lot.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-20: *This parking lot has significant amounts of landscape area balanced with parking spaces.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-21: *Along this commercial street, well-maintained landscape areas replace parking spaces in order to create a pleasing streetscape.*

The very notion of green streets and green parking lots is to incorporate as much green space as possible in order to better manage stormwater runoff. However, adding green space can often be in conflict with the need for on-street or storefront parking. The best green street and parking lot designs should provide balance between parking and landscape space. Given that many urban streets are designed primarily for vehicular travel and on-street parking, with little or no green space, and parking lots are often oversized, some level of compromise will be necessary to truly design a balanced condition.

Some parking loss might be acceptable or even desirable if the overall street or parking lot condition has a stronger aesthetic appeal due to increased landscape area and enhanced pedestrian spaces. Studies have shown that greening of business districts increases community pride and positive perception of an area, drawing customers to the businesses (Project Evergreen, 2008).

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-22: *This innovative example in Mountain View, CA boldly greens the street with street trees and moveable planters. The planters can be placed in the parking zone to create additional space for tables and seating or can be removed to maintain on-street parking. This is an excellent example of balancing parking spaces with landscape and people space.*

In order to promote and mimic a more natural hydrologic condition, it is important to remember that the natural landscape does not convey stormwater runoff quickly off of a site. Rather, stormwater infiltrates into the ground, or is conveyed slowly on the surface to low spots in the landscape. The latter condition is the kind of design scenario that this guidebook hopes to recreate.

Designing a network of small stormwater surface conveyance features can be done for new development and retrofit projects. Traditional landscape areas can be transformed into naturalized stormwater conveyance systems simply by depressing greenspace into the existing landscape. Larger stormwater facilities can be interconnected with swales, runnels, trench drains, and other surface conveyance systems. Having this conveyance network reduces peak flows and volumes, recharges groundwater aquifers, and provides water quality treatment.

Allowing stormwater to flow on the surface has other benefits besides improving water quality, such as:

• Increasing awareness and connecting people to natural systems. Stormwater is no longer perceived as "out of sight, out of mind."

• Reducing stormwater facility sizes. Stormwater facilities that accept runoff from surface conveyance are generally less deep than stormwater facilities receiving underground piped runoff.

• Simplifying maintenance. It is easier to detect and repair any problems when stormwater conveyance is on the surface.

• Reducing up-front installation costs. Surface conveyance systems can be less expensive to install than underground systems.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-23: *A trench drain connects runoff between two landscape areas.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-24: *A concrete valley gutter allows water to flow through an intersection on the surface. The landscape system in the background is a good candidate for a vegetated swale retrofit.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-25: *Vegetated channels like this can be designed even in urban conditions for the purpose of conveying stormwater runoff.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-26: *Trees are a vital resource for managing stormwater. Leaves, branches, and the roughness of bark intercept rainfall and decrease the rate of stormwater runoff.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-27: *These mature trees along a residential street in San Mateo County help shade the pavement.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-28: *These mature oak trees in a San Mateo County neighborhood have been preserved and are an aesthetic resource to the community.*

Trees contribute significantly to the slowing, absorbing, and filtering of rainwater. They intercept water on leaf surfaces, as well as "drink" water that does infiltrate into the soil. An averaged size tree can intercept and absorb hundreds of gallons of water a day depending on the tree species.

Adding significant amounts of tree canopy has other important environmental benefits not directly related to stormwater management.

Energy Benefits: Trees provide natural cooling benefits by evaporating water and providing direct shading of surfaces. Planting more trees can help reduce the urban heat island effect.

Air Quality Benefits: Trees act as natural filters or "lungs" to remove air pollutants, such as ozone, nitrogen oxides, sulfur dioxide, and ammonia.

Economic Benefits: Studies have shown that having mature trees and well-maintained landscaping can increase property values and provide a more enjoyable shopping experience in business districts.

It is important to preserve existing, healthy trees whenever possible. Mature existing trees should influence how and where stormwater facilities are designed. If the location of an existing mature tree is in direct conflict with the location of a proposed stormwater facility, it might be more advantageous to alter the design of the stormwater facility in order to preserve and protect the existing tree. Mature trees are often able to soak up water at a rate comparable to what can be infiltrated in a stormwater facility. In terms of overall stormwater benefit, it is usually worth reducing stormwater facility size in order to save a mature tree.

Stormwater facilities are often used to capture and cleanse various pollutants that originate from motor vehicles. An alternative to this treatment approach is to prevent pollutants from being released by motor vehicles in the first place. There are essentially two ways to accomplish this goal. One option is to build cleaner automobiles, but this technology is still evolving and "clean" cars may still be decades away. The second option is to give people more transportation choices, such as walking, biking, and mass transit. The equation is simple: a reduction in cars equals a reduction in the pollution associated with cars. The solution, however, is not so easy. Our street infrastructure is designed predominately for the movement of automobiles, providing little incentive for people to walk, ride their bikes, or take a bus or train to reach a nearby destination. Designing streetscapes that are pleasant, safe, and have a strong sense of livability is the best way to inspire people to use alternative forms of transportation.

In order to balance the need for walking, biking, and mass transit, some difficult decisions will undoubtedly need to be made. However, there are many opportunities to provide a more balanced transportation system. Cost-effective strategies include providing:

• Access to bus and light rail by creating incentives for new development and redevelopment to occur near stops/stations or by providing shuttle service

• Bicycle lanes on streets

• Bicycle racks in parking lots

• Bicycle storage and changing rooms

• Preferred parking or drop-off areas for car/vanpooling

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-29: *This well-designed street emphasizes a strong pedestrian realm.*

SOURCE: WWW.FLICKR.COM/PHOTOS/KGRADINGERS

Figure 2-30: *A bike-friendly street design.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-31: *This street in South San Francisco accommodate both pedestrians and bus transit.*

SOURCE: NEVUE NGAN ASSOCIATES

Pervious paving systems allow rain water to pass through their surface and soak into the underlying ground. While these systems help reduce the amount of stormwater runoff by creating a pervious surface, they are not considered a treatment measure. Pervious paving must be designed to not only manage stormwater runoff adequately, but also maintain the same load bearing capacity as conventional paving in order to support the weight and forces applied by vehicular traffic.

Functionally, the distinguishing feature among the different pervious pavement systems is the means by which the surface is made permeable. Pervious concrete and asphalt are formulated with pore spaces within the material itself. Permeable joint pavers allow rainwater to pass through evenly spaced gaps between the pavers' edges. Reinforced grass and gravel grid systems also allow rainwater to soak into open pore spaces in the soil medium.

The most desirable approach to using pervious paving is to combine this strategy with landscape-based stormwater management whenever possible. Pervious paving is primarily used on roadways with low-traffic speeds and volumes, but there are successful examples of pervious asphalt and concrete employed on high-traffic streets. Pervious paving should not be used in situations with known soil contamination or high groundwater tables. Generally, soil infiltration rates that exceed or meet the accepted standard of 0.5"/hr are suitable for pervious paving systems.

Good Places For Using Pervious Paving:

- Low-volume streets
- Parking stalls (streets and parking lots)
- Alleys
- Residential driveways
- Sidewalks (depending on material and ADA-compliance)

Why Choose Pervious Paving:

- Reduces the size of stormwater treatment measures
- Can be the only viable option in ultra-urban conditions or in parking lots that are interiorly drained

Potential Constraints of Pervious Paving:

- Requires well-drained native soil
- Has a relatively high installation cost
- Can be difficult to maintain and difficult to repair in small batches if using porous concrete and asphalt.
- Has a limited infiltration effectiveness on street slopes over 5%

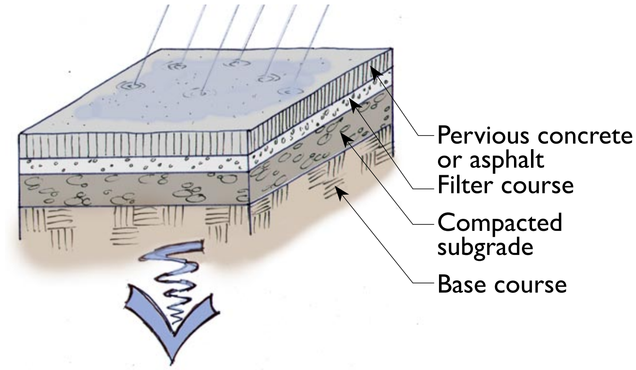


***Figure 2-32:* Pervious Concrete/Asphalt Diagram**

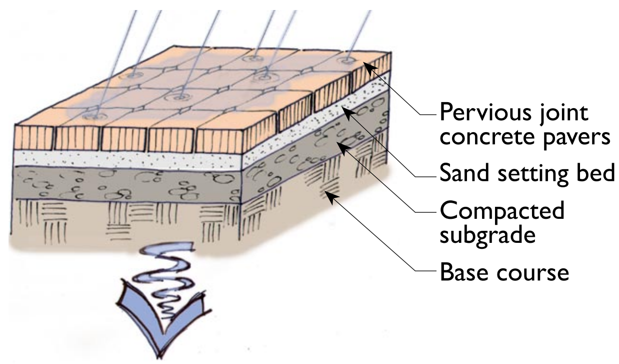


***Figure 2-33:* Typical Pervious Joint Paver Diagram**

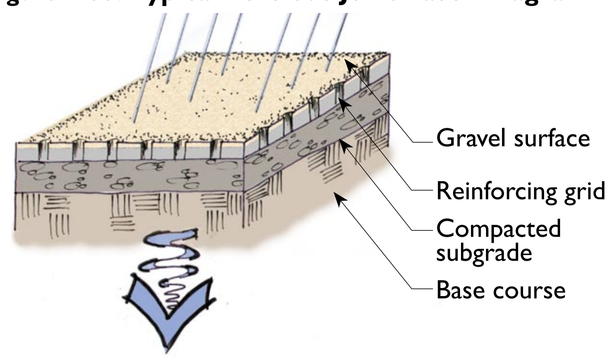


***Figure 2-34:* Reinforced Gravel Paving Diagram**

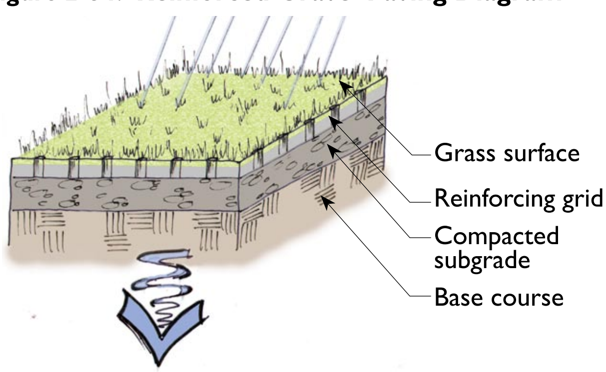


***Figure 2-35:* Reinforced Grass Paving Diagram**

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-36: *The difference between drainage on pervious asphalt and impervious asphalt is evident in this photo.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-37: *This residential driveway utilizes pervious joint pavers in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-38: *A plastic grid system filled with gravel provides the structural strength for a vehicle to slowly drive on.*

SOURCE: WWW.RITTER-TECHNIK.CO.UK

Figure 2-39: *Reinforced grass paving allows water to pass through the root zone of the grass and into the underlying soil while still maintaining a hard surface for vehicular travel.*


SOURCE: WWW.HANNEMANANDFINEIS.COM

***Figure 2-40:** Pervious concrete allows water to pass through pore spaces within the aggregate.*


SOURCE: NEVUE NGAN ASSOCIATES

***Figure 2-41:** Pervious concrete allows for stormwater management and its light color helps reflect heat rather than absorb it.*


SOURCE: NEVUE NGAN ASSOCIATES

***Figure 2-42:** As shown in this photo, the forces applied by tires at turning, stopping, and starting locations can sometimes leave depressions on the surface of pervious paving.*

Pervious Asphalt and Concrete:

Pervious asphalt and concrete production is similar to that of standard asphalt and concrete. The main difference is that the fines are left out of the aggregate added to the mixture. This results in small holes within the paving that allows water to drain through the surface. When installing pervious asphalt and concrete, it is critical that the subgrade is properly prepared and that the surface is poured correctly. As with conventional paving, if pervious asphalt and concrete are not properly installed, they are prone to failure. Also, once installed, both pervious asphalt and concrete tend to be difficult to patch repair because the paving mixture is typically made in large batches.

One problem cited in past parking lot projects using pervious paving is that sometimes the forces applied by wheels turning, stopping, and starting tore up the surface of pervious asphalt and create depressions within parking lot stalls (see Figure 2-42). However, the technology of pervious paving systems is constantly improving, and this may not be as much of an issue with current technology.

Pervious asphalt has been used successfully on interstates and other limited access roads where there are no turning vehicles. Compared to conventional asphalt, the use of pervious asphalt on high-speed roads reduces the accumulation of puddles and the danger of hydroplaning. It is also generally less expensive to install than pervious concrete.

Pervious concrete is more expensive than conventional concrete; hence, it is economically more viable to use in large batches. Pervious concrete works well for parking lot applications and low volume streets.

Regular maintenance of pervious asphalt and concrete is required for the long-term viability of the paving system. Vacuum cleaning the pervious paving system on a regular basis is imperative to limit the amount of sediment clogging the pore spaces.

Pervious Joint Pavers:

Any type of paver can create a pervious surface if there are spaces between them and those spaces are filled with sand or other porous aggregate. Many interlocking concrete unit pavers are designed specifically for stormwater management applications. They allow water to pass through joint gaps that are filled with sand or gravel and infiltrate into a thick gravel subgrade. This system is widely applicable to both small and large paving applications and it offers the flexibility to be repaired because small sections can be removed and replaced. Interlocking concrete unit pavers offer flexibility in color, style, joint configuration, and paving pattern It is important to note that selected pervious joint pavers along pedestrian walkways must be ADA-compliant and not cause tripping hazards. When installing pervious joint pavers, care should be taken to assure that the base and subgrade is properly constructed in order to minimize the potential for differential settlement. Regular vacuum cleaning of the paver joints will help prevent clogging and extend the longevity of the system. Pervious joint paving tends to be more costly to install than other pervious paving systems.

Reinforced Gravel Paving:

A gravel paving system uses small, angular gravel without the fines and a structure that helps provide support to create a rigid surface. Gravel can be a viable alternative to a traditional paved surface in areas of low use that still require a rigid surface.

Reinforced Grass Paving:

In the right situations, grass paving, or other hybrids between paving and planting, can be used to provide structural support while also allowing for some plant growth and stormwater infiltration. These systems may be appropriate in areas of low use and where soil, drainage, sunlight, and other conditions are conducive to plant growth.

SOURCE: ABBY HALL-EPA

***Figure 2-43:** Pervious joint pavers within a parking lot application. Any overflow from the pervious pavers drains into a swale.*

SOURCE: MUTUAL MATERIALS

***Figure 2-44:** Sand-set interlocking concrete unit pavers create gaps between adjoining pavers and allow water to soak into the ground.*

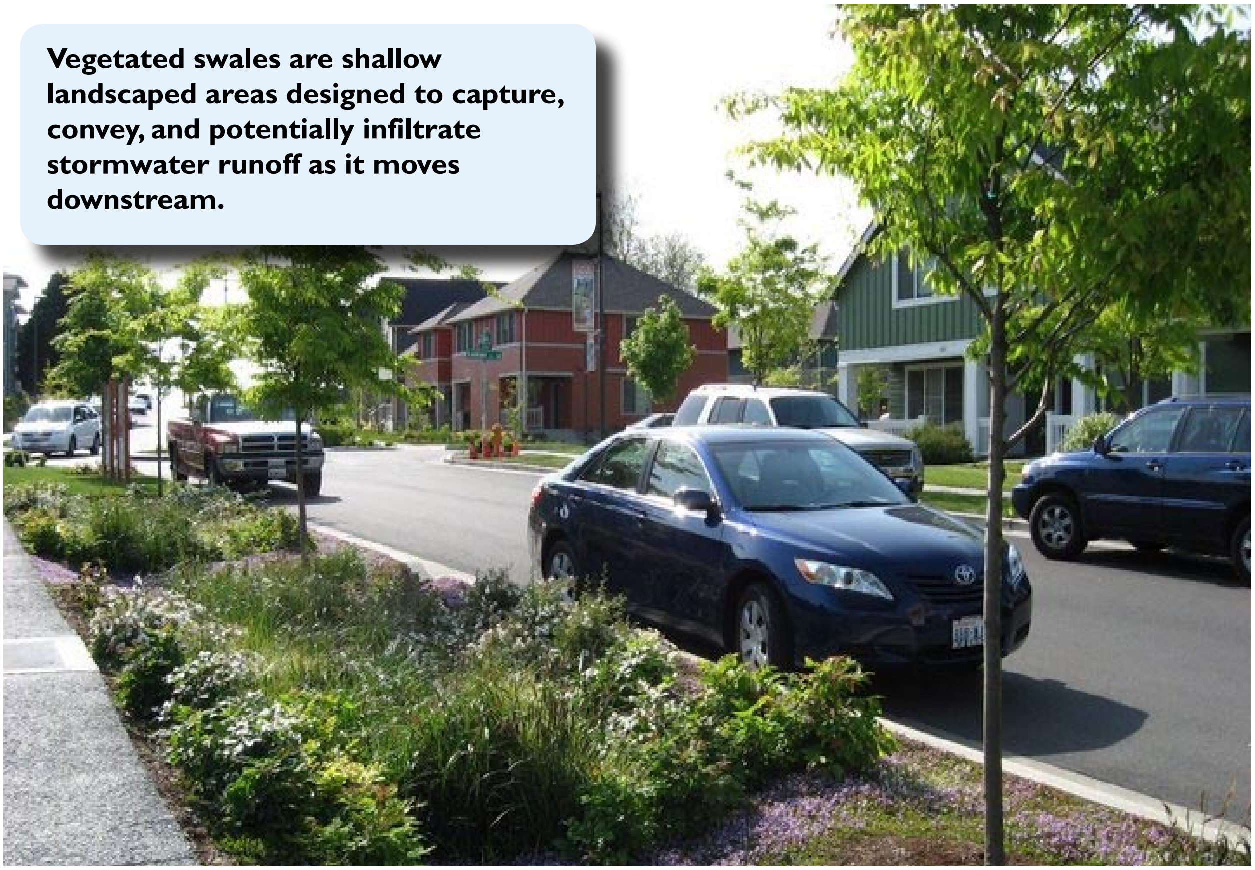
SOURCE: NEVUE NGAN ASSOCIATES

***Figure 2-45:** A close up view of gravel paving within a reinforced plastic grid system.*

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 2-46:** Grass paving installed in a residential driveway.*

Vegetated swales are shallow landscaped areas designed to capture, convey, and potentially infiltrate stormwater runoff as it moves downstream.



SOURCE: ABBY HALL-EPA

Vegetated swales are long, narrow landscaped depressions, with a slight longitudinal slope. They are primarily used to convey stormwater runoff on the land's surface while also providing water quality treatment. As water flows through a vegetated swale, it is slowed by the interaction with plants and soil, allowing sediments and associated pollutants to settle out. Some water soaks into the soil and is taken up by plants, and some may infiltrate further if native soils are well drained. The remaining water that continues to flow downstream travels more slowly than it would through pipes in a traditional stormwater conveyance system. Vegetated swales are typically built very shallow and contain runoff that is only a few of inches deep.

Parking lots and certain street conditions that have a long, continuous space to support a functioning landscape system are excellent candidate sites for vegetated swales. The longer a vegetated swale is, the greater the residence time for slowing and filtering of stormwater runoff.

Vegetated swales are relatively low-cost, simple to construct, and widely accepted as a stormwater management strategy.

Vegetated swales can be planted in a variety of ways ranging from mown grass to a diverse palate of grasses, sedges, rushes, shrubs, groundcovers and trees.

For green street and parking lot applications, vegetated swales can be used in both relatively flat conditions or steeper conditions up to a 5% longitudinal slope. For swales above a 2% slope, check dams or terraces should be used to help slow the flow of water. Additional guidance on check dams for green street and parking lot applications is provided in Chapter 5 of this guidebook.


SOURCE: ABBY HALL-EPA

Figure 2-47: *A residential street with a vegetated swale.*


SOURCE: SHERWOOD DESIGN ENGINEERS

Figure 2-48: *A local San Francisco Bay Area parking lot with a vegetated swale.*

Good Places for Vegetated Swales:

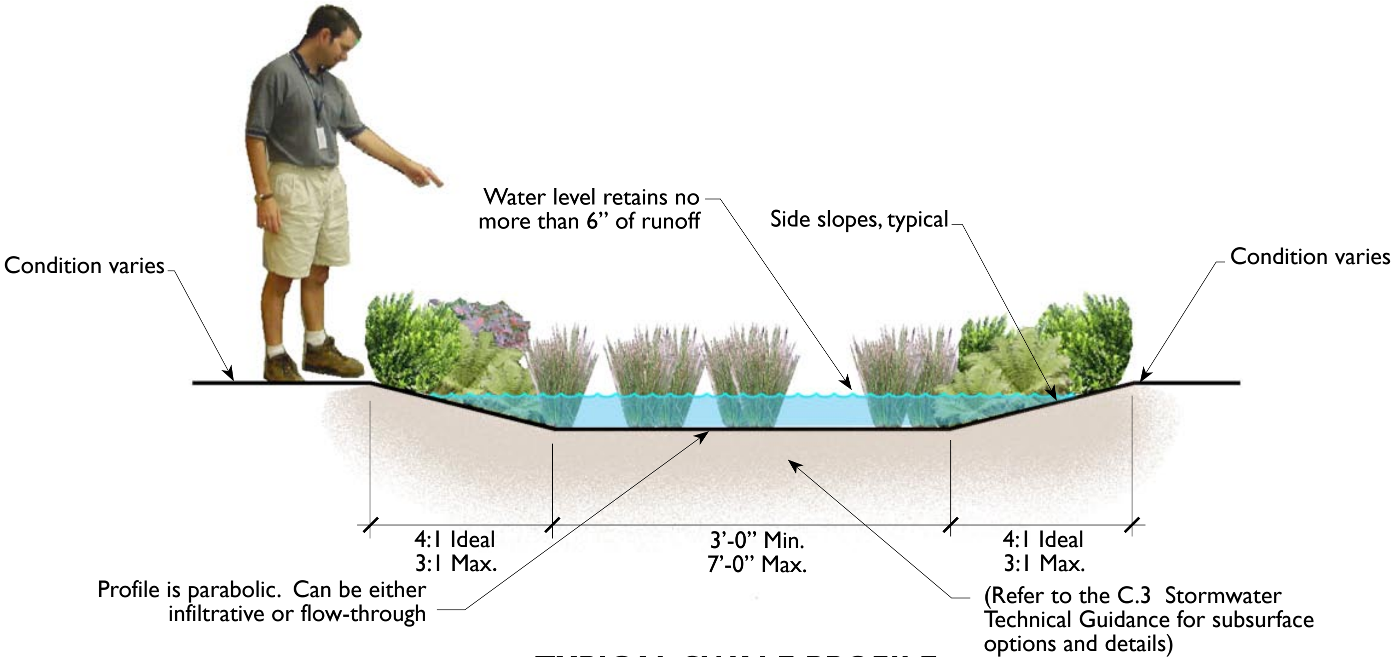
- New residential and commercial streets
- Arterial streets and boulevards
- Within street medians on new streets
- Within the interior and along the edges of parking lots

Why Choose Vegetated Swales:

- Widely-accepted stormwater strategy
- Simple to construct
- Relatively low-cost to implement

Potential Constraints:

- Need long, continuous spaces which can be difficult to find in retrofit conditions
- Difficult to incorporate other streetscape elements within swales (lighting, signage, etc.)
- More difficult to provide good pedestrian circulation through swales
- Often designed to be "too deep" and, as a result, are not aesthetically pleasing



TYPICAL SWALE PROFILE

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-49: *These oversized parking spaces could be made just a few feet shorter in order to create space for swales between rows of parked cars.*

SOURCE: NEVUE NGAN ASSOCIATES

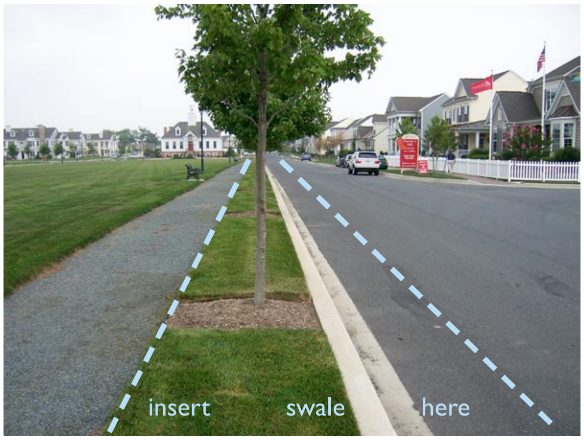


Figure 2-50: *A potential residential street swale opportunity in an existing planting strip. Dashed lines show where a vegetated swale could be added.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-51: *A potential urban street swale opportunity in an overly wide sidewalk zone. Dashed lines show where a vegetated swale could be added.*

How can swales be used in streets and parking lots?

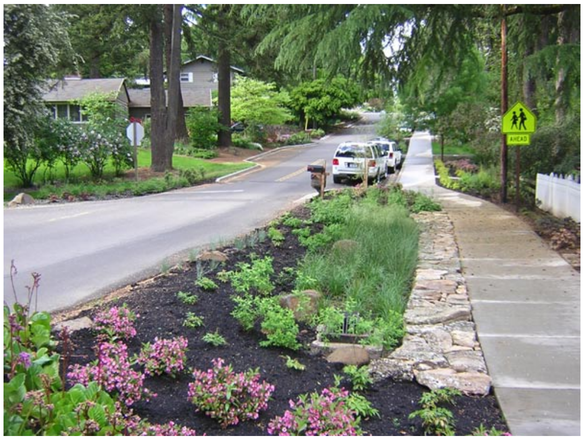
Streets

Streets can be ideal places to incorporate swales, provided that there is a long uninterrupted stretch of landscape or paved area that can be converted to capture and manage runoff. Often existing streets have a wide right-of-way space that is under-utilized. Look for long, unplanted median strips or unused planting strips between the sidewalk and the street. These areas can often be retrofitted to serve as vegetated swales. Is the center turn lane necessary? Can turn lanes be removed, travel lanes moved to the center, and vegetated swales added on the sides? Can the travel lane widths on a particular street be reduced? Sometimes reducing a lane from 12 feet to 10 feet can allow the placement of a vegetated swale alongside a street. Does a street really need or effectively use on-street parking? Can some of that extra impervious area be consolidated into swales?

Parking Lots

There are many creative ways to include swales in parking lots. For example, shorter parking stalls can yield a few extra feet of area that can be used for swales. The leftover space in front of angled parking configurations can also be consolidated into landscaped swales. Narrowing driveway/back-up aisles can free up space for extra landscape area. One of the best applications is to incorporate vegetated swales into the perimeter of existing parking lot landscaping. If there is an abundance of surface parking available, it might be possible to redesign this extra space into vegetated swales.

Street Applications



SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-52: *Residential street with a vegetated swale.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-53: *A vegetated swale alongside a steep residential street.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-54: *An arterial street with a vegetated swale.*

Parking Lot Applications

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 2-55: *An elementary school parking lot with a vegetated swale.*

SOURCE: WWW.IA.NRCS.USDA.GOV/FEATURES/URBAN PHOTOS

Figure 2-56: *A vegetated swale within a large parking lot.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-57: *A commercial center with a parking lot vegetated swale.*

Infiltration and flow-through planters are contained landscape areas designed to capture and retain stormwater runoff.

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Planters are narrow, flat-bottomed, often rectangular, landscape areas used to treat stormwater runoff. Their most distinguishing feature is that the side slopes typically used in swales are replaced with vertical side walls. This allows for more storage volume in less space.

There are two types of planters used for stormwater management: infiltration and flow-through planters. Infiltration planters depend on native soil conditions that allow runoff to soak into the underlying soil. Flow-through planters are completely contained systems that only allow runoff to soak through the planter's imported soil bed and then into an underdrain system. Infiltration planters are more desirable because they allow for greater volume reduction and further ease the burden on local storm drain facilities. Flow-through planters should be used where native soil conditions are unfavorable to infiltration, where there is underlying soil contamination, and/or where the seasonal high water table is within 10 feet of the landscape surface. When using infiltration planters and similar infiltration practices, follow the Infiltration Guidelines contained in the C.3 Stormwater Technical Guidance.

Stormwater planters are easily incorporated into retrofit conditions and in places where space is limited. They can be built to fit between driveways, utilities, trees and other existing site elements. They can be planted with a simple palate of sedges and/or rushes or a mixture of trees and shrubs. Because planters have no side slopes and are contained by vertical curbs, it is best to use plants that will grow at least as tall as the planter's walls in order to help "soften" the edges. Planters can be used in both relatively flat conditions and in steep conditions if they are appropriately terraced.

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 2-58: *An urban street infiltration planter.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-59: *A parking lot infiltration planter.*

Good Places for Stormwater Planters:

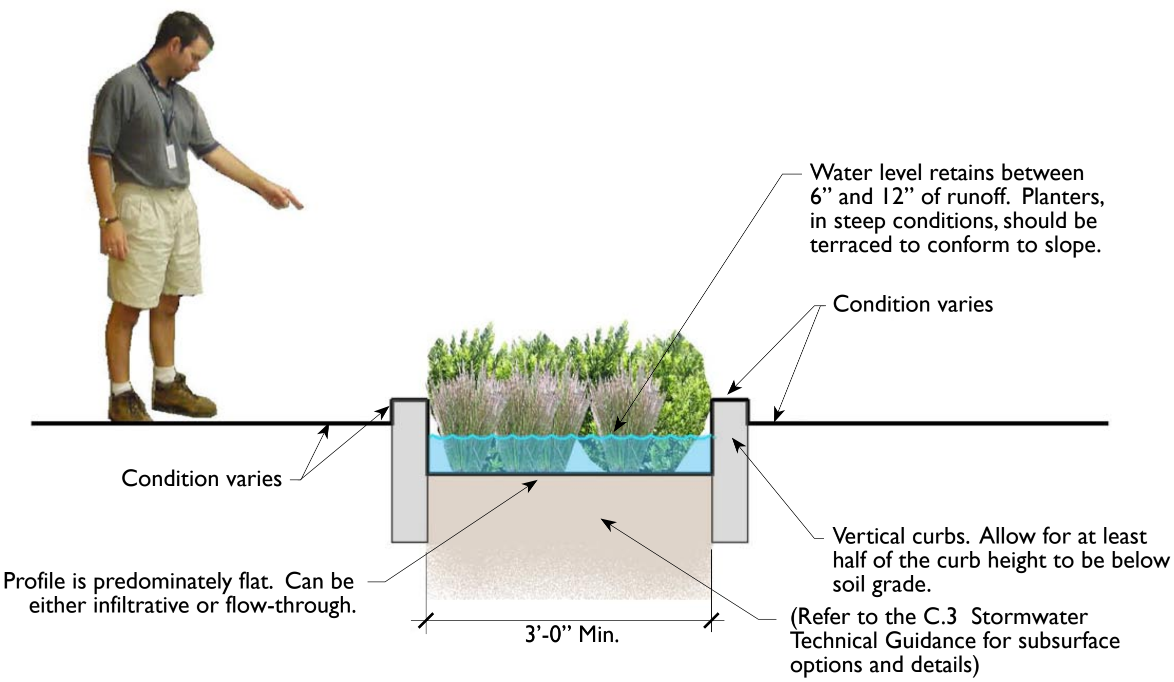
- Commercial streets and parking lots where space is often constricted

Why Choose Stormwater Planters:

- Are best landscape solution for ultra-urban conditions
- Can be used with or without on-street parking depending on available space
- Can fit between other streetscape elements (trees, utilities, signage, etc.) and are highly versatile in shape and size
- Can provide both volume and flow stormwater benefits

Potential Constraints:

- Are generally more expensive than swales due to increased hardscape infrastructure
- Are only contextually appropriate in high density urban settings



TYPICAL PLANTER PROFILE

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-60: *Planters can be retrofitted within the existing stalls in parking lots. Dashed lines show where a planter could be added.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-61: *Planters can be retrofitted on urban streets with overly wide sidewalk zones. Dashed lines show where a planter could be added.*

How can planters be used in streets and parking lots?

Streets

Planters are a good candidate for dense urban streets because they can often fit between driveway curb cuts, utilities, trees, and street furnishings. As long as there is an adequate path for people to access their vehicles and the sidewalk, planters can be a very good choice for streets that require on-street parking. For streets not requiring parking, planters can be used in very narrow conditions adjacent to the street curb.

Parking Lots

Planters can also be an effective design tool for parking lot applications. Parking lot planters can be designed to take the place of a few parking spots, or they can fit in the long, narrow space between the front-ends of parking stalls.

SOURCE: NEVUE NGAN ASSOCIATES

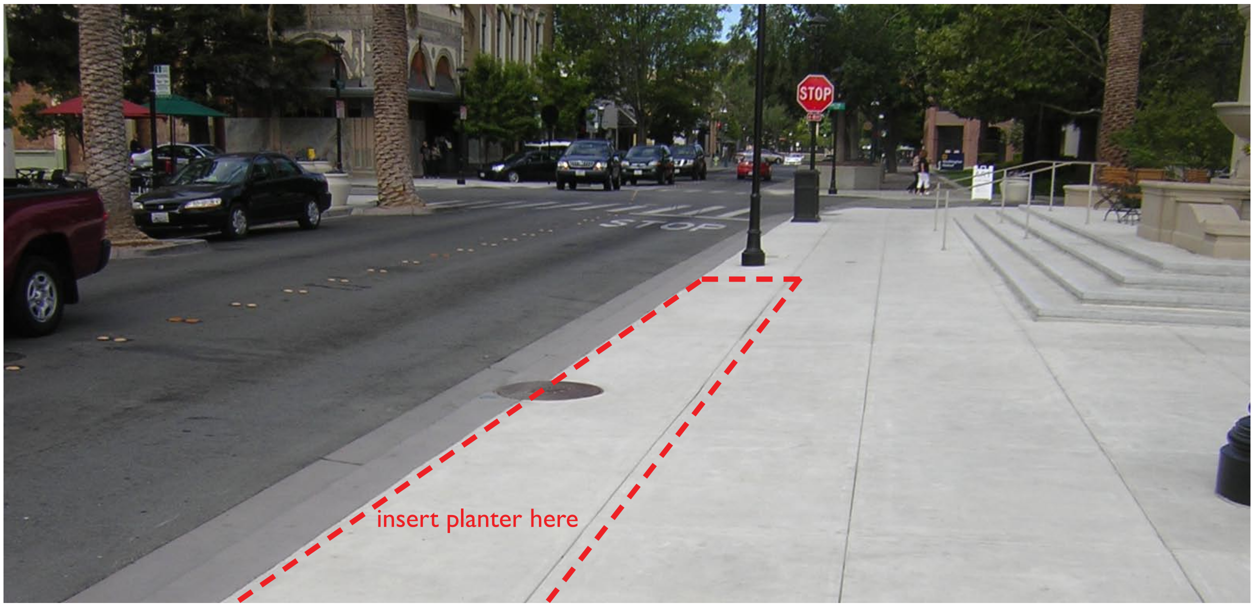


Figure 2-62: *This urban street in San Mateo County has no on-street parking and a very wide sidewalk space. This is a perfect opportunity for inserting a stormwater planter. Dashed lines show where a planter could be added.*

Street Applications

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-63: *Stormwater planters located on a street without on-street parking.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 2-64: *Stormwater planters located on a street with on-street parking.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-65: *A bold example of an urban residential stormwater planter.*

Parking Lot Applications

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-66: *A stormwater planter within a parking lot's landscape island.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-67: *A narrow stormwater planter on the edge of a parking lot.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-68: *A stormwater planter within the interior median of a parking lot.*

STORMWATER FACILITY STRATEGY: Rain Gardens

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Rain gardens are large, shallow, vegetated depressions in the landscape. They can be any size or shape, and are often molded to fit in "leftover" spaces in parking lots, along street frontages, and in situations where streets intersect at odd angles. They are also typically designed to be flat-bottomed without any longitudinal slope in order to maximize storage potential for stormwater.

Rain gardens retain stormwater, thereby attenuating peak flows and overall volume. They can also allow for infiltration, depending on the capacity of the native soil. Although rain gardens can share certain characteristics with swales and planters (they can be designed with vertical curbs or side slopes), they differ from swales in that their primary function is the maximum storage of runoff, not conveyance.

The primary advantage of rain gardens is their versatility in size and shape. Because rain gardens are larger in size, they can potentially cost more than other stormwater facility options, but they also manage correspondingly larger volumes of stormwater. Hence, they can offer a good value. Simple rain garden applications that do not use extensive hardscape or pipe infrastructure can be very cost effective to install.

It is best if rain gardens allow for natural infiltration. However, if infiltration is not possible, rain gardens can also be designed as a flow-through system with an underdrain.

Rain gardens are also known as bioretention areas in the California Stormwater Quality Association's *"Best Management Practices Handbook"* and in the C.3 Stormwater Technical Guidance.

Rain gardens can be planted with a variety of trees, shrubs, grasses, and groundcovers, depending on the site context and conditions.

Generally, locations with soil infiltration rates that exceed or meet the accepted standard of 0.5"/hr are suitable for using infiltrative rain gardens.

Figure 2-69: *A triangle-shaped rain garden retrofitted along a busy arterial street.*

Figure 2-70: *A large rain garden retrofitted in a school parking lot.*

Good Places for Rain Gardens

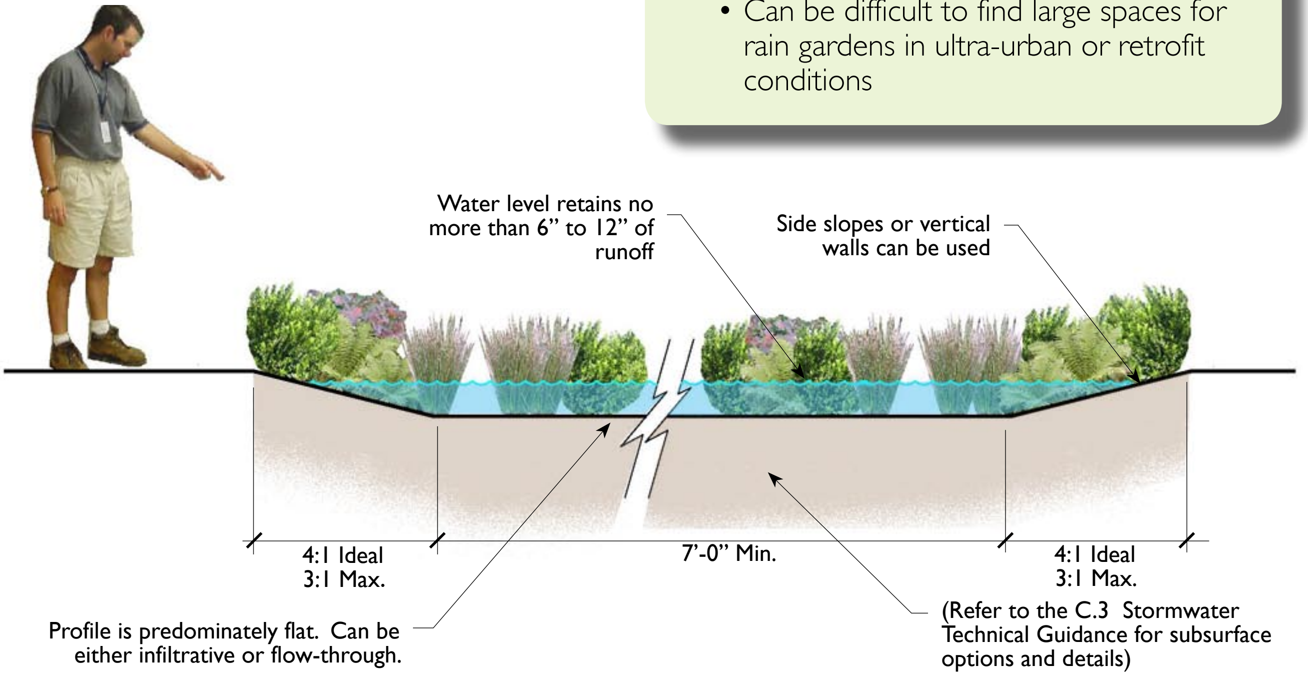
- Underutilized space adjacent to parking lots and streets
- Large parking lot islands
- Residential areas
- Left over spaces created by angled street intersections

Why Choose Rain Gardens:

- Can often significantly "green" a space that would otherwise be leftover asphalt area
- Can be inexpensive to build depending on the amount of hardscape and pipe system used
- Can provide the greatest stormwater flow and volume benefit because of their large size
- Offer versatility in shape

Potential Constraints:

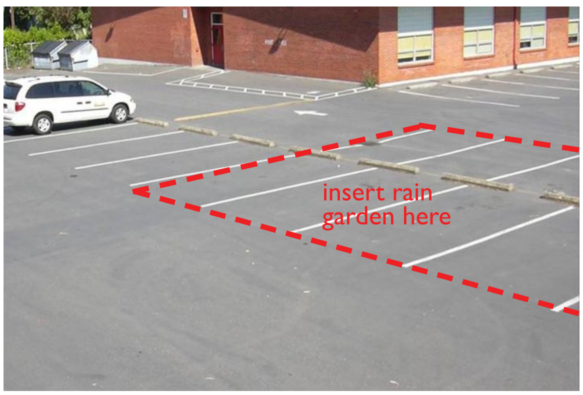
- Often more maintenance required because of their large size
- Can be difficult to find large spaces for rain gardens in ultra-urban or retrofit conditions



TYPICAL RAIN GARDEN PROFILE

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-71: *Large unused landscape space on the periphery of parking lots offers good retrofit opportunities. Dashed lines show where a rain garden could be added.*



SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 2-72: *Oversized and under-used parking areas in the interior of parking lots can easily be transformed into rain gardens. Dashed lines show where a rain garden could be added.*

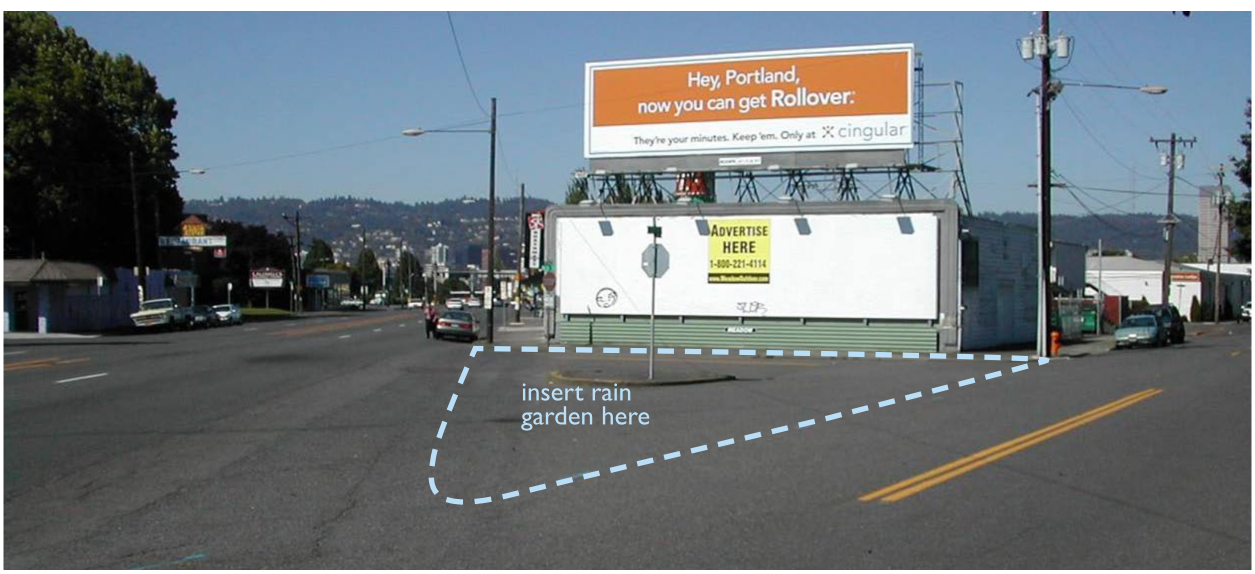
How can rain gardens be used in streets and parking lots?

Streets

Rain gardens can be retrofitted in a variety of street applications. Large areas of unused or inefficiently used spaces are prevalent throughout downtown centers, industrial areas, and residential neighborhoods. These leftover landscape and asphalt spaces are prime candidates for building rain gardens.

Parking Lots

Rain gardens areas are quite useful in larger parking lot conditions (i.e., shopping malls, big box stores) because they can be designed to manage large amounts of stormwater runoff. For retrofit conditions, it is often a popular choice to convert several parking stalls into one larger rain garden rather than use smaller swale and planter applications.



SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-73: *Large under-used areas where streets intersect at odd angles are excellent opportunities for rain gardens. Dashed lines show where a rain garden could be added.*

Street Applications

SOURCE: WWW.IA.NRCS.USDA.GOV/FEATURES/URBAN PHOTOS

Figure 2-74: *A simple residential street rain garden.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-75: *An artful urban rain garden application.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-76: *Rain gardens can conform to any shape, but should be appropriately sized for the amount of catchment area.*

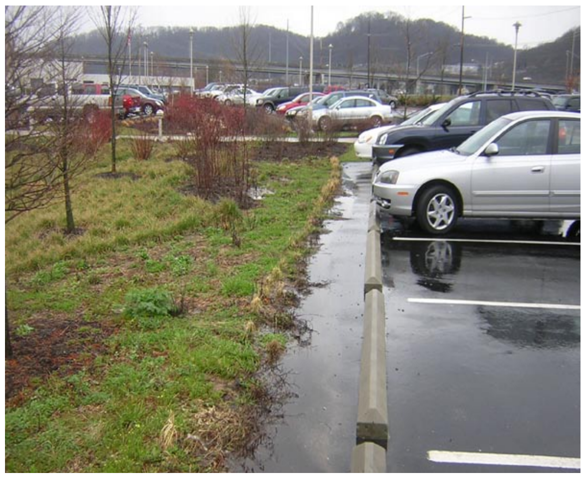
Parking Lot Applications

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 2-77: *This rain garden next to an elementary school collects runoff from adjacent neighborhood streets and the school's parking lot.*

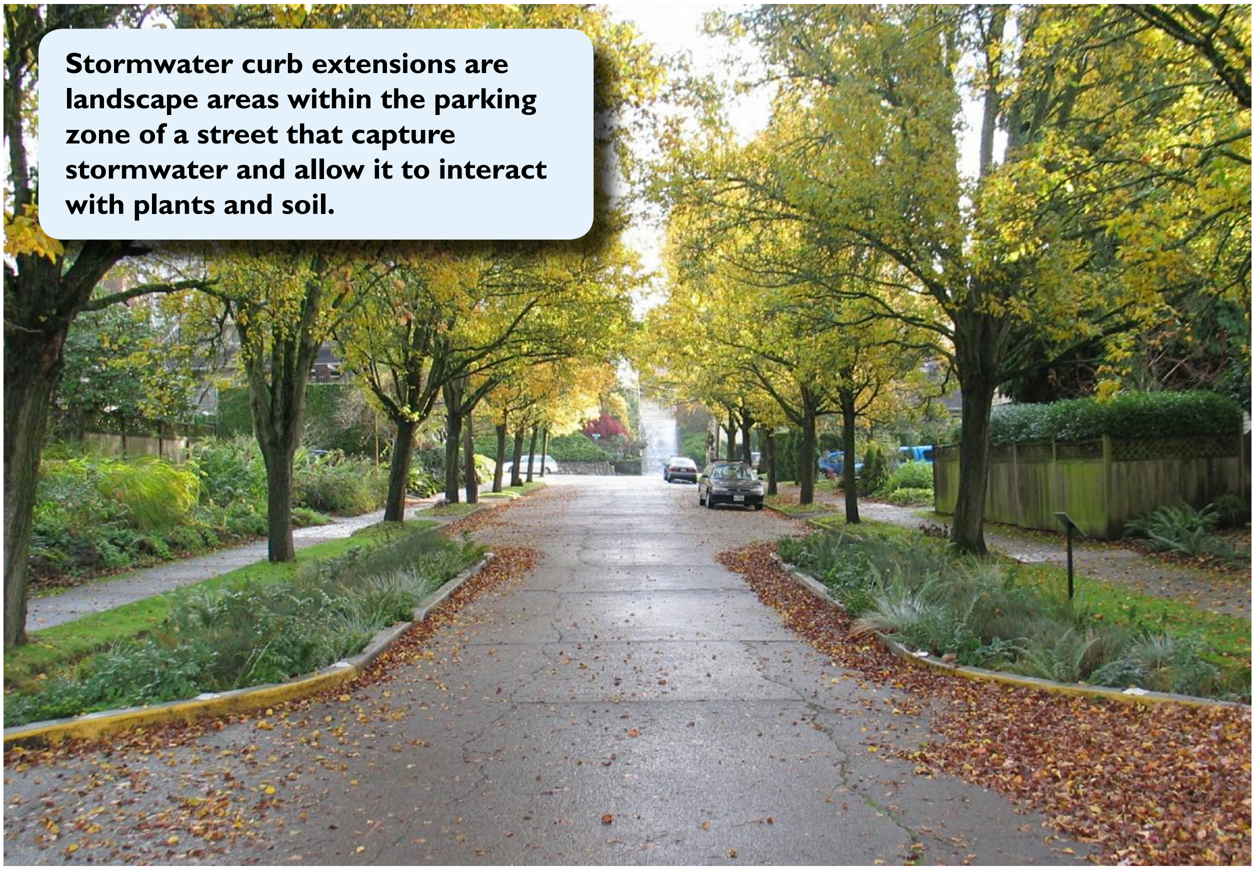
SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-78: *This rectangular rain garden area receives runoff from both a parking lot and the building's rooftop.*



SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-79: *A simple grassy rain garden with trees collects runoff from adjacent parking lot stalls.*



SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Stormwater curb extensions are landscape areas that extend into the street and capture stormwater runoff. Conventional curb extensions (a.k.a. bulb outs, chokers, chicanes) are commonly used to increase pedestrian safety and help calm traffic. A stormwater curb extension shares these same attributes plus adds a stormwater benefit by allowing water to flow into the landscape space. This landscape space can be designed with the physical characteristics of vegetated swales, planters, or rain gardens depending on the available space and specific site conditions.

Stormwater curb extensions are particularly advantageous in retrofit situations because they can often be added to existing streets with minimal disturbance. The small footprint of stormwater curb extensions allows for an efficient stormwater management system that often performs very well for a relatively low implementation cost.

Stormwater curb extensions can be used in a variety of land uses from low-density residential streets to highly urbanized commercial streetscapes. Curb extensions are excellent to use in steep slope conditions because they can act as a "backstop" for capturing runoff from upstream flow. For use in green street applications, curb extensions should have check dams installed for street slopes over 2%. For streets slopes over 5%, the interior of the curb extensions should be terraced with check dams and act more as a series of planters. Stormwater curb extensions can be planted with a variety of trees, shrubs, grasses and groundcovers, depending on site context and conditions.

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

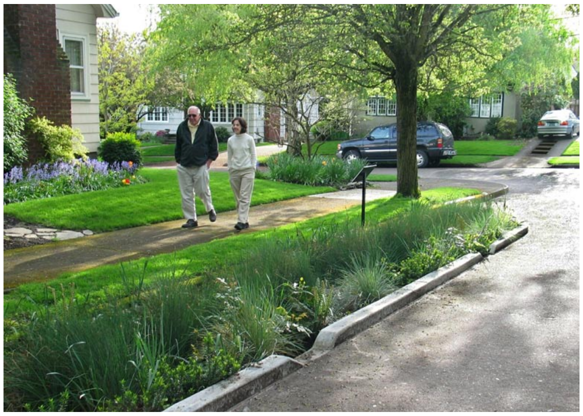


Figure 2-80: *In this residential street example, runoff is completely managed within a stormwater curb extension.*

SOURCE: CONTEXTSENSITIVESOLUTIONS.ORG

Figure 2-81: *Curb extensions can fit nearly anywhere and help calm traffic for a safer pedestrian experience.*

Good Places for Curb Extensions:

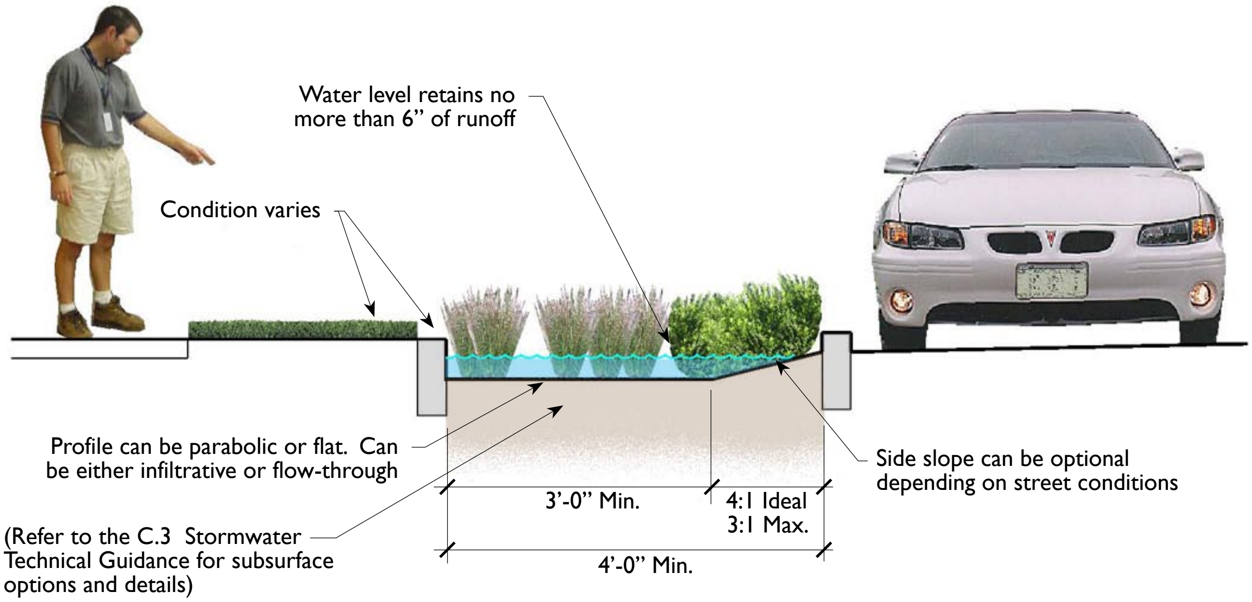
- Parking zones along commercial streets
- Low-density residential settings where on-street parking is under-used

Why Choose Curb Extensions:

- Can significantly "green" a street with minimal investment
- Can be inexpensive to build depending on the local land use context
- Can be flexible in both shape and size to conform to site conditions
- Can act as a "backstop" to capture stormwater flow on steep streets
- Can narrow portions of a street and provide traffic calming benefits

Potential Constraints:

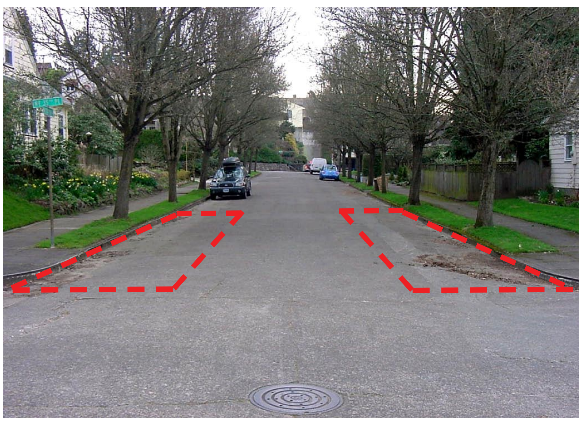
- Generally requires the removal of on-street parking
- Can sometimes conflict with bike travel if adequate space is not allowed between edge of curb extension and a street's travel lane



TYPICAL CURB EXTENSION PROFILE

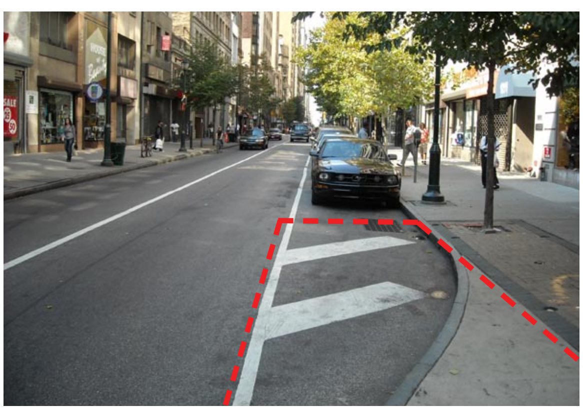
SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-82: *Angled parking stalls in downtown streets can be converted into stormwater curb extensions and would provide more of a balance between landscaping and parking. Dashed lines show where a stormwater curb extension could be added.*



SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 2-83: *Parking zones on residential streets are prime candidates for stormwater curb extension retrofits. Dashed lines show where a stormwater curb extension could be added.*



SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-84: *Parking zones along many urban streets have areas that are striped as "no parking" and could be converted into stormwater curb extensions. Dashed lines show where a stormwater curb extension could be added.*

How can stormwater curb extensions be used in residential or urban conditions?

Low-Density Residential Conditions

Existing residential streets offer some of the best opportunities to convert a portion of the street's parking zone into stormwater curb extensions. Many low-density residential streets in San Mateo County do not have many parked cars during average conditions, so utilizing the parking zone to capture stormwater often may have little or no parking impact to residents. Stormwater curb extensions in low-density residential areas can often be installed with minimal impact to existing infrastructure. In some cases, the curb extensions can be designed so that the existing street curb and stormwater inlets can be left in place.

High-Density Residential/Urban Conditions

In areas where on-street parking is fully utilized, smaller stormwater curb extensions, spaced more frequently, can be used to minimize parking loss to any individual property. It is important, though, that they are appropriately sized to handle the amount of stormwater runoff from the catchment area (see "Sizing" in Chapter 5). In many urban examples, there are streets striped with "no parking" zones that could be converted into stormwater curb extensions without any loss of parking. There are also instances where existing curb extensions that are paved with concrete or have landscaping can be redesigned to manage stormwater. Stormwater curb extensions can also be designed on streets with an angled parking configuration.

Residential Applications

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-85: *A pair of stormwater curb extensions installed along a low-density neighborhood street.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 2-86: *A stormwater curb extension along a neighborhood collector street. For this project, the existing street curb was retained.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 2-87: *Curb extensions can provide for stormwater management and safer crossings for pedestrians.*

Urban Applications

SOURCE: DAVE ELKIN - CITY OF PORTLAND

Figure 2-88: *Accessible pedestrian ramps can also be integrated into the design of stormwater curb extensions.*

SOURCE: DAVE ELKIN - CITY OF PORTLAND

Figure 2-89: *An urban intersection retrofitted with stormwater curb extensions.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-90: *This large stormwater curb extension provides a safer intersection and enhanced bus stop.*

SOURCE: NEVUE NGAN ASSOCIATES

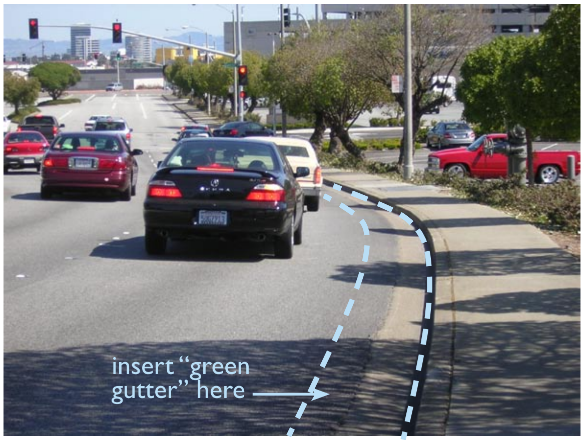
Green gutters are very narrow, landscape systems along street frontages that capture and slow stormwater flow. Typically less than three feet wide, green gutters most resemble planters in that they are confined by vertical curbs and have a flat-bottom profile. Unlike typical planters, however, green gutters are designed to be very shallow with little or no water retention. While infiltration of stormwater is a possibility, the primary purpose of using green gutters is to provide a site design measure using strip of landscaping to help filter out pollutants and slow the flow of water.

The most promising use of green gutters is along excessively wide streets that do not require, or need, on-street parking. In many cases, simply narrowing a residential or commercial street's travel lanes can yield room for a green gutter application.

Green gutters have other benefits besides filtering stormwater pollutants from roadways. They also introduce more green space along streets that lack landscaping. Furthermore, these narrow strips of green help provide a landscape buffer between auto traffic and pedestrians, resulting in a more desirable and potentially safer condition for people.

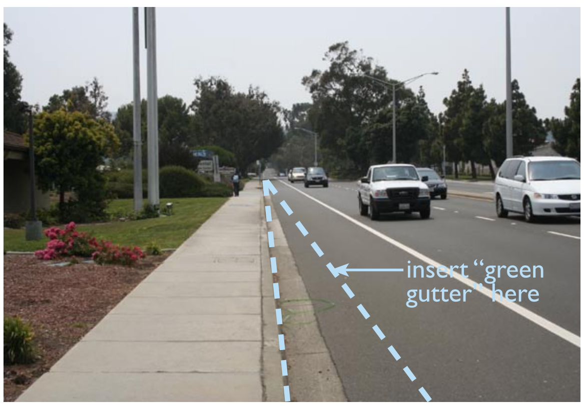
Green gutters are a new design strategy, and there are not yet any projects built to date. However, there are multiple conditions in San Mateo County where green gutters would be suitable.

The main disadvantage of using green gutters is that they require a fairly long footprint in order to adequately filter and slow stormwater. In addition, they most likely will not meet sizing requirements needed for compliance with C.3 Stormwater Technical Guidance, so they are most applicable for the types of retrofit projects that do not trigger compliance with C.3 regulations. Even with these limitations, there are abundant opportunities in San Mateo County to implement green gutter projects.



SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-91: *Green gutters can often be installed parallel to an excessively wide travel lane. Dashed lines show where a green gutter could be added.*



SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-92: *This wide shoulder space can be converted to have both a green gutter and a bike lane.*

Good Places for Green Gutters:

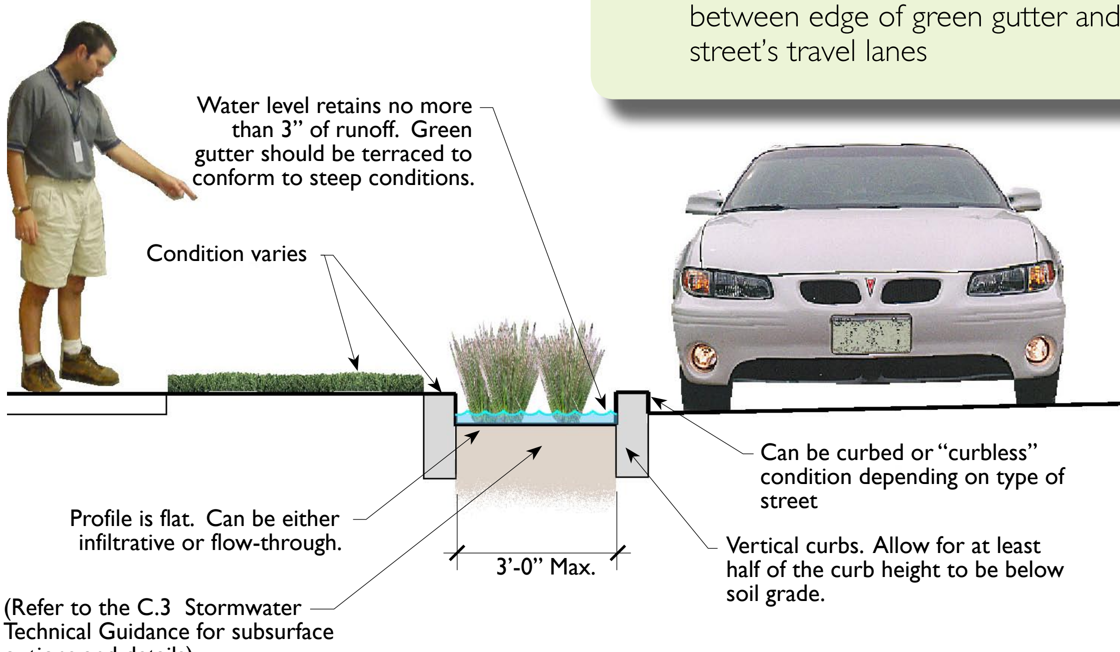
- Residential, commercial, and arterial street frontages that have oversized wide travel lanes or "dead space" between travel lanes and the sidewalk zone

Why Choose Green Gutters:

- Can often significantly "green" a street with minimal investment
- Can be inexpensive to build depending on the local land use context
- Can help create a more walkable street environment by providing a green buffer between auto traffic and the sidewalk

Potential Constraints:

- Require a long, continuous space to effectively slow and filter stormwater pollutants
- Are very shallow and do not retain large amounts of runoff
- Most likely cannot be designed to meet C.3 stormwater treatment requirements
- Can sometimes conflict with bike travel if adequate space is not allowed between edge of green gutter and a street's travel lanes



TYPICAL GREEN GUTTER PROFILE

CHAPTER 3

THE STREETS AND PARKING LOTS IN SAN MATEO COUNTY

Chapter 3 is a relatively short chapter that describes the various street and parking lot conditions that generate stormwater runoff in San Mateo County. These distinctions are important to consider because the successful design of green streets responds to the context, opportunities, and constraints found in differing land use conditions.

In terms of streets, four general street types can be described for San Mateo County based on the surrounding land use context or use of the street. They are:

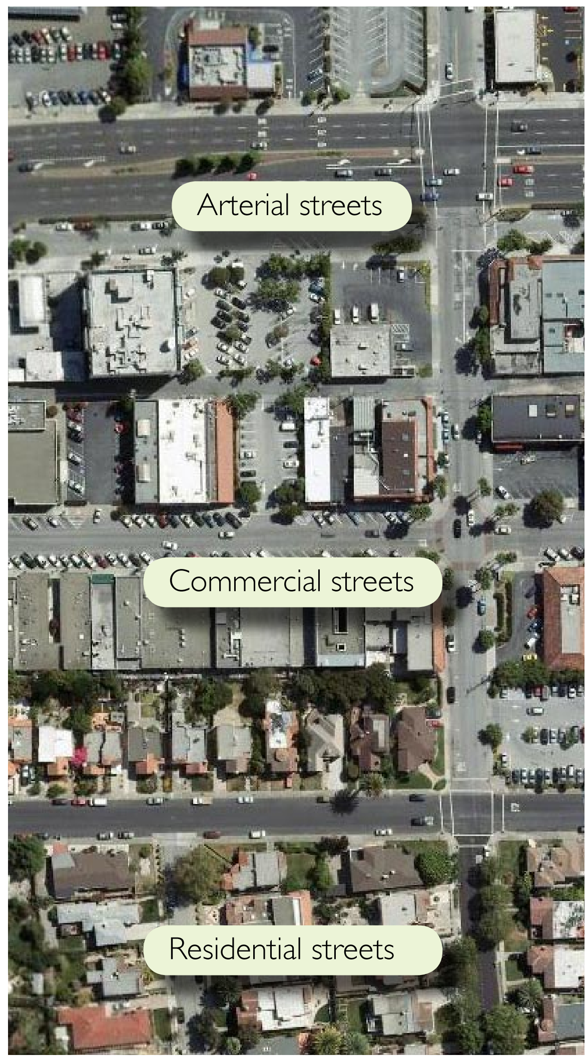
- Low-Density Residential Streets
- High-Density Residential Streets
- Commercial Streets
- Arterial Streets and Boulevards

The predominant land use type found in San Mateo County is residential. As a result, there are a considerable amount of low and high-density residential streets within the region. While residential streets alone do not generate the same amount of runoff as larger commercial or arterial streets, their cumulative area results in significant amounts of stormwater runoff.

For parking lots in San Mateo County, the issue of site context is not much of a factor in determining design solutions. What is important to note is prevalence of extremely large parking lots that are connected to high-traffic volume arterial streets such as El Camino Real. In many cases, these large parking lots are so extensively paved that they contribute runoff from up to 20 acres of surface area. Even the smallest storm events, given this amount of impervious area, can generate substantial amounts of stormwater runoff.

Due to the predominance of residential streets and large-size parking lots within San Mateo County, this might be an excellent area to prioritize for implementing future green street and parking lot retrofits.

The following pages illustrate a "snapshot" of common San Mateo County street and parking lot conditions found in the region. All of the aerial photographs are taken at an altitude of approximately 1,000 feet. Take notice of the impervious area, denoted in shaded areas of red, for each street and parking lot type. In addition, keep in mind that the buildings in each scenario, although not highlighted, also contribute to stormwater runoff that may or may not be discharged to adjacent streets or parking lots. When taking this into account, many areas in San Mateo County are almost completely impervious.



SOURCE: GOOGLE EARTH

Figure 3-1: *Residential, commercial, and arterial street types can be found in close proximity to each other in San Mateo County. However, the design solutions for each can vary considerably in complexity.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 3-2: *A typical low-density residential street in San Mateo County.*

Low-Density Residential Streets

As the most prevalent street type in San Mateo County, low-density residential streets offer the best opportunities for green street design solutions. These types of streets have the fewest conflicts with utilities, the greatest ability to easily create landscape space or modify existing landscape space for stormwater management, and typically have under-used parking zones. Some low-density residential streets in San Mateo County have been built on very steep slopes that quickly convey stormwater runoff downstream. Even these streets can be redesigned into green streets that slow the conveyance of stormwater runoff.

SOURCE: GOOGLE EARTH

Figure 3-3: *The red areas superimposed on this aerial photo illustrate the impervious street area that generates runoff from low-density residential streets.*


SOURCE: NEVUE NGAN ASSOCIATES

Figure 3-4: *A typical high-density residential street in San Mateo County.*

High-Density Residential Streets

Like low-density residential streets, high density residential streets also offer opportunities for green street design solutions. However, the close proximity and frequency of driveway entrances, plus a higher demand for on-street parking, creates little space for landscape-based stormwater facilities. For green streets to work on high-density residential streets, some compromises will need to be made. Pervious paving could be used alone or in conjunction with landscape solutions in high-density residential streets, providing that the site conditions support it.


SOURCE: GOOGLE EARTH

Figure 3-5: *The red areas superimposed on this aerial photo illustrate the impervious street area that generates runoff from high-density residential streets.*

Commercial Streets

Downtown streets in San Mateo County offer some great opportunities for turning a "gray street" into a green street. They also present some of the most difficult constraints to try to overcome. There is fierce competition of space among on-street parking, pedestrians, street trees, and above ground/below ground utilities. Many downtown streets (such as the example shown in Figure 3-6) use angled parking along the street frontage. One way to create a more balanced streetscape is to change the use of angled parking to parallel parking. This simple change in parking configuration would yield significant space for wider walkways, bike lanes, and stormwater facilities with minimal parking loss.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 3-6: *A typical commercial street in San Mateo County.*

SOURCE: GOOGLE EARTH

Figure 3-7: *The red areas superimposed on this aerial photo illustrate the impervious street area that generates runoff from commercial streets.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 3-8: *A typical multi-lane arterial street in San Mateo County.*

Arterial Streets and Boulevards

Wide, high-volume arterial streets and boulevards generate significant amounts of stormwater runoff and primarily serve vehicle traffic with little emphasis on walkability or bike transit. Travel lanes and paved shoulders are often oversized. Some arterial streets might benefit from having redundant travel lanes converted into new landscape space, bike lanes, and/or wider sidewalks. In addition, some existing arterial streets have large, landscaped center medians. While this landscape area does help reduce imperviousness, this space would function better if it was transferred next to the street curb where it can buffer the pedestrian zone and capture stormwater

SOURCE: GOOGLE EARTH

Figure 3-9: *The red areas superimposed on this aerial photo illustrate the impervious street area that generates runoff from a multi-lane arterial street.*

Small and Large Parking Lots

Parking lot sizes vary significantly from site to site in San Mateo County. However, their sum total contributes to significant amounts of impervious area. Smaller parking lots are the most difficult to retrofit because there is a high demand for available space. When landscape-based stormwater facilities cannot adequately fit in small parking lots, pervious paving is a good choice. As for larger parking lots, most are oversized for an average day's parking demand and can be easily redesigned with a variety of stormwater solutions. The most prevalent constraint for larger parking lots is that their sheer size requires considerable investment to adequately manage stormwater runoff.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 3-10: *A typical parking lot condition in San Mateo County.*

SOURCE: GOOGLE EARTH

Figure 3-11: *The red areas superimposed on this aerial photo illustrate the impervious parking lot area that generates runoff from small and large parking lots.*

CHAPTER 4

DESIGN EXAMPLES FOR SAN MATEO COUNTY

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-1: *An existing low-density residential street in San Mateo County. Low-density residential streets offer some of the best opportunities to incorporate green street elements.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-2: *Existing high-density residential streets offer special challenges for implementing stormwater strategies, but several options exist to help manage runoff from these conditions.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-3: *Existing commercial downtown streets in San Mateo County can also be retrofitted for stormwater management using several design techniques.*

The design scenarios presented in this chapter illustrate different ways that vegetated swales, planters, rain gardens, pervious paving, stormwater curb extensions, and green gutters can be applied to the variety of conditions found in San Mateo County. The examples are just a sampling of the many opportunities that exist in the region. Designers and developers are encouraged to adapt these examples to best fit the needs and conditions of their own projects.

Several "before and after" sketches show the potential for green streets and parking lot retrofit opportunities in San Mateo County. The goal of illustrating multiple site strategies is to give the user of this guidebook a broad range of site-scale design applications that can be similarly reproduced throughout the region. The examples shown are for reference only and are not "real" projects, but perhaps projects like those illustrated can be developed into future demonstration projects.

Whether a particular site is located in a low or high-density residential neighborhood, a commercial "main street" district, along an arterial or boulevard street, or within a small or large parking lot, there are multiple stormwater design options available. Figure 4-4 on the next page provides a matrix for choosing what types of stormwater facilities are best suited for various conditions.

Figure 4-4:

CHOOSING STORMWATER FACILITIES THAT BEST FIT FOR DIFFERENT CONDITIONS

	VEGETATED SWALE	STORMWATER PLANTER	CURB EXTENSION	PERVIOUS PAVERS	GREEN GUTTER	RAIN GARDEN
 Low-Density Residential	●	● (site dependent)	●	●	●	●
 High-Density Residential		●	●	●		
 Commercial Main Street	● (site dependent)	●	●	●	● (site dependent)	● (site dependent)
 Arterial and Boulevard	●	●	●		●	
 Parking Lots	●	●		●	●	●

A typical residential street intersection

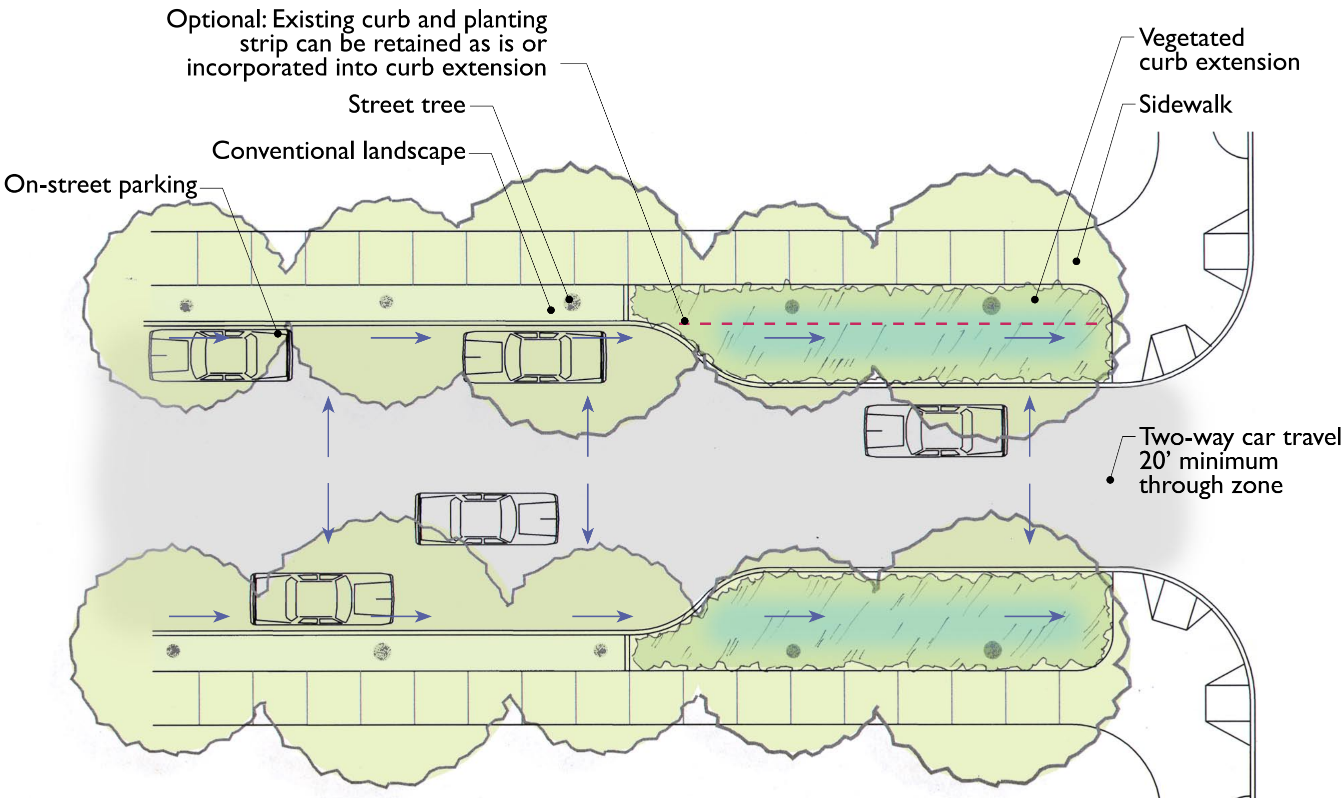
This residential street example illustrates how stormwater curb extensions can be easily retrofitted alongside the existing curb line. Runoff from the street can simply enter these landscape areas and overflow into the existing drain inlets. Because this street has a lot of unused on-street parking, installing curb extensions does not adversely impact existing parking. With the new stormwater curb extensions and street trees in place, the narrower street provides a more aesthetically pleasing and potentially safer traffic environment.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-5: EXISTING: *A typical low-density residential street in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-6: RETROFIT OPPORTUNITY: *The same residential street retrofitted with stormwater curb extensions, as well as additional street trees.*



Stormwater Curb Extension at Intersection Plan View

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-7: EXAMPLE: *A pair of stormwater curb extensions used in a residential street's parking zone. Notice that there is still plenty of on-street parking available.*

Mid-Block Applications

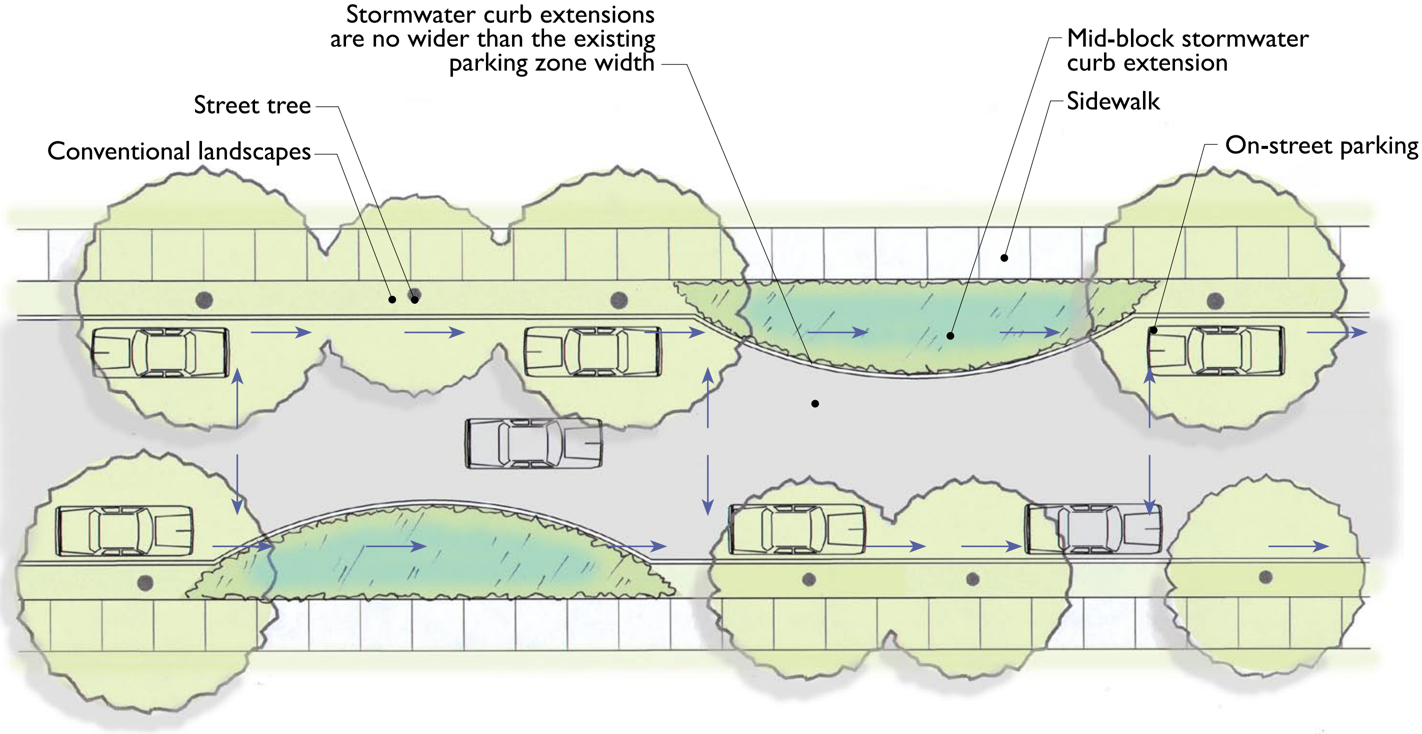
The existing street in Figure 4-8 illustrates a street's mid-block area that offers an opportunity to use stormwater curb extensions. Mid-block curb extensions can be designed in many shapes and layouts. The illustrations on the following page show stormwater curb extensions in either a symmetrical or staggered pattern to create a traffic calming feature. Stormwater curb extensions do not have to be paired on both sides of the street. Figure 4-9 below shows a mid-block curb extension used on one side of the street to accommodate existing driveways on the other side of the street. Pervious paving placed within the driveway side of the street could complement the mid-block curb extension and allow better management of the street's stormwater runoff.

SOURCE: NEVUE NGAN ASSOCIATES

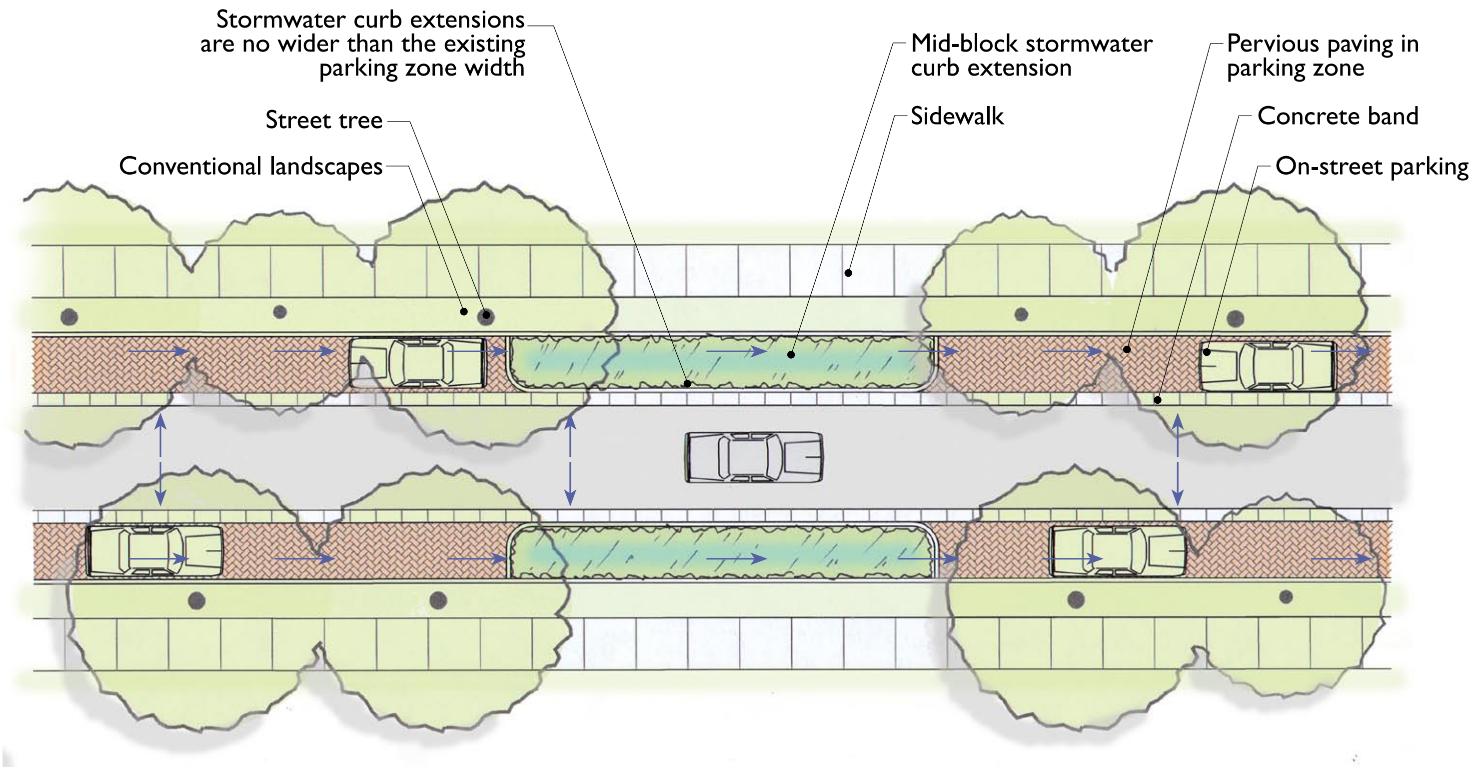
Figure 4-8: EXISTING: *A typical low-density residential street in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-9: RETROFIT OPPORTUNITY: *The same residential street retrofitted with mid-block stormwater curb extension, as well as an additional street tree.*



Mid-Block Stormwater Curb Extension Plan View (Staggered Layout)



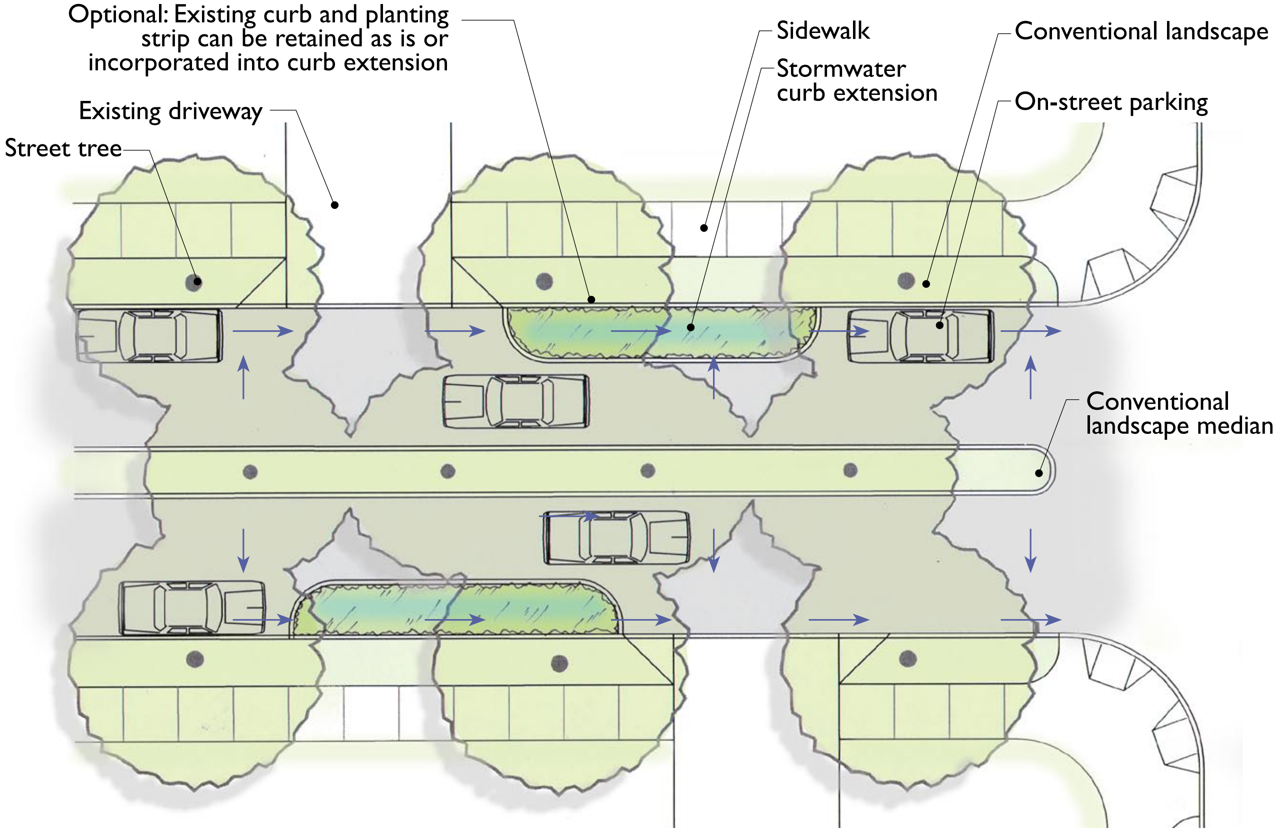
Mid-Block Stormwater Curb Extension Plan View (Symmetrical Layout)

Converting a Wide Residential Street

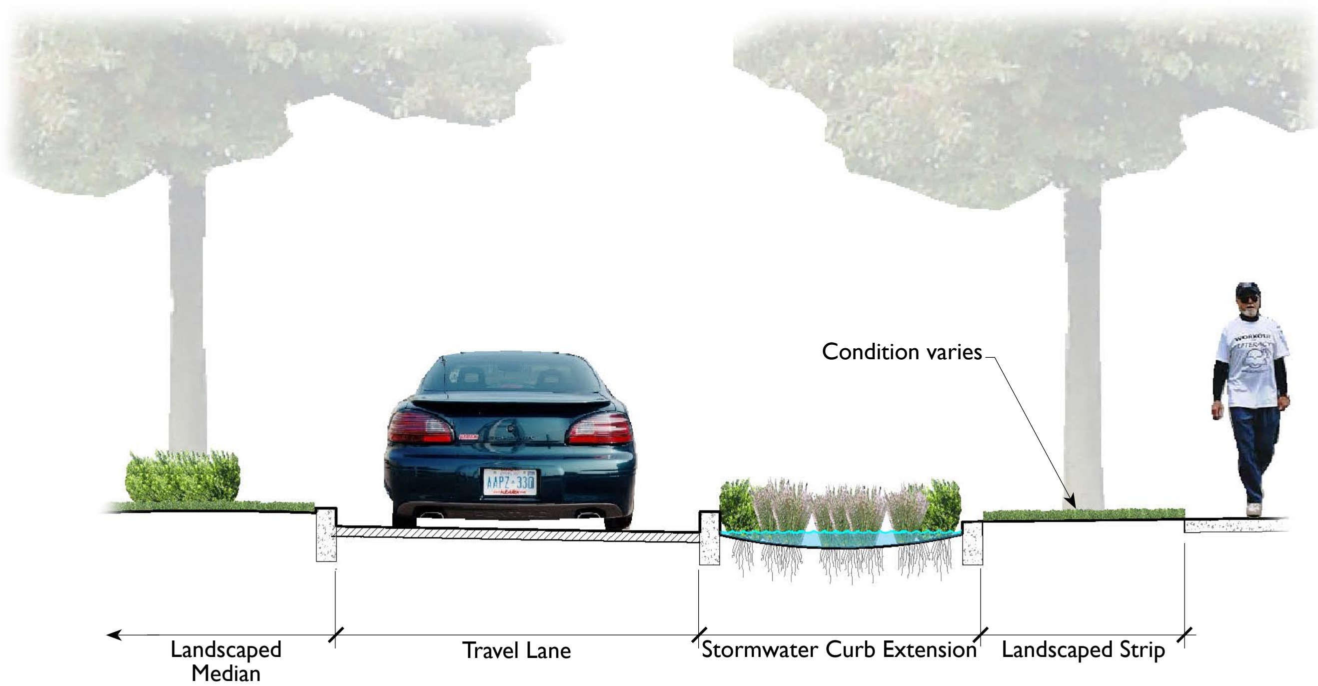
Excessively wide residential streets in San Mateo County are common and could be redesigned to better manage stormwater by using a combination of site design strategies. By adding a landscape median in the center of the street, the overall impervious area is reduced. In addition, stormwater curb extensions can be strategically placed alongside existing curbs with room remaining for on-street parking. Street trees can be added within the stormwater curb extensions and the landscape median to further manage runoff and add character to the street. These improvements don't have to be introduced as a whole; simply adding a conventional landscape median at the crown of the street would reduce overall impervious area. Another option would be to add pervious paving within the parking zone as illustrated below.

***Figure 4-10: EXISTING:** A typical wide residential street in San Mateo County.*

***Figure 4-11: RETROFIT OPPORTUNITY:** The same residential street retrofitted with stormwater curb extensions and a conventional landscape median with street trees.*



Stormwater Curb Extension & Landscape Median Plan View



Stormwater Curb Extension & Landscape Median Typical Cross Section

Don't need parking? Big opportunity.

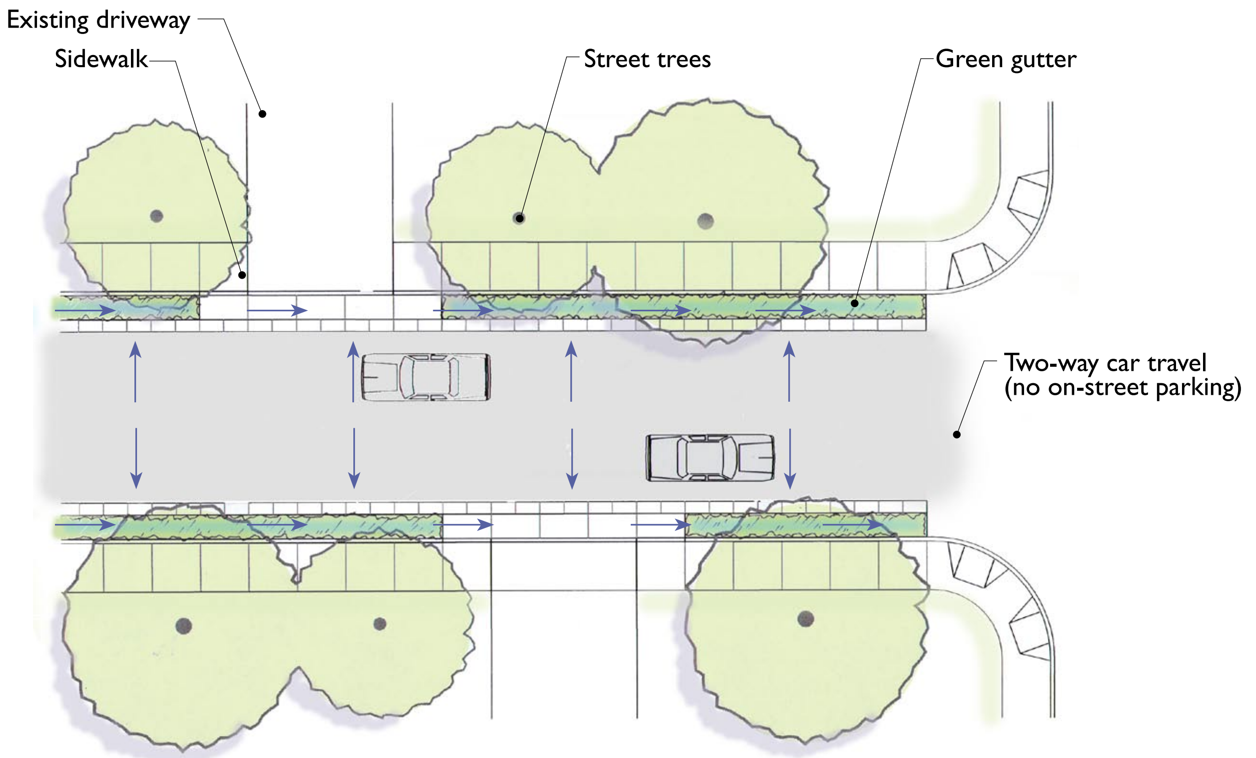
Residential streets that have a wide right-of-way and do not need on-street parking are good candidates for retrofitting with a "green gutter" system. A green gutter is a narrow stormwater planter that can be placed alongside streets that do not need on-street parking. Green gutters are typically shallow and designed to slow and filter stormwater runoff. By removing a couple of feet of asphalt on both sides of this street, a green gutter system is viable without impeding two way travel along the street. The example below illustrates a "curbless" condition where runoff can sheet flow into the green gutters. A standard curb and gutter, however, can also be built with frequent curb cuts if there is a concern about vehicular traffic.

SOURCE: NEVUE NGAN ASSOCIATES

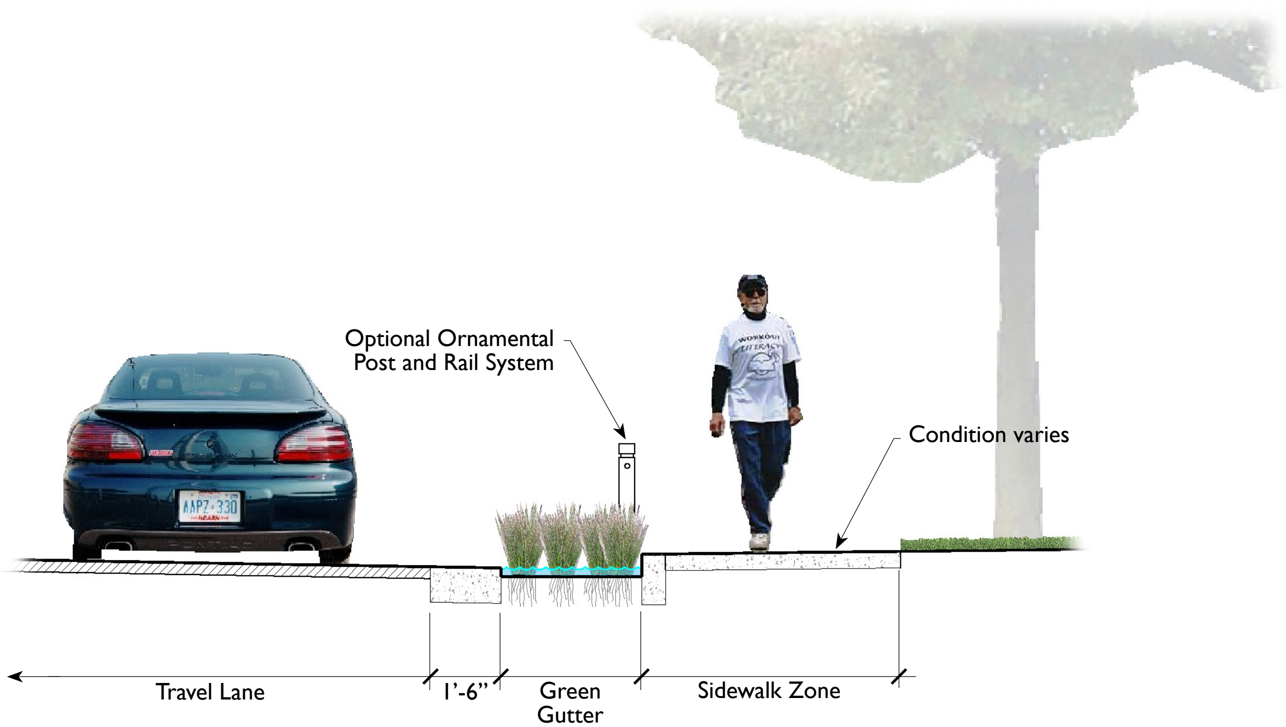
Figure 4-12: EXISTING: *A typical wide residential street in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-13: RETROFIT OPPORTUNITY: *The same residential street retrofitted with a green gutter system.*



Green Gutter Plan View



Green Gutter Typical Cross Section

Different Options for Pervious Paving

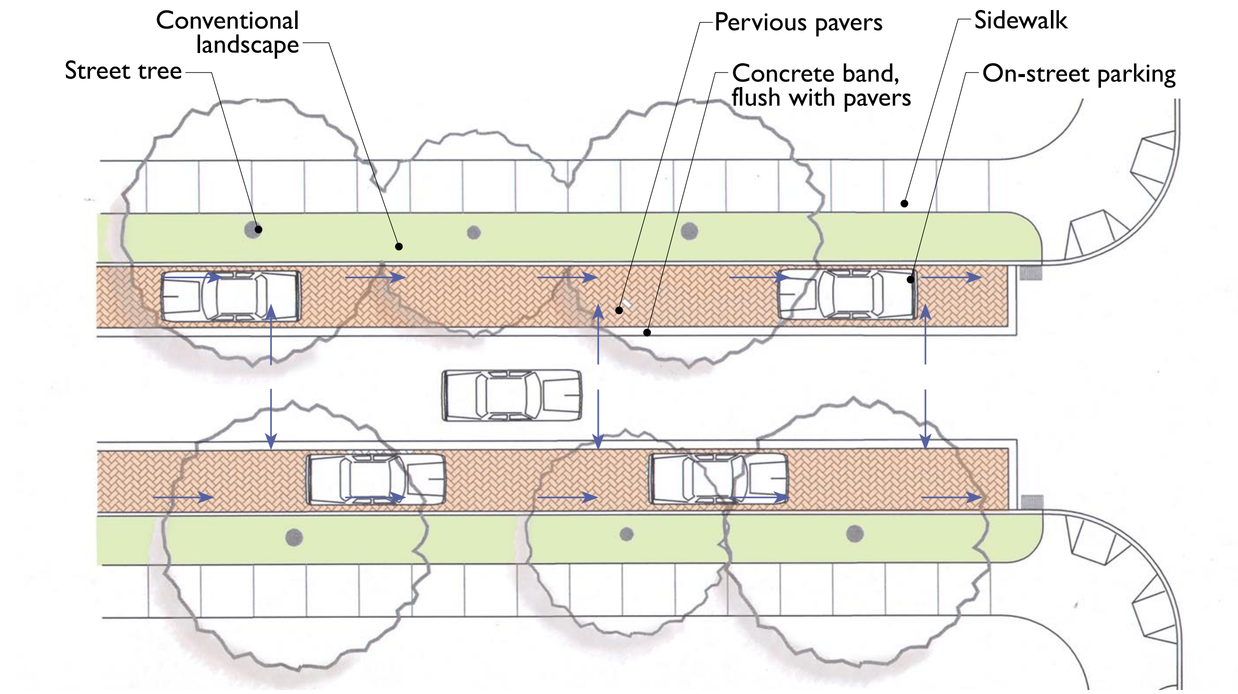
In low-density residential streets, pervious paving can be used in the parking zone. Pervious paving can be employed in new construction (as seen below) or retrofitted within existing street conditions. Pervious paving also can be used for the entire street surface. One of the advantages of using pervious concrete or sand-set pervious pavers strictly in the parking zone is that there is a perceived narrowing of the street due to the contrast between the conventional asphalt and the pervious paving material. This perceived narrowing may help slow the speed of traffic. The use of pervious paving reduces the amount of stormwater runoff, but it does not provide permit-required stormwater treatment compared to a vegetated swale, planter or rain garden.

SOURCE: NEVUE NGAN ASSOCIATES

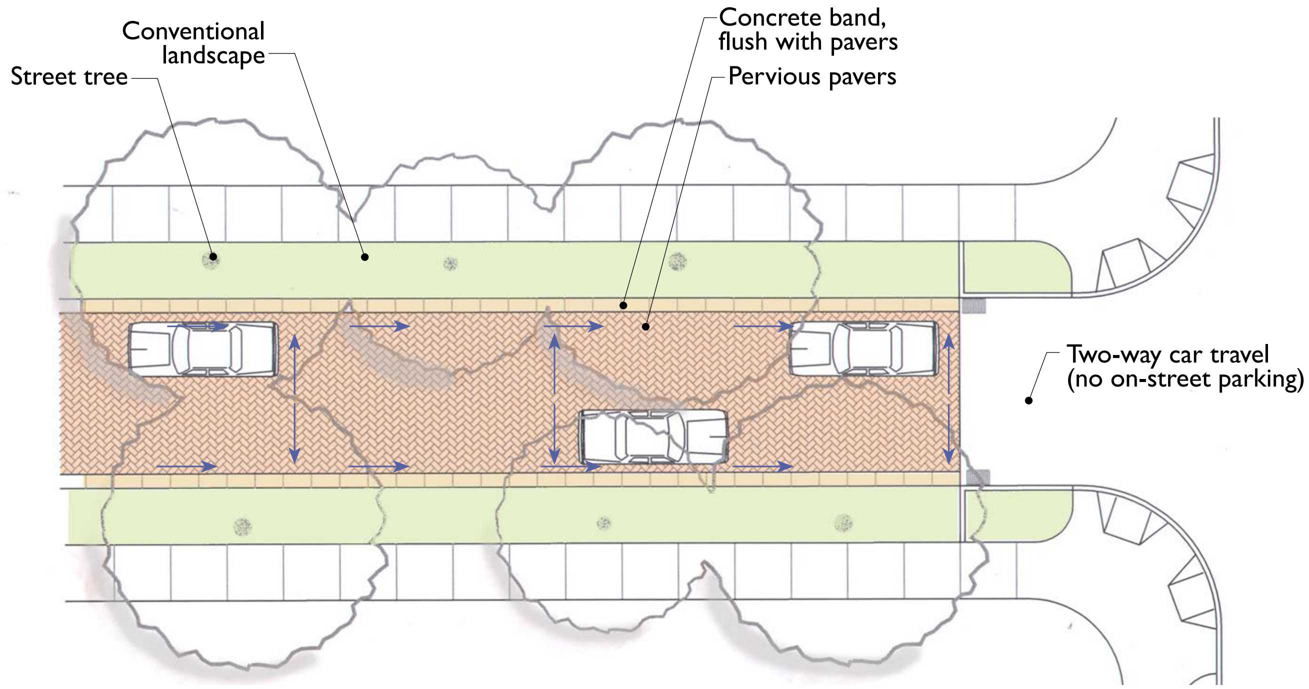
Figure 4-14: EXISTING: *A residential street within a new development project.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-15: RETROFIT OPPORTUNITY: *The same residential street retrofitted with pervious paving in the parking zone.*



Pervious Paving in Parking Zone Plan View



Pervious Paving (Full Application) Plan View

Options for New Development

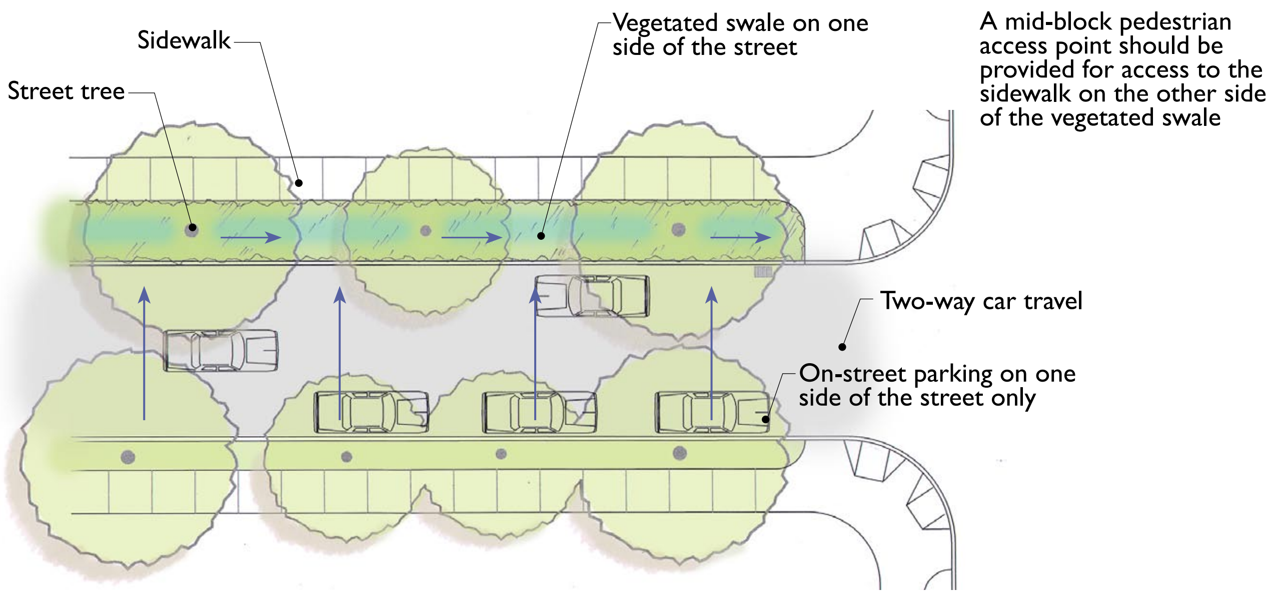
In San Mateo County, retrofitting vegetated swales within existing neighborhood streets may be difficult because there are typically too many driveways that interrupt the continuous space needed for swales. New and redeveloped residential streets, though, present an opportunity to use swales effectively since there is greater control of where driveways are located. The most desirable scenario is to have driveways located toward the back of the house and accessed by an alley. This allows for the long, continuous landscape space at the front of the house that is well-suited for swales. The design example below illustrates how new development can incorporate vegetated swales in the street's planting strips. The designs on the opposite page show additional options for using vegetated swales depending on how the street drainage is designed.

SOURCE: NEVUE NGAN ASSOCIATES

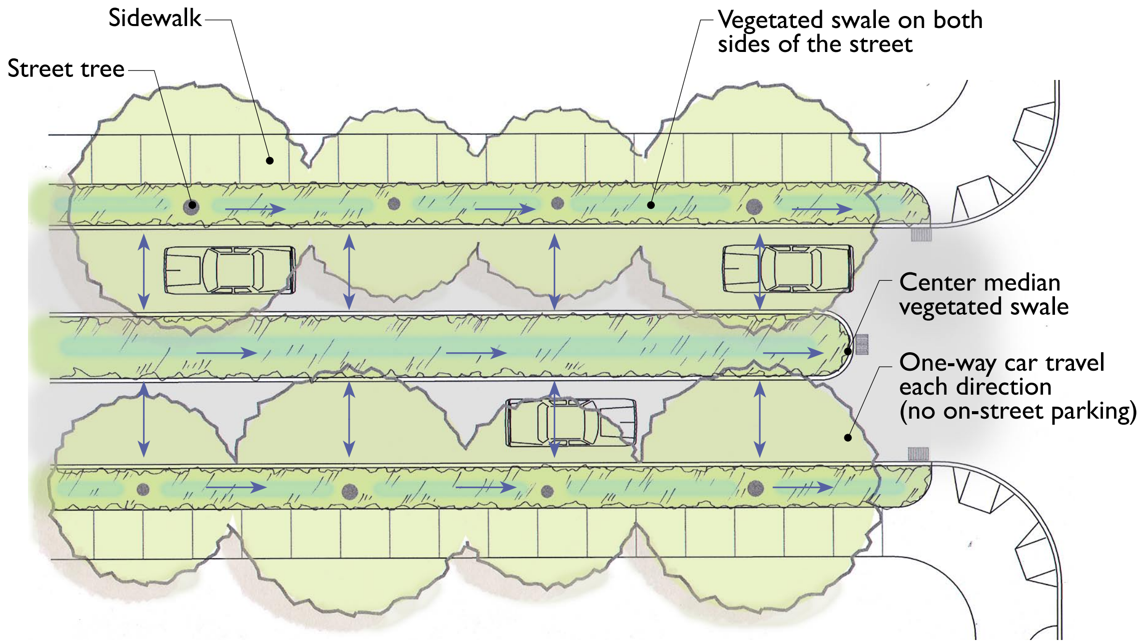
Figure 4-16: EXISTING: *A typical new development residential street.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-17: RETROFIT OPPORTUNITY: *The same residential street using vegetated swales within the street's planting strips.*



Swale on One Side of Street, Parking on Other Side Plan View



Side Swales and Median Swale (No On-Street Parking) Plan View

Narrow, Dense, and Pervious!

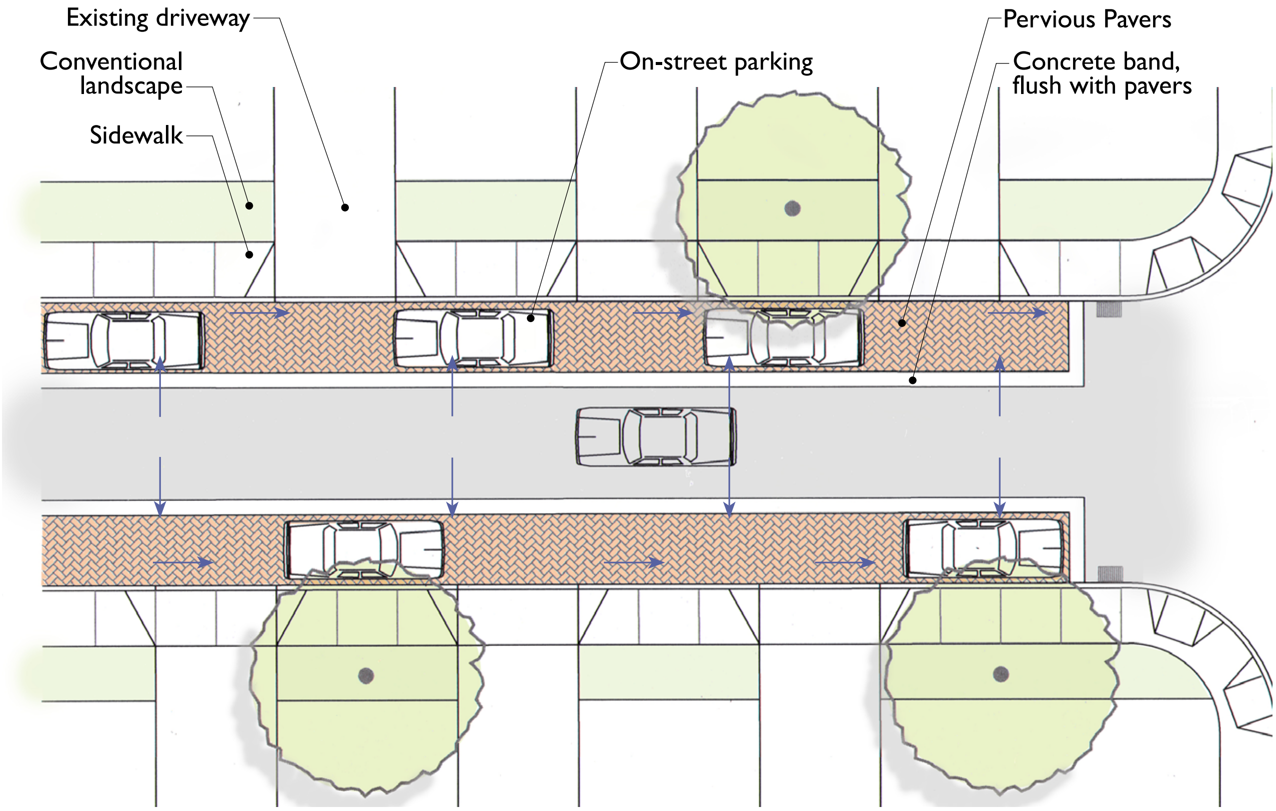
Some residential streets in San Mateo County are so dense that there is barely room to squeeze a parked car in between driveways. If the need for on-street parking limits the use of landscape-based stormwater facilities, then pervious paving may be the best retrofit option. The retrofit opportunity below shows an application of pervious, sand-set concrete pavers. The result is a unique-looking street that reduces the amount of stormwater runoff. Some high-density residential streets in San Mateo County are narrow enough that the use of pervious paving on the entire street may be cost effective if the native soils and physical conditions are well-suited for pervious paving.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-18: EXISTING: *A typical narrow and highly dense residential street in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-19: RETROFIT OPPORTUNITY: *The same residential street retrofitted with pervious paving in the parking zone of the street.*



Pervious Paving in Parking Zone Plan View

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-20: EXAMPLE: *Concrete pavers used in a residential street's parking zone. Notice the visual "narrowing" of the street.*

Narrow Street with Curb Extensions

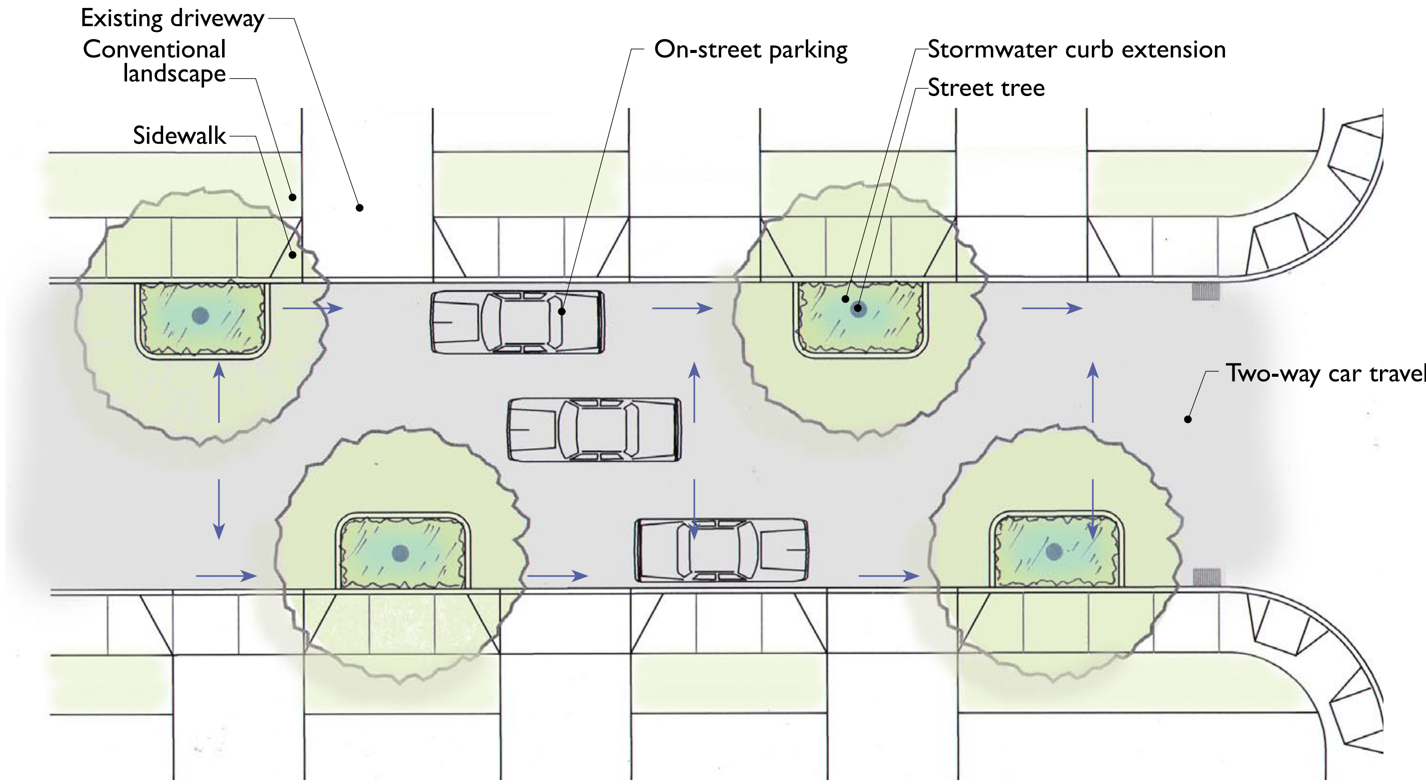
In areas where there can be some conversion of parking space to landscape space, small curb extensions can be placed between driveway curb cuts. Because these curb extensions will most likely be smaller than what would be ideal for managing a street's runoff, they should be spaced frequently to better distribute flow to each landscape area. For better curb appeal, residents may prefer to have a stormwater curb extension with landscaping and trees in front of their house instead of a parked car. For high-density residential streets, the best option may be to combine pervious paving in the parking zone with stormwater curb extensions. However, the two design strategies can work independently.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-21: EXISTING: *A typical narrow and dense residential street in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-22: RETROFIT OPPORTUNITY: *The same residential street using short curb extension in between driveways.*



Stormwater Curb Extensions in the Parking Zone Plan View

SOURCE: WWW.FLICKR.COM - RLLAYMAN'S PHOTOSTREAM

Figure 4-23: EXAMPLE: *Conventional curb extensions are placed in a staggered orientation on this residential street. Although these curb extensions do not allow stormwater runoff to soak into the ground, they could be modified to do so.*

Wide Residential Streets

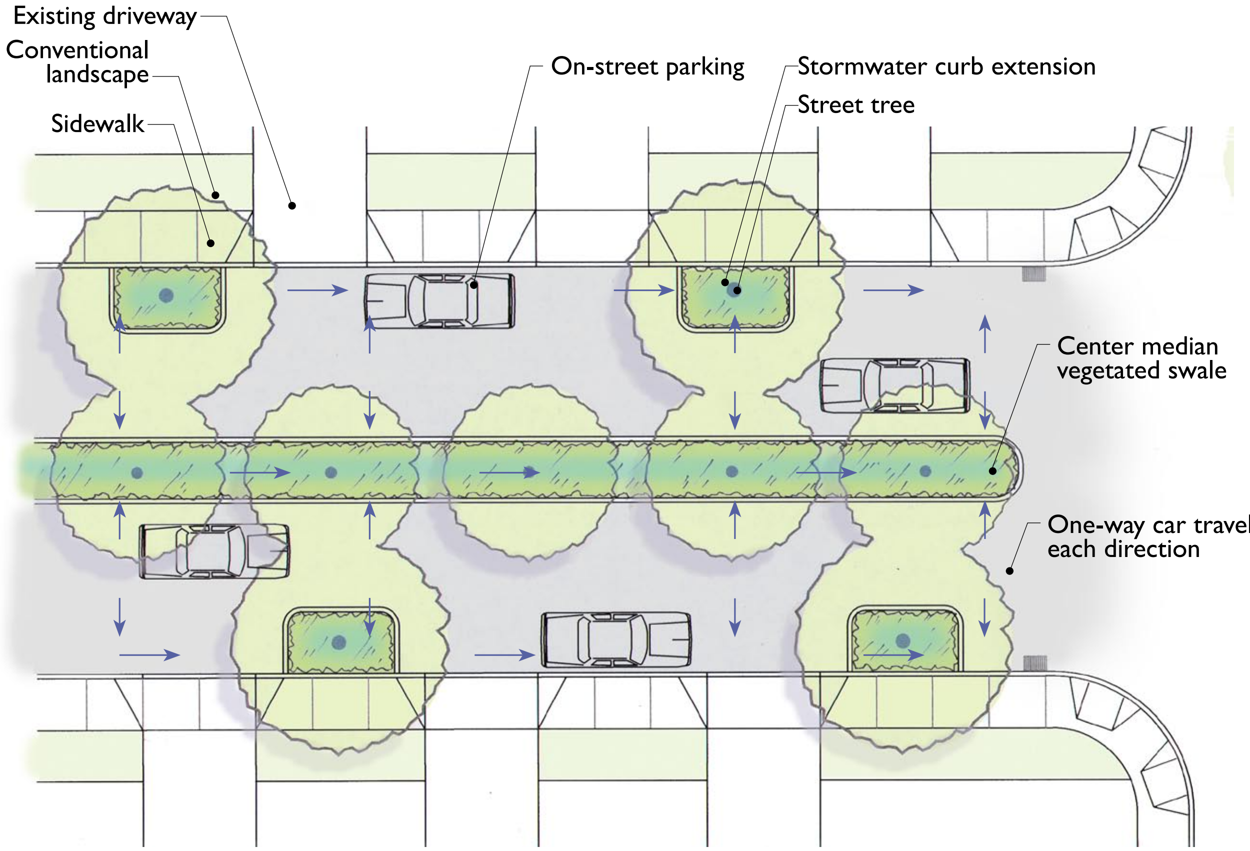
Some high-density residential streets in San Mateo County are very wide. In some cases, a particularly wide street also has a center landscape median. This presents an opportunity to convert an existing median into a vegetated swale or to retrofit a wide street with a new center median. The challenge of retrofitting a center median swale is how to direct runoff to the center of the street (which is typically the high point of drainage). On moderately sloped streets, there is a way to redirect stormwater from the street curb to the center of street. A small speed bump set on a diagonal can direct water to the median swale. It is a simple technology that could be used in specific situations in San Mateo County. The illustration below shows how an existing center median can be retrofitted using this design technique.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-24: EXISTING: *A steep high density residential street with an existing lawn median in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-25: RETROFIT OPPORTUNITY: *The same residential street retrofitted with a stormwater median swale. Note the illustrated check dams and weirs that help terrace the steep grade of the street and help control the desired water retention depth.*



Center Median Swale and Curb Extensions Plan View

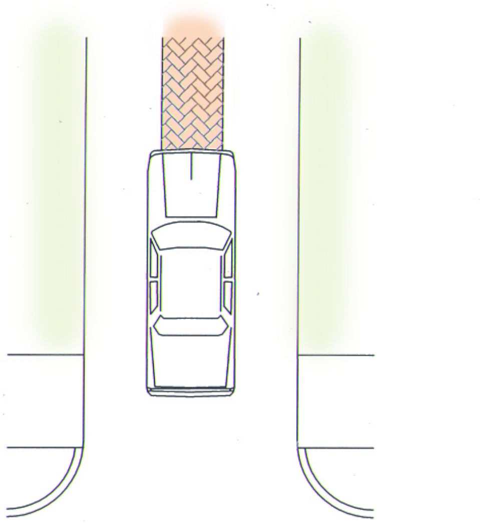
SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-26: EXAMPLE: *This vegetated swale utilizes check dams and adjustable weirs to control the ponding of stormwater runoff.*

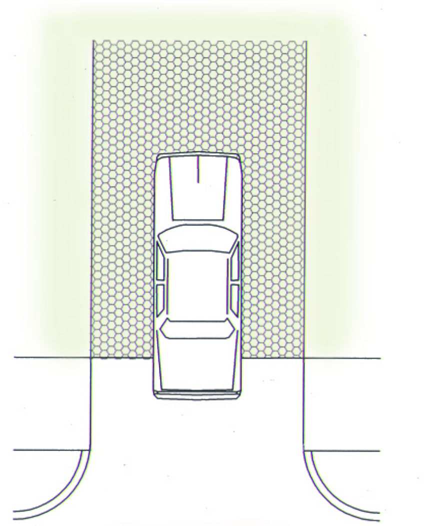
Figure 4-27: *This residential development in San Mateo County utilizes sand-set concrete pavers.*

Multiple Options for Driveways

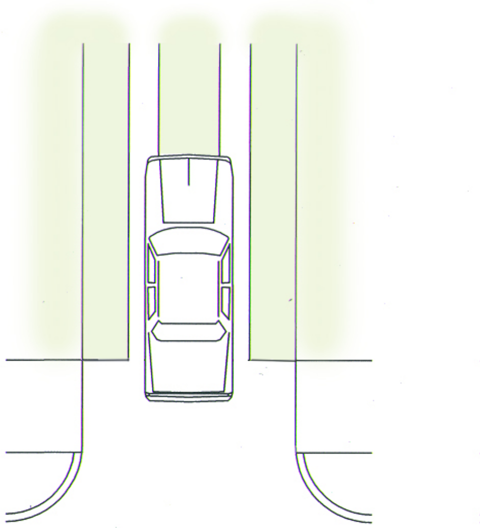
Pervious paving systems in driveways are often a good way to help mitigate stormwater runoff. If pervious paving is not a viable option due to steep slopes then converting portions of the driveway approach to lawn, other types of low-growing vegetation, or gravel can help reduce the amount of stormwater runoff entering the public stormwater system.



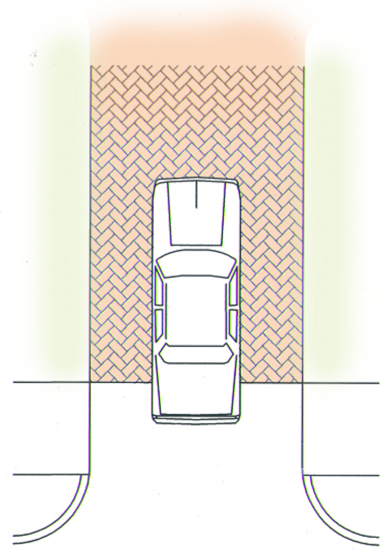
Concrete Pavers Center Strip Plan View



Reinforced Grass Paving Plan View



Grass Center Strip Plan View



Concrete Pavers Plan View

SOURCE: WWW.DAKOTACOUNTYSWCD.ORG/LIDDEMO.HTM

Figure 4-28: *Sand-set concrete pavers installed within a driveway.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-30: *Sand-set concrete pavers installed in the center strip of a multi-family housing driveway approach.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-29: *Reinforced grass paving with wheel base concrete bands.*

SOURCE: WWW.SANFRANCISQUITO.ORG/

Figure 4-31: *A combination of grass and pervious concrete pavers replaced a conventional driveway in Palo Alto, CA.*

Urban Street with Stormwater Planters

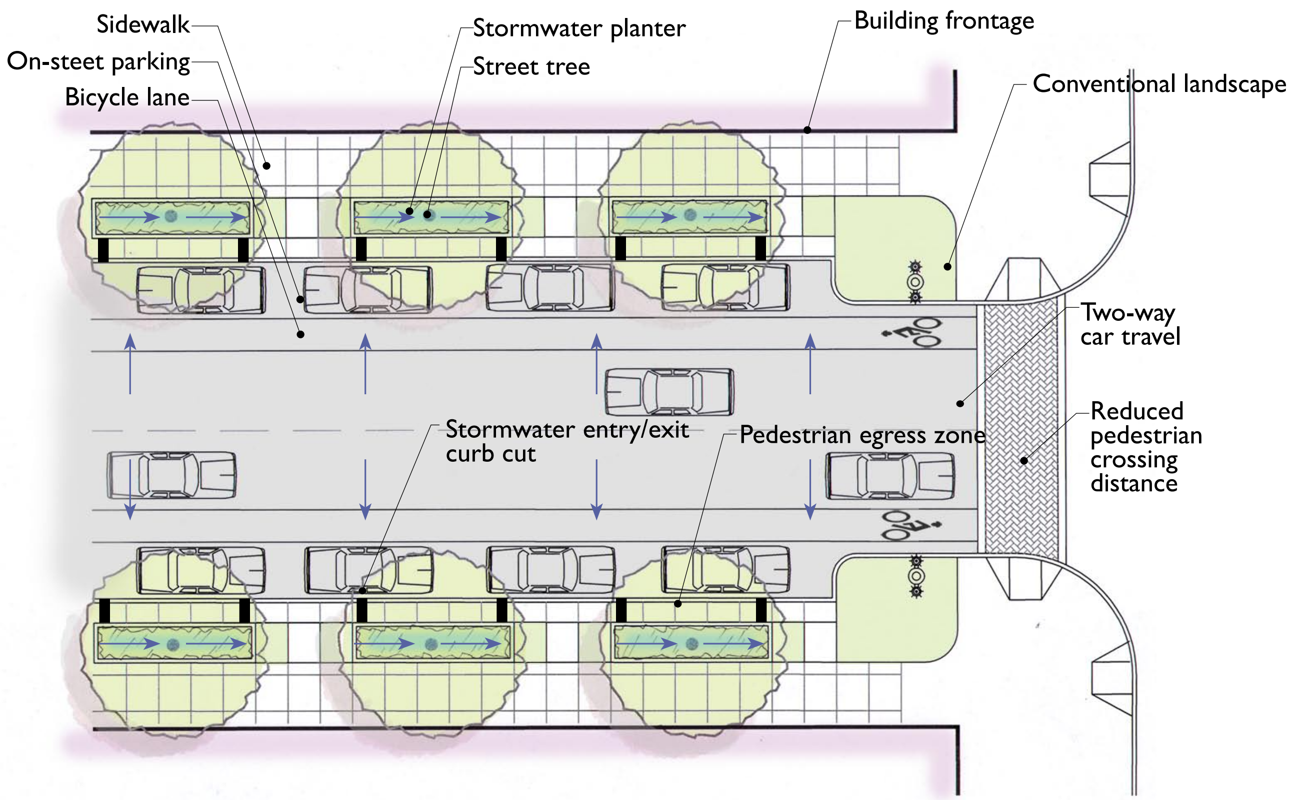
Stormwater planters can be added to the furnishing zone between the sidewalk and the street while retaining on-street parking. Pedestrian circulation can be accommodated by creating walkways in between the planters and a pedestrian egress zone adjacent to on-street parking. The retrofit opportunity illustrated below links a series of flow-through or infiltration planters. As the upstream stormwater planter fills up with runoff, it overflows out onto the street and enters the next downstream planter. In urban areas, using planters is advantageous because they allow for stormwater treatment in limited spaces.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-32: EXISTING: *A commercial street in San Mateo County with on-street parking.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-33: RETROFIT OPPORTUNITY: *The same commercial street retrofitted with stormwater planters.*



Stormwater Planters With On-Street Parking Plan View

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 4-34: EXAMPLE: *Stormwater planters used along a downtown street. Notice that there needs to be adequate space allocated for people to get in and out of their vehicles and access the sidewalk zone.*

Parking On One Side, Stormwater On The Other

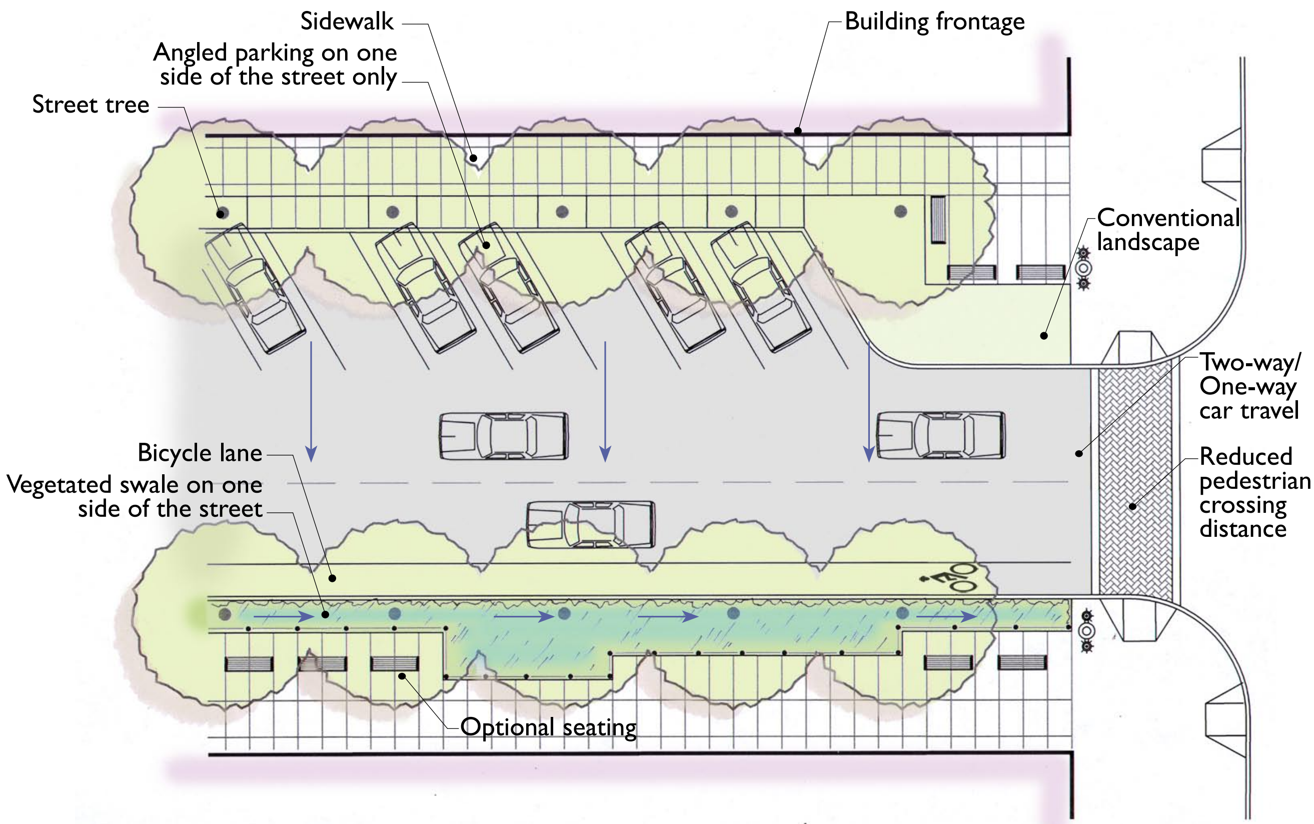
A bold way to significantly green a streetscape is by consolidating a traffic lane or allowing on-street parking on only one side of the street. The area gained can be converted into a vegetated swale or inter-connected stormwater planters. The result is a unique streetscape design that provides for stormwater management and adds pedestrian space next to buildings. The example shown below is a "curbless" urban street with a travel lane converted into a vegetated swale and bike lane. Many different variations on this theme can be used depending on site conditions.

SOURCE: NEVUE NGAN ASSOCIATES

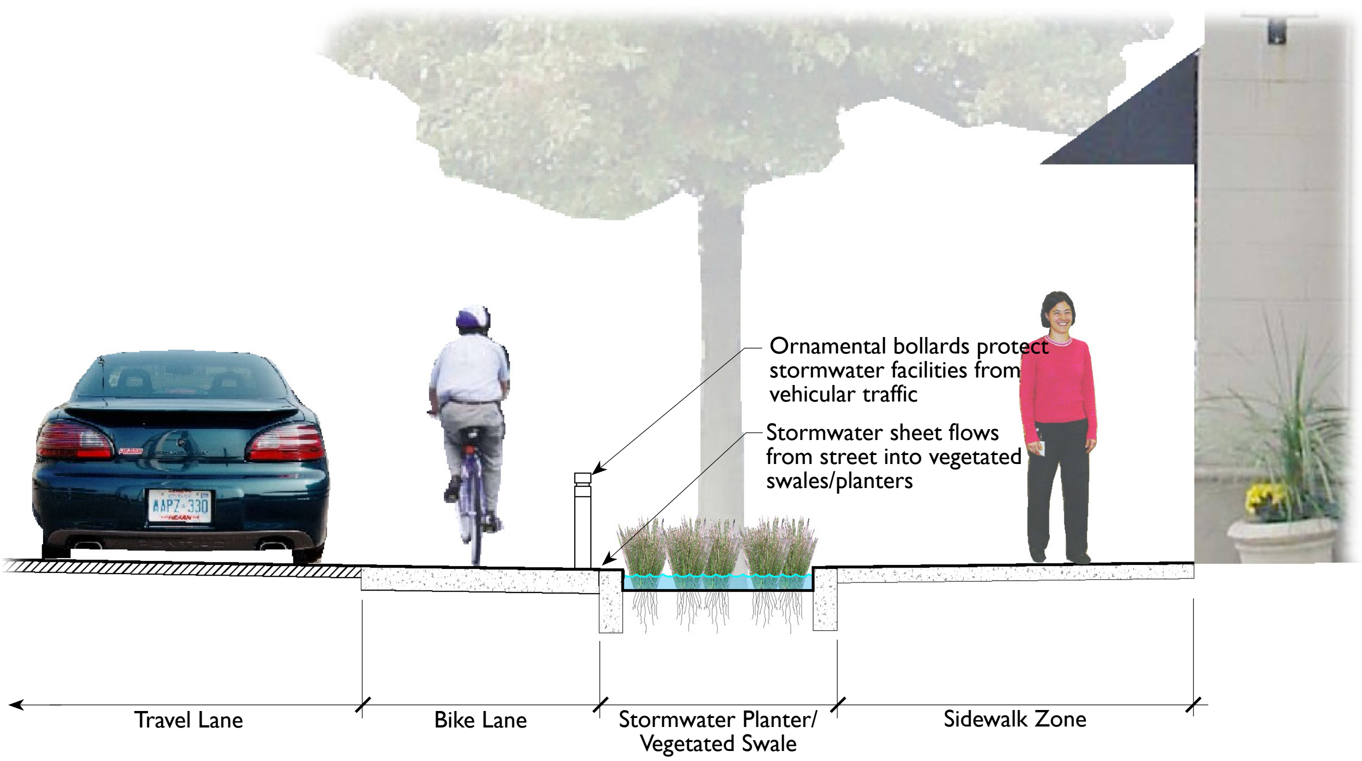
Figure 4-35: EXISTING: *A typical urban street.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-36: RETROFIT OPPORTUNITY: *The same street without one traffic lane and retrofitted with a "curbless" street, vegetated swale, and bike lane.*



"Curbless" Street With A Vegetated Swale/Planter On One Side Plan View



"Curbless" Street With A Vegetated Swale/Planter On One Side Typical Cross Section

Angled Parking Solutions

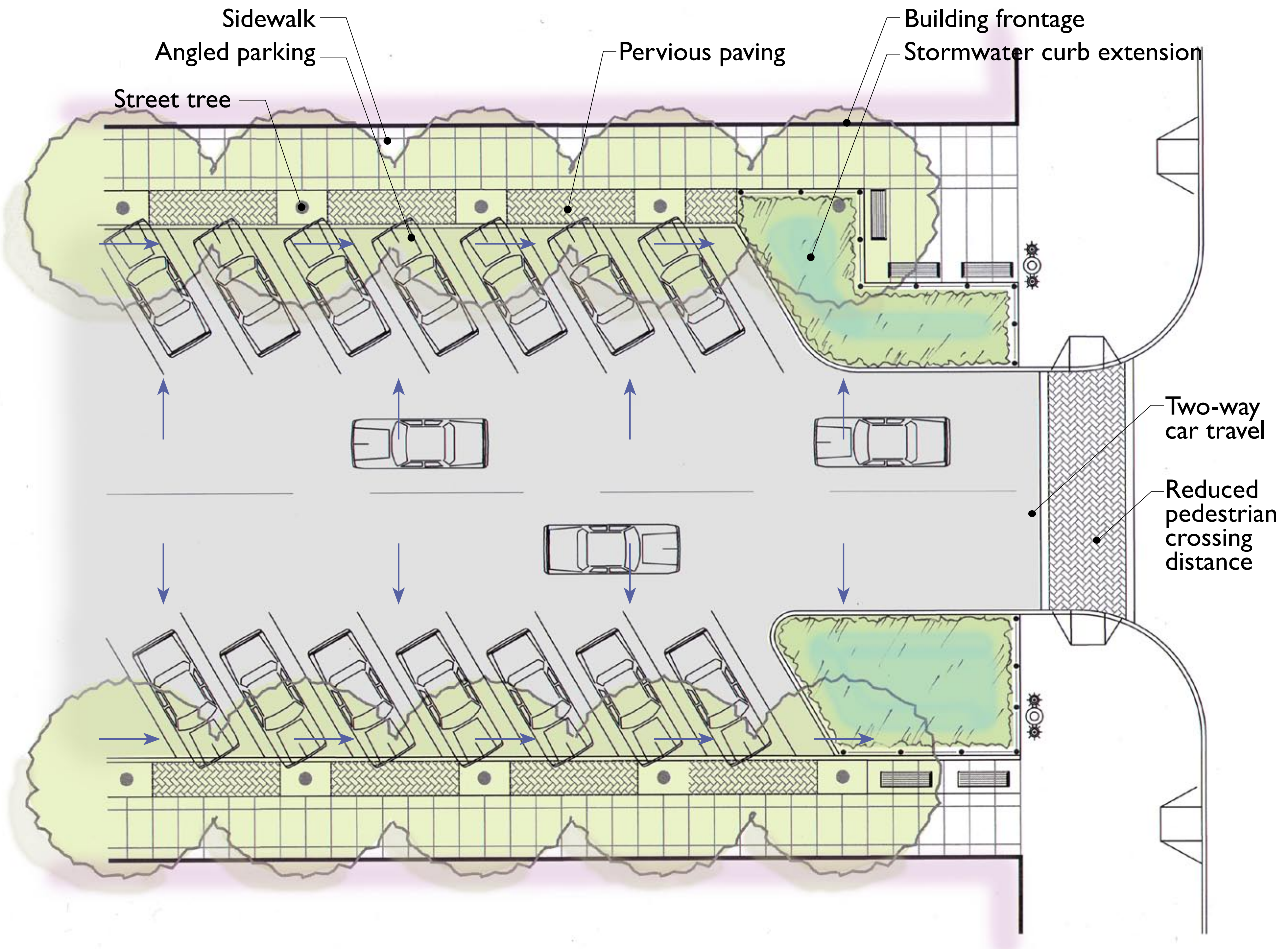
Angled parking along commercial main streets is very common in San Mateo County. Although parallel parking is a more efficient use of space, as shown in the "Provide Efficient Site Design" section in Chapter 2, there are some green street options available for an angled parking scenario. One potential green street design scenario is to consolidate one or more parking spaces into a stormwater curb extension area. This would be a relatively simple retrofit application if parking could be impacted. Converting angled parking spaces into curb extensions adds more landscaping to the street, which also has the potential to enhance the aesthetics of storefront businesses.

SOURCE: NEVUE NGAN ASSOCIATES

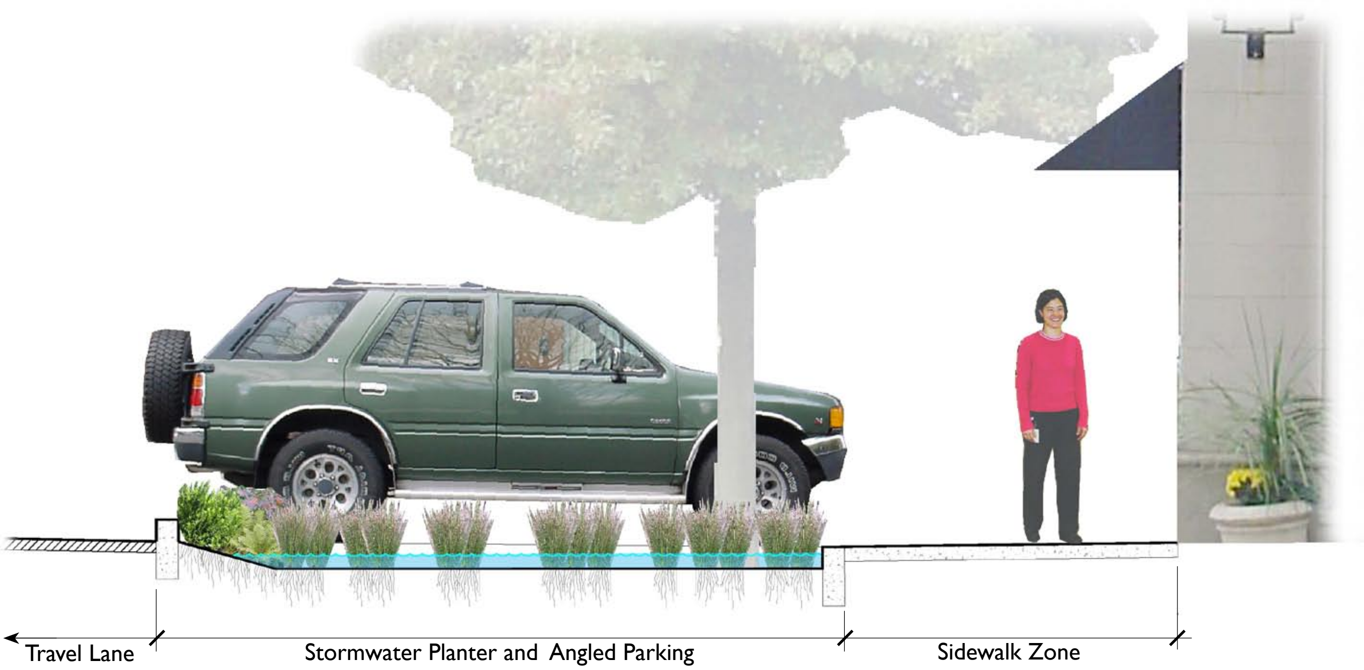
Figure 4-37: EXISTING: *A typical commercial main street with angled parking in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-38: RETROFIT OPPORTUNITY: *The same commercial street with two angled parking stalls converted into a stormwater curb extension.*



Angled Parking Curb Extensions Plan View



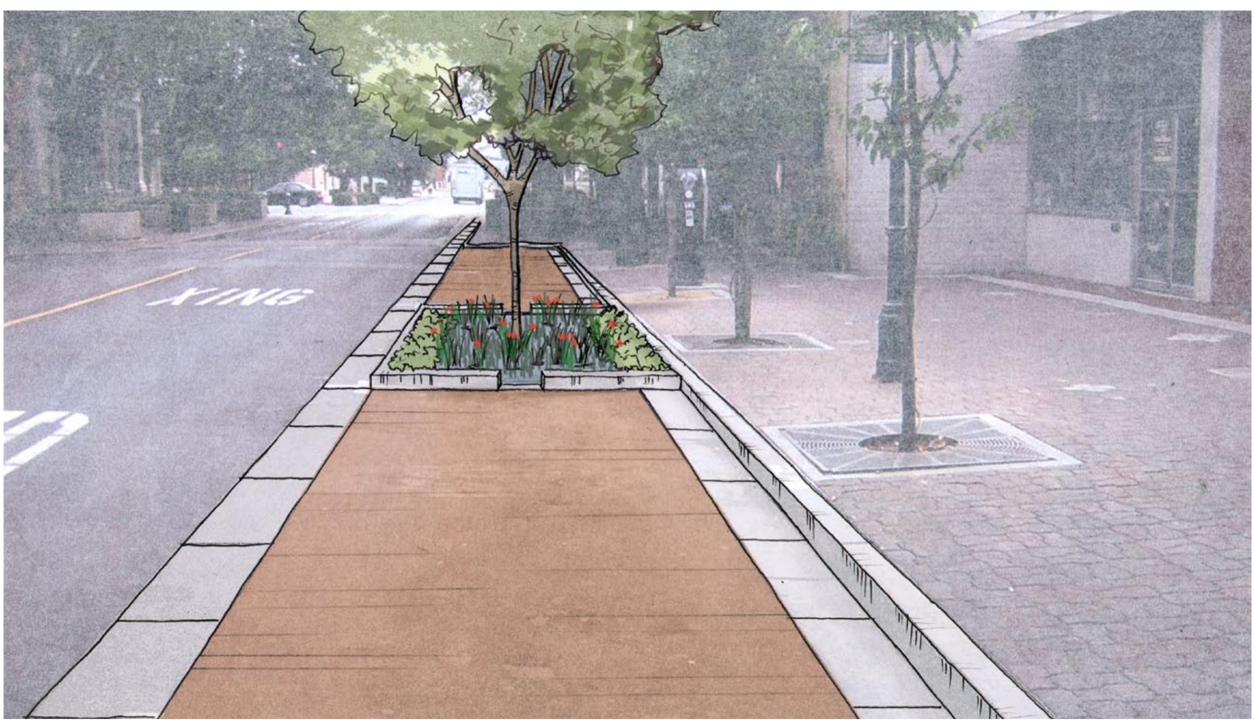
Angled Parking Curb Extensions Typical Cross Section

Curb Extensions at Intersection and Pervious Paving in Parallel Parking Zone

This example shows both mid-block and end-block stormwater curb extensions combined with pervious paving in the parking zone. Combining pervious paving with shortened curb extensions allows for maximum stormwater management with minimal parking loss. For this example, the curb extensions are built as stormwater planters (with vertical walls instead of having a defined side slope).

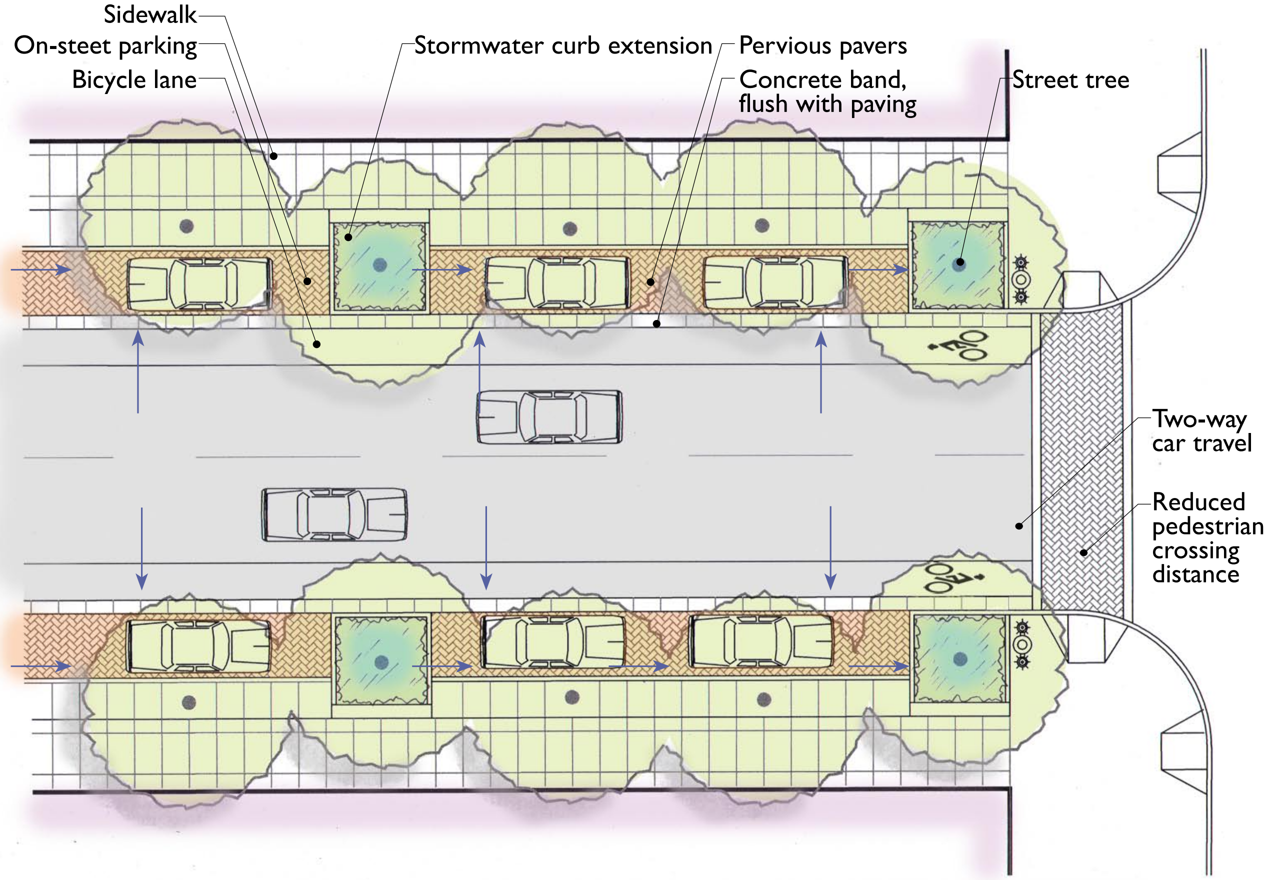
SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-39: EXISTING: *A typical commercial main street with on-street parking in San Mateo County.*



SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-40: RETROFIT OPPORTUNITY: *The same commercial street with a combination of stormwater curb extensions and pervious paving in the parking zone.*



Pervious Paving and Curb Extensions in Parking Zone Plan View

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-41: EXAMPLE: *This urban street uses pervious paving in its parking zone and could have been further refined with stormwater curb extensions.*

A Good Retrofit Opportunity

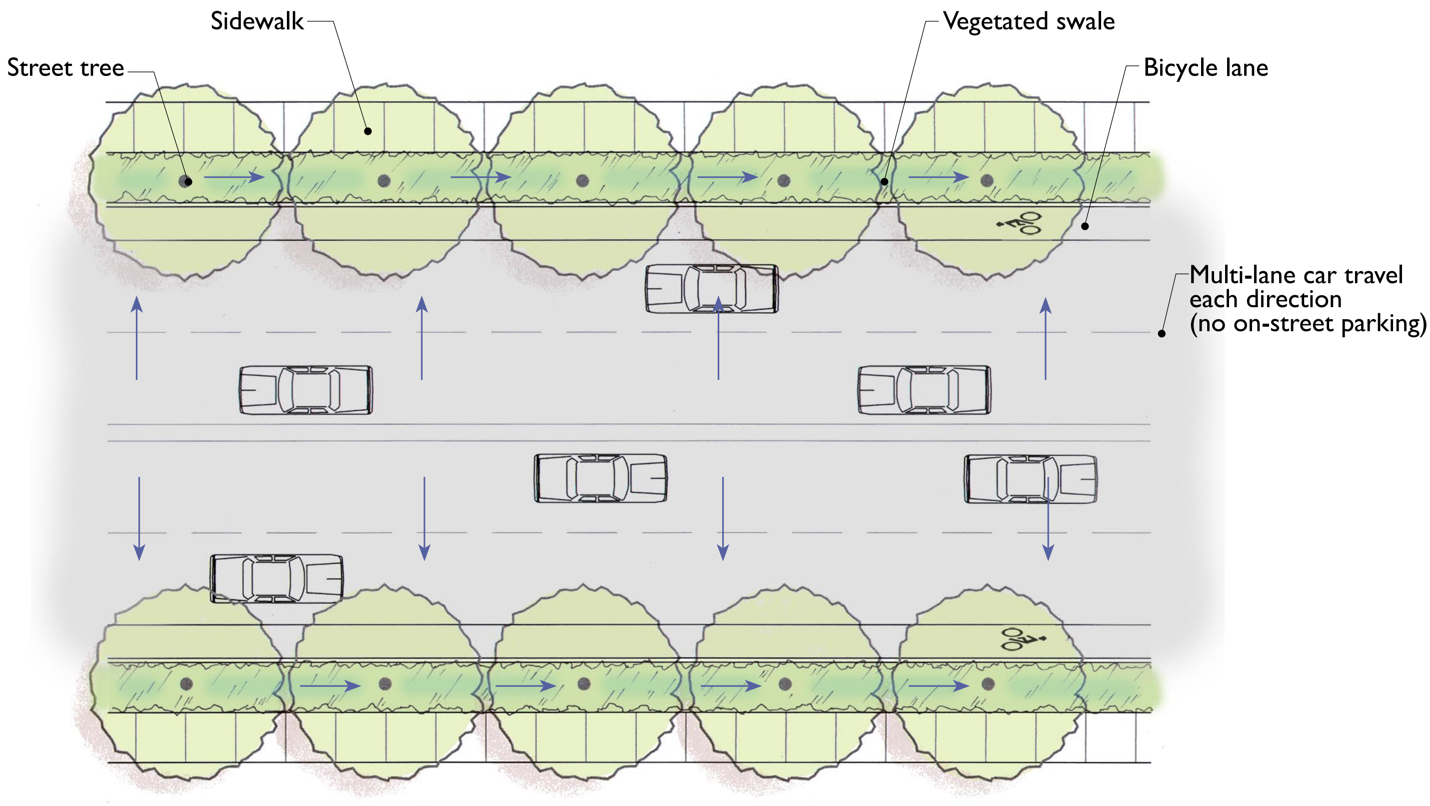
This example shows how a planting strip along a busy arterial street can be easily retrofitted with a vegetated swale. Retrofitting under-used landscape space is often a very cost-effective way to create a green street. Where the native soils have moderate to high infiltration rates, simply regrade the soil, install new landscaping, and construct a series of curb cuts to allow for water to enter and exit the new vegetated swale. These types simple retrofit opportunities should be considered a priority.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-42: EXISTING: *A typical multi-lane arterial street in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-43: RETROFIT OPPORTUNITY: *The same street retrofitted with a vegetated swale within the existing planting strip.*



Stormwater Side Swales Plan View

Figure 4-44: EXAMPLE: *This arterial street utilizes a vegetated swale to accept stormwater from the street. This green street also uses sidewalks made from pervious concrete.*

Gray Gutters to Green Gutters

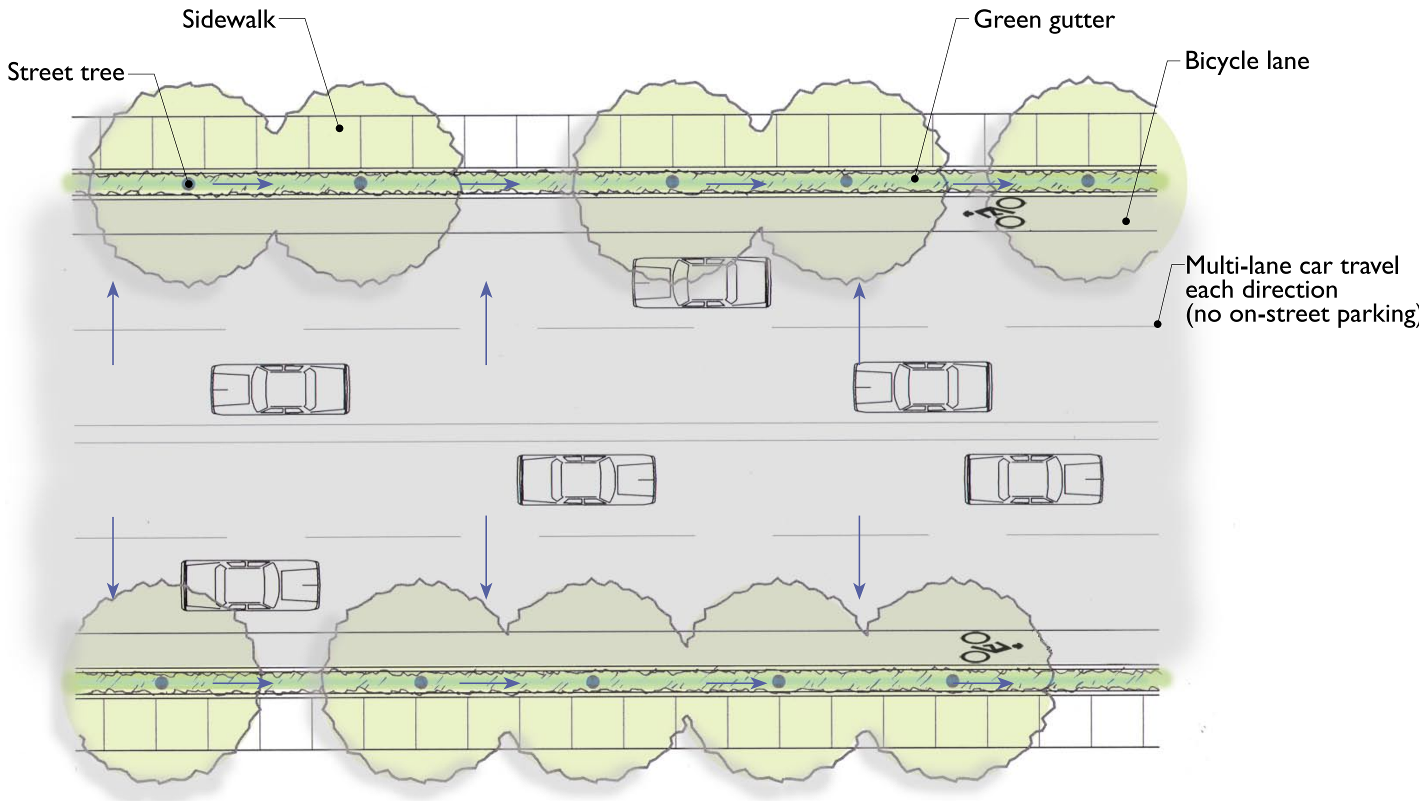
This oversized shoulder area may be used as a bike lane. However, there is sufficient space on the shoulder of this arterial street to accommodate both bike travel and a green gutter system. A green gutter along the curb line of this street would only take up 3 feet of space leaving at least 4 feet of space for a bike lane. The green gutter also helps provide a buffer between the high speed traffic of the arterial and pedestrians using the sidewalk.

SOURCE: NEVUE NGAN ASSOCIATES

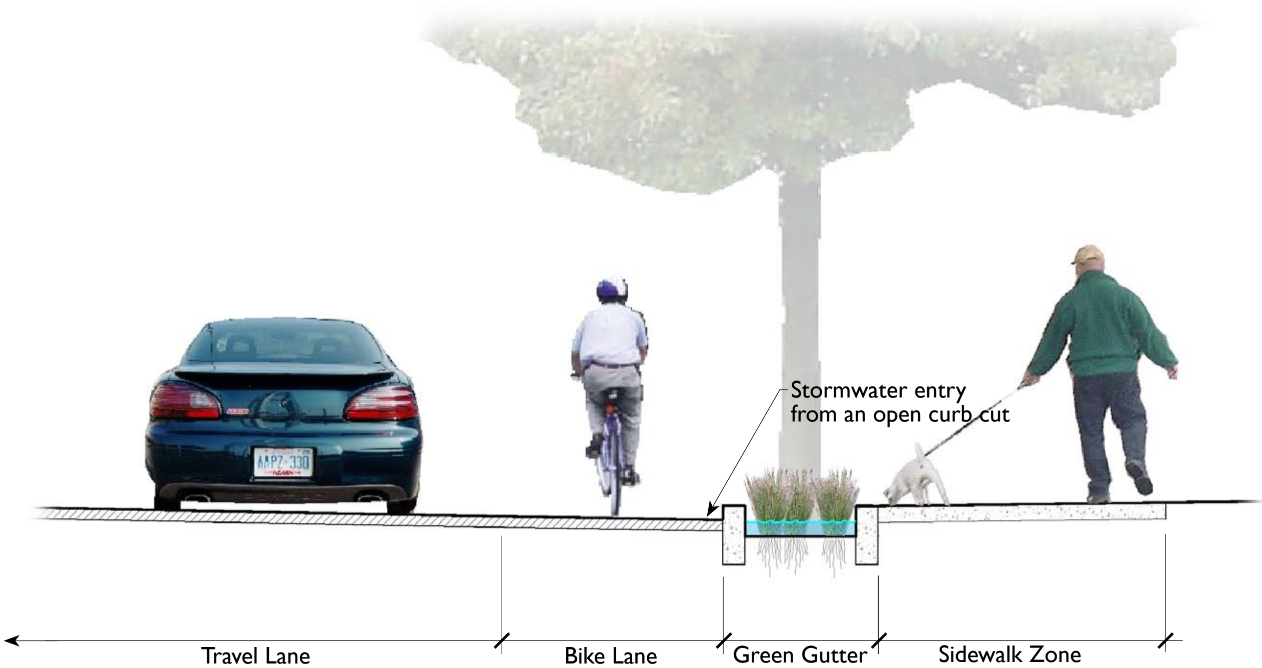
Figure 4-45: EXISTING: *A typical multi-lane arterial street in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-46: RETROFIT OPPORTUNITY: *The same street retrofitted with a green gutter along the existing asphalt shoulder.*



Green Gutter and Bike Lane Plan View



Green Gutter and Bike Lane Typical Cross Section

Helping "Green" a Boulevard

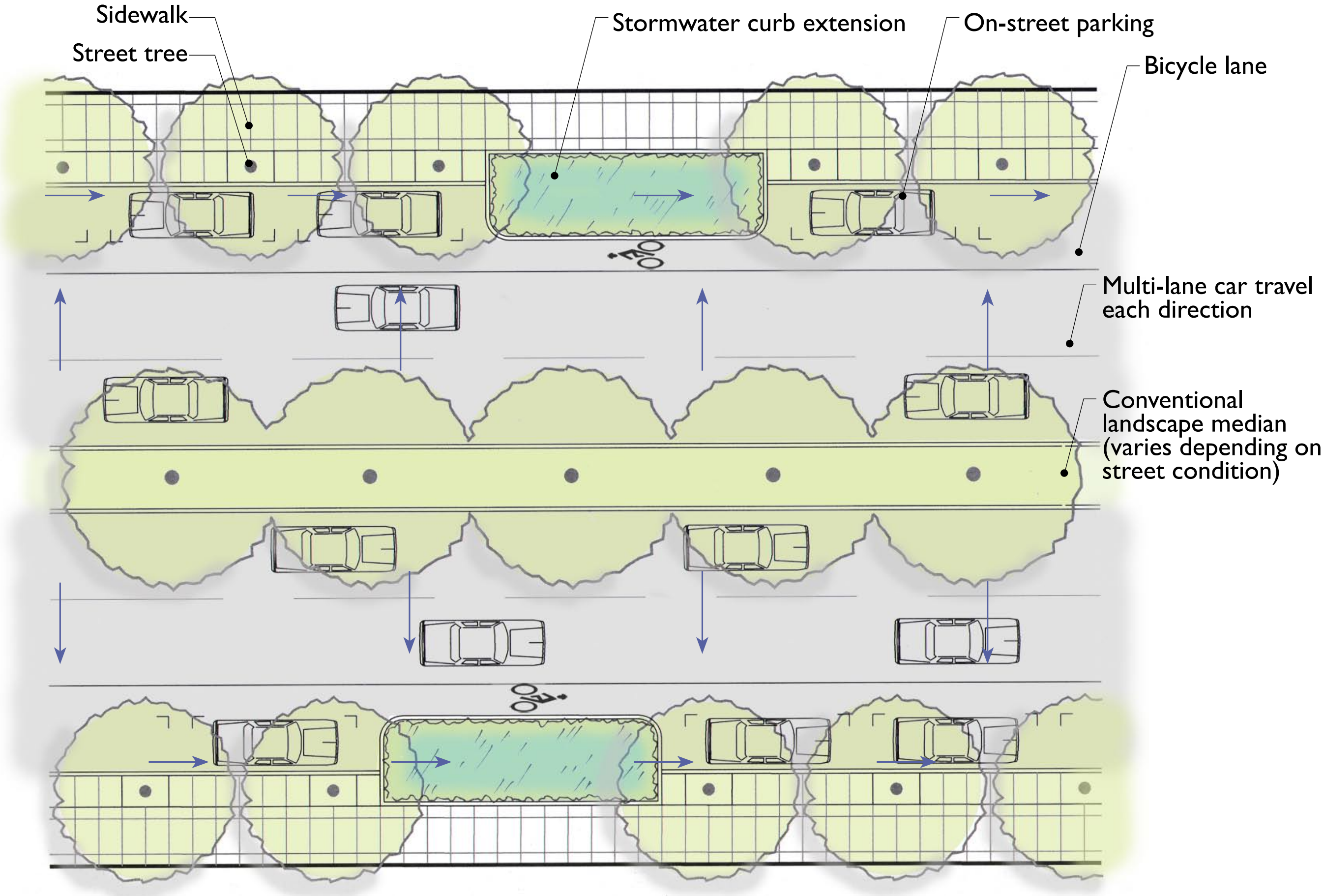
Along busy arterial streets, converting some on-street parking into stormwater curb extensions provides room for green space and street trees. Smaller curb extensions could be placed close together, or, conversely, larger curb extensions could be spaced further apart. This newly introduced landscape area next to the sidewalk can help buffer the pedestrian zone from high-speed traffic, as well as treat stormwater runoff.

SOURCE: NEVUE NGAN ASSOCIATES

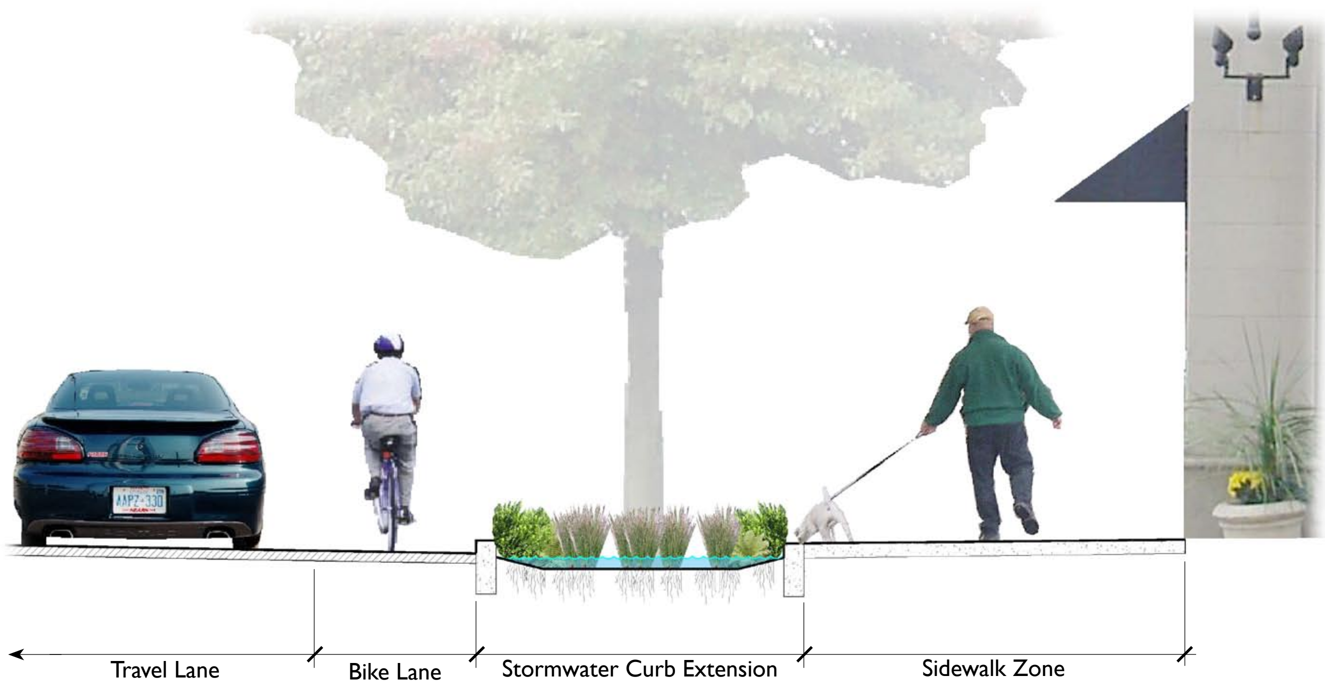
Figure 4-47: EXISTING: *A typical multi-lane arterial street's sidewalk zone in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-48: RETROFIT OPPORTUNITY: *The same street retrofitted with a stormwater curb extension in the parking zone. In this example a low-profile railing has also been added to the streetscape.*



Arterial/Boulevard Curb Extensions Plan View



Arterial/Boulevard Curb Extensions Typical Cross Section

A Bold Stroke of Green

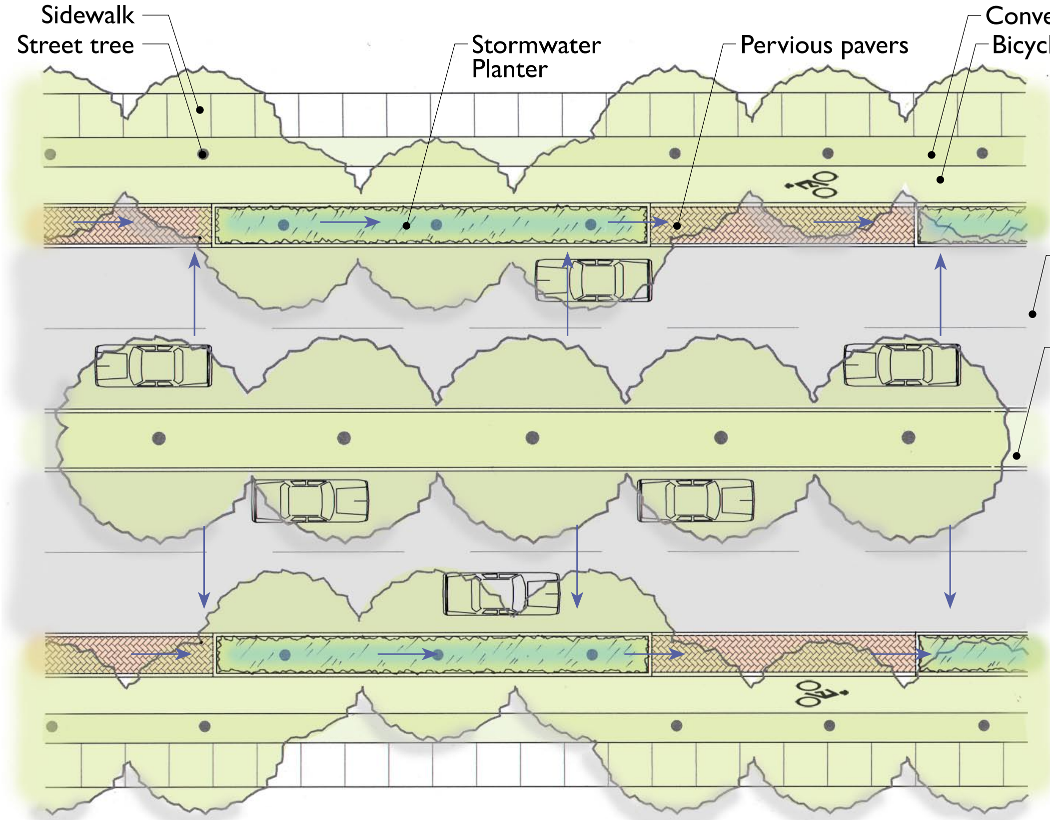
In some conditions along arterial streets there is extra paved shoulder space that can be converted into vegetated swales or planters. Depending on how much space there is, it is also possible to introduce a new separated bike path next to the stormwater facilities. Using such an approach helps reinforce the concept of providing alternative transportation in concert with managing stormwater runoff treatment (a Level 4 green street). Figure 4-50 below showcases this green street concept. While this concept may work well for stormwater, careful design is needed to ensure that bicycles on a separated bike path can pass safely through driveway intersections.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-49: EXISTING: *A typical multi-lane arterial street's under-utilized paved shoulder in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-50: RETROFIT OPPORTUNITY: *The same street retrofitted with a series of stormwater planters, a separated bike path, and additional street trees.*



Stormwater Planters and Separated Bike Path Plan View

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-51: EXAMPLE: *This streetscape (located in San Francisco) does not have a stormwater component, but it illustrates a separated bike path system and additional landscaping.*

Leftover Space In Front of Angled Parking Stalls

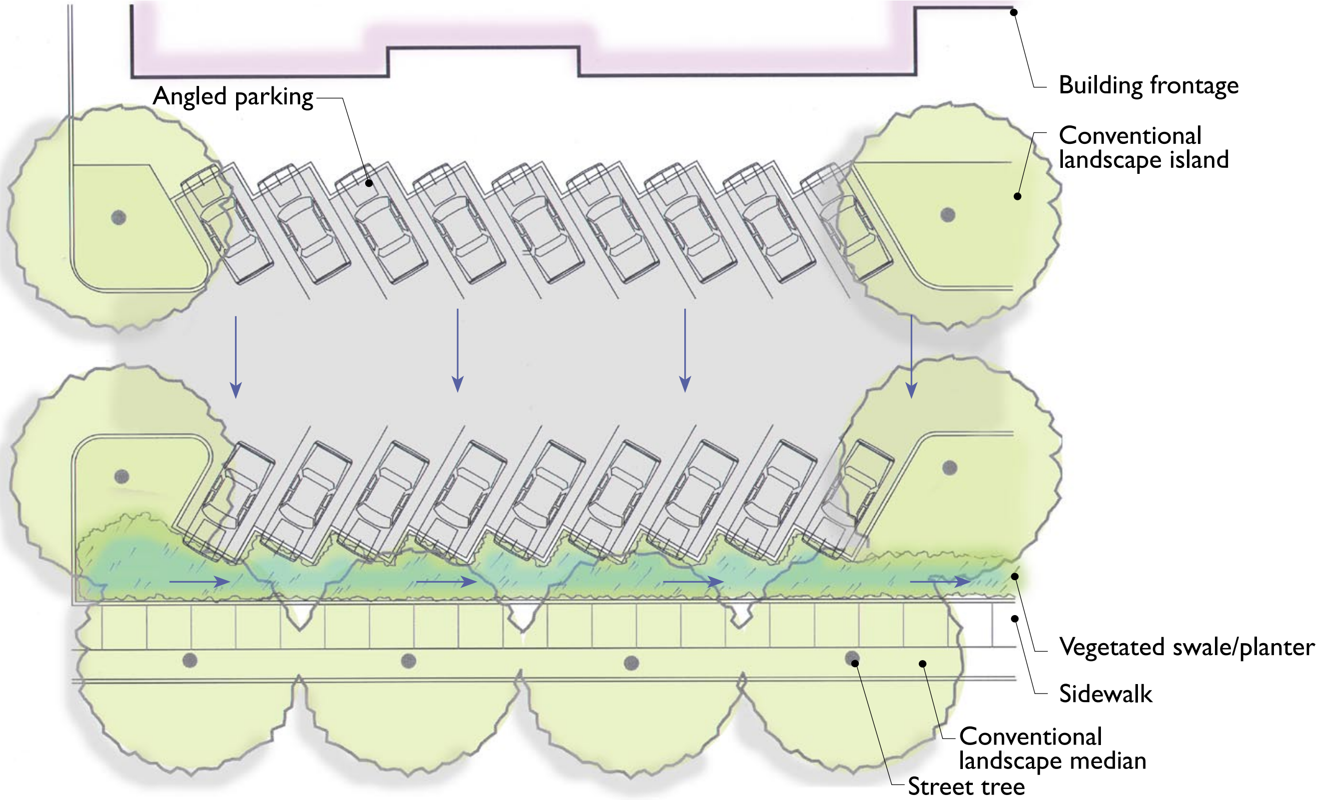
In this example, angled parking leaves unused space between the wheel stop and edge of an existing non-landscaped planter strip. Consolidating this left-over paved space into new landscaping can yield enough room for a parking lot swale. Under-utilized paved or landscape space may also exist in front of 90 degree, head-in parking. Sometimes shortening parking stall lengths by 1' to 2' can provide sufficient combined room to introduce a vegetated swale or planter.

SOURCE: NEVUE NGAN ASSOCIATES

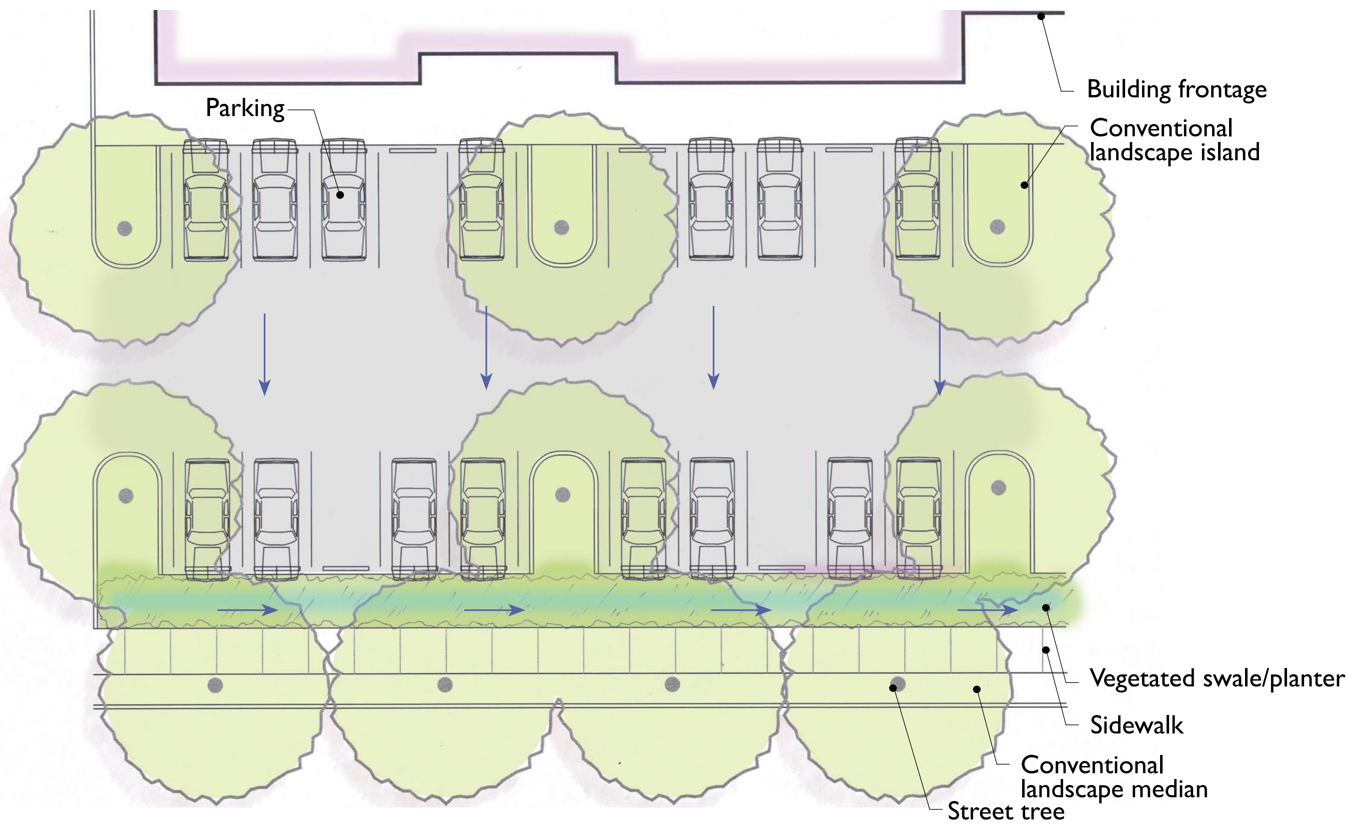
Figure 4-52: ***EXISTING:*** *An angled parking lot example.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-53: ***RETROFIT OPPORTUNITY:*** *The same parking lot retrofitted with a vegetated swale/planter.*



Side Vegetated Swale/Planter with Angled Parking Plan View



Vegetated Swale/Planter with 90-Degree Head-In Parking Plan View

Converting Parking Stalls into Planters

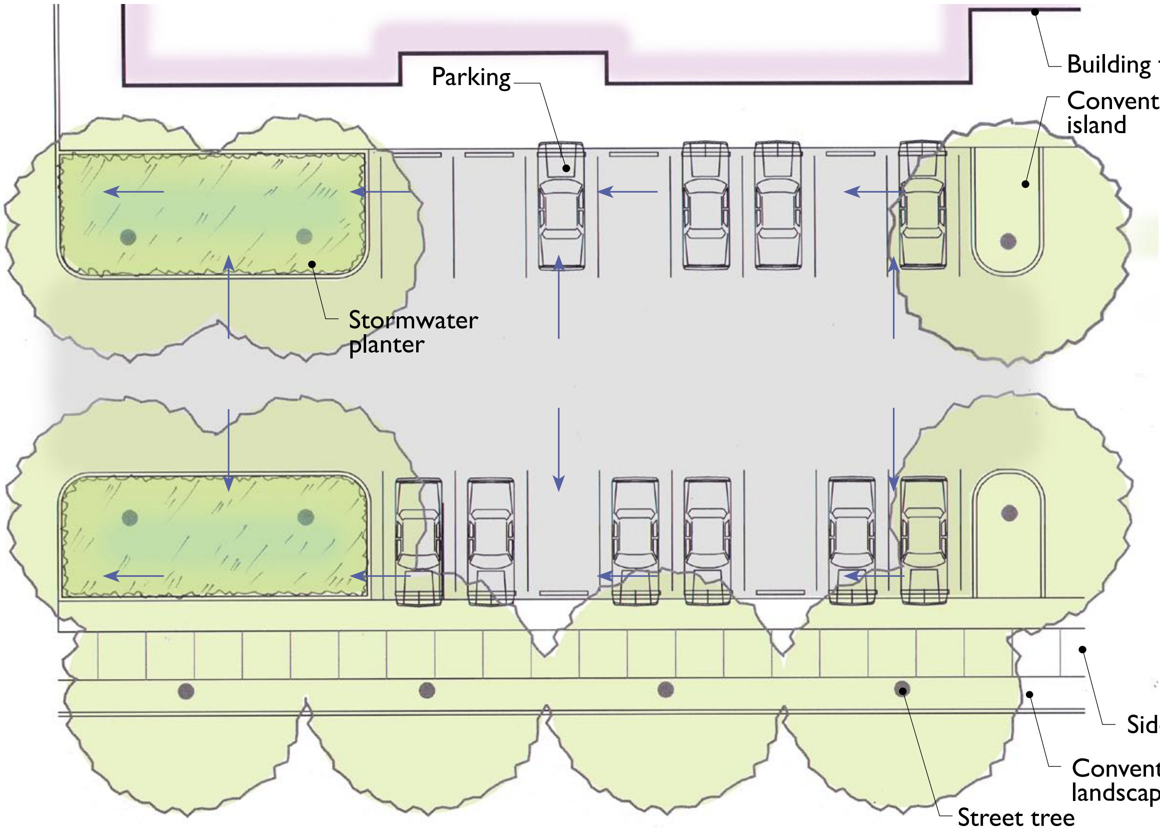
This example shows a parking lot with stormwater planters replacing under-used parking stalls. This is one of the simplest parking lot retrofit actions to implement. The best approach is to convert the parking stalls immediately adjacent to a drain inlet. Depending upon the size and parking demand of a particular parking lot, a series of parking stalls may be consolidated into stormwater planters.

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 4-54: EXISTING:** A typical parking lot in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 4-55: RETROFIT OPPORTUNITY:** The same parking lot retrofitted with a stormwater planter. Notice that this stormwater planter is located near the existing drainage inlet.*



Stormwater Planter with 90-Degree Head-In Parking Plan View

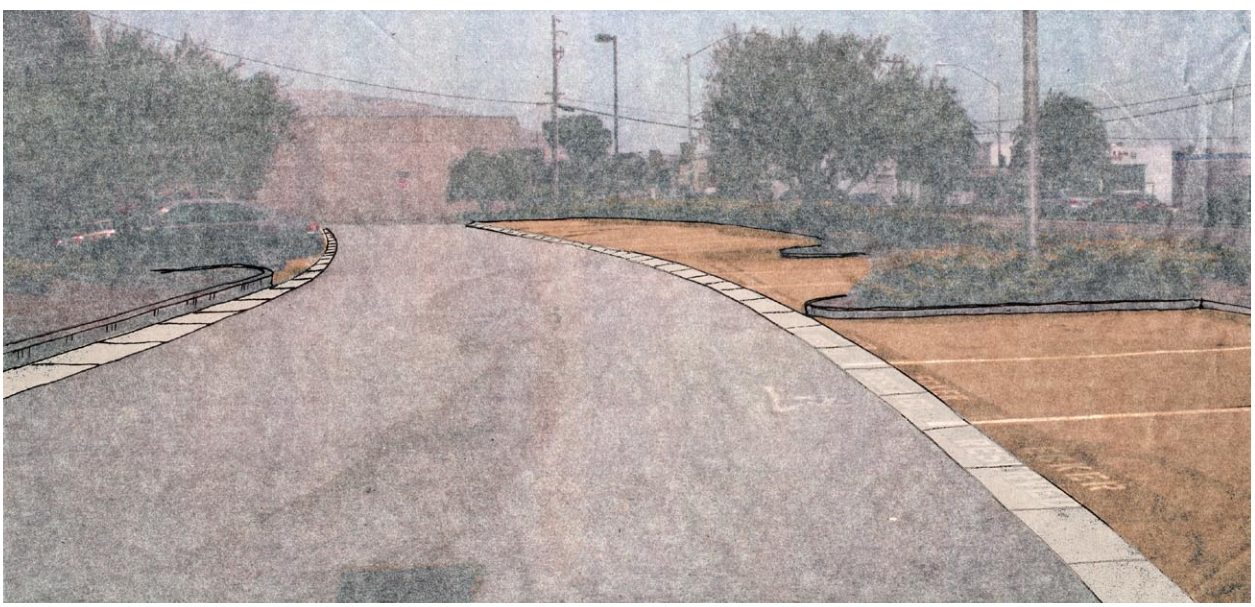
Figure 4-56: EXAMPLE: *This parking lot treats a portion of its stormwater runoff within multiple stormwater planters.*

Pervious Paving in Parking Stalls

This example shows a parking lot whose stormwater drains into the center of the parking drive aisles (internally drained) as opposed to sheet flow to the periphery of the site. This is a fairly common condition and very common with small-scale parking lots. Without redesigning the drainage system, the best, and most practical option is to utilize pervious paving. The illustrated example below employs pervious paving within the parking stalls and allows any excess stormwater runoff to drain into the existing storm inlet. By effectively using pervious paving in parking stalls, there can be up to a 50% reduction of impervious area that generates stormwater runoff. A parking lot can be retrofitted entirely with pervious paving. It may be more cost effective, though, to only use it in the parking stalls, especially in larger parking lot applications. In addition to internally drained parking lots, pervious paving can also be used in parking lots that drain runoff to the periphery of the site.

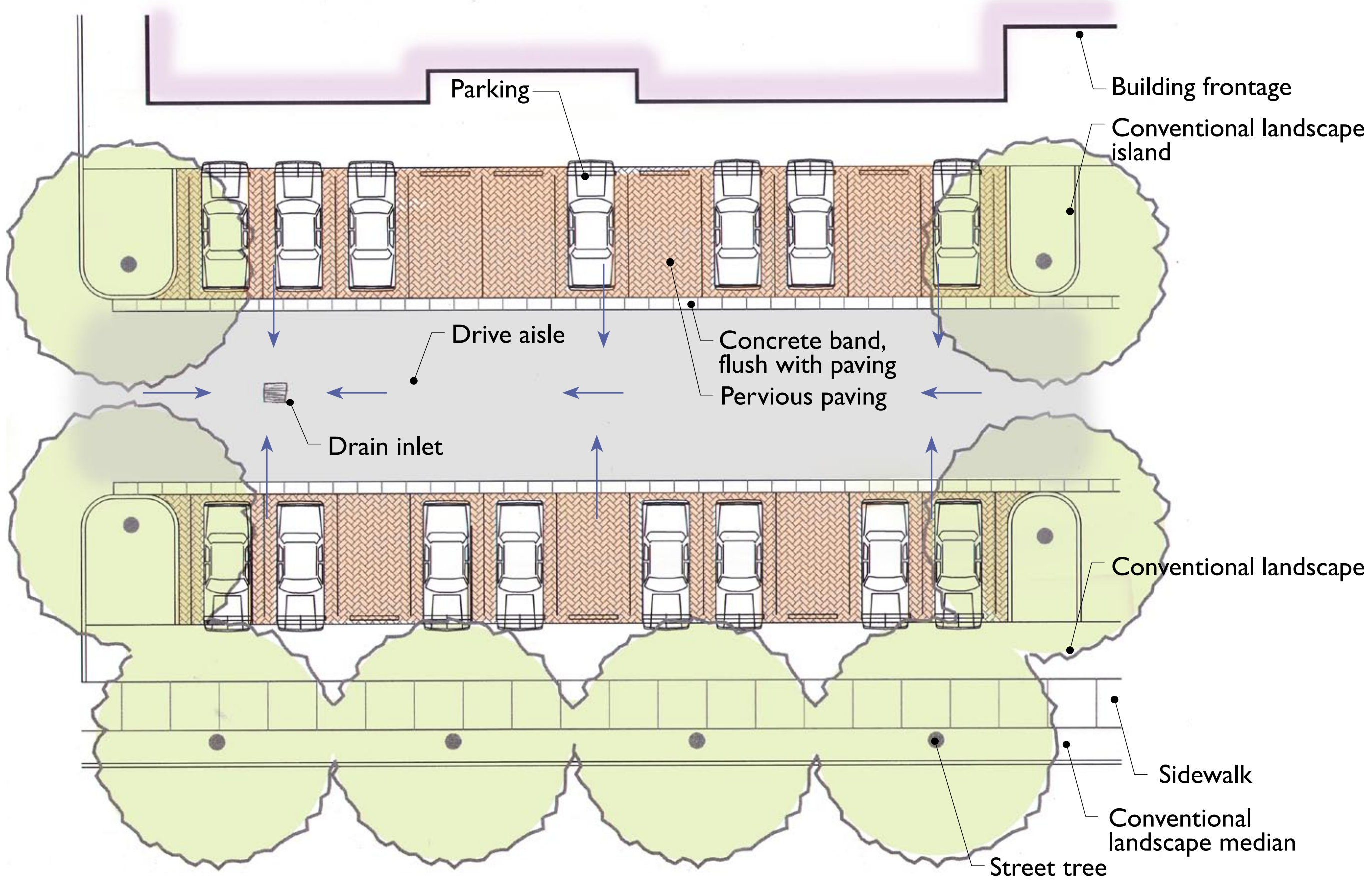
SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-57: EXISTING: *A typical internally drained parking lot in San Mateo County.*



SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-58: RETROFIT OPPORTUNITY: *The same parking lot retrofitted with pervious paving in the parking stalls.*



Pervious Paving within Parking Stalls Plan View

Figure 4-59: EXAMPLE: *This new parking lot utilizes pervious concrete within the parking lot's parking stalls.*

Vegetated Swale or Planter within a Shopping Mall Parking Lot

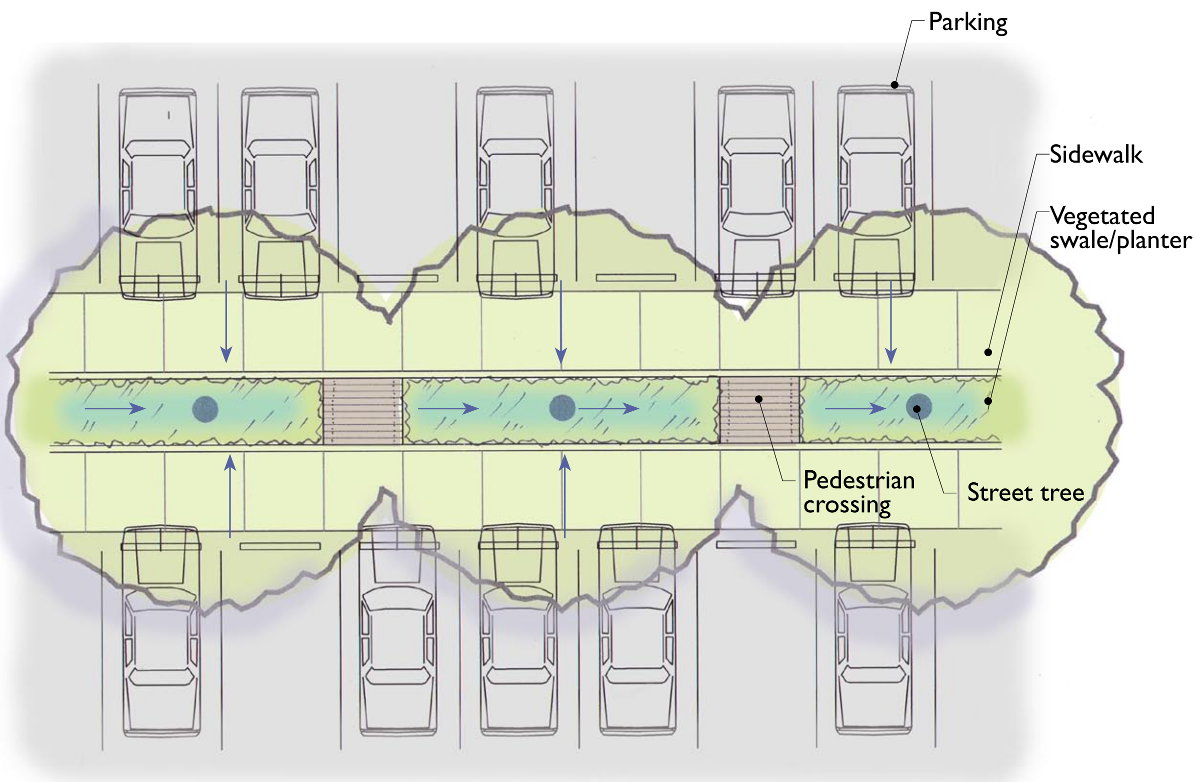
The example below shows the length of the parking stalls shortened in order to provide space for a vegetated swale or planter. This example also illustrates walkways in front of the parked cars and bridges that cross over the stormwater facility to connect these walkways. This design element allows people a refuge to walk to and from their destination without having to walk through a stormwater facility. More detailed design information on this is described in Chapter 5. Introducing more landscaping and trees within large urban parking lots also keeps asphalt surfaces cooler and helps reduce the urban heat island effect.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-60: EXISTING: *A typical large shopping mall parking lot in San Mateo County.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 4-61: RETROFIT OPPORTUNITY: *The same parking lot retrofitted with a stormwater planter/vegetated swale. Notice the sidewalk zones and dedicated crossings to allow for adequate pedestrian circulation.*



Center Median Swale/Planter Plan View

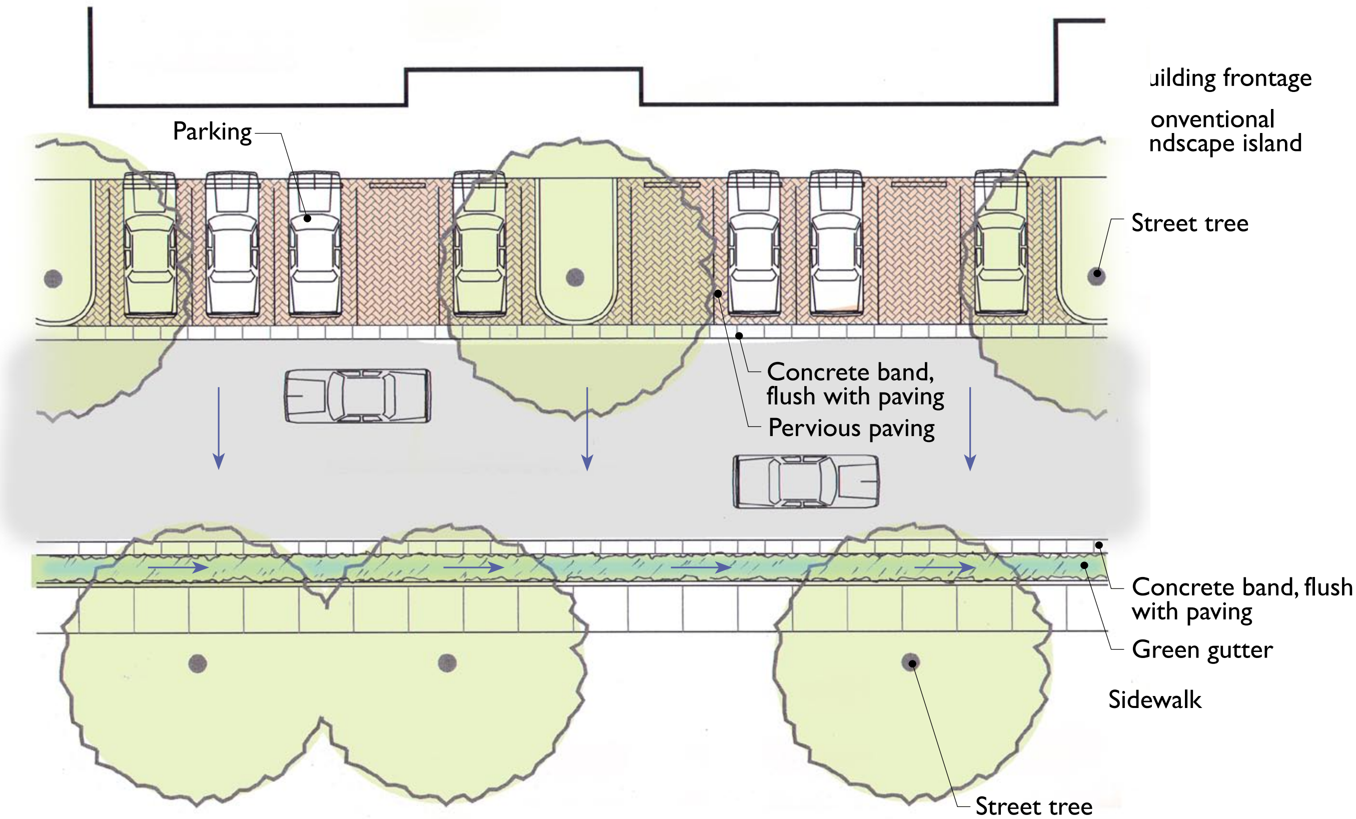
Figure 4-62: EXAMPLE: *This parking lot was retrofitted with a stormwater swale with pedestrian crossings.*

Green Gutter with One-Sided Loaded Parking Lots

In some situations, a parking lot is only loaded on one side with a driveway aisle. This scenario lends itself to retrofitting a green gutter along the drive aisle side of the parking lot if the drainage flows in that direction. Often drive aisles are oversized and can be reduced by a couple of feet in order to accommodate a green gutter. To better manage stormwater on-site, pervious paving and a green gutter system are combined in the illustrated scenario below.

Figure 4-63: EXISTING: *A typical one-sided loaded parking lot in San Mateo County.*

Figure 4-64: RETROFIT OPPORTUNITY: *The same parking lot retrofitted with a green gutter and pervious paving in the parking stalls.*



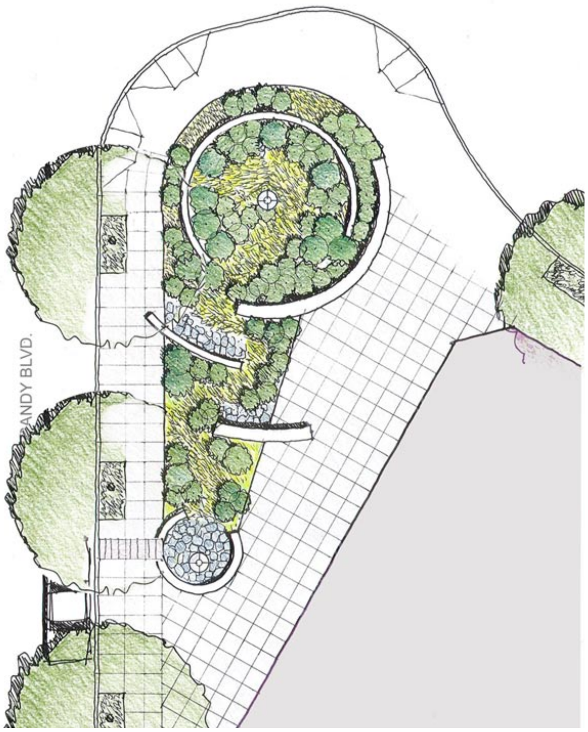
Green Gutter with Pervious Paving in Parking Zone Typical Plan View

Figure 4-65: EXAMPLE: *A shallow green gutter accepts runoff from the adjacent parking lot surface.*

CHAPTER 5

KEY DESIGN AND CONSTRUCTION DETAILS

The previous chapter envisioned opportunities that exist for green streets and parking lots in San Mateo County. This chapter helps to support this vision by providing a more detailed discussion on key design and construction considerations in building green street and parking lot projects. These details support the information found in the C.3 Technical Guidance, but they are specifically tailored to green street and parking lot applications. Some of the information presented in this chapter is in response to the ongoing concerns and/or questions that many designers, policy makers, and contractors have about creating successful projects. This chapter contains two main sections: "Design Details" and "Construction Details." The final subsection of the chapter provides a chart illustrating the key components of green street and parking lot construction administration.



SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-1: *The conceptual design of a rain garden on Sandy Boulevard in Portland, Oregon.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-2: *The rain garden construction process along Sandy Boulevard.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-3: *The rain garden as it exists today.*

General Sizing Guidelines

One of the major questions when planning for and designing a green street or parking lot stormwater facility is: "How much landscaped space is needed?" For an effective stormwater treatment facility, a quick rule of thumb is that the dedicated landscape space be 4% of the total impervious catchment area. However, the specific answer depends on soil properties, whether or not the project is subject to C.3 requirements, and the specific type of stormwater facility chosen.

The sizing of stormwater facilities depends largely on the soil infiltration capacity. The 4% rule mentioned above is based on percolation rates of 5-10 inches/hour. If the native soil is outside of that range, soil amendments can be imported to help meet that criterion. In most cases where soil amendments are used, it will also be necessary to construct the facility with an underdrain in order to maintain hydraulic capacity throughout the duration of the storm. In all cases, in-situ testing must be conducted by a qualified professional (soils scientist, licensed geologist, or registered professional engineer) to verify that the material meets the percolation requirements.

If the percolation rate is less than 5.0 inches/hour, but the native soil is Hydrologic Soil Group A or B (> 0.5 inch/hour), direct infiltration can still be an effective strategy without soil amendments. However, the stormwater facility should be proportionately larger than 4% of the tributary impervious area. For instance, if the native soil has a demonstrated percolation rate of 1.0 inch/hour, then the facility should be sized at 20% of the tributary impervious area. Additional details on numerical sizing can be found in the C.3 Technical Guidance.

A reasonable native soil infiltration rate estimate can be made by physical inspection of the soil and by using the NRCS interactive online soil survey tool (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx).

In all cases, thoughtful site design measures that reduce stormwater runoff from impervious areas can help reduce the amount of landscape area needed for stormwater treatment.

Projects Subject to C.3 Requirements

There are specific minimum hydraulic capacity and facility sizing requirements for projects subject to C.3 stormwater regulations. The C.3 Technical Guidance describes the sizing criteria for both volume-based and flow-based facilities. In summary, volume-based facilities must be sized to capture and treat 80% or more of annual runoff. There are three allowable methods to size flow-based facilities, but the simplest and most commonly used method is to size the facility to treat a flow rate equal to the runoff resulting from a constant rainfall intensity of 0.2 inches/hour. For additional information for both volume-based and flow-based facilities, see Section 5.1 of the C.3 Technical Guidance.

Projects <u>Not</u> Subject to C.3 Requirements

Smaller projects do not have to meet the C.3 requirements. However, they are encouraged to have landscape-based stormwater facilities incorporated to the maximum extent practicable. All the same benefits are realized as with larger projects, just on a smaller scale. In retrofit conditions, where site constraints can be overwhelming, the goal of simply introducing as much stormwater-related landscape area as possible is encouraged even if the general 4% sizing criteria cannot be achieved. If only limited measures can be implemented due to site constraints, these measures still carry proportional benefits.

In addition, non-C.3 required stormwater facilities may not need an underdrain system in poor soil conditions if the facility is shallow enough to prevent prolonged periods of standing water (see "Designing with Poor Soils" in this chapter).

SOURCE: GOOGLE EARTH

Figure 5-4: *A typical low-density residential street example in San Mateo County.*

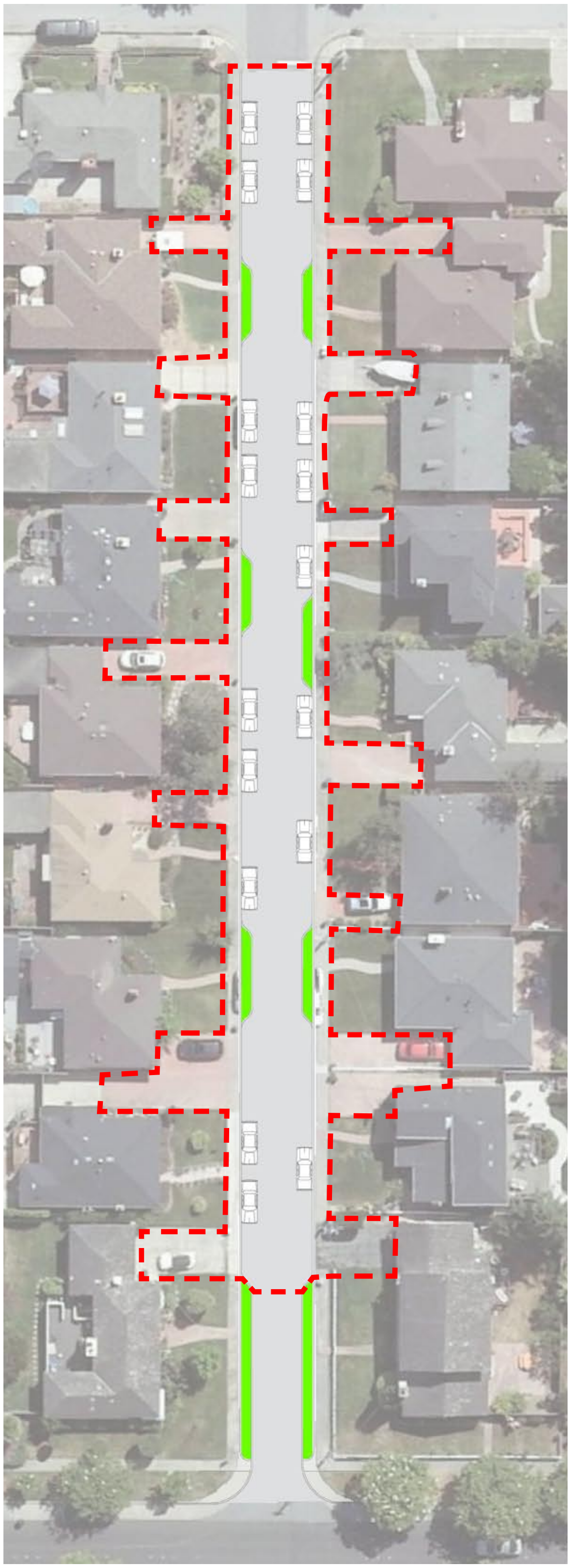
Sizing Example for a Residential Street

The following example illustrates the amount of landscaped space needed to manage the stormwater runoff when using the 4% rule of thumb sizing criteria.

Figure 5-4 shows a typical low-density residential street condition in San Mateo County. This two-way, low-volume street measures approximately 28 feet wide and allows for on-street parking on both sides of the street. There are sidewalks on both sides of the street with no landscape strip along the street curb. The existing driveways, some of which are shared, drain toward the street and contribute additional stormwater runoff.

Due to the wide spacing between driveway locations and the infrequent use of the parking zone, this particular street lends itself to using stormwater curb extensions at specific locations along the street frontage. Using curb extensions would be the simplest and most cost effective stormwater strategy. There would be some on-street parking loss along the street to accommodate the new stormwater facilities.

Figure 5-5 on the opposite page shows eight stormwater curb extensions that could be retrofitted within the parking zones of the street. The green space shown meets the amount of landscape needed using the 4% rule. The stormwater catchment area is delineated by the red dashed line (which includes the residents' driveways). The stormwater curb extensions vary in length in order to fit in between existing driveway locations and to provide for some on-street parking. Figure 5-6 on the opposite page provides more detailed information on this example.



SOURCE: GOOGLE EARTH

Figure 5-5: *The same street utilizing stormwater curb extensions sized according to the 4% rule of thumb. The dashed red line delineates the catchment area and the green space denotes stormwater curb extensions.*

Figure 5-6:
STREET EXAMPLE DETAILS

Street Type: Residential

Street Width: 28 feet wide

On-Street Parking: Both sides of street, not frequently used

Proposed Stormwater Facility:
Stormwater curb extensions

Stormwater Facility Dimensions:
4' wide, length varies from 30' to 60'

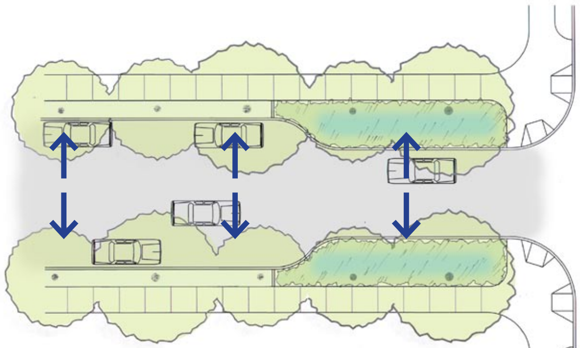
Total Landscape Area:
960 square feet

Total Stormwater Catchment Area:
22,940 square feet (6,785 square feet of runoff is from driveways)

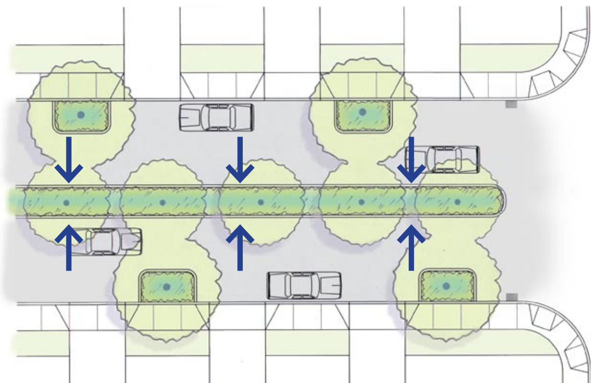
Overall Sizing Percentage:
4.2% (6% if driveway runoff is not a contributing factor)

On-Street Parking Spaces Retained:
17 spaces (a loss of 10 spaces)

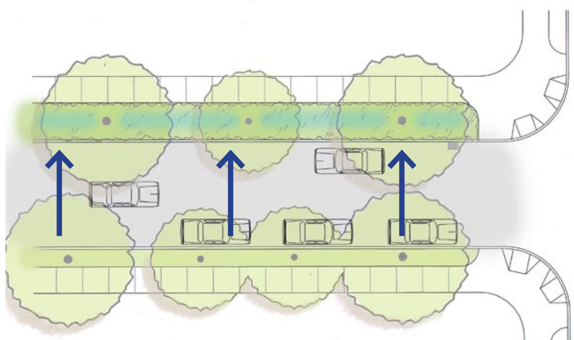
Of particular note in this sizing example, is the amount of runoff that residential driveways contribute. This driveway runoff could be reduced or eliminated by incorporating any of the techniques described earlier in Chapter 4 under "Residential Driveway Options" or by redirecting the flow into rain gardens within existing front yards. Taking such measures would reduce the amount of stormwater runoff flowing into the street and could increase the



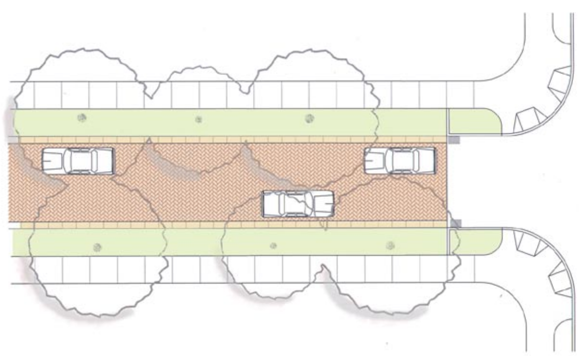
Crowned Street



Reverse Crowned Street



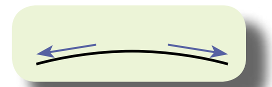
Side Shed Street



Flat Street

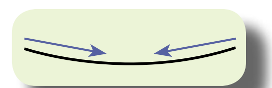
The street profile determines how stormwater runoff flows off of a street. Streets can be crowned, reverse crowned, drain to one side, or flat.

Crown



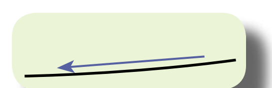
The most common street profile is a crowned street with stormwater draining to the sides of a street. There is often a curb and gutter system directing flow into a stormwater drain inlet. These drain inlets are located at the middle or end of each block depending on the block length. A variation of the crowned street is a "double crown street." This type of street is two crowned profiles next to each other with a median in the middle. This type of street profile is common with arterial streets and boulevards.

Reverse crown:



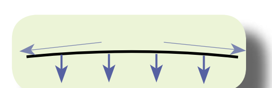
A reverse-crowned street, is the opposite of a crowned street and directs runoff to the center line of the street. This type of street is common with alley ways, arterial streets, and even freeways.

Side Shed:



Streets can be also be designed to shed all the water to one side of the street.

Flat:



Flat drainage is referred to in this document in the context of pervious paving. With pervious paving, the primary drainage of water is directly through the paving surface into the subsoil. Typically, these streets are graded slightly so they drain to the sides or center when there is too much water to filter through the paving.

New Construction:

When building new streets, a decision on what kind of street profile a particular street will have is one of the first steps in determining what kind of stormwater solution should be used. Two variables that should be considered and addressed when designing green streets and parking lots are: 1) how to maximize the amount of stormwater runoff that can potentially be managed in a landscaped system, and 2) how to realize the stormwater facility's physical capability to effectively manage the runoff. For new construction, there is far more flexibility for stormwater management because the street profile can be designed in a variety of ways.

Retrofit Conditions:

Retrofit projects tend to offer fewer options for flexibility. When retrofitting existing streets, one of the first details to look for is how stormwater drains from the street. It can often be prohibitively expensive to rebuild the street profile and underground infrastructure. Hence, conforming to the existing street profile and identifying stormwater solutions that work with this drainage condition, is the simplest and most cost-effective approach to retrofitting a street. Using this approach not only saves money, but it also minimizes the amount of street reconstruction.

The example in Figure 5-9 illustrates a crowned street with a center median at the high point of the crown. It would be a great opportunity to retrofit this landscape median for stormwater management, but the existing profile of the street drains water *away* from the median to the outside curb of the street. Regrading the street would turn a simple retrofit into an expensive project. In this case, a better option would be to build stormwater facilities between the street and sidewalk or use stormwater curb extensions.

Figure 5-7: *This newly constructed green street is designed as a reverse-crowned street, allowing runoff to flow into a center median vegetated swale. In the example above, stormwater runoff enters the swale through inlet pipes. A better design solution would be for the runoff to enter on the surface via curb cuts.*

Figure 5-8: *This green street retrofit is designed with a narrow curb extension that captures runoff from an existing crowned street.*

Figure 5-9: *This crowned street has an existing landscape center median. Unfortunately, runoff cannot be easily routed to the center median because runoff is directed away from it.*

SOURCE: KEVIN PERRY - CITY OF PORTLAND

Figure 5-10: *This street utilizes stormwater planters adjacent to on-street parking. It provides a continuous 3-foot pedestrian egress zone and walkways that allow people to access the sidewalk and parking zone.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-11: *A series of "stormwater bridges" allows people to cross over a vegetated swale.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-12: *A perimeter concrete curb was installed around this urban rain garden to help protect both pedestrians and the stormwater facility.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-13: *Low-profile railing systems can be an aesthetically pleasing way to direct pedestrian traffic.*

Providing adequate pedestrian circulation along streets should always be a priority and should not be compromised when considering stormwater facilities. Many green streets can offer solutions for better pedestrian circulation by providing more buffer against vehicular traffic, reducing pedestrian crossing distances, or improving sight angles at intersections. Most conflicts between pedestrian circulation and stormwater facilities stem from the need to provide on-street parking. There are, however, ways that stormwater facilities can be integrated into differing street conditions while still maintaining on-street parking and adequate pedestrian circulation.

When on-street parking is designed next to a stormwater facility, it is critical to consider where people will walk when they get out of their cars. People need adequate room and a place to step when they get out of their car that does not interfere with the stormwater facility. This is called an egress zone and this area should be a minimum of 3 feet wide adjacent to the street curb. Furthermore, pedestrians need to have sufficient access from the sidewalk to the parking zone. This can be provided by installing frequent walkways or bridges across stormwater facilities. Figure 5-10 illustrates how on-street parking can be accommodated with stormwater planters and still allow pedestrians to access parked vehicles and the sidewalk.

Another consideration for pedestrian circulation is assuring that people can safely detect where there is a drop in grade adjacent to walkways. Where there is a vertical grade change of more than 6 inches immediately adjacent to a sidewalk zone, an effort should be made to visually and/or physically denote this vertical drop in grade. There are several ways to accomplish this, such as installing a raised curb edge, a low-profile railing, or detectable warning/paver strips. These design elements give people, especially the visually-impaired, a means to safely navigate around any grade changes.

Pedestrian circulation is also an important design consideration when using stormwater facilities in parking lots. The question that must be asked is: Where is the primary pedestrian destination(s) in relation to the parking lot? For stormwater management, it is best to align landscape facilities perpendicular to the sheet flow of water in order to maximize the potential for capturing runoff. Sometimes this optimum alignment is in conflict with the desired pedestrian flow to and from a destination. It is important to design a parking lot that provides bridges/pathways over the stormwater facilities and/or walkways for people to safely walk alongside the stormwater facilities (See diagrams below). Assuring that pedestrians can easily cross over stormwater facilities is essential to prevent people from cutting through the landscaped areas. Inadequate provisions for pedestrian circulation may result in trampled plants, compacted soil, and increased erosion in the stormwater facility.


SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-14: *Failed pedestrian circulation within a parking lot. Due to poor design, people have trampled this vegetated swale to the point where the landscape cannot grow.*

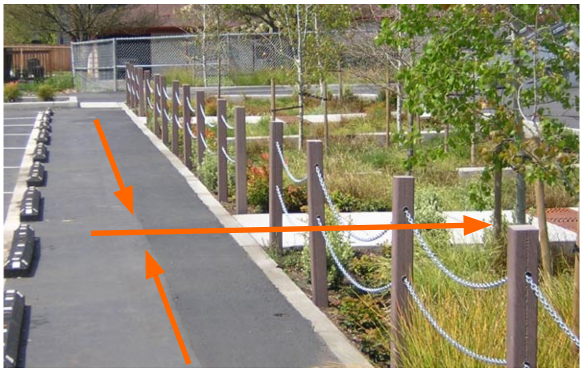
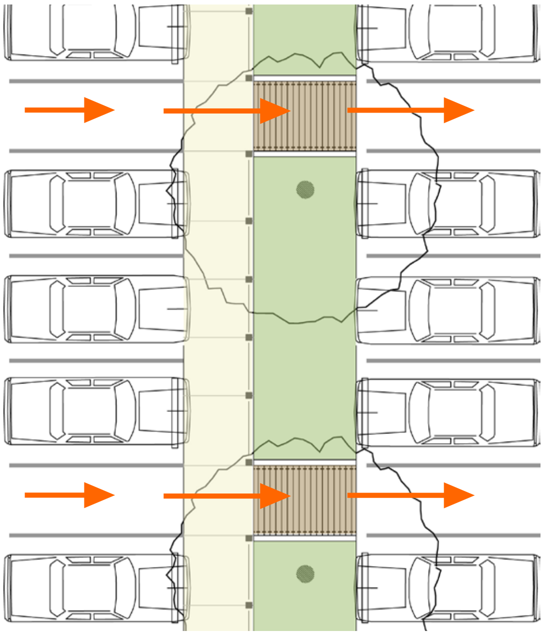
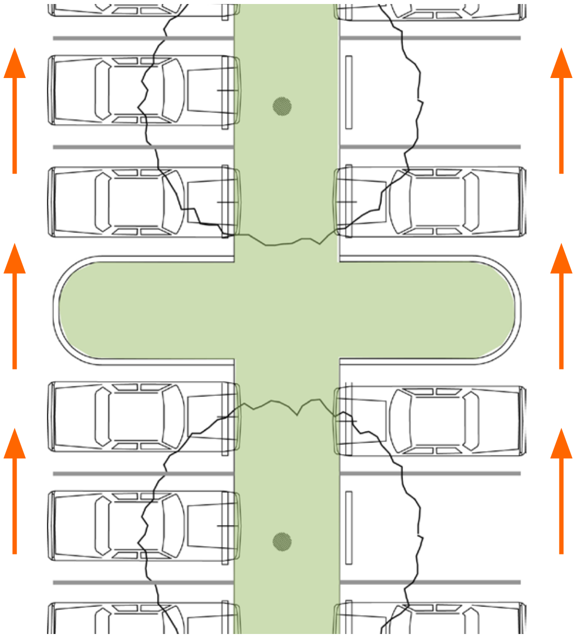

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-15: *Good circulation within a parking lot. This vegetated swale has several walkways that allow pedestrians to access their destination without walking through the landscape area.*



Pedestrian circulation perpendicular to a stormwater facility.



Pedestrian circulation parallel to a stormwater facility.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-16: *A steep residential street condition in San Mateo County.*

SOURCE: WWW.SEATTLE.GOV/.../INDEX.ASP

Figure 5-17: *Terraced concrete weirs allow for a vegetated swale to be graded with a slope less severe than the adjacent street's grade.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-18: *Closely spaced check dams help terrace the interior landscape of this stormwater curb extension project. The slope of this street is approximately 6%.*

There are many steep slope conditions found within San Mateo County. The primary land use type in these conditions is low and high-density residential development with relatively narrow right-of-ways. Although these narrower streets may not generate large volumes of stormwater runoff, the velocity of stormwater runoff from developed hillsides is a potential concern. Hence, a good approach is to design stormwater facilities that help slow runoff as much as possible. There are several methods that can be used.

First, look for ways to improve the overall site design so that space can be provided for stormwater facilities. Second, build terraced stormwater planters and swales that help flatten the interior slopes of landscape areas compared to the steepness of a street or parking lot. Closely-spaced check dams and weirs can then help slow down the flow of water, mimicking a more natural condition. Depending on the underlying soil conditions, some of this water might also infiltrate into the native soils.

A geotechnical engineer should be consulted during the design process to evaluate and analyze steep areas for susceptibility to landslides.

Using Check Dams and Weirs

Check dams and weirs are the "speed bumps" of stormwater management. They are designed and strategically placed within a stormwater facility to slow the flow of runoff. Check dams are structures in the landscape that retain stormwater. Weirs are a notch within a checkdam with an adjustable height to allow for varied amounts of stormwater retention. Check dams should retain stormwater to relatively shallow depths, with a maximum ponding depth of 6-12 inches of runoff during storm events.
Both check dams and weirs can be made from a variety of construction materials, such as rock, concrete, metal, wood, or any other

durable material. The number and spacing of check dams is largely dependent on the stormwater goal of a project and the particular site conditions. For green street and parking lot applications, slopes greater than 4% should have a check dam at least every 25 feet. In steeper conditions, checkdams will need to be placed at a greater frequency and may need to be made from the most durable hardscape materials to withstand the forces of the water.

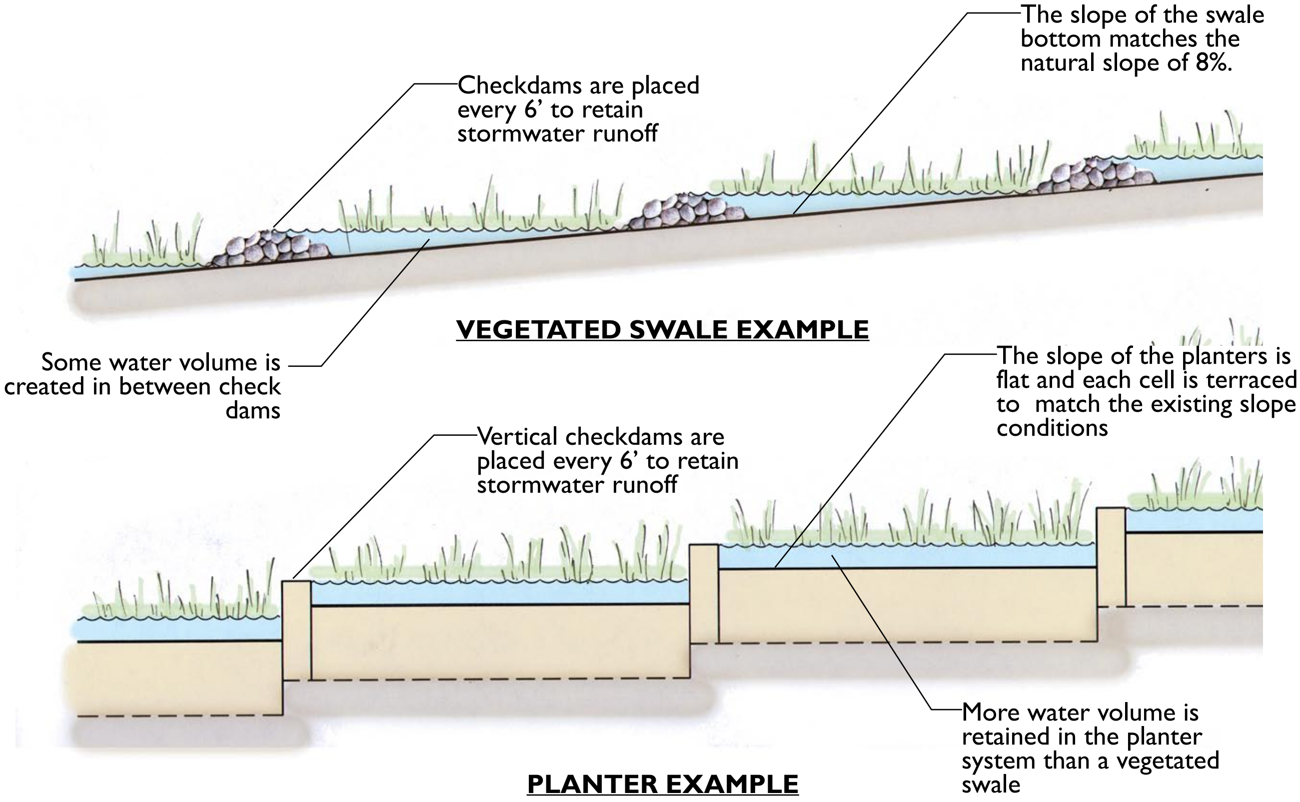
Check dams may also be placed within swales and planters that have little or no longitudinal slope in order to promote infiltration. This should be done only where soil conditions are conducive to infiltration (Class A or B soils) or where there is an underdrain system installed in the stormwater facility.


SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-19: *This adjustable weir can control how much water is to be retained within a rain garden.*


SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-20: *Simple checkdams made of stacked rocks or gravel can be used on gently sloped stormwater facilities.*



In San Mateo County, many sites will not have both the relatively flat terrain and high percolation rates required for infiltration facilities. Infiltration facilities should not be designed to retain stormwater in areas with Class C or D soils, that have a high water table, or that have known soil contamination. Infiltration is also infeasible in areas with steep slopes or high clay content soils. Therefore, these sites will have to incorporate design measures that do not rely primarily on stormwater infiltration.

The best first step for these poor soil sites is to reduce impervious area, thereby reducing the amount of runoff needing treatment. Remember, increasing a site's landscape area by 25% is in essence decreasing the site's stormwater runoff by almost 25% even without the use of active stormwater facilities. These passive site design strategies are described in Chapter 2.

Once a site is designed to minimize stormwater runoff to the fullest extent possible, stormwater facilities should treat the remaining runoff. Stormwater facilities designed in Class C or D soils will require the use of imported soil and often an underdrain system. As water moves through the amended soil bed of any given facility, it enters the underdrain to be discharged back into the storm drain system or dispersed back into the natural environment. These types of flow-through facilities attenuate peak flows and reduce total runoff volume through evapotranspiration.

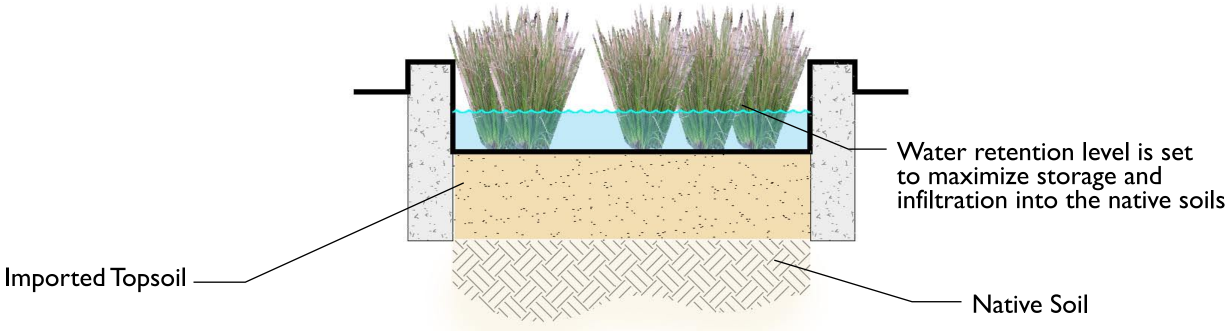
The San Mateo Countywide Water Pollution Prevention Program recommends that perforated or slotted underdrains be used where the native soil infiltration rates are low (Class C and D soils). The C.3 Stormwater Technical Guidance document provides information on the design and construction of underdrains for a variety of stormwater facility types. It should be noted that the use of underdrains to collect treated stormwater runoff will often increase the overall project costs. The C.3 Stormwater Technical Guidance also provides information on imported soil specifications. If the proper soil is used and the stormwater facility is built in accordance with the referenced guidelines, the soil bed should be able to infiltrate stormwater at a rate of 5 inches/hour.

To encourage the use of green street and parking lot projects, some flexibility in use of the C.3 Stormwater Technical Guidance should be allowed. For example, on Hydrologic Soil Groups C and D there may be situations where the stormwater treatment system could be designed without an underdrain provided sufficient stormwater treatment is achieved without retaining stormwater runoff for a prolonged period of time. For example, shallower and larger stormwater treatment systems may be used or an adequately sized vegetated swale may be constructed where there is sufficient slope not to retain stormwater runoff for a prolonged period of time.

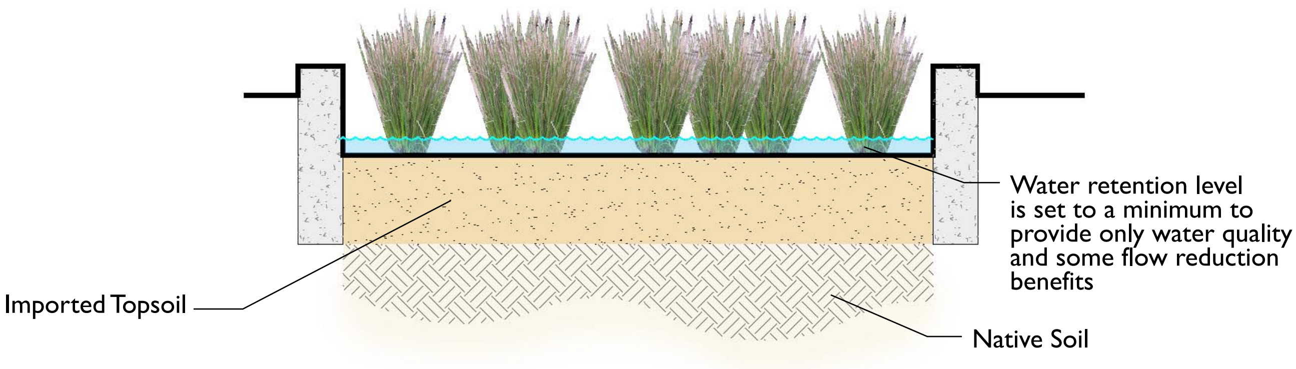
Planting trees, shrubs, and other plant material with extensive root systems can help loosen tight clayey soils, provide more capillary storage space, and allow for greater evapotranspiration of water.

When stormwater facilities are used in poor soil conditions, it is important to include design flexibility for check dams and weirs. Recently-constructed stormwater facilities and stormwater facilities built in poor soil conditions, may initially infiltrate less stormwater. Once plants have established and a stormwater facility has matured, infiltration rates may increase and allow for more ponding of water during storm events. The overall ponding of stormwater can be controlled by adjusting the height of check dams and weirs as needed. Designing for flexibility will ultimately allow for maximum performance efficiency over time.

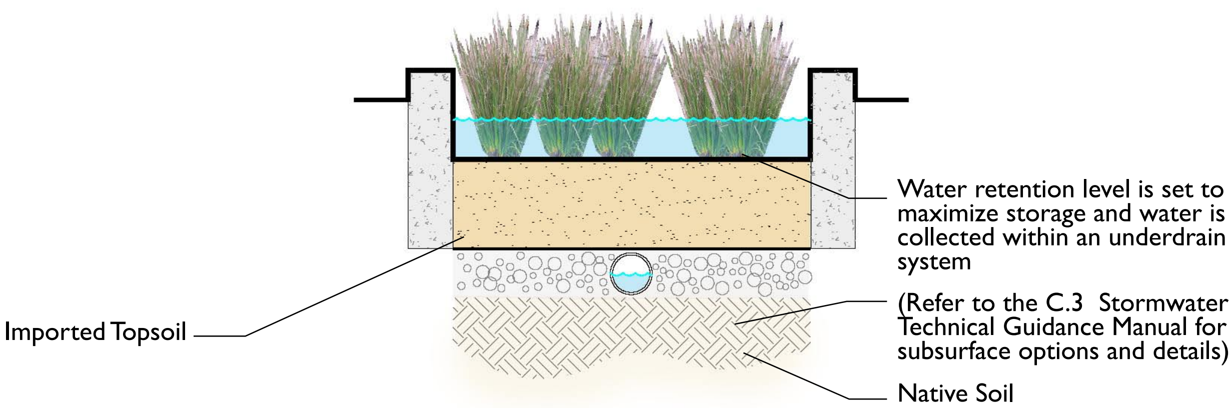
There are a multitude of soil conditions within San Mateo County, and each stormwater facility should be designed to function properly given the specific site constraints. The diagrams below illustrate three basic conditions: **Condition 1** consists of native soils that are relatively good at allowing infiltration of stormwater runoff, thus the facility design maximizes the amount of retained water. This design solution can be utilized whenever soils allow moderate to good infiltration (Class A or B Soils). **Condition 2** illustrates a design option for sites with poor native soils (Class C or D soils). This design solution maximizes the stormwater facility's horizontal footprint and reduces the ponding depth of stormwater in order to prevent any prolonged periods of standing water. This option may be appropriate for projects that are not subject to C.3 stormwater requirements but still want to provide water quality and flow reduction benefits. **Condition 3** shows how including an underdrain system in poor soil conditions (Class C or D soils) allows greater water retention, similar to Condition 1. Condition 3 may be necessary to meet C.3 stormwater requirements, however, adding an underdrain system can increase overall project costs.



Condition 1- Good Native Soils without an Underdrain



Condition 2- Poor Native Soils without an Underdrain



Condition 3- Poor Native Soils with an Underdrain

Utility conflicts with stormwater facilities are probably the greatest perceived physical constraint in implementing green street and parking lot projects. There is a perception that utilities and stormwater facilities cannot coexist, but they definitely can given the right site conditions. With some green street projects, especially those within low-density residential areas, there may be very few, if any, utility conflicts.

One significant constraint involving utilities and stormwater facilities is providing adequate access to utility lines for repair or replacement. This may require repair of a stormwater facility's landscape and associated hardscape elements. The potential conflict, or question, is: Who is responsible for repairing any temporary damage to the stormwater facility? If this can be resolved between entities, then a major portion of the notion of "utility conflicts" can be resolved. Ironically, the use of sand-set pervious pavers and low-expenditure landscape stormwater facilities over utility lines might actually reduce the need for cutting and replacing concrete and asphalt and improve access to underground utilities.

Other utility conflict issues with green streets and parking lots include, but are not limited to: 1) providing adequate soil cover around utility lines and gravel envelopes; 2) minimizing the migration of infiltrated stormwater; and 3) finding adequate space for vaults and valve boxes next to stormwater facilities. Some of the typical utilities that need to coexist with stormwater facilities are listed in this page's inset.

Prior to discussing in detail these secondary constraints, it is important to first describe the different approaches to dealing with potential utility constraints. The following page illustrates a process to help identify and resolve utility conflicts. This process emphasizes the ideal choices of either avoiding utilities or accepting the conflict in order to reduce construction costs. If this is not possible, more costly design solutions, such as mitigation or replacement/relocation of utility lines, can be explored.

- Water lines
- Gas lines
- Sanitary sewer and stormwater lines
- Underground power lines
- Aboveground power and telephone poles.
- Light poles and street signals
- Fiber optic and telecommunication cables
- Steam lines
- Valves and vaults associated with the utilities listed above

The following pages showcase examples of specific green street and parking lot projects in Portland, Oregon that were built with varying degrees of utility conflict and have employed the different design approaches described in Figure 5-22. Showing specific projects should help put utility conflicts into perspective. It should be noted, however, that the specific project examples listed were built several years ago and might not reflect Portland's current design standards or policy with utilities and stormwater facilities.

Figure 5-22:
UTILITY CONFLICT DESIGN APPROACHES

COST EFFECTIVE ↔ COST PROHIBITIVE

EASY TO IMPLEMENT ↔ DIFFICULT TO IMPLEMENT

STEP 1: AVOIDANCE

Whenever possible, locate stormwater facilities clear of any utility conflicts. This may require that one particular stormwater design strategy (i.e., curb extension, stormwater planter, etc.) might be better suited for the site condition than others, even if it is more costly to build. Avoidance can also mean that a stormwater facility's dimensions are reduced in order to provide an adequate setback from utilities. C.3 stormwater requirements must still be met for applicable projects.

↓

STEP 2: ACCEPTANCE

Stormwater facilities may conflict with existing utility locations, but involved entities accept that utility constraints do not preclude the stormwater facility from being built. There is an acceptance that there is enough soil coverage or general clearance between the stormwater facility and a utility line(s). Also, if a utility line needs to be accessed, it is accepted that the stormwater facility would be temporarily impacted, but restored to its original condition.

↓

STEP 3: MITIGATION

Stormwater facilities are allowed to coexist near a particular utility, but the original design or layout of a stormwater facility is adjusted in order to mitigate any concerns about the proximity to the utility. A stormwater facility's design may need to be significantly altered to provide enough soil cover over a utility line, or key features of the stormwater facility (check dams, inlets, outlets, trees, etc.) may need to be moved to avoid conflict. An altered stormwater facility design must meet the C.3 stormwater requirements for applicable projects.

↓

STEP 4: REPLACEMENT

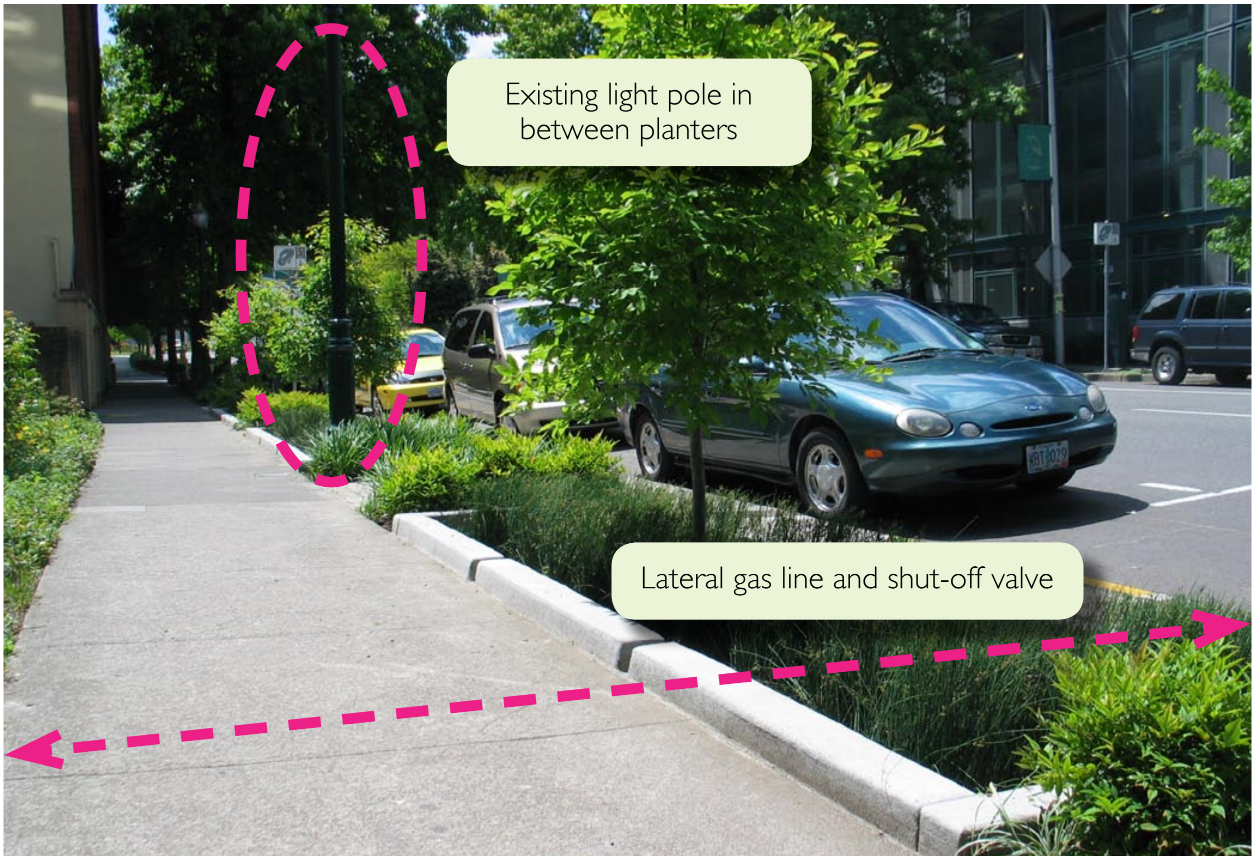
In order to have the stormwater facility work, the utility line needs to be replaced and/or relocated so that a conflict no longer exists. This can be the most complex, cost-prohibitive, and difficult design option to implement. However, in some cases, the age of the utility line is a factor in selecting this solution. It might be more advantageous to plan on replacing an aging utility line during the green street or parking lot construction than to wait to replace it at a later date.

SOURCE: NEVUE NGAN ASSOCIATES

PROJECT EXAMPLE: ACCEPTANCE

NE Siskiyou Green Street (2003)
Portland, Oregon

A 6-inch water line runs parallel and through each curb extension. Also, lateral service lines tie into water meters within the existing grass strip. This project was built accepting that these water lines exist and adequate soil cover (36" inches +/-) exists over the water main lines and (18 inches +/-") of cover was provided over the lateral service lines.



SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

PROJECT EXAMPLE: ACCEPTANCE AND AVOIDANCE

SW 12th Avenue Green Street (2005)
Portland, Oregon

A lateral gas line runs perpendicular and through one of the four stormwater planters and connects to a nearby gas meter. A gas valve is also located within the stormwater planter and has a 6-inch PVC riser installed around the valve that allows for manual shutoff if necessary. This was a green street retrofit project that also had an existing light pole location to consider. The project's design allowed for the light pole to remain in its original location, outside of the stormwater facility, and placed in a traditional landscape bed.

SOURCE: NEVUE NGAN ASSOCIATES

PROJECT EXAMPLE: AVOIDANCE AND MITIGATION

SE 57th and Pine Green Street (2006)
Portland, Oregon

A 6-inch water line runs parallel to this curb extension project and two large water utility vaults are located at the end of the curb extension. To avoid conflict with the need to have access for repair of the utility line, the curb extension was narrowed from 6' wide to 4' wide. A deeper curb profile was poured in order to help direct stormwater infiltration downward rather than laterally into the adjacent roadbed and gravel-filled water line trench. The curb extension was also shortened in order to avoid the water line vaults.

SOURCE: NEVUE NGAN ASSOCIATES

PROJECT EXAMPLE: AVOIDANCE

Harold Kelly Plaza Sandy Boulevard (2006)
Portland, Oregon

Harold Kelly Plaza is a neighborhood plaza with a vegetated swale placed on the side of the space. This plaza has an 8" water main running through its centerline. Early designs considered having the vegetated swale placed over the top of the water line, but it was determined that sufficient space was available to place the vegetated swale alongside of the plaza and avoid any water line conflict. In addition, sand-set concrete unit paving within the plaza to allow for access to the existing water line should the need arise.

SOURCE: NEVUE NGAN ASSOCIATES

PROJECT EXAMPLE: MITIGATION

New Seasons Market/SE Division Street (2004)
Portland, Oregon

This green street's original design called for the consecutive placement of four stormwater planters to collect runoff from the adjacent street. An existing power pole and utility vault, however, forced the design to include only three stormwater planters and one planter filled with conventional landscaping. Relocating the utilities was too expensive, hence the design of the green street was adjusted to avoid the utility conflict. The missing fourth planter reduces the amount of runoff that receives treatment, but compromising on the design allowed this green street to still be built.

SOURCE: NEVUE NGAN ASSOCIATES

PROJECT EXAMPLE: REPLACEMENT & RELOCATION

SE 55th and Belmont Green Street (2007)
Portland, Oregon

This green street uses a large stormwater curb extension to realign the intersection and treat runoff from the adjacent street. The street had an aging 6-inch water line that ran parallel to the existing curb and through the proposed stormwater facility. Because of the age of the water line, it was decided that the utility should be replaced and relocated at the time of the green street's construction. In addition, the utility company that owned the water line agreed to pay a portion of the water line's replacement and relocation costs; which helped justify implementation of the stormwater curb extension.

SOURCE: NEVUE NGAN ASSOCIATES

PROJECT EXAMPLE: AVOIDANCE

NE Sandy Boulevard Green Street (2006)
Portland, Oregon

There are several rain gardens built along Sandy Boulevard. The location shown above is an example of a large rain garden that had no utility conflicts. There are many instances in the built environment where green streets and parking lots can be built without any utility conflict. These conditions should be considered ideal spaces for retrofit projects.

Unwanted Migration of Infiltrated Stormwater

The following measures can help limit migration of infiltrated stormwater into surrounding utility systems, adjacent road beds, or adjacent building foundations:

•Install a thin, impermeable plastic liner along curbs or next to utility trenches.

•Construct a deeper than conventional curb profile to help physically separate the roadbed subgrade or parallel utility lines from the stormwater facility.

•Install a clay plug within the utility trench to inhibit the movement of stormwater within the trench line.

•Implement any combination of the aforementioned measures.

It should be noted that if soil permeability is relatively good on a project site, infiltrated water will primarily migrate downward rather than laterally. However, along streets with heavy-load traffic such as buses and trucks, it may be desirable to install one, or a combination, of the mitigation measures described above.

No Room For Utility Vaults/Infrastructure

Utility vaults can be a difficult constraint to overcome when placing stormwater facilities within streets and parking lots. In general, all utility vaults should be located outside of the "wet" zone of stormwater facilities. Many small utility vaults associated with lateral services (i.e., water service vaults) can be located outside of the footprint of stormwater facilities without needing to replace the infrastructure. However, when every square foot of space is at a premium, sometimes even these smaller vaults need to be relocated and replaced in order to maximize the amount of landscape space available for stormwater treatment. Larger utility vaults should be avoided whenever possible or completely lined so that water cannot migrate into the vault.

SOURCE: TIM KURTZ - CITY OF PORTLAND

Figure 5-23: *An impermeable liner is placed within a flow-through curb extension project to inhibit water migration into a nearby utility vault.*

SOURCE: DAVE ELKIN - CITY OF PORTLAND

Figure 5-24: *An impermeable liner is placed along the sidewalk side of an infiltration stormwater curb extension in order to protect the foundation of an adjacent building.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 5-25: *A deeper curb profile is poured along this green street project to help inhibit lateral migration of stormwater into the street's subgrade.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-26: *This "curbless" street example allows for sheet flow of runoff into a vegetated swale.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 5-27: *A typical curb cut used to allow water to enter a stormwater curb extension.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-28: *Sheet flow of stormwater runoff enters a vegetated swale from a public plaza space.*

One of the primary considerations for designing stormwater facilities associated with streets and parking lots is determining how the runoff enters a stormwater facility. There are two primary ways that runoff is directed into stormwater facilities- sheet flow and curb cuts. Sheet flow describes stormwater runoff that enters a stormwater facility evenly distributed on the pavement surface without concentrating flow. Curb cuts allow stormwater to enter a stormwater facility at specific points along a raised curb, thus concentrating runoff both in velocity and volume.

Of the two methods, sheet flow is by far the better design because it mimics the natural flow of water across the landscape, employs a less complicated design, and is less prone to failure. Sheet flow, or "curbless" streets and parking lots, typically employ a concrete band edging that is flush with the stormwater facility and the street/ parking lot surface. Having this concrete band provides a clean edge along the more malleable asphalt surface. In addition, the concrete band is easier to fine grade than asphalt in order to direct water into the stormwater facility.

Curb cuts along a raised curb system are commonly used to allow water to flow into stormwater facilities, This approach channelizes water flow and can be prone to failure if the curb cut design is poor and/or there is a build up of sediment or debris at the curb cut. If curb cuts are used, they should be carefully designed. Curb cuts should be spaced frequently along the length of the curb to distribute the water flow as evenly as possible within the stormwater facility.

In new street design, the decision to have curbed or uncurbed streets is typically based on the anticipated type and intensity of vehicular and pedestrian use. In general, the higher the traffic speed and less pedestrian-oriented the street is, the more likely a raised curbed street edge will be required. Conversely, streets that have slower traffic speeds and are more pedestrian-friendly are good candidates for a curbless condition. Even commercial streets with on-street parking can be designed as curbless streets if there is enough right-of-way space and traffic speeds are relatively low.

Curb cuts along stormwater facilities should be as wide as possible to accept flow from along the street or parking lot edge. A flaw in curb cut design is to try to "cover" or create a notched curb cut. These designs often fail because the opening for stormwater runoff is restricted and results in trapped sediment and debris. When a notched curb cut is plugged with debris, it often goes unnoticed. It is recommended that an 18 inch minimum width "open" curb cut be used at entrances to stormwater facilities. On steeper streets, it is a good idea to build a small, low-profile asphalt or concrete berm at each curb cut inlet to guide stormwater flow into the stormwater facility. Without such a measure, runoff can sometimes flow past the curb cut and bypass the stormwater facility during intense storm events. Grated curb cuts are often used in street applications to allow water to flow underneath sidewalks. Grated curb cuts for green streets need special design attention and maintenance to assure water will flow into the stormwater facility. Also, grates need to be slip resistant and American Disability Act (ADA) compliant.

Both sheet flow and curb cut systems need to allow for a minimum 2 inch drop in grade between the street/parking lot grade and the finish grade of the stormwater facility. This drop in grade assures that water will freely enter the landscape space even if there is some sediment accumulation.

The following pages illustrate the most common ways that runoff enters street and parking lot stormwater facilities.

SOURCE: NEVUE NGAN ASSOCIATES

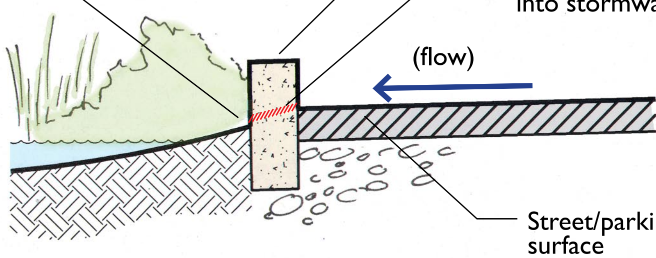
Figure 5-29: *Bad example - a notched curb cut is way too small and constantly overloaded with sediment.*

SOURCE: NEVUE NGAN ASSOCIATES

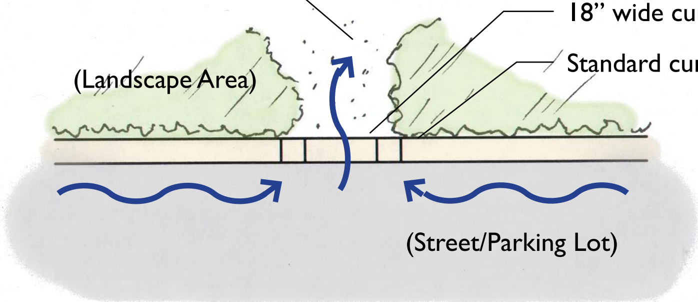
Figure 5-30: *Bad example - a curb cut placed immediately adjacent to the overflow inlet.*

SOURCE: PROTECTING WATER QAULITY IN THE NORTHERN SAN FRANCISCO BAY AREA, 2005

Figure 5-31: *Bad example - a curb cut blocked by sediment prevents water flow into this stormwater facility. There is not enough grade change between the curb cut entry and the finish grade of landscaping.*



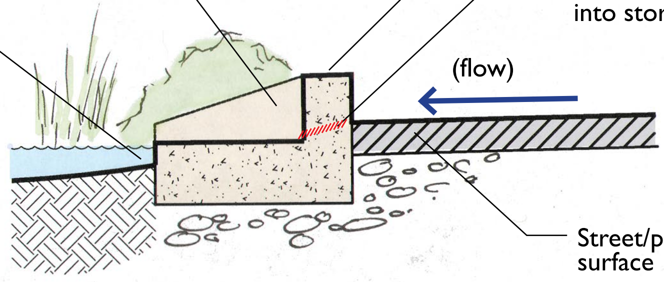
Standard Curb Cut Section View



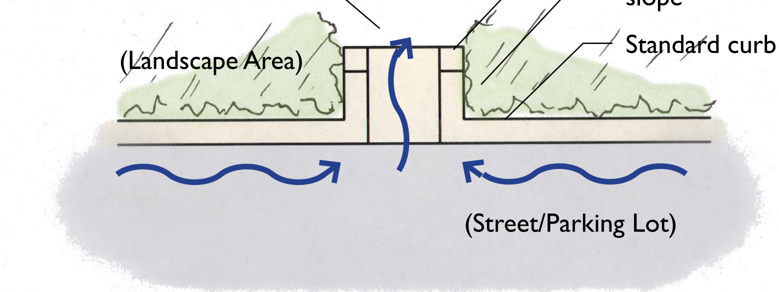
Standard Curb Cut Plan View

Figure 5-32: *A standard curb cut allows stormwater runoff to enter a parking lot rain garden. This curb cut has 45 degree chamfered sides.*

- Opening should be at least 18 inches wide
- The curb cut can have vertical sides or have chamfered sides at 45 degrees (as shown)
- Works well with relatively shallow stormwater facilities that do not have steep side slope conditions
- Need to slope the bottom of the concrete curb cut toward the stormwater facility
- A minimum 2 inch drop in grade should occur between the curb cut entry point and the finish grade of the stormwater facility
- Pea gravel can be used as a stable mulch material at the curb cut opening to prevent erosion



Standard Curb With Side Wings Cut Section View



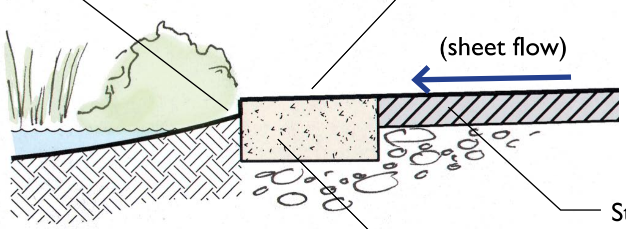
Standard Curb Cut With Side Wings Plan View

- Opening should be at least 18 inches wide
- Works well with stormwater facilities that have steeper side slope conditions
- Need to slope the bottom of the concrete curb cut toward the stormwater facility
- A minimum 2 inch drop in grade should occur between the curb cut entry point and the finish grade of the stormwater facility
- Pea gravel can be used as a stable mulch material at the curb cut opening to prevent erosion

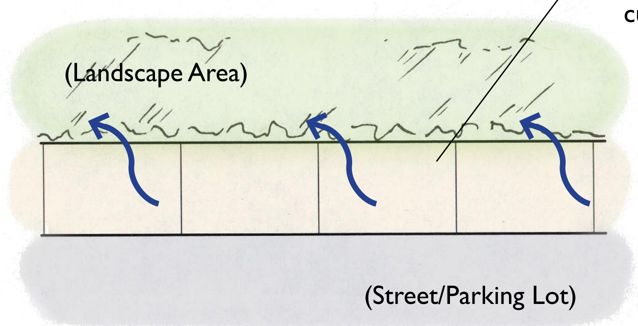
SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 5-33: *A standard curb with wings allows stormwater runoff to enter a stormwater facility. The wings help retain the side slope grade on each side of the curb cut opening.*

DESIGN DETAILS: Types of Curb Cuts



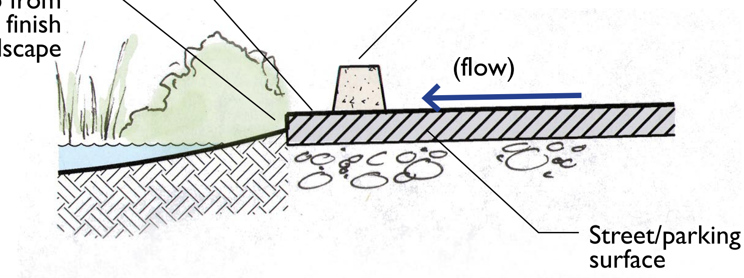
Concrete Flush Curb Section View



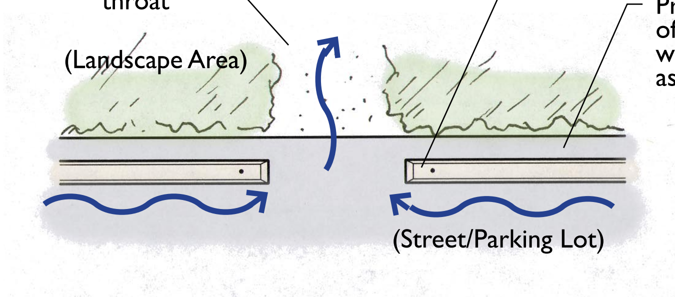
Concrete Flush Curb Plan View

***Figure 5-34:** This flush concrete curb allows stormwater runoff to enter, evenly distributed, within a vegetated swale.*

- Concrete flush curbs allow stormwater runoff to enter a stormwater facility evenly alongside a street or parking lot edge
- Need to slope the concrete flush curb toward the stormwater facility
- A minimum 2 inch drop in grade should occur between the flush curb and the finish grade of the stormwater facility
- There is no need for pea gravel along the curb edge for dissipating concentrated flow



Opening Between Wheelstops Section View



Opening Between Wheelstops Curb Plan View

•Wheelstops allow water to flow through frequently spaced openings.

•Wheelstops are most common in parking lot applications, but they can also be applied to certain street conditions

•Need to provide a minimum of 6 inches of space between the wheelstop edge and edge of asphalt paving. This is to provide structural support for the wheelstop

•A minimum 2 inch drop in grade should occur between the edge of paving and the finish grade of the stormwater facility

•Pea gravel can be used as a stable mulch material at the wheelstop opening to prevent erosion

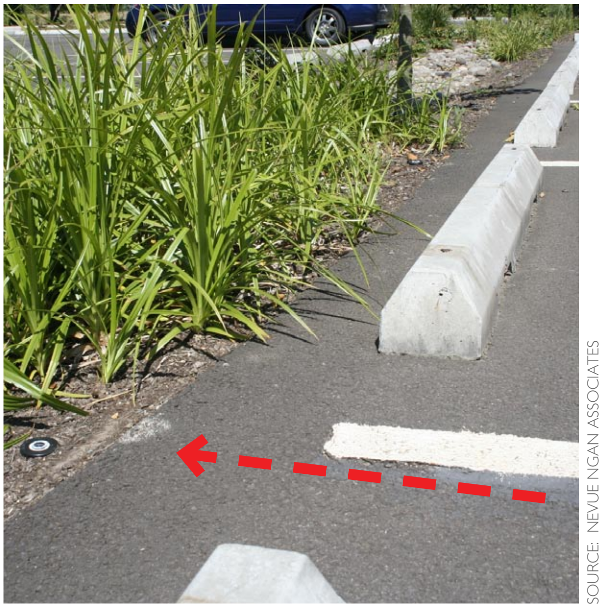
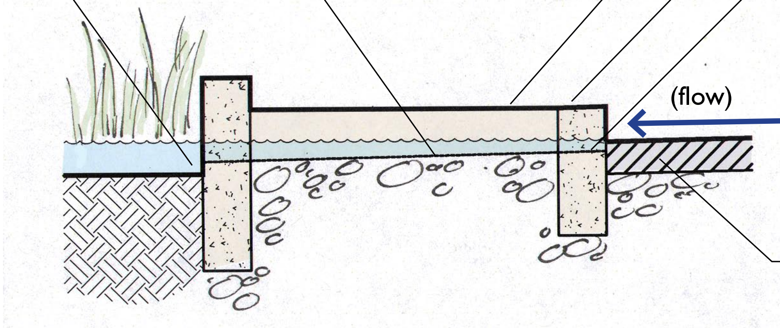
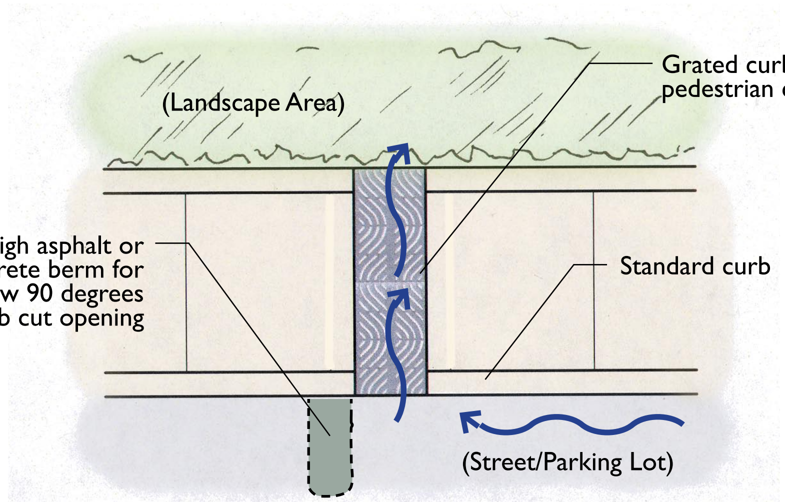


Figure 5-35: *The 3 foot space in between these wheelstops allows stormwater runoff to enter a vegetated swale within a parking lot. This design could be improved by including more of a drop in grade between the asphalt and the landscape area.*



Grated Curb Cut Section View



Grated Curb Cut Plan View

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 5-36: *A grated curb cut allows stormwater to pass under a pedestrian egress zone to the stormwater facility.*

- Grated curb cuts allow stormwater to be conveyed under a pedestrian walkway. The curb cut opening should be at least 18 inches wide

- Grates need to be ADA compliant and have sufficient slip resistance

- A 1-2 inch high asphalt or concrete berm should be placed on the downstream side of the curb cut to help direct runoff into the curb cut

- A minimum 2 inch drop in grade should occur between the concrete channel and the finish grade of the stormwater facility.

Conveying stormwater runoff on or near the surface can be accomplished with a number of techniques. Using trench drains and small-scale speed bumps are good ways to efficiently direct runoff to landscape areas without using underground pipes.

Trench drain systems are designed to convey stormwater runoff within a shallow channel while maintaining unimpeded pedestrian or vehicular access. Trench drain grates can vary considerably in size and shape, as well as material choice and patterns. Trench drain channels, to which a grate is affixed or mounted to, can be designed with a variety of profiles and depths.

Using speed bumps to direct water into landscape areas is a simple and inexpensive design strategy. Speed bumps can be used to direct surface runoff near the beginning of a stormwater facility to increase treatment time. Also, small speed bumps can be installed as a "backstop" near curb cut entries to direct water into the stormwater facility. Speed bumps do not have to be very high. A 2 inch high speed bump is typically adequate for directing stormwater flow.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-37: *This trench drain example connects two stormwater facilities within an industrial parking lot site.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-38: *A concrete unit paver is placed at the exit point of this trench drain. The pad helps prevent erosion by dissipating water velocity as water drops from the trench drain to the finish grade of the stormwater facility.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-39: *This asphalt speed bump redirects stormwater into a vegetated swale. Without the speed bump in place, stormwater runoff would enter the vegetated swale much lower within the system, bypassing some of the area available for treatment.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-40: *A sediment forebay within a stormwater curb extension.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-41: *A small, 18 inch wide sediment forebay at the entry curb cut of a street stormwater planter.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-42: *A 3x3 foot concrete pad is used as a sediment forebay for a large street rain garden. The plant material acts as a dam allowing debris to settle on the pad for regular removal.*

In sheet flow situations, sediment and other debris drop out evenly along the length of the stormwater facility. This can reduce the need for frequent removal of sediment from within the facility. However, when curb cuts are used and runoff enters a stormwater facility as concentrated flow, so too does the debris load. The value of using sediment forebays depends highly on how much sediment debris the street typically produces. Some stormwater facilities may not need a sediment forebay at all. Other stormwater facilities, particularly those located on streets that have high traffic loads or substantial leaf drop, would most likely benefit from having a sediment forebay and a regular maintenance schedule to clear debris from it.

Sediment forebays help define a space at the entry of a stormwater facility for sediment and debris to collect and be periodically removed. Providing this space can help reduce maintenance by trapping sediment before it is transported into established landscape areas. The goal of a sediment forebay is to minimize the amount of sediment to be transported, not to completely eliminate it.

Ultimately, a sediment forebay should be sized and designed so that it is seamlessly integrated into the landscape area. The design of a sediment forebay can be as simple as leaving a small, shallow-graded, non-planted area right after the entry curb cut. It is recommended that the sediment forebay be mulched with pea gravel to minimize erosion. High density planting located on the downstream side of a sediment forebay can help act as a containment dam for sediment and debris.

Overflow within rain gardens can be managed in several ways depending on what type of stormwater infrastructure is already available. Try whenever possible to have a viable surface overflow as the primary overflow and the piped system as a secondary overflow. In retrofit conditions, simply allowing water to overflow from the stormwater facility through a curb cut and exit back into the street or parking lot where it can eventually be captured by an existing storm drain inlet is the most cost-effective and least intensive option. Another option for handling overflow is to construct a new storm drain inlet located either within the stormwater facility or immediately adjacent to an exit curb cut.

SOURCE: TOM LIPTAN - CITY OF PORTLAND

***Figure 5-44:** Overflow from this rain garden enters a 6 inch riser connected to the storm drain system.*

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 5-43:** This curb cut serves as the only overflow within an infiltration rain garden.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

***Figure 5-45:** Overflow from a mid-block stormwater curb extension exits from a curb notch and flows back onto the street.*

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 5-46:** An adjustable weir retains stormwater to an 8 inch depth within this stormwater planter before overflowing into the storm drain system.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

***Figure 5-47:** Differing texture and color of plant species combined with a high density of plant material can create very beautiful stormwater facilities.*

SOURCE: TOM LIPTAN - CITY OF PORTLAND

***Figure 5-48:** Formal stormwater facilities that have a very manicured look can sometimes be indistinguishable from conventional landscapes.*

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 5-49:** More natural-looking stormwater facilities can often provide a striking contrast to the formal appearance of urban streets and parking lots.*

Green street and parking lot projects should all be designed as community amenities. Hence, the decision on what plant material should be installed within a green street or parking lot project is an important one. There are essentially two primary considerations in choosing plants for a particular stormwater project: 1) general aesthetics; and 2) choosing plants that can survive in both "wet" and "dry" conditions. A more detailed discussion of each design issues is presented below.

General aesthetics

The overall look of a green street or parking lot project can vary considerably. Plantings can have a relatively formal and manicured appearance (Figure 5-48), or they can have a more "natural" look (Figure 5-49). Regardless, the choice of plant material should fit with the surrounding landscape context (i.e., residential, urban, etc.).

The overall diversity of plant material within a green street or parking lot project can also affect aesthetics. A highly diverse planting palette with differing textures, colors, and growing heights can be very desirable. This is especially true for larger stormwater facilties and those that incorporate side slopes in the design. For those stormwater facilities that are smaller and more linear, such as stormwater planters, a single-species planting may be more appropriate. Regardless of the chosen palette, it is important to design and install the plant material at an appropriate density. Too often, stormwater facilities are installed with too few plants, so few, in fact, that one can't really call the project a "green street." A well-designed stormwater facility should have no bare ground showing after a two-year plant establishment period.

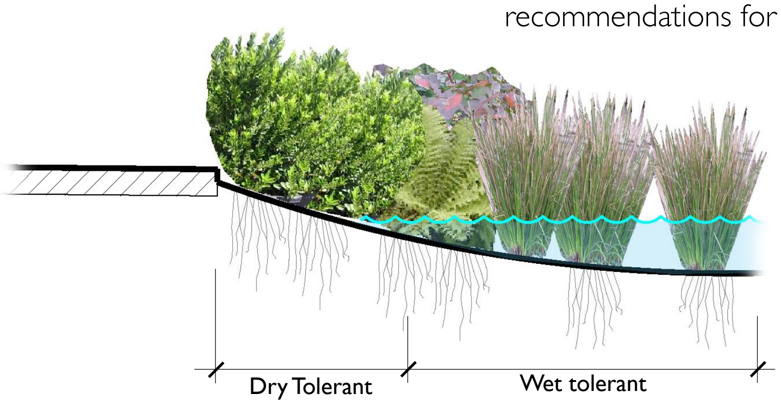
Except for trees, choose lower-growing plant material that do not exceed three feet in height. Low-growing plants tend to be more aesthetically and functionally preferable for green street and parking lot applications. In addition, low-growing plant varieties help to reduce ongoing maintenance by eliminating the need for plant trimming.

The last aesthetic consideration is how much of the plant material should be designed as evergreen versus deciduous. It is recommended that at least 70% of the plant palette, excluding trees, be evergreen. This helps to ensure that green street and parking lot projects have year-round plant structure. Having a predominantly evergreen green street also helps slow water runoff due to the persistence of leaves.

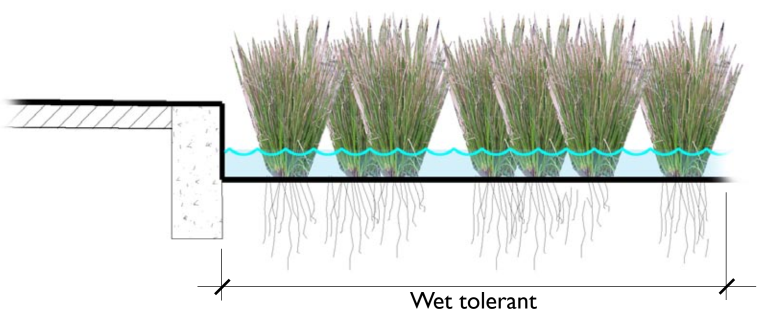
Choosing "wet" and "dry" plants

Green street and parking lot projects may have different planting zones based on the type of stormwater facility used. Stormwater facilities that are designed with a side slope condition (e.g., vegetated swales) have two planting zones: dry and wet. Shrubs, groundcovers, and perennials that thrive in drier conditions should be placed on the upper portions of the side slopes while wet tolerant plants, such as sedges and rushes, are best suited for the low, flat bottom zone of the stormwater facility. Stormwater facilities that have only a flat-bottom condition with no side slope (e.g., stormwater planters) have only one planting zone that should only be planted with wet-tolerant plant material. Figure 5-50 illustrates the typical planting conditions based on stormwater facility type. It should be noted plants chosen for wet zone conditions should also have some level of drought tolerance in order to minimize, or potentially eliminate, the need for supplemental irrigation during dry periods.

Appendix A of this guidebook offers several local resources to help choose appropriate wet and drought tolerant plants. In addition, the C.3 Technical Guidance offers plant recommendations for stormwater facilities.



Typical Side Slope and Flat-Bottom Planting Condition



Typical Flat-Bottom Planting Condition

Figure 5-50: *Different planting conditions exist depending on the amount of water retained and the specific geometry of stormwater facilities.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 5-51: *Native soil is rototilled to break up construction compaction.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 5-52: *New imported topsoil is placed within a planter. Soil is graded 2 inches lower than finish grade to allow for a mulch layer.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-53: *Sand bags are placed in front of curb cut inlets in order to help protect soil and plant material immediately after planting.*

In general, it is good to amend soils with organic material because a rich soil allows for healthy plant growth and helps promote the microbiological processes beneficial for the removal of certain types of pollutants. Many sites, especially retrofit conditions, have little or no organic material within the soil structure because they have been been paved over for many years.

If possible, consult with a soil scientist to determine the best mix for a site's imported topsoil. In general, a three-part mix of weed-free compost, sand, and loamy topsoil works well. Specific recommended mixture percentages are detailed in the C.3 Technical Guidance. It is important to rototill newly imported topsoil with the native soil in 6 inch lifts. This provides an even mixture between native and imported soil. Do not compact soil with heavy equipment during construction. This is often the cause of stormwater facilities' failure to perform well. Use only foot-compaction or a landscape-roller to finish the grade of a stormwater facility. Soil preparation should only be done in dry conditions when there is no standing water on the soil's surface.

Upon the completion of soil preparation and final grading of stormwater facilities, it is best to inhibit stormwater runoff from entering the stormwater facility until the plant material has been installed (possibly even later to ensure the successful establishment of the plant material). Using sand bags to block curb cuts is one method of keeping a stormwater facility "offline." In some cases, inhibiting stormwater runoff cannot be achieved if there is no viable way to direct flow around the stormwater facility. In these cases, it is important to protect the soil from erosion and to ensure that the the installed plant material is well-established prior to the onset of the wet season.

Accurate grading of stormwater facilities is critical for assuring the success of a green street or parking lot project. The designer and contractor must work together during construction to assure that the project is correctly built to plan. In most situations, adjustments to the grades will need to be made in the field. This is especially true when attempting to match existing conditions to new conditions in retrofit projects.

While a major component of grading stormwater facilities is to accurately build the finish grade of soil, it is equally important to assure that the grades of the hardscape elements (i.e., curb cuts, trench drains, curb heights, etc.) are also constructed correctly. Even an 1/8 inch discrepancy in elevation can mean the difference between stormwater freely entering a curb cut or not.

Designers should be prepared both in terms of time and budget to regularly be in the field to help assure that the design is being constructed properly.

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 5-54: *A shallow graded stormwater curb extension retains a maximum of 7 inches of water.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 5-55: *Hardscape elements, such as this trench drain channel, should be inspected to ensure positive drainage into the stormwater facility.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 5-56: *The design team should be on-site regularly during the grading process to determine whether or not the grading is consistent with the plans, and if necessary, work with the contractor to make field adjustments.*

When designing and installing stormwater facilities, the grade of the imported topsoil should be left 3 inches below the desired finish grade to allow for a layer of mulch. If the finish grade of the stormwater facility is built without taking into account a mulch layer, the stormwater facilities will be graded too high and water cannot get into the stormwater facility/curb cut.

Mulch material can be made of organic material (e.g., bark mulch) or it can consist of rocks. For organic mulches, care should be taken to use a weed-free source. Bark mulch does have a tendency to float during a stormwater facility's initial storm events, however, this tends to decrease over time as the mulch material settles and the plant material matures. Rock mulch is a good choice for stormwater facilities that experience high velocities of runoff and have a higher potential for erosion.

For rock mulch used in green street and parking lot projects, care should be taken to select rock that is sized appropriately based on the expected sediment load of the runoff. The type of rocks chosen depends on where the runoff is coming from and its pollutant/sediment load. It can be a maintenance headache to clean out sediment in the voids between larger rocks. For green street and parking lot projects, the best type of rock mulch is pea gravel because it allows for easier removal of sediment accumulation. Rock mulch should only be applied to the flat-bottom portion of stormwater facilities.

When removing sediment from a pea gravel mulch, it is easy to tell where the sediment load ends and the pea gravel layer begins. If necessary, the entire sediment and pea gravel layer can be removed as a whole, and a new pea gravel layer can be applied. This allows for the original finish grade of the stormwater facility to always be maintained.

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

***Figure 5-57:** A 2 inch layer of pea gravel mulch is applied within a stormwater planter.*

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 5-58:** Standard bark mulch is applied to a green street project.*

Figure 5-59:
KEY ELEMENTS FOR CONSTRUCTION ADMINISTRATION

Pre-Construction Planning:

- Set up bid contract to separate general contractor work and landscape contractor work.
- Establish specific qualifications for each discipline's work to ensure quality assurance in the contractor selection process.
- Ensure sufficient time and funding are available for the design team to complete an adequate construction administration process.

Demolition Phase:

- For retrofit projects, after sawcutting existing concrete or asphalt areas, inspect native soil conditions to determine if there needs to be any changes made to the imported soil mix. Also, check for any undetected utility lines or vaults.

Hardscape Construction Phase:

- Inspect forms prior to pouring concrete/asphalt elements to ensure accurate grades and elevations for conveying runoff into stormwater facilities.

Soil Preparation/Grading Phase:

- Make sure that soil preparation and grading activities are done in dry conditions without standing water on the soil surface.
- Excavate native soil to design depth, rototill any compacted soil during excavation.
- Till in imported topsoil mix with native soil conditions in 6 inch lifts. Finish topsoil grade 3 inches below final grade of the stormwater facility to account for a mulch layer.
- Check final grades of stormwater facility to assure that basin elevations and side slopes are built accurately. Make adjustments in field as necessary.
- Temporarily block off stormwater entrances, if possible, to protect the newly graded soil conditions from receiving stormwater flow.

Plant Installation Phase:

- Make sure that plant installation activities are done in dry conditions without standing water on the soil surface.
- If plants are installed in dry summer months, ensure that there is an irrigation source to water plants during the predetermined establishment period.
- Verify with contractor the correct plant species and quantities prior to the plants being delivered to project site.
- Apply specified mulch material to establish final grade of the stormwater facility.

Post-Construction Observation Phase:

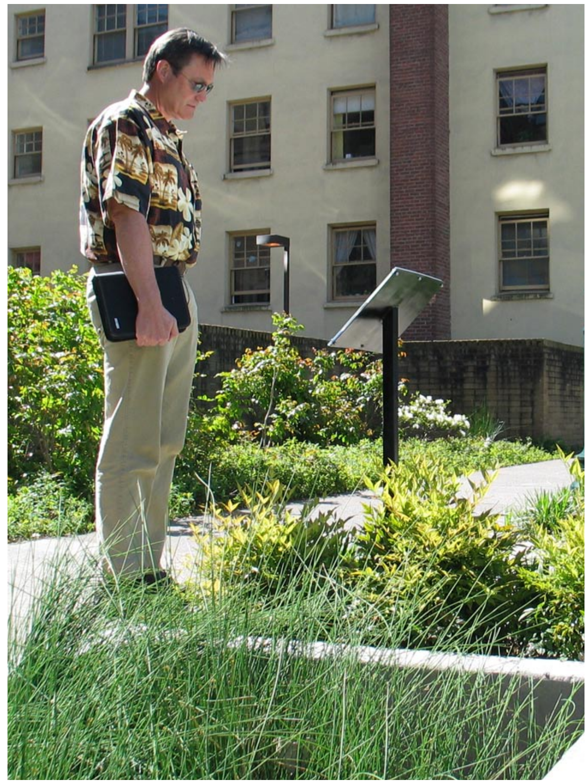
- Visit project site often to determine if it is performing successfully. Look for any signs of erosion, poor plant health, lack of maintenance, prolonged periods of ponding of water, and inlet/overflow/checkdam malfunctions.
- Survey the general public to determine if the project is successful from a community perspective.

CHAPTER 6

IMPLEMENTING GREEN STREET AND PARKING LOT PROJECTS

This final chapter of the guidebook looks at specific ways green street and parking lot projects can be implemented in San Mateo County. Topics covered include reducing implementation costs, changing policy and code, creating incentive programs, providing public education and outreach, and choosing demonstration projects.

The latter half of this chapter looks specifically at the conceptual design of three demonstration projects within San Mateo County as well as a hypothetical project where a large commercial site is retrofitted with a green parking lot and green streets. These demonstration projects showcase a variety of site design and stormwater facility strategies described within this guidebook and appropriate in different regions within San Mateo County. The intent of these future demonstration projects is to encourage widespread use of green street and parking lot projects within the region.



SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

***Figure 6-1:** Successful small-scale demonstration projects are the key to building support for wide-spread green street and parking lot efforts.*

Figure 6-2:

IMPLEMENTING GREEN STREETS AND PARKING LOTS IN SAN MATEO COUNTY

Key Implementation Strategies	San Mateo County Demonstration Projects
Reducing Project Costs	Fitzgerald Marine Reserve Parking Lot
Changing Municipal Code/Policy	Holly Road Green Street
Creating Incentives	Belle Air/Third Avenue Green Street
Public Education and Outreach	Large Shopping Mall Area
Demonstration Project Approaches	

Since the major opportunity in San Mateo County is to retrofit the existing built environment, the overall goal should be to reduce costs as much as possible and deliver additional non-stormwater-related benefits when applying design solutions. In general, retrofitting green street and parking projects is more costly than implementing new development projects simply because the former have site constraints that must be addressed. For example, there are often extra costs associated with removing existing concrete or asphalt in order to make way for new green space. In some cases, using a "green" approach might cost more, but the ancillary benefits (such as traffic calming, improved neighborhood aesthetics, and a safer pedestrian environment) should also be considered.

The following describes four ways to reduce costs when implementing green street and parking lot projects:

Minimize Existing Impacts

One way to reduce construction costs is to minimize the impact to the existing storm drain infrastructure as much as possible and maintain existing storm drain inlet locations. Altering drain inlet locations and installing new storm drains at intersections can be very cost prohibitive in some projects. In many cases, stormwater facilities constructed up-gradient of existing storm drain inlets may require little, if any, alteration to infrastructure. Many green streets projects in Portland, Oregon were built inexpensively because they minimized impacts to the existing piped infrastructure. For example, the NE Siskiyou Green Street project installed two stormwater curb extensions just upstream of the existing stormwater drain inlets and never touched the existing storm infrastructure. By avoiding any such impact, the project's overall costs were reduced significantly. Further details of Portland's green street projects can be found in Appendix A "Further Resources."

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 6-3: *NE Siskiyou Green Street in Portland, Oregon avoided alterations to the existing storm pipe infrastructure and was therefore built cost-effectively.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 6-4: *SW 12th Avenue Green Street in Portland, Oregon is another downtown green street project that was built inexpensively because it did not impact the existing piped infrastructure.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 6-5: *This stormwater curb extension project constructed in Portland, Oregon reduced project costs by leaving the existing street curb in place.*

SOURCE: TIM KURTZ - CITY OF PORTLAND

Figure 6-6: *Simple green streets, such as this residential example in Portland, Oregon, convert under-utilized landscape area next to streets into stormwater facilities. Since the improvements consist largely of regrading and planting, the projects can be very cost effective to build.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 6-7: *A prime retrofit candidate in San Mateo County. This landscape strip along El Camino Real could be retrofitted with new landscaping and curb cuts to create an inexpensive green street example.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 6-8: *This green street curb extension project was funded in conjunction with a pedestrian safety and traffic calming project.*

Look for High-Opportunity Projects

When searching for cost effective green street projects, look for candidate sites that have minimal site constraints and maximum space for stormwater facilities. In some cases, there is available landscape space that can be easily regraded and planted to provide stormwater management. In other cases, there are streets and parking lots that have excess asphalt area that can be converted into a stormwater facility at minimal cost. High-opportunity projects also include street and parking lot projects that have willing stakeholders, agencies, owners, or neighbors that can help provide advocacy or funding for a particular project.

Combine Green Streets with Other Street Improvements

Continual capital improvements are needed to maintain street longevity. Asphalt paving often needs to be replaced; curbs, sidewalks, and utility lines need to be repaired; and overall traffic/pedestrian improvements are constantly being planned. The most opportune time to incorporate a green street element is when a street is already planned and budgeted for improvement. Coordinating the efforts between regular street improvements and green street improvements can help reduce the cost of green street implementation by achieving positive economies of scale. In many situations, green street projects can be integrated and budgeted as part of solutions for local traffic problems. For example, stormwater curb extensions can help narrow street widths, provide traffic calming benefits, and potentially be paid for by a non-green street-related budget.

Keep Design Solutions Simple

During the design phase of green street and parking lot projects, it is important to keep the design as simple as possible. Highly engineered design solutions can often increase project costs. Remember, green streets rely on a natural, landscape-approach to stormwater management.

One often over-designed component in green street and parking lot construction is the means by which water gets in and out of landscape stormwater facilities. Over-designed inlet structures not only increase project costs, but they often detract from the aesthetics of a project. Keeping the design simple and allowing water to surface flow in and out of stormwater facilities will help keep costs more manageable. Likewise, using only surface overflow to an existing downstream storm drain inlet, when possible, can simplify a project's design and greatly reduce costs.

Another effective cost saving strategy is to limit the amount of imported hardscape materials. For example, it may be tempting to use deeper concrete walls to facilitate greater ponding depth, but the marginal benefit compared to shallower stormwater facilities, which use less resources, may not justify the additional expense.

With larger construction projects, the designer should balance the total cut and fill on a project. It can be expensive to excavate, haul, and dispose of excess soil.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 6-9: *This high-cost, engineered green street example uses a lot of concrete infrastructure, as well as uses an inlet structure that makes stormwater appear to be a waste rather than a resource.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 6-10: *In contrast to the example above, a simple cost-effective curb cut allows water to move freely into a stormwater facility without detracting from the aesthetics of the project.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 6-11: *This mid-block stormwater curb extension project keeps the existing street curb in place and allows stormwater runoff to overflow back into the street without using any piped overflow structures. The combination of these strategies helped reduce construction costs.*

With 21 different municipalities within San Mateo County using this design guidebook as a reference document, it would be difficult to account for all of the code conflicts that could arise in implementing green street and parking lot projects. However, some relevant policy and code information from various County municipalities is presented, separate from this guidebook, on the SMCWPPP website (www.flowstobay.org).

There are three major ways to help encourage code changes that support the use of green streets and parking lots: 1) build demonstration projects; 2) provide the opportunity for open communication and collaboration between municipal staff to discuss issues; and 3) provide flexibility in green street and parking lot design standards.

Changing Code with Demonstration Projects

One of the best methods to help municipalities change their development codes to favor green street and parking lot projects is to build demonstration projects. By labeling a project as a "demonstration" or "pilot" project, it often allows city staff to relax their standards and allow the use of alternative methods without the burden of implementing widespread change. Demonstration projects allow city staff to evaluate the particular code on the site level rather than a city-wide scale. This can provide a much clearer perspective of what issues are truly in conflict. Most importantly, when city staff experience first-hand that the particular code conflict is not as critical in light of the other benefits provided by the demonstration project, they tend to standardize the approach for widespread application.

Changing Code with Staff Collaboration

Another other major tool for helping change existing municipal codes is to provide an avenue for inter-city and inter-county collaboration of ideas and concerns. The ideal condition would be for all municipalities within the County to adopt a uniform and consistent set of codes and policies that support the needs of green street and parking lot projects. This would undoubtedly take a great deal of time, effort and political will to accomplish, but this effort would provide the most comprehensive approach to dealing with potential code conflicts. More realistically, resolution of code and policy conflicts that arise during implementation of green street and parking lot projects will occur through discussion and negotiation among municipal staff. Staff will need to consider multiple perspectives to arrive at a reasonable compromise that serves the greatest good.

Providing Flexibility in Green Street and Parking Lot Design Standards

It is important to note that it is possible for municipalities to rush to provide inflexible green street and parking lot design standards prior to developing a comprehensive array of design solutions for a wide variety of conditions. As a result, developers and municipalities could be limited to only one or two design solutions that are not well suited to the varying street and parking lot conditions in San Mateo County. It is best to provide flexible design guidelines that can be easily updated as green street solutions are refined and properly tested in demonstration projects.

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 6-12:** This green street project built in 2004 in Portland, Oregon was a first-of-its-kind on a commercial street. Demonstration projects like this one have helped spur other green street projects, as well as provided the impetus for changing municipal design standards and codes.*

There are several options for creating incentives for municipalities and property owners to retrofit green streets or parking lots. As described below, these incentives can be classified into three different categories: reward-based incentives, mandate-based incentives, and community-based incentives.

Reward-based Incentives

Reward-based incentives compensate a developer or property owner for incorporating green street and parking lot elements into their project. This type of incentive may include utility fee discounts, tax benefits, project grant funding, or even expedited review of development proposals. Reward-based incentives are particularly applicable to private development associated with parking lot projects. However, when private development occurs in conjunction with public streets, reward-based incentives can also apply. An example of a reward-based incentive is the City of Portland's Clean River Rewards Discount Program that allows up to a 35% reduction in residential or commercial stormwater utility fees for employing certain landscape-based stormwater management strategies on-site.

Mandate-based Incentives

This type of incentive require a developer or property owner to employ green street and/or parking lot strategies or their on-site stormwater management fee will be levied or increased. Mandate-based incentives can result in a more wide-spread application of green street and parking lot projects, but they can also set a more negative tone to a positive effort. Mandate-based incentives may also create a burden for municipal staff by creating a larger green street and parking lot program than originally anticipated.

Community-based Incentives

Many neighborhoods and business districts see the value of "greening" their environment in terms of improving quality of life, increasing property values, and increasing business profits. Local neighborhoods are often willing to combine resources and help pay for a green street project, or agree to undertake long-term maintenance, or simply provide advocacy for a municipality's green street efforts.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 6-13: *This residential green street project in Portland, Oregon was built using a combination of funding among the neighborhood residents, a grant, and municipal funding.*

One way to bring to bear full community resources is to form a community benefit district. Such an entity is comprised of a network of businesses and other property owners within a defined area who voluntarily agree to pay additional property tax in order to finance capital improvements and services that enhance, but do not replace, those provided by the city. Alternatively, parking benefit districts serve the same function, but derive their funding from on-street parking meters or non-resident parking passes.

General problem-solving is another common form of community-based incentives. For example, green street and parking lot projects have the potential to reduce neighborhood flooding, provide traffic calming, and provide pedestrian safety benefits. Communities are more inclined to endorse and provide incentives toward green street projects when they are part of a more comprehensive solution to neighborhood problems.

SOURCE: NEVUE NGAN ASSOCIATES

Figure 6-14: *An interpretive sign describing a vegetated swale project and the hydrologic cycle in San Mateo County.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 6-15: *Students, visiting another school's rain garden project, hope that a similar project will be built on their school's grounds.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 6-16: *A green street public workshop describes several options for retrofitting a boulevard.*

One of the best tools for successful stormwater management is educating the general public. There is a lot of confusion and misconceptions about using various stormwater management strategies. People sometimes think of stormwater facilities as "swamps" or "mosquito nests" and are unaware of well-designed stormwater facility examples. Likewise, people may not realize well-designed stormwater facilities can look just as good as conventional landscapes.

Therefore, it is important to show the general public specific examples of successful demonstration projects (local or otherwise) in order to assure them that stormwater facilities can help protect the environment and can also provide a unique and attractive neighborhood amenity. There are several ways to promote stormwater education and outreach, such as:

- Conduct public tours of successful stormwater projects built in the local area, including field trip tours for school children who would like to learn more about environmental sustainability.
- Offer public meetings/workshops on the topic of sustainable stormwater management. Provide specific education materials that explains that well-designed stormwater facilities should not allow any prolonged periods of standing water that promote mosquito breeding.
- Send out brochures or provide fact sheets that describe different ways to manage stormwater runoff.
- Install interpretative signs for key stormwater demonstration projects. The signs should describe the particular elements of a project and where to find more information.

Green street and parking lot demonstration projects can be selected and designed using one or a combination of three approaches. Depending on the approach taken, demonstration projects can range from small to large, retrofit to new construction, and simple to complex.

Strategic Approach

This approach locates stormwater facilities intermittently, but strategically, to provide the most efficient level of stormwater management. Because this approach uses smaller facilities, it tends to be the least expensive to construct and maintain. This approach is widely used for retrofitting existing streets. An example project using this approach is the SW 12th Avenue Green Street in Portland, Oregon (Figure 6-17).

Opportunity Approach

This approach locates stormwater facilities in areas where there are very few constraints and that offer high demonstration value. By using this approach, under-utilized landscape or impervious areas are converted into stormwater facilities of any size. An example of this approach are the five rain gardens located along NE Sandy Boulevard in Portland, Oregon (Figure 6-18).

Full-Integration Approach

This green street approach integrates the entire street frontage for stormwater management. A full-integration approach offers the most stormwater management benefits, but it is usually the most expensive to build and maintain. This approach is most compatible with new construction projects or if a street is planned to be completely rebuilt. An example of this approach is the Street Edge Alternatives in Seattle, Washington (Figure 6-19).

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 6-17: *Portland's SW 12th Avenue Green Street project utilizes a strategic approach in placing smaller stormwater facilities intermittently along the streetscape.*

SOURCE: NEVUE NGAN ASSOCIATES

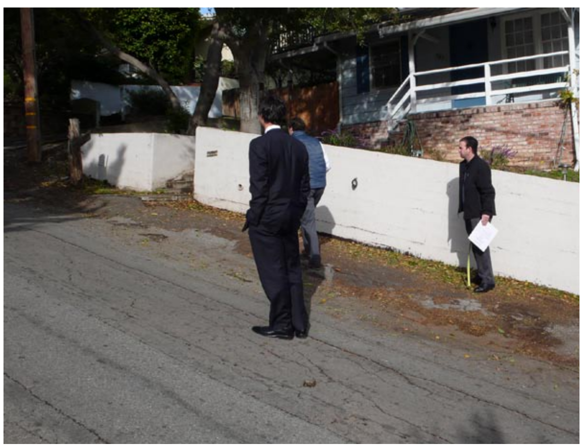
Figure 6-18: *The five rain garden projects located along NE Sandy Boulevard in Portland are located where the site constraints were minimal.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 6-19: *When a street is completely reconstructed, such as the Street Edge Alternatives (SEA) Streets in Seattle, Washington, the project uses a full-integration approach.*

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 6-20:** The Fitzgerald Marine Reserve Parking Lot project looks at redesigning an entire site to better manage stormwater runoff.*



SOURCE: NEVUE NGAN ASSOCIATES

***Figure 6-21:** The Holly Road Green Street project is an example of how to retrofit an existing narrow and extremely steep residential street with a variety of design options.*

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 6-22:** The Belle Air/Third Avenue Green Street is a simple stormwater curb extension project located near an elementary school.*

The City/County Association of Government's approach to gaining support for sustainable green streets and parking lots started "small," with a few demonstration projects that showcase the different design strategies described in this guidebook. Developing a green street and parking lot program that serves the 21 different municipalities in San Mateo County may seem daunting. It is easier to reach general consensus among varying agencies and municipality departments by testing new and innovative strategies within multiple demonstration projects.

Demonstration projects not only provide a good opportunity for public outreach, but also allow municipalities to gauge what resources are needed to move towards more ambitious green street and parking lot projects. Some of the best demonstration projects are retrofits that can creatively demonstrate how, through good design, gray space can be converted into green space for stormwater management.

The following pages illustrate the conceptual design of three demonstration projects that have been awarded grant funding from the SMCWPPP's Sustainable Green Streets and Parking Lot Program. Each of these projects vary in complexity, scale, and types of stormwater strategies used. Furthermore, there are differing implementation schedules for each project. However, all three grant projects will be completed by 2010.

An additional conceptual design example describes an innovative, large-scale commercial parking lot retrofit,. This example is not an actual demonstration project and is included in this guidebook for illustration purposes only.

The conceptual drawings and information in the following pages provide only a snapshot of each project's design development at the time of this guidebook's completion. Depending on each project's complexity and/or schedule, the overall design described in this guidebook may differ from what is actually constructed.

Project Type: Complete Site Retrofit

Project Approach: Full-Integration

Site Design Strategies Used: Efficient site design, balanced parking, surface stormwater conveyance, and preservation of existing trees

Stormwater Facility Strategies Used: Pervious paving, vegetated swales, stormwater planters, and rain gardens

SOURCE: GOOGLE EARTH

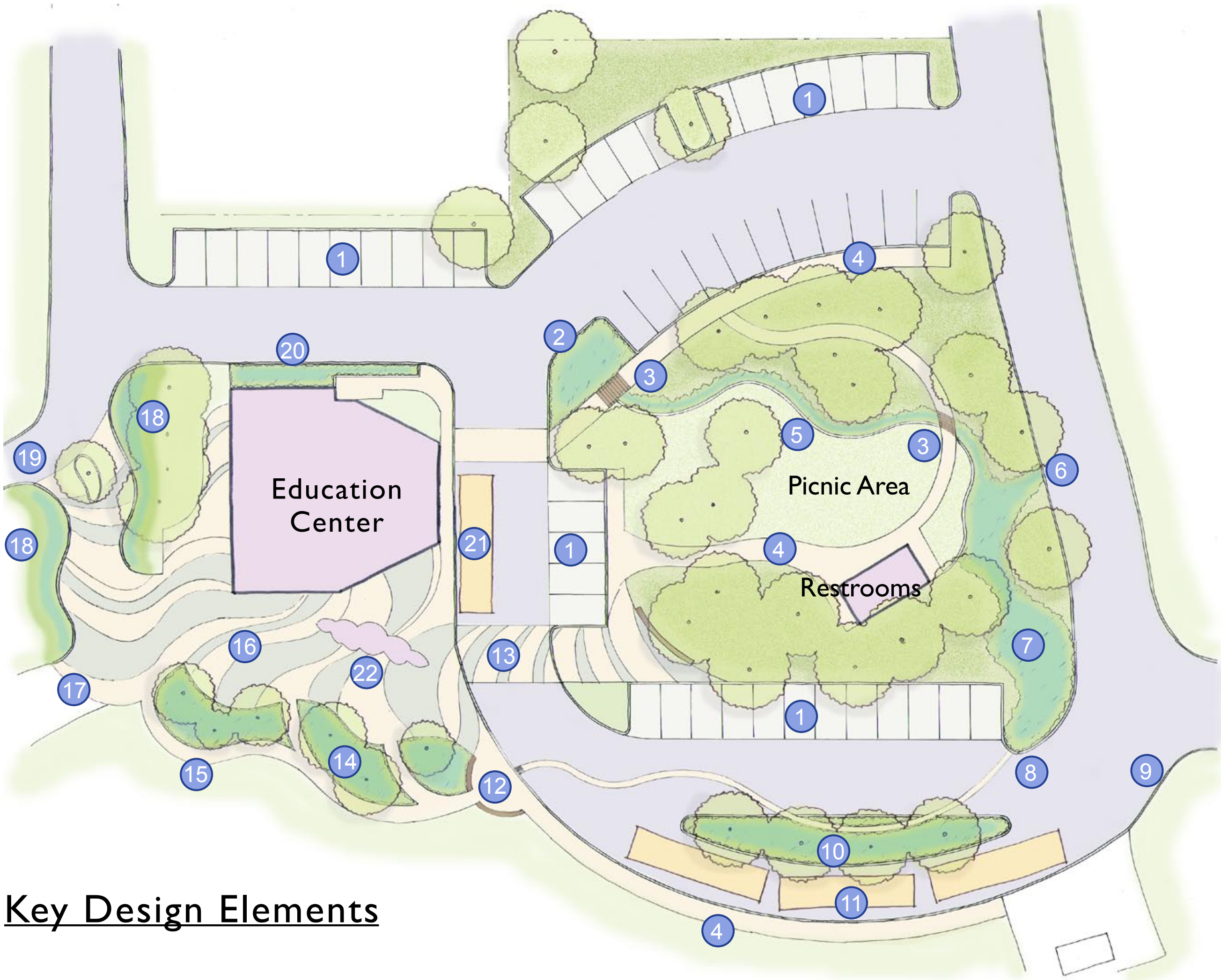
Figure 6-23: *The existing visitors parking lot and outdoor space at the Fitzgerald Marine Reserve. This space will be redesigned to provide a new education center and various site improvements.*

The Fitzgerald Marine Reserve, located in Moss Beach, California, is a popular destination for people to experience the wonderful scenery, hiking trails, and tide pools along the Pacific Ocean. To help mitigate the impacts of high visitation to this area, a master plan for the Fitzgerald Marine Reserve was prepared in 2002. Following this effort, a Conceptual Plan for Interpretation at the Fitzgerald Marine Reserve was completed in 2004. This conceptual plan, completed by Ron Yeo FAIA Architect, Inc., included better vehicular access, a redesigned parking area, a new interpretative education center building, and improvements to outdoor amenities.

In an effort to fully manage the parking lot and street stormwater runoff, the 2004 conceptual plan has been revised into a new plan that incorporates pervious paving, vegetated swales, rain gardens, and stormwater planters. The following pages illustrate an initial conceptual stormwater design for this project site. Further conceptual design refinement for this project is expected after the completion of this guidebook.

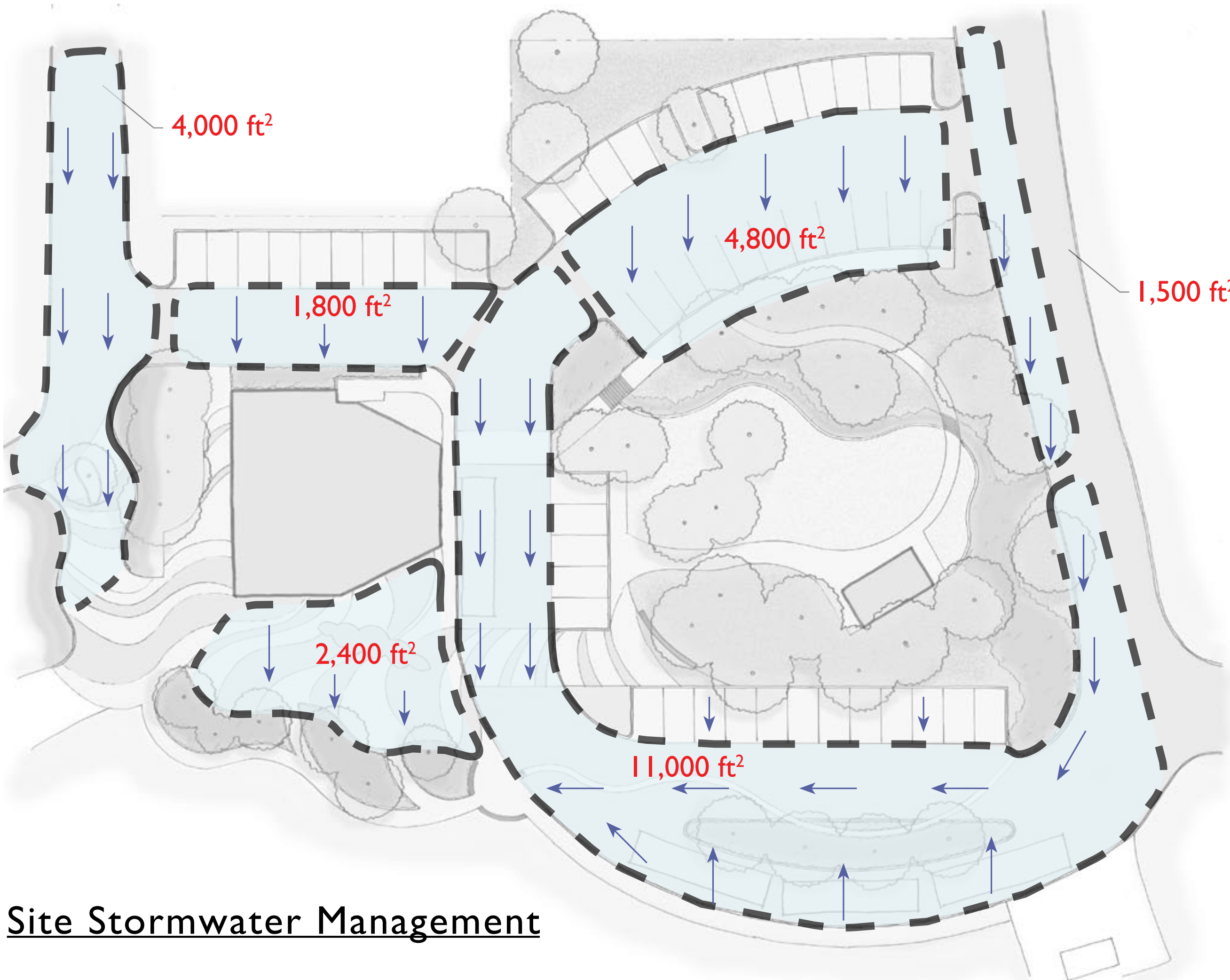
SOURCE: NEVUE NGAN ASSOCIATES

Figure 6-24: *The existing parking lot at the project site and the mature cypress trees that dominate the site's grounds.*



Key Design Elements

1. Pervious paving within parking stalls
2. Stormwater planter accepting parking lot runoff
3. Stormwater bridge over a vegetated swale
4. Pedestrian walk
5. Vegetated swale defines edge of the picnic area
6. Runoff enters from street into the vegetated swale
7. Stormwater continues to flow into a larger rain garden area
8. Overflow enters a sinuous concrete valley gutter
9. Pedestrian access to the Coastal Trail
10. Stormwater swale collects runoff from bus parking zone
11. Bus parking zone only
12. Stormwater "confluence" with interpretative signage
13. Entry walkway with decorative paving
14. Rain gardens collect water from parking lot and plaza space
15. Pathways intersect rain gardens
16. Education Center plaza space with decorative paving
17. Coastal access ramp
18. Vegetated swales accept stormwater from adjacent street
19. Driveway to residence (not on Fitzgerald Marine Reserve property)
20. Stormwater planter accepts runoff from parking lot
21. Bus/auto drop off-zone
22. Education Center outdoor sculpture



Site Stormwater Management

Total Amount of Impervious Area Managed:	25,500 ft^2
Total Amount of Pervious Paving:	5,900 ft^2
Total Amount of Landscape-based Stormwater Facilities	4,500 ft^2
Total Percentage of Landscape Area to Impervious Area	18%

Parking Lot Stall Dimensions: 9'x16' from back of stall to front of wheelstop/curb

Parking Lot Drive/Back-up Aisle Widths: Vary from 20-24' wide

⟶ Direction of Stormwater Flow

Project Type: Street Retrofit

Project Approach: Full-Integration or Strategic depending on design solution

Site Design Strategies Used: Efficient site design, balanced parking, surface stormwater conveyance, and preservation of existing trees

Stormwater Facility Strategies Used: Stormwater curb extensions or stormwater planters

SOURCE: KAREN BORRMANN - CITY OF BELMONT, CA

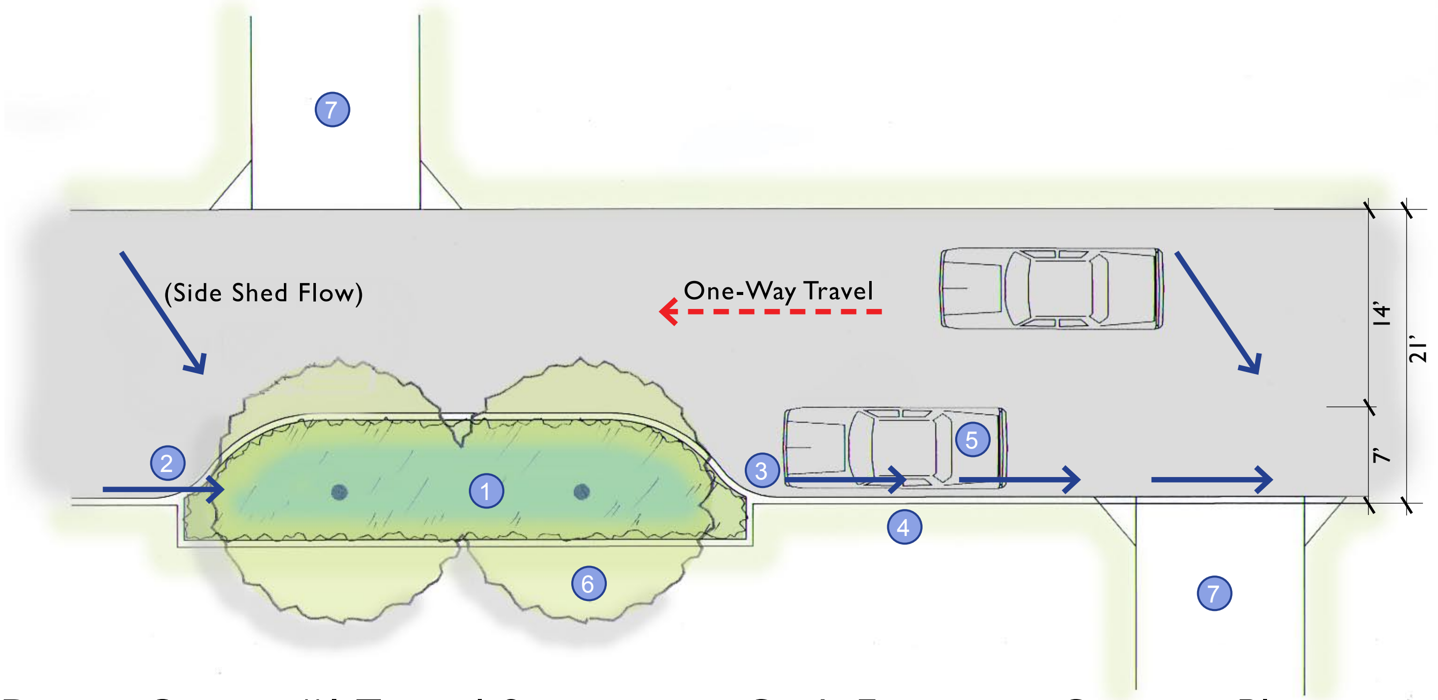
Figure 6-25: *The existing conditions on Holly Road include a steep street slope, a narrow right-of-way, irregular driveway locations, and several mature street trees at the roadway's periphery.*

Holly Road, located in Belmont, California, provides an opportunity to retrofit an existing narrow and steep residential street in order to reduce the velocity and volume of stormwater runoff flowing into Belmont Creek. The street itself is approximately 1,300 feet long and has a varied right-of-way width that varies between 30 feet and 40 feet. The existing roadway paved area varies in width from 17 feet to 21 feet. Portions of Holly Road have slopes that exceed 12%. Though the neighborhood is low-density residential, driveway placements are erratic, with some driveways spaced closely and others far apart.

The main design intent of this green street project is to fit as many stormwater facilities as possible in between driveway locations and still provide some on-street parking. To limit project costs, stormwater facilities will be placed on only one side of the street with a shed profile directing runoff to the landscape features. At the time of this guidebook, the City of Belmont and neighborhood residents are discussing multiple design options for this green street depending on parking needs, the desire for one-way or two-way vehicular travel, and the type and quantity of stormwater facilities to be built. It is estimated that 10-15 stormwater facilities will be built along Holly Road. This green street demonstration project will be an excellent example of how to retrofit an existing narrow residential street in steep conditions. Two design options are illustrated on the following pages.

SOURCE: GOOGLE EARTH

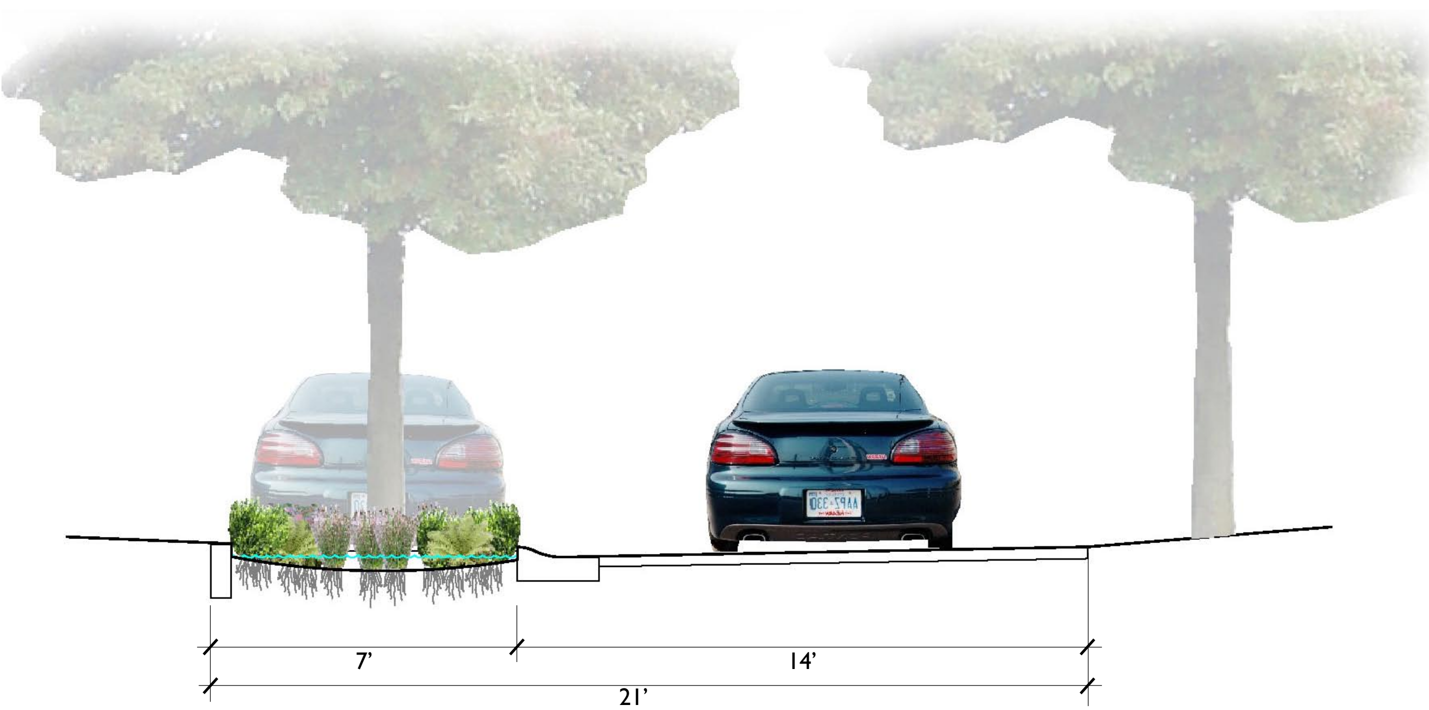
Figure 6-26: *An aerial view of the Holly Road right-of-way.*



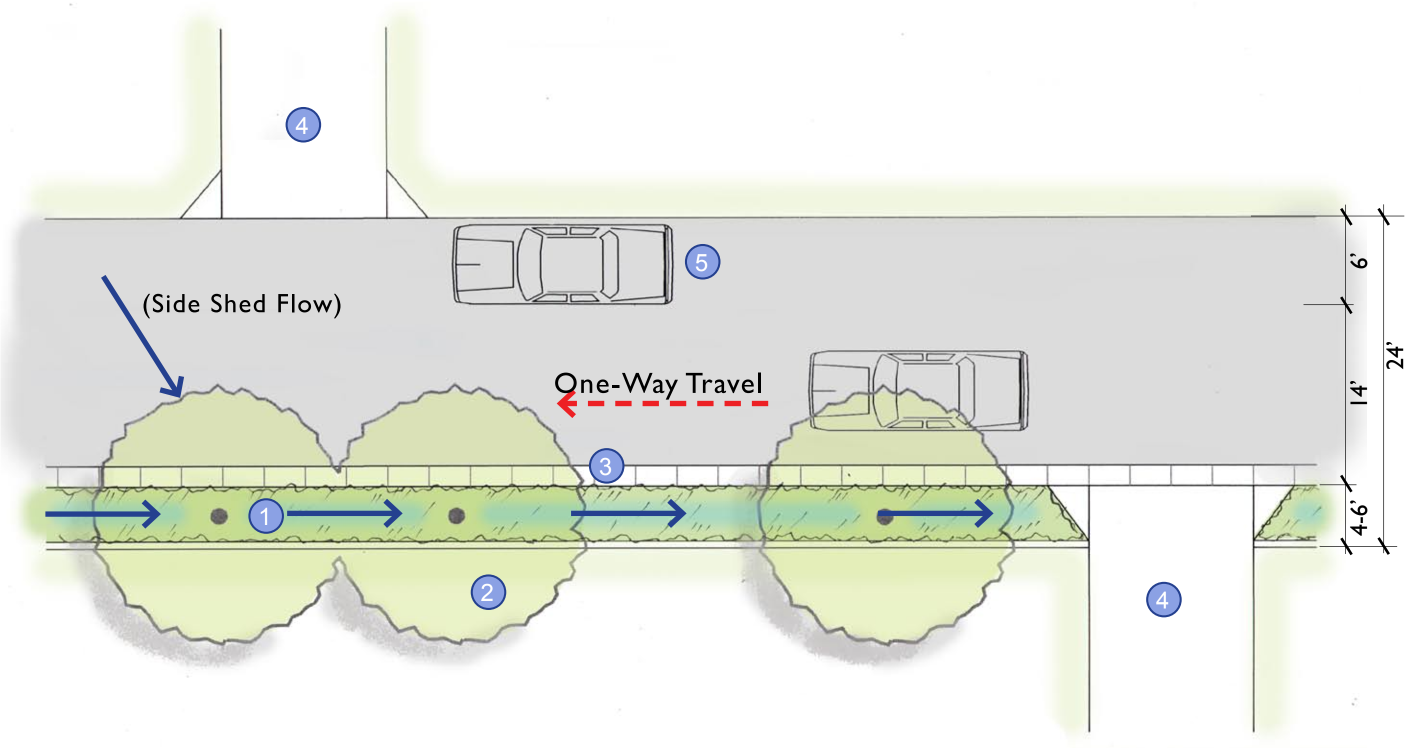
Design Option #1 Typical Stormwater Curb Extension Concept Plan

1. New stormwater curb extension on west side of street only
2. Stormwater entry
3. Stormwater exit
4. New concrete rolled curb
5. New parking lane between stormwater curb extensions
6. Optional new street trees
7. Existing driveway

→ Direction of stormwater flow



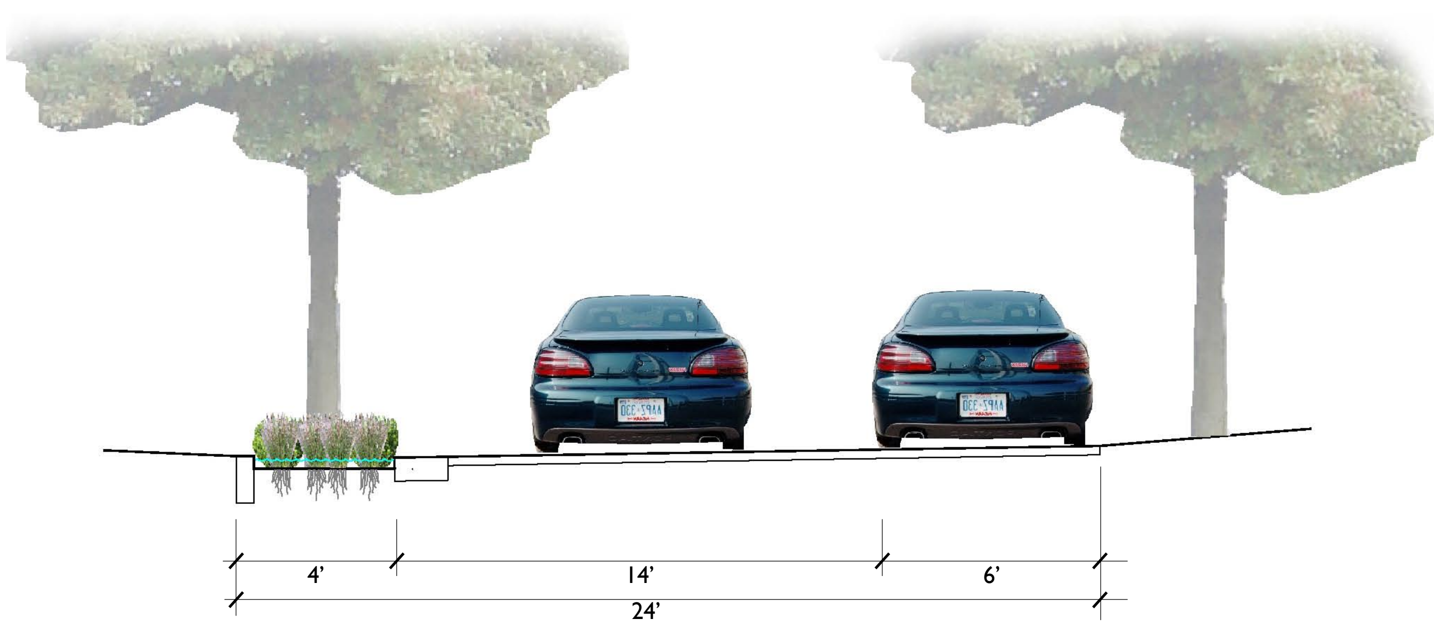
Typical Cross Section



Design Option #2 Typical Vegetated Swale Concept Plan

1. New vegetated swale/stormwater planter on west side of street only
2. Optional new street trees
3. New 18 inch wide concrete flush curb
4. Existing driveway
5. New parking lane

→ Direction of stormwater flow



Typical Cross Section

SOURCE: NEVUE NGAN ASSOCIATES

Figure 6-27: *Holly Road looking downhill as it existed in December 2007.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 6-28: *An early concept rendering showing how Design Option #2 would function with a vegetated swale/planter along the west side of Holly Road.*

Project Type: Street Retrofit

Project Approach: Strategic

Site Design Strategies Used: Efficient site design, balanced parking, surface stormwater conveyance, and additional tree canopy

Stormwater Facility Strategies Used: Stormwater curb extensions


SOURCE: NEVUE NGAN ASSOCIATES

Figure 6-29: *The new stormwater curb extension will convert approximately three on-street parallel parking stalls into a landscape stormwater system.*


SOURCE: GOOGLE EARTH

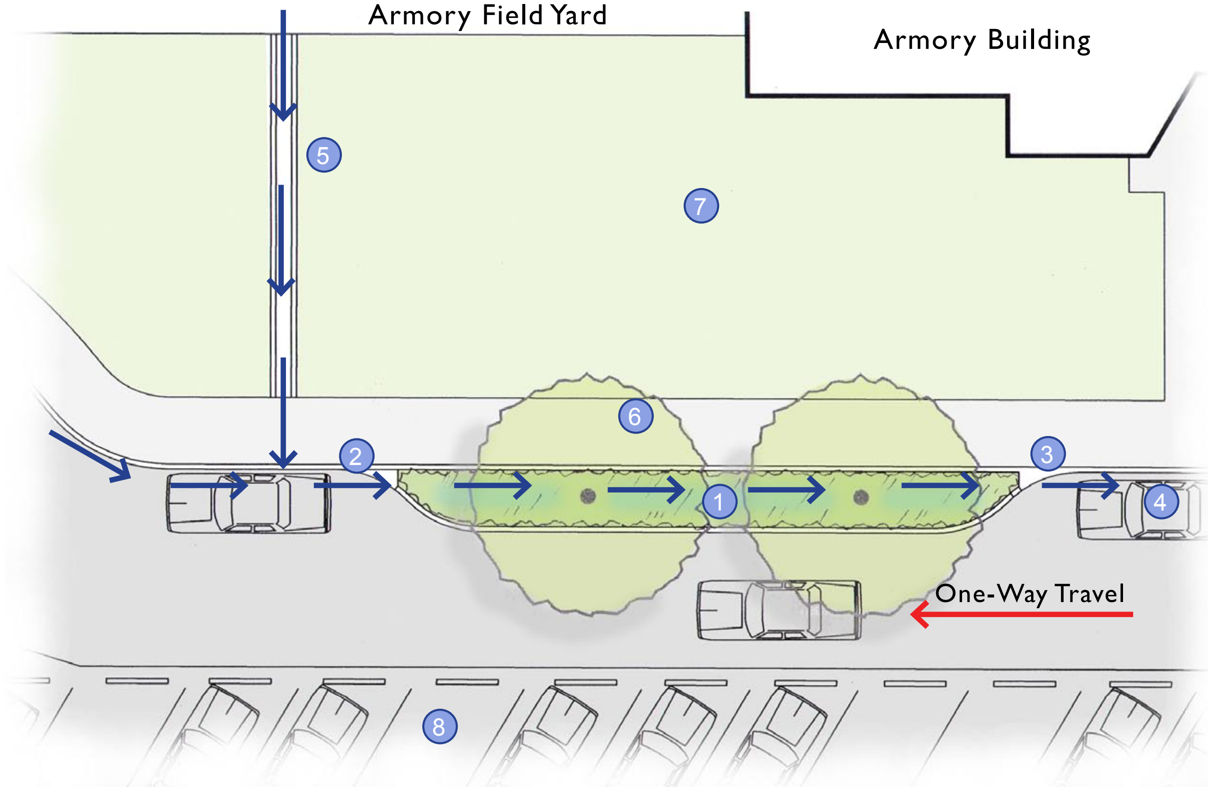
Figure 6-30: *This aerial view of the project site shows the footprint of the proposed stormwater curb extension.*

The Belle Air/Third Avenue Green Street project, located in San Bruno, California is a retrofit project that converts a portion of a street's parking zone into a stormwater curb extension. The street itself is located in a residential neighborhood adjacent to the Belle Air Elementary School, Belle Air Park, and National Armory Building.

The stormwater curb extension's landscaped area will measure approximately 7 feet by 50 feet, yielding approximately 350 square feet of landscape area for stormwater treatment. Approximately 9,500 square feet of runoff drains from the street and adjacent parking lot towards the stormwater curb extension. The design yields approximately 4% landscape area to the total catchment area.

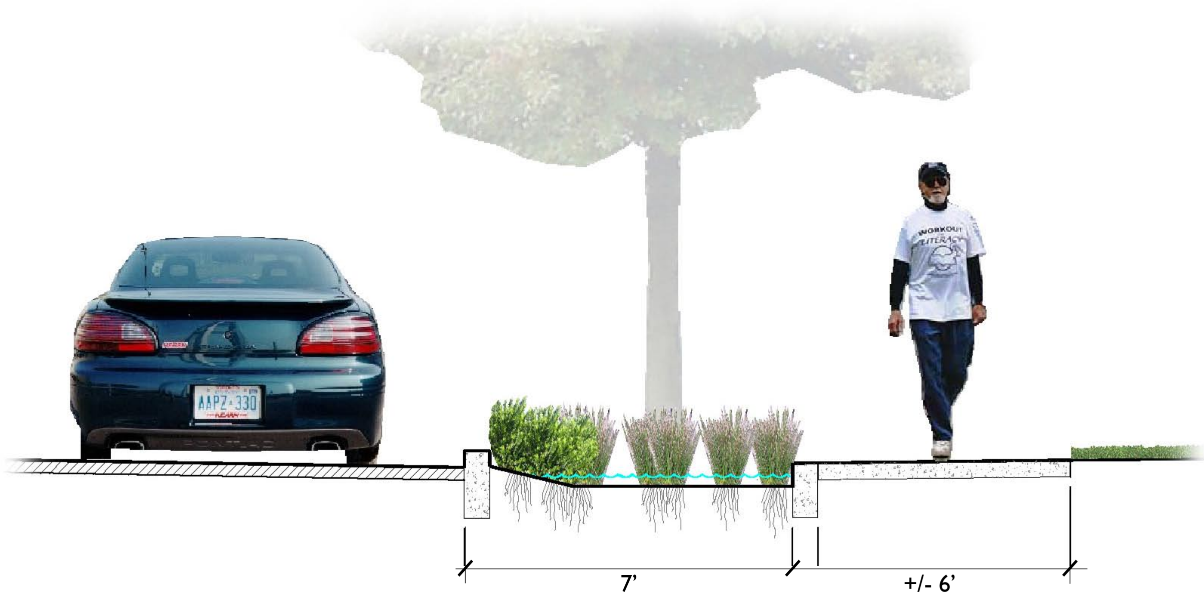
The street's longitudinal slope is extremely flat, measuring below a 1% grade. A soil infiltration test was conducted and the results indicated little potential for infiltration. There is also no cost-effective means to install an underdrain system because there are no nearby storm drain inlets to connect to. As a result, the stormwater curb extension will be graded relatively shallow, and retain a maximum of 3 inches of water. It is expected that the new plantings within the stormwater curb extension, including new street trees, will uptake much of this water through evapotranspiration and help improve water quality and reduce flow.

As the first stormwater curb extension built in San Mateo County, this project will demonstrate that, even without the potential for infiltration and an underdrain system, retrofitted stormwater facilities that are not subject to C.3 regulations can be built to help improve water quality and reduce flow. Hopefully, the Belle Air/Third Avenue Green Street project will set a precedent for similar green street projects.



Stormwater Curb Extension Concept Plan

1. New stormwater curb extension on west side of street only
2. Stormwater entry
3. Stormwater exit
4. On-street parking zone
5. Trench drain conveys runoff from Armory site to the street
6. Optional new street trees
7. Potential future rain garden opportunity in adjacent grass area
8. Existing parking lot for elementary school



Typical Cross Section

Project Type: Large Commercial Site Retrofit

Project Approach: Full-Integration

Site Design Strategies Used: Efficient site design, balanced parking, surface stormwater conveyance, added tree canopy, and alternative transportation

Stormwater Facility Strategies Used: Vegetated swales, stormwater planters, stormwater curb extensions, and rain gardens

SOURCE: NEVUE NGAN ASSOCIATES

Figure 6-31: *This parking lot, like many, has little or no landscaping for shade or stormwater management.*

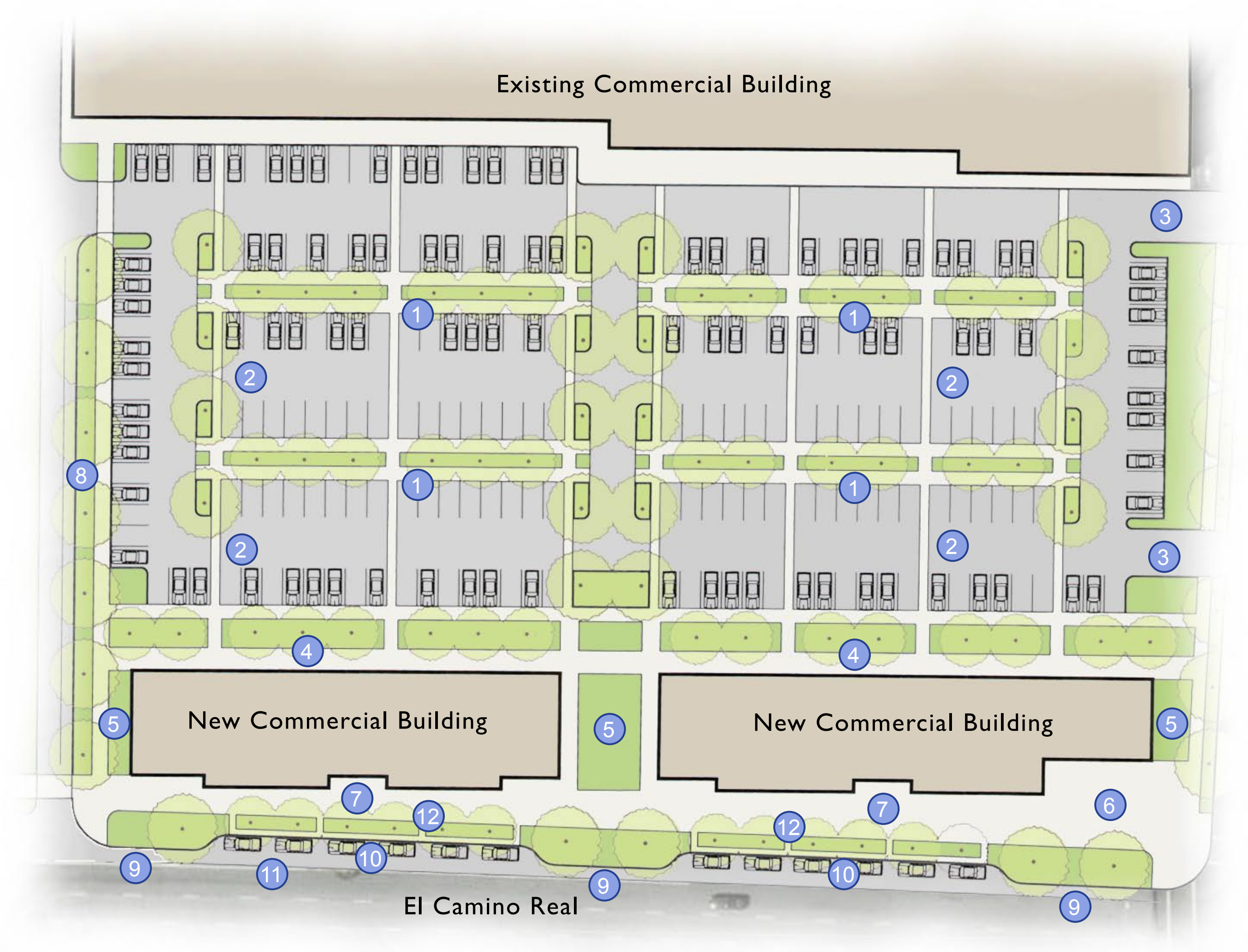
The aerial photo in Figure 6-31 illustrates a typical large parking lot in San Mateo County immediately adjacent to El Camino Real. One can see in the photo the vast amounts of pavement with only a small percentage of the parking spaces being occupied.

The plan on the opposite page illustrates how a commercial site like the one shown can be reorganized with a more efficient site design and retrofitted for various stormwater facilities. This plan now incorporates vegetated swales, stormwater planters, rain gardens, stormwater curb extensions, new trees, better pedestrian circulation, and the potential for additional retail buildings along the street frontage. Parking stalls measure 9 feet x 15 feet from the back of the stall to the front of the wheelstop/ curb, and travel aisles are 22 feet wide. This conceptual design provides plenty of available parking and depicts the same amount of parked cars as shown in Figure 6-32.

Though the new conceptual design is not a planned demonstration project, the site does actually exist in San Mateo County and gives perspective of larger-scale opportunities.

SOURCE: GOOGLE EARTH

Figure 6-32: *An aerial view of a typical large shopping mall parking lot in San Mateo County.*



Key Design Elements

1. New stormwater planter/vegetated swale systems with enhanced pedestrian circulation
2. Defined pedestrian walkways throughout parking lot
3. Secondary parking lot entrances
4. Stormwater swales capture runoff from both the parking areas and building rooftops
5. Rain gardens for building runoff
6. Plaza space in front of new retail building
7. Comfortable sidewalk zone along El Camino Real
8. Vegetated swale captures drainage from parking lot and primary entrance road
9. Stormwater curb extensions capture runoff from El Camino Real
10. On-street parking in front of new retail
11. Bike lane
12. Stormwater planters can either capture runoff from El Camino Real or adjacent retail buildings

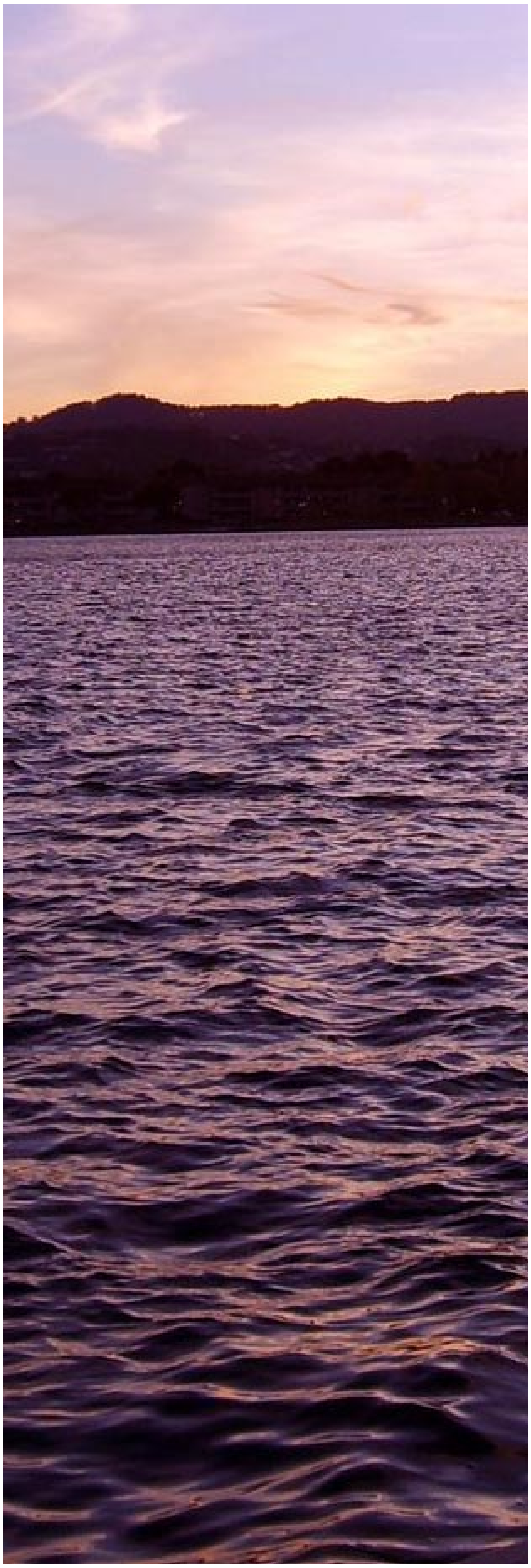
IN CONCLUSION

The completion of the *San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook* marks the first step in implementing a new, bold, and sustainable approach to street and parking lot design.

The various site layout and stormwater facility strategies described in Chapter 2 provide a "toolkit" for designers, builders, and municipal staff. The multiple "before and after" sketches and design examples provided in Chapter 4 illustrate many of the opportunities to implement green street and parking lot projects in San Mateo County. Some of the most promising opportunities, and what should perhaps be the focus of a countywide effort due to the large percentage of impervious surfaces they represent, are retrofitting residential streets and large parking lots. Because these types of retrofit projects are typically easier to implement due to fewer site constraints, this approach could act as a catalyst for an even more comprehensive green street and parking lot program.

Chapter 5 introduced a variety of the design and construction details associated with green street and parking lot projects. This information provides some of the "nuts and bolts" knowledge for completing demonstration projects. However, the art of stormwater facility design is not static. As successful projects are built in San Mateo County, the information in Chapter 5 should be re-evaluated and refined based on implementation knowledge.

The next logical step toward a comprehensive green street and parking lot program in San Mateo County is completing successful demonstration projects. As illustrated in Chapter 6, a small number of these projects are already underway. Yet, thousands of green street and parking lot opportunities, both large and small, exist in San Mateo County. Hopefully, this guidebook will inspire their discovery and realization.



The San Francisco Bay, San Mateo County, California >>

SOURCE: WWW.PICASAWEB.GOOGLE.COM - SATRAJIT

ACKNOWLEDGEMENTS

The San Mateo Countywide Water Pollution Prevention Program (Program) appreciates all who contributed to this guidebook, which was authorized by the City/County Association of Governments of San Mateo County and developed with guidance from the Program's New Development Subcommittee and input from the City/County Engineers' Association of San Mateo County. Among the technical reviewers, the Program especially wishes to acknowledge the efforts of the following individuals:

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The Program also recognizes the City of Portland for its ongoing efforts to forward the practice of sustainable stormwater management. Portland's vision, commitment, and leadership in implementing outstanding green street and parking lot project examples have been instrumental for developing this guidebook and inspiring the San Mateo Countywide Water Pollution Prevention Program to develop its own sustainable stormwater management efforts.

SAN MATEO COUNTYWIDE
Water Pollution Prevention Program
Clean Water. Healthy Community.

[nev-ū-non]
Nevue Ngan Associates

SHERWOOD
Design Engineers

Local Bay Area Resources (Policy and Design)

C.3 Stormwater Technical Guidance, San Mateo Countywide Water Pollution Prevention Program, San Mateo, California, 2007.
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Shoreline Plants: A Landscape Guide for the San Francisco Bay, San Francisco Bay Conservation and Development Commission, San Francisco, California, 2007.
Available at: www.bcdc.ca.gov/pdf/planning/SPLG.pdf

Sustainable Landscaping, California Integrated Waster Management Board
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Plants and Landscapes for Summer - Dry Climates, East Bay Municipal Utilities District Water Conservation, Oakland, California, 2004.

Water-Wise Gardening in the Bay Area, Bay Area Water Supply and Conservation Agency, San Mateo, California, 2008.
Online software available at: www.bawsca.watersavingplants.com/bawsca.php

Regional and National Resources

United States Environmental Protection Agency: Smart Growth & Water Resources
Available at: www.epa.gov/watertrain/smartgrowth/resources/index.htm.

United States Environmental Protection Agency: Managing Wet Weather with Green Infrastructure
Available at: www.cfpub.epa.gov/npdes/home.cfm?program_id=298

United States Environmental Protection Agency: Low Impact Development (LID)
Available at: www.epa.gov/nps/lid/

Using Smart Growth Techniques as Stormwater Best Management Practices
U.S. Environmental Protection Agency, December 2005
Available at: www.epa.gov/smartgrowth/pdf/publications.htm

California Stormwater Best Management Practices: New and Redevelopment Handbook
California Stormwater Quality Association, 2004
Available at: www.cabmphandbooks.com/Development.asp

Portland Stormwater Management Manual
City of Portland (Oregon), September 2004
Available at: www.portlandonline.com/bes/index.cfm?c=35122

City of Portland, Sustainable Stormwater Management Program
Available at: www.portlandonline.com/BES/index.cfm?c=34598

Pervious Paving Resources*

Pacific Southwest Concrete Alliance (website)
Available at: www.concreteresources.net

California Asphalt Pavement Association: Porous Asphalt Pavements (website)
Available at: www.californiapavements.org/stormwater.html

Interlocking Concrete Pavement Institute: Permeable Pavements (website)
Available at: www.icpi.org/design/permeable_pavers.cfm

Invisible Structures, Inc.: Grasspave^2 (website)
Available at: www.invisiblestructures.com/GP2/grasspave.htm

* Note: This listing is for reference use only. The SMCWPPP, C/CAG, and this guidebook does not endorse any proprietary products found within the Pervious Paving Resources list.

Many of the new technologies suggested within the guidebook represent a break from traditional stormwater management practices. New technologies represent progress towards a more natural, integrated management strategy. However, with change comes doubt, and some stakeholders fear negative repercussions that may result from adopting these new technologies. Developers, contractors, designers, and regulatory agencies are all undergoing a learning process through which all parties are gaining familiarity with the critical elements of green street and parking lot projects.

In February 2008, the SMCWPPP invited member municipalities within the City/County Association of Governments (C/CAG) to participate in a survey to determine the potential barriers (constraints), real or perceived, in implementing green streets and parking lots within their respective jurisdictions. Participants of the survey were asked to rank several barriers to implementation in order of importance/significance. There were 27 different constraints identified in the survey, which were organized in four different sections, as follows:

- Policy and Communication Constraints
- Site Characteristic Constraints
- Design-Related Constraints
- Construction/Long-Term Maintenance Constraints

Each respondent was asked to rate the perceived barriers on a scale of 1 to 5. A constraint that ranked closer to the value of "1" is more significant than one ranking closer to "4". The results were tallied and the perceived constraints ranked within each category as shown in the table on the opposite page.

The information gathered from the survey's respondents helped in gauging how to best address their concerns within the guidebook. However, many of the concerns are policy related and need to be addressed outside of the scope of the guidebook. Addressing these "real-world constraints" is a critical component in providing a region-wide program. This guidebook provides potential solutions, or at least, a basis for discussion of how specific concerns can be mitigated.

Survey Results

There were 17 responses from 13 different municipalities. The following page shows the actual survey that was sent to various public works staff as well as the tallied results and individual rankings of each potential constraint. Some of the results are fairly typical of most cities looking to implement green street efforts for the first time. Other responses are interesting to report and help reinforce need for this design guidebook.

Those that participated in the survey predominantly expressed concern over policy/programming-related issues as opposed to design-related constraints. Factors contributing to this result could include: 1). People are looking through a lens of creating a very large and widespread approach to implementing green street programs rather than a smaller-scale, start up program; 2). There is not enough design-related information available regarding green streets and parking lots to trigger design concerns; or 3). There was simply more of an emphasis on policy-related questions presented in the survey than design questions.

Regardless, it is important to note that design and policy go hand in hand. The goal of the guidebook is to provide support for building successful demonstration projects that will ultimately supplement future discussion of policy issues associated with the larger and wide-spread application of green streets and parking lots in San Mateo County.

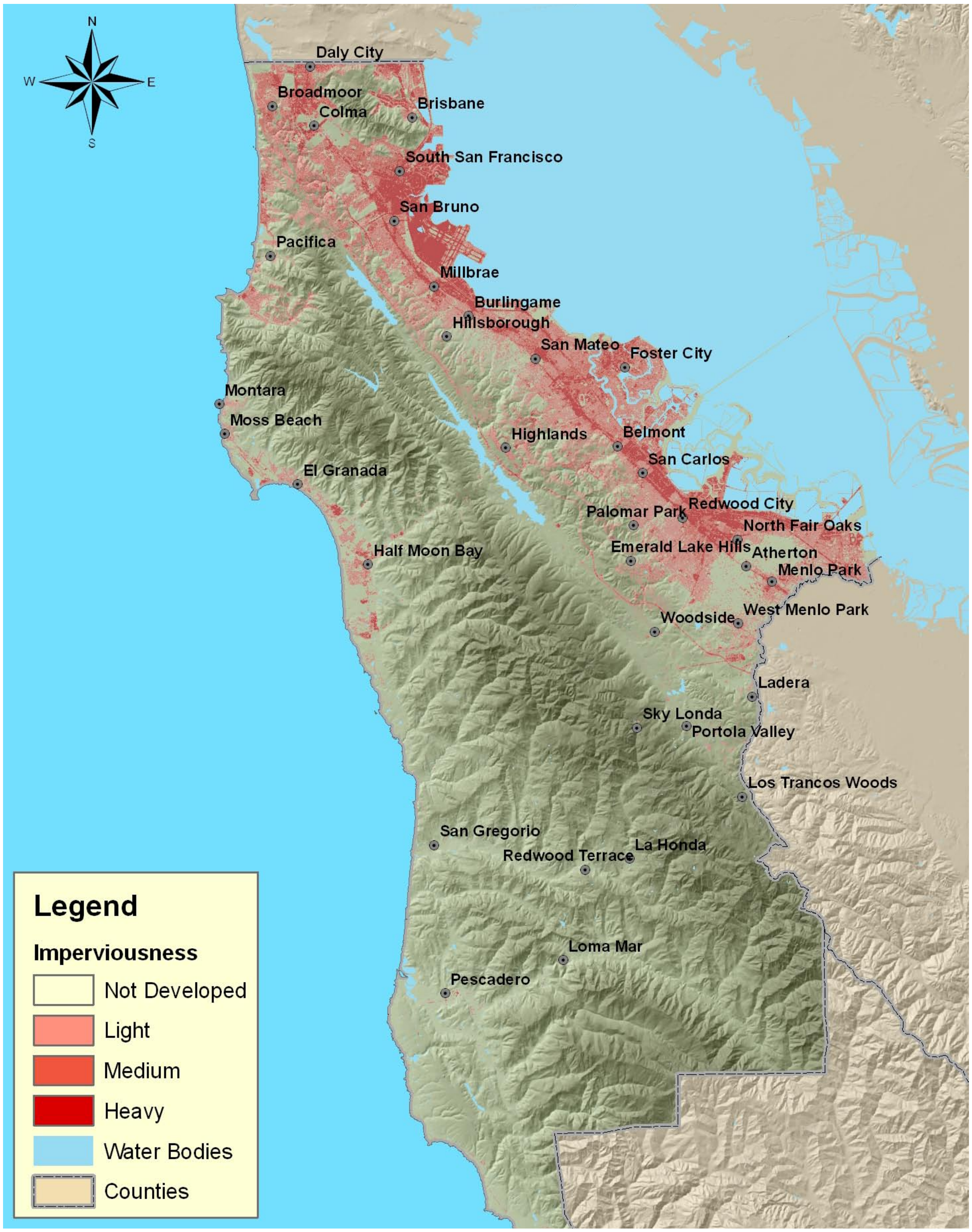
Participants Survey for the San Mateo County Sustainable Green Street and Parking Lot Project

Directions: Please rate the following constraints in implementing green street and parking lot stormwater projects within San Mateo County. Please rate each of these constraints by circling or highlighting the appropriate numbered box. A rating of "1" means the constraint listed is a significant concern. A rating of "4" means the constraint is not a barrier to implementation. A rating of "5" means you don't have enough information to say whether the item is a constraint. Once completed, please fax or email this survey to Fred Jarvis at EOA. The results of your input will be used to better identify, evaluate, and recommend solutions within the San Mateo County Sustainable Green Street and Parking Lot Design Guidebook. Thank you for your help.

CONSTRAINTS TO IMPLEMENTING GREEN STREET AND PARKING LOT PROJECTS

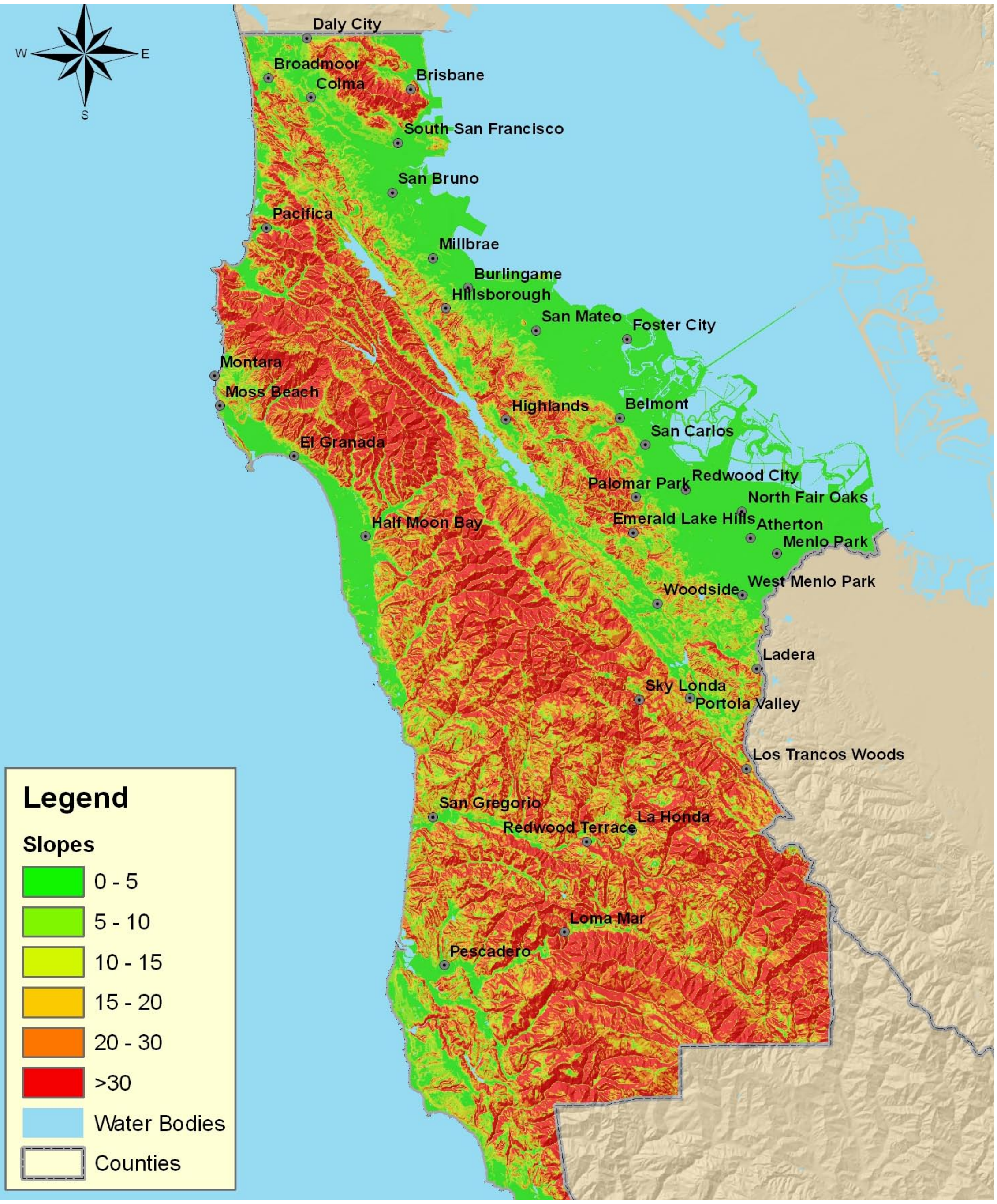
Rating	1	2	3	4	5	
Average Rating	**Rating/Responses**					**Policy and Communication Constraints**
1.3	12	1	0	1	1	Cost issues, especially with retrofit projects.
1.4	10	2	2	0	1	Municipalities do not have the staff resources for creating new policy, design, or maintenance.
1.8	6	4	3	0	2	Lack of incentive for retrofit applications. This would include small private parking lots or public streets.
2.1	4	4	3	1	3	Unrealistic standards and goals are placed upon municipalities by elected officials or policy makers.
2.3	4	4	5	2	0	Lack of municipal staff experience and understanding of landscape-based stormwater design.
2.5	3	4	1	4	3	Some existing municipal codes or policies prohibit use of roadside swales or alternative stormwater designs and don't allow narrowing streets due to emergency vehicle access concerns.
2.6	2	3	4	3	3	These types of projects are not a priority for our municipality.
3.0	0	5	2	5	3	Concern about trying new stormwater management techniques that we are unfamiliar with (risk aversion).
3.3	0	2	7	6	0	Presentation of current guidance/technical information is not user friendly .
3.3	2	3	6	4	0	Difficult to communicate or lack of consensus between affected municipal staff (public works, planning, fire, transportation, etc.).
	Rating					**Site Characteristics Constraints**
1.9	5	5	2	1	2	Not able to infiltrate water because of impermeable soils.
2.4	3	6	3	3	0	Steep slopes in some areas.
2.5	2	4	4	2	3	Conflict with existing utilities.
2.8	6	2	5	2	0	No extra space available for stormwater treatment structures.
	Rating					**Design Related Constraints**
2.1	2	7	4	0	2	Driveway locations along streets limit a continuous stretch of landscape area for potential stormwater facilities.
2.4	2	6	3	2	2	The need for parking trumps the need for landscape space.
2.5	2	3	2	1	7	Potential impact to pavement subgrade from migrating infiltrated water
2.5	4	5	3	1	2	Concerns about the use of pervious paving.
2.6	0	5	6	1	3	Limited variety of design options.
2.7	2	3	5	4	1	Lack of design firms knowledgeable about landscape stormwater design.
2.8	1	4	5	3	2	Lack of local stormwater demonstration projects.
4.0	1	0	3	4	7	Existing built stormwater projects are poorly designed/constructed or exhibit poor peformance.
	Rating					**Construction & Long-Term Maintenance Related Constraints**
1.3	11	2	1	0	1	Municipalities cannot afford for landscape maintenance in the ROW.
2.0	6	2	4	1	2	Inadequate long-term maintenance plan.
2.2	5	3	3	2	2	Lack of contractor experience building stormwater management facilities.
2.4	2	6	4	2	1	Lack of guidance on construction procedures specific to urban BMPs and retrofit projects.
2.7	3	4	0	6	2	Lack of consensus of who is best suited to conduct maintenance activities.

Land use, soil permeability, vegetation, and topography vary considerably across the County. All of these considerations must be taken into account to accurately evaluate the unique opportunities and challenges for stormwater management at any particular site. In order for the strategies described in this guidebook to be effective, they must be matched with the proper physical settings. The figure below shows the countywide distribution of development intensity according to the 2001 National Land Cover Dataset (NLCD).



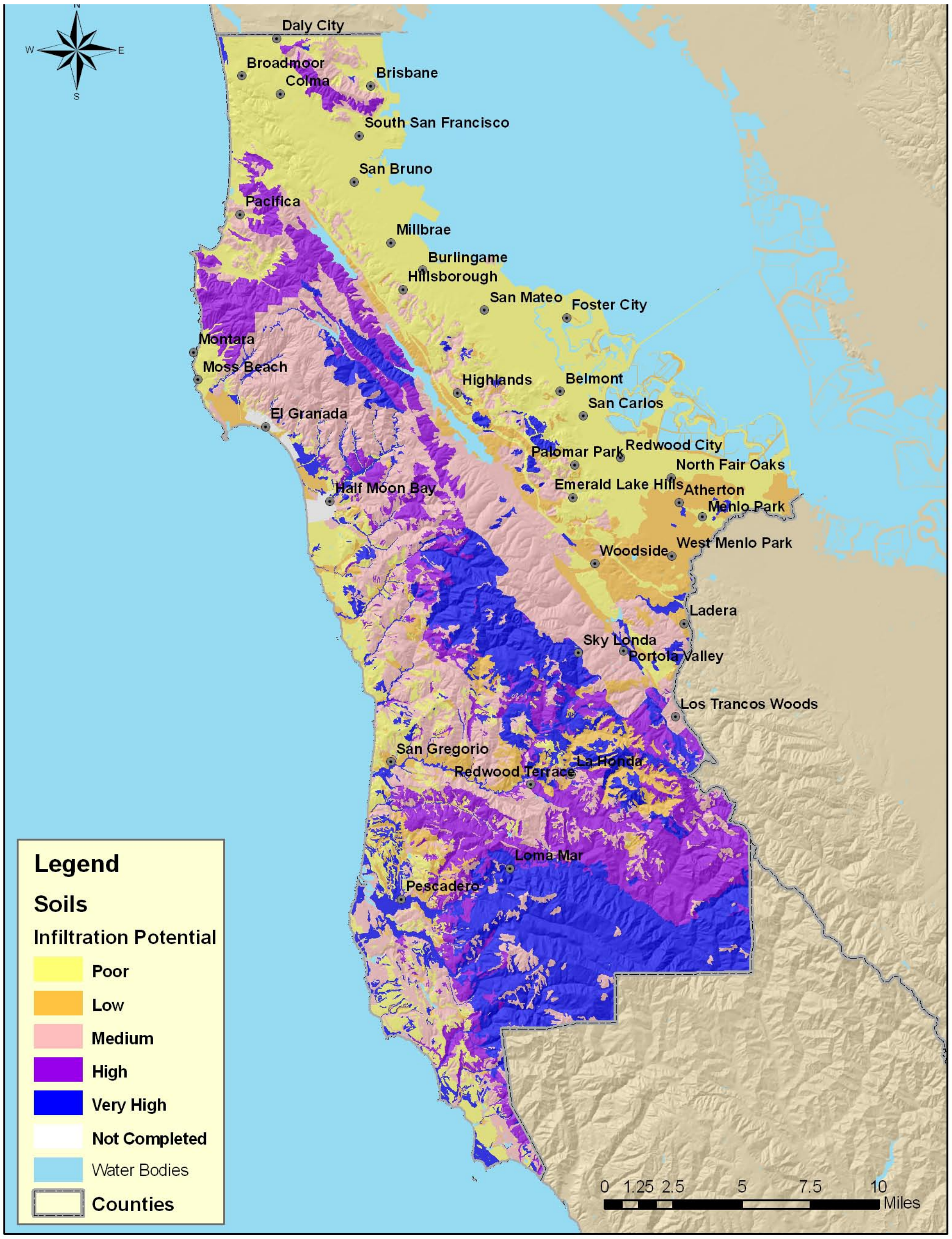
San Mateo County Distribution of Impervious Area

The vast majority of development in the county has occurred in the eastern section bordering the Bay. The figure below shows the distribution of flat (green), moderate (yellow), and steep (red) slopes. As San Mateo County residents know, there are broad swaths of flat land along the Bay and to a lesser extent the coastline, both of which transition sharply moving into the interior to the Santa Cruz Mountains of the Coastal Range. Not surprisingly, the developed areas mainly coincide with flat lands. This is generally positive in terms of integrating stormwater management strategies into new development and retrofitting existing development because stormwater management facilities are easier to install on flat to mild terrain.



San Mateo County Slope Distribution

The figure below shows how hydraulic conductivity (K), which correlates to infiltration capacity, varies across the county. Raw data were obtained from the National Resource Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database, and the most hydraulically restrictive layer within the top 30 inches was identified and taken to represent an expected range of K values. There is a fairly strong correlation between flat lands and low K values, which means that facilities in the flat lands will likely require an underdrain in order to maintain adequate hydraulic capacity. This map should not be used to determine percolation rates at individual sites. More detailed information can be obtained from the NRCS Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx), but site-specific percolation tests must be performed to determine the percolation rate at any given property.



San Mateo County Soil Hydraulic Conductivity Range