EPA United States Environmental Protection Agency

Incorporating Green Infrastructure into Roadway Projects in Santa Fe

Prepared for the City of Santa Fe through Technical Assistance from the U.S. Environmental Protection Agency, Office of Wastewater Management

Cover Photo: Sante Fe Railway Water Tower. Photo: Ron Cogswell (Flickr/CC)

Contents

THIS PAGE INTENTIONALLY LEFT BLANK

1. Introduction

The City of Santa Fe has begun to incorporate green infrastructure practices more and more into public projects and promote the use of green infrastructure on private projects. Green infrastructure includes stormwater management techniques designed to mimic natural site hydrology and promote absorption, infiltration, evapotranspiration, capture and use, or reuse of stormwater. These practices are an effective, efficient way to improve water quality, provide groundwater recharge, and reduce potable water needs for irrigation. Some green infrastructure practices can help Santa Fe build resilience to drought by promoting infiltration, as well as harvesting and using rainwater to help conserve potable water. They also green and beautify roadways, parking lots, patios, or sidewalks. Unlike pipes and other gray infrastructure, green infrastructure practices are usually incorporated into the urban landscape, giving Santa Fe residents and visitors a chance to see and understand the link between green infrastructure and clean water.

The Benefits of Green Infrastructure

- Water quality.
- Reduced heat island effect.
- Groundwater recharge.
- Ecological habitat.
- Public green space.
- Public health.
- Air quality.

Green infrastructure practices manage stormwater through conveyance and filtration systems while removing nutrients and other pollutants through soils and plants. They also provide a host of other benefits:

- Reduction in the urban heat island effect through the replacement of impervious surfaces with pervious pavement options, the addition of greenspace, and increased tree canopy.
- Increased groundwater recharge through infiltration. This is particularly appealing for Santa Fe, where drought can be prevalent.
- Better public health and air quality: they provide green spaces and new habitat for native species.

In 2018, Congress amended Section 502 of the Federal Water Pollution Control Act (33 U.S.C. 1362) to define green infrastructure as "the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters. The resolution promotes green infrastructure as part of an integrated planning process.

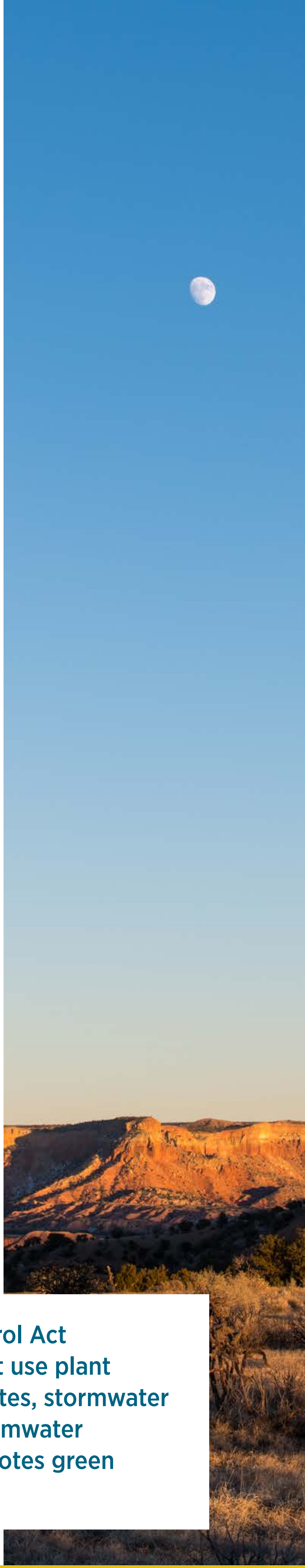


Figure 1. Acequia underpass bioretention. Source: City of Santa Fe

This document focuses on green infrastructure practices in roadway settings, including collector roads and arterial roads, as identified by the Santa Fe Metropolitan Transportation Plan 2015–2040 (Santa Fe MPO, 2015), as well as roundabouts, curb and gutter roads, pedestrian walkways/sidewalks, bike paths, and complete streets (see Figure 1). This document is intended to be a basic primer of practices being employed to promote green infrastructure for stormwater management.

Types of Public Roadways

Public road classifications are defined by state and federal highway transportation agencies. The New Mexico Department of Transportation (NMDOT, 2014) defines those classifications for Santa Fe.

- **Local roads:** Roads that carry no through traffic movement and are used for access to adjacent land.
- **Collector roads:** Roads that collect traffic from local roads and connect them to arterial roads. Collectors typically have a blend of mobility and accessibility characteristics. They are categorized in Santa Fe as urban, rural major, or rural minor.
- **Arterial roads:** Roads that provide high mobility, are used for throughput of travel, and have limited or controlled access. They are categorized in Santa Fe as principal or minor.

The Santa Fe MPO (2015) assigns a classification to each of Santa Fe's roads, using the categories above.

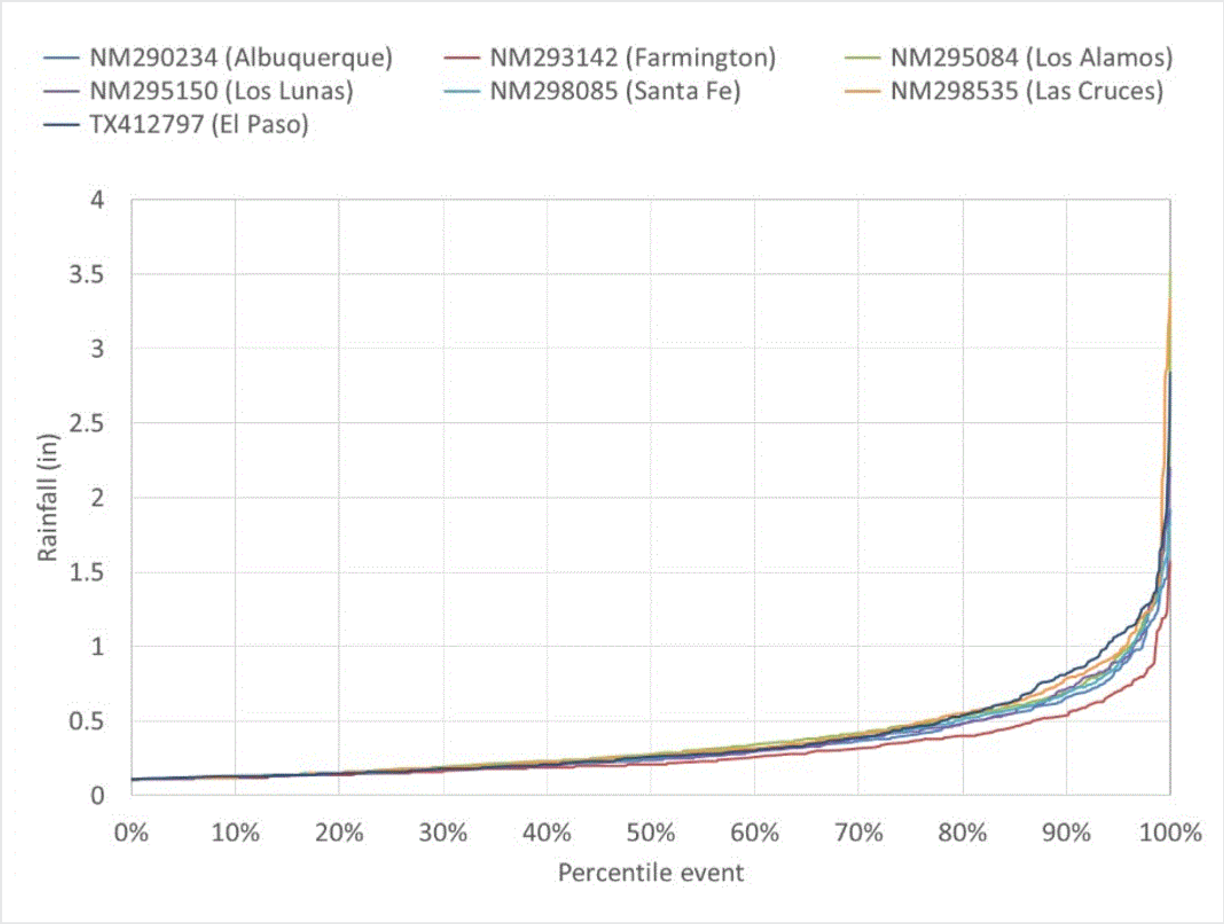


Figure 2. Percentile rainfall analysis for Santa Fe and other New Mexico locations. Source: EPA, 2015
In Santa Fe, 90% of rainfall events produce less than 0.68 inches of rain. It is beneficial to infiltrate this water to replenish the aquifers and support the natural ecosystem.

The green infrastructure practice examples and guidance contained in this document were informed by engineers experienced in stormwater management and green infrastructure design, including planning and engineering staff from the City of Santa Fe. Familiarity with the local landscape and climate is important, particularly in areas like Santa Fe with unique topographical and precipitation-related challenges. In Santa Fe, 90% of rainfall events produce less than 0.68 inches of rain (see Figure 2). It is beneficial to infiltrate this water to replenish the aquifers and support the natural ecosystem. Additionally, design manuals and guidance relevant to the Santa Fe region were used to aid in the guidebook's development. The resources and references list included in Section 7 gives credit to these resources and can also act as a starting point for those in Santa Fe looking to further research green infrastructure implementation and design.

2. Considering Green Infrastructure Within the Broader Project Development Process

Like any other urban area, Santa Fe has a large network of impervious roadways that generate runoff and prevent rain from soaking into the ground. Runoff picks up and transports pollutants from the road surface into nearby waterways, generates flows that cause erosion, and contributes to flooding. Implementing green infrastructure practices in and along roadways can infiltrate, treat, capture, and use stormwater runoff at the source. Roadways also require regular maintenance and improvements; therefore, considering green infrastructure implementation during the early design phase is critical to ultimately constructing roadways that are functional and sustainable over the long term.

Further, Santa Fe can incorporate green infrastructure into improvements the City plans for existing roadway projects, including streetscape improvements, safety upgrades, projects to comply with the Americans with Disabilities Act Act (e.g., curb ramps and pedestrian crossings, or road repairs and other utility work). If the City is prepared with a list of potential green infrastructure projects, it can more easily implement stormwater controls alongside planned redevelopment, road improvement, or pathway projects during the concept and design phases. This reduces not only costs for construction and labor, but also time and costs associated with roadway and sidewalk closures when compared to stand-alone projects. This can also result in a decreased impact to the community due to the hassle of detours and other inconveniences.

In addition, green infrastructure practices that are part of roadway projects may be eligible for government-sponsored clean water or transportation grant and loan program funding. For example, if green infrastructure designs are integrated into roadway projects at the concept or design phase of a roadway project, costs for excavation and landscaping can be covered by different government grant or loan funding programs if the project is contributing to water resource protection goals, such as reduced nutrient or pollutant loading to nearby waterways.

Incorporating green infrastructure into long-term planning may also allow Santa Fe to leverage public-private partnerships and take advantage of mutually beneficial opportunities to install these practices on private properties adjacent to city rights-of-way (ROWs). Public-private partnerships can offer opportunities, not only for green infrastructure implementation, but also for help with maintenance of public and private assets.

The process below—adapted from the Low Impact Development [LID] Standards (Los Alamos National Laboratory, 2017)—offers a project process for implementing green infrastructure at the definition or concept, proposal, and design phases of infrastructure projects. Santa Fe can consider these steps to integrate green infrastructure through different project phases and may want to create a similar checklist representing its own process.

Project Definition Phase

- Incorporate green infrastructure into project scopes and budgets.
- Identify who will maintain and monitor green infrastructure after project completion.

Project Proposal Phase

- Obtain site information showing boundary and existing improvements within project area.
- Identify general topography and drainage pattern.
- Identify existing utilities alignments.
- Identify access and environmental needs.
- Identify the urban-rural design quality for green infrastructure improvements to be used in the project design.
- Add expectation for green infrastructure into design guidance in proposal request.
- Confirm that costs and environmental benefits for green infrastructure improvements are reflected in the bids and final contract.

Want to Know More?

Los Alamos National Laboratory's ***LID Standards*** provides a great deal of information on the benefits of implementing LID and green infrastructure in the region, detailed design specifications, maintenance considerations, and graphical representations of applicable green infrastructure practices for the region.

Los Alamos National Laboratory's LID Standards: https://engstandards.lanl.gov/esm/civil/LID-Standards.pdf.

Project Design Phase

- Analyze the site for potential green infrastructure improvements during plan concept development.
- Ensure a subject matter expert familiar with green infrastructure is involved in reviews and approvals and participates in project development.
- Obtain a topographical survey of the site at minimum 1-foot contours.
- Confirm existing conditions.
- Conduct soils analysis and percolation rate tests as required for proposed design.
- Analyze contributing surface runoff and the potential stormwater capture area.
- Confirm how existing stormwater structures or improvements will affect or be affected by the proposed project.
- Confirm during 30/60/90/100 percent project reviews that green infrastructure is incorporated in the design, cost and environmental benefits estimates.
- Identify hold points for mandatory inspections and approvals during construction.

3. General Design Considerations

This section discusses opportunities and constraints to consider during site analysis and green infrastructure practice selection. The design and programmatic considerations below can be applied across green infrastructure practices. Where applicable, specific practices are referenced. Santa Fe can refer to specific design considerations, provided in the Green Infrastructure Factsheets located in Section 6 of this guidebook. Factors such as water quality and other environmental benefits, the cost associated with maintenance, and the City's ability to perform the maintenance should be considered in the selection process. The City should decide on a specific way to track these stormwater assets so that they continue to function as designed over the life cycle of the practice. There should be a clear understanding of which City department will be managing the design and implementation, and which City department will be the long-term owner and operator of the asset. Defining these responsibilities up front in the design phase will significantly increase the likelihood of successful asset management of green infrastructure practices over the long term.

Soils

- Soils should have optimal infiltration rates above 0.5 inches/hour. Soil percolation tests can confirm infiltration rates. If infiltration rates are low, consider amending soils, adding an underdrain, or installing a minimum 12-inch sand layer under certain practices like bioretention and bioswales.
- Soils that are beneath structural components (e.g., footings, concrete walls) should be compacted to 90 percent or greater dry density. Reduce soil compaction by either mixing with soil amendments or replacing with structural soils or other suitable soil media.
- If trees are planted as part of green infrastructure practices (e.g., tree trenches or trees within bioswales), make sure soil infiltration rates are high enough to prevent tree roots from over-watering. An overflow mechanism may be needed for larger rain events.
- For green infrastructure practices with vegetated plantings, make sure soils can sustain the chosen plantings. In general, tree soils require more moisture holding capacity than soils that support herbaceous plants or xeriscape.
- For permeable pavement practices, carefully consider soil infiltration rates. An overflow mechanism should be installed if needed for larger storms.

Sub-catchment Area

- Consider the drainage area. Most green infrastructure practices in Santa Fe, like tree trenches and bioretention systems, are best for smaller drainage areas. A series of practices can be implemented in the ROW to treat larger drainage areas from major and minor arterial roads.

Site Selection and Available Space

- Avoid steep slopes.
- Evaluate if the site has shallow bedrock or high groundwater. Maintain a separation distance of 2 to 3 feet between the bottom of the practice and the groundwater table, depending on the practice.
- Many green infrastructure practices can be incorporated in distributed, small spaces along ROWs.

Maintenance

- Prune trees and shrubs, remove dead vegetation, and remove plantings as needed to avoid overcrowding. Do not mow vegetation.
- Check for and remove invasive species.
- Remove sediment from forebays in applicable practices (e.g., bioretention). Clean out sediment and debris at inlet structures.
- If soils become compacted, turn or till them.
- Stabilize areas to prevent erosion. Check for signs of erosion and improper root growth.
- Inspect underdrains for obstructions, if applicable.
- Regularly maintain permeable pavement using a vacuum-assisted street sweeper and inspect it for proper drainage as well as to identify any deterioration, cracks and settling.
- Inspect adjacent areas for sources of sediment, such as erosion of uphill areas.
- Be careful in conducting vegetation management that could affect performance (e.g., clogging from grass clippings, leaves dropping/blowing onto the surface).
- Snow plowing should also be done with care to prevent chipping of pavement; avoid storing snow piles on the permeable pavement surface so that sediment and debris will not clog the pores as the snow melts.

Budget

- Propose budget estimates for construction and maintenance at the concept and design phases of a project. Often, maintenance costs are not provided or estimated, and are thus overlooked.
- Certain maintenance—like pruning and trash/debris cleanout—can often be done by private property owners, private sector partners, or through citizen volunteer efforts like Santa Fe's Adopt-a-Median program. However, volunteers who maintain green infrastructure practices should be properly trained. See Section 4 for an example from Portland, Oregon.

4. Maintenance of Green Infrastructure Practices

All stormwater controls - whether green or gray - require maintenance to keep them functioning as designed. The types of maintenance activities vary depending on the practice. Green infrastructure practices are engineered systems, which require regular inspection and maintenance. Maintenance keeps components working as designed and avoids expensive repairs. As Santa Fe implements more green infrastructure practices as part of ROW projects, it may wish to develop a maintenance and monitoring plan for all practices. These plans serve as a reference for engineers, designers, and planners at various stages of the project process. Once a maintenance and monitoring plan is developed, personnel can be trained on maintenance practices specific to green infrastructure including inspection timing and maintenance schedules, costs to include during project budget development, and helpful ways to achieve maintenance goals. It may also be worthwhile to identify departmental responsibilities for maintenance on various sites, such as parks and schools and public ROWs.

In its maintenance and monitoring plan, the City might:

- Identify who is responsible for maintenance and monitoring.
- List the types of maintenance and monitoring activities needed, when they should occur, and (through a checklist) what aspects need to be evaluated.
- Identify performance criteria for each maintenance activity.
- List the estimated annual cost for each activity, including monitoring.

The maintenance and monitoring plan could be integrated with the City's overall asset management plan and tracking software. In addition, departmental procedures can be implemented to ensure that staff members follow the plan and maintenance budgets are adequate. The plan should be updated with changes in technologies and improved engineering practices. The actions listed below are programmatic in nature and would likely require approval from department heads or other decision makers.

- Ensure ongoing maintenance and monitoring by qualified staff.
- Include maintenance and monitoring activities within the annual budget by developing estimates based upon the defined green infrastructure maintenance and monitoring plan.
- Distribute and communicate the schedules for maintenance and monitoring activities at determined locations, outlining the scope of work to be done.
- Perform maintenance and monitoring provide feedback to the maintenance point of contact for unusual conditions, areas needing repairs or special maintenance.
- Integrate changes to the green infrastructure maintenance and monitoring plan based on feedback from the field.

Developing a maintenance and monitoring plan and integrating it with the asset management plan and software can help streamline the process of building green infrastructure in City ROW projects. It can serve as an ongoing resource to City staff and consultants so that these practices do not get lost. By their nature, green infrastructure practices tend to look like traditional landscaping, but maintenance is key to keeping them functional.

If the City implements a volunteer-based "adopt a median" or "adopt a street" program, all volunteers should be properly trained. For example, the Green Street Stewards Program in Portland, Oregon, trains volunteers to help prune vegetated plantings; remove sediment, trash, and debris from practice areas; and add more plantings. Figure 3 illustrates City staff and volunteer maintenance responsibilities for green infrastructure practices in the ROW in Portland, Oregon.

2-YEAR PLANT ESTABLISHMENT PHASE

During this phase, the City or a site developer contracts with professional landscapers to care for and maintain green streets.

The City or professsional landscaper will:

- ☑ Have employees who perform maintenance or monitoring provide feedback to the maintenance point of contact, describing unusual conditions, areas needing repairs, or special maintenance.
- ☑ Remove sediment
- ☑ Clear curb openings and top of overflow drain
- ☑ Remove trash and debris
- ☑ Water vegetation
- ☑ Trim trees and plants, if necessary
- ☑ Replace or remove trees or plants, if necessary

A green street steward can:

- ☑ Remove trash and debris
- ☑ Clear curb openings and top of overflow drain
- ☑ Remove or push aside sedmiment from inlets
- ☑ Water vegation during the summer or an other period of drought

LONG-TERM MAINTENANCE PHASE

The City will monitor and maintain green street facilities, but stewards can help.

The City will

- ☑ Check for proper green street function
- ☑ Remove sediment
- ☑ Clear curb openings and top of overflow drain
- ☑ Remove trash and debris
- ☑ Remove weeds
- ☑ Water vegetation, if necessary
- ☑ Replace or remove trees or plants, if necessary

A green street steward can:

- ☑ Remove trash and debris
- ☑ Clear curb openings and top of overflow drain
- ☑ Remove or push aside sedmiment from inlets
- ☑ Water vegation during the summer or an other period of drought
- ☑ Remove weeds after completing a training course
- ☑ Add additional plants after getting written approval from Environmental Services

Figure 3. Maintenance responsibilities example from Portland's Green Street Stewards Program. Source: City of Portland, 2017

5. Permitting/Regulatory Considerations

Building green infrastructure in roadway settings can help Santa Fe meet municipal and state permitting requirements and regulatory goals. These include, but are not limited to, complying with the City's National Pollutant Discharge Elimination System (NPDES) municipal separate storm sewer system (MS4) permit, New Mexico Department of Transportation (NMDOT) drainage standards for roadways, landscaping requirements, and groundwater recharge or sustainability goals.

- **NPDES/MS4 permit.** EPA issues the New Mexico MS4 general stormwater permit to prevent harmful pollutants from entering Waters of the United States. Green infrastructure practices treat and manage runoff and can serve to meet permit requirements, since they reduce stormwater discharges to storm sewer systems and improve water quality.
- **NMDOT street design.** New Mexico's roadway and highway design standards include specific drainage requirements. Depending on the size and site considerations, green infrastructure practices can improve drainage and thereby help to meet NMDOT drainage requirements (NMDOT, 2018).
- **Landscaping requirements.** Landscaping is often required as part of the design of certain roadway elements, such as sidewalk bump-outs or curb extensions. Green infrastructure in landscaping can be an efficient use of public spaces, managing stormwater while providing other amenities and improving aesthetics. Incorporating green infrastructure into landscaping can reduce irrigation needs by using captured stormwater to sustain plantings.
- **Water resources protection.** Augmenting water supply is critically important in the arid Southwest. Green infrastructure practices can be designed to absorb water on site, rather than discharging runoff to the storm sewer system. At the same time, they offer local flood protection benefits—capturing a portion of runoff and minimizing roadway flooding. Green infrastructure plantings may self-sustain from rainfall, needing minimal potable water for irrigation. This can reduce water needs and staff time and equipment to irrigate roadside landscaping.
- **Drought resilience goals.** Communities in arid climate regions, like Santa Fe, experience both long droughts and isolated heavy precipitation events. Green infrastructure practices offer the ability to capture relatively large volumes of stormwater on site and recharge groundwater supplies, meeting drought resilience goals and reducing the need for irrigation to plantings.
- **Sustainable Santa Fe (SSF).** In its 2015 Sustainability Benchmarks Report, SSF recommends that city staff collaborate with the Santa Fe Watershed Association. The Santa Fe Watershed Association is in the process of

implementing strategies to achieve achieve sustainability goals, including the development of a 75-year plan for a healthy urban forest that sequesters carbon, reduces the heat island effect, absorbs stormwater, controls erosion, keeps moisture in the local environment, and improves air quality. As mentioned in Section 1, green infrastructure practices can incorporate trees and increase tree canopy, helping the City meet a combination of these goals.

6. Green Infrastructure Practice Factsheets

This section details five green infrastructure practices in a series of factsheets (all specific to ROW implementation and focused on promoting infiltration and absorbing runoff and filtration of pollutants to improve water quality).

- **Bioretention system.** A shallow landscape depression sited at a low point to collect, treat, and infiltrate stormwater. Typically designed for water quality treatment; can also provide minor flood storage with enough space.
- **Tree trench.** A double-duty street tree pit, apparently ordinary above ground and matching the natural surroundings. Underneath, engineered soils, gravel bedding, and underdrain pipes promote healthier tree growth with the added benefits of nutrient uptake, pollutant removal, and some capacity for flood storage.
- **Permeable pavement.** An alternative to traditional pavement that allows infiltration through openings in the pavement and into a gravel drainage layer to reduce runoff and trap suspended solids. Permeable pavement includes porous asphalt, pervious concrete, and permeable pavers. It is typically designed to reduce runoff volumes. In the appropriate setting, it can include an extended gravel reservoir for additional minor flood storage. Porous asphalt can be used as a friction course on existing pavement to reduce road noise, splash and spray, and hydroplaning. Permeable pavement can promote traffic calming in certain installations.
- **Bioswale.** A linear landscape element widely used along roads with narrow ROWs.
- **Impervious pavement reduction.** Roadway projects should evaluate the amount of pavement needed. Often referred to as a "road diet," reducing unneeded pavement can improve pedestrian safety by reducing crossing distances and creating distance between cars and cyclists and pedestrians. Pavement can be replaced with planting beds, washed gravel, permeable pavement, or vegetated stormwater management practices.

These practices can be used in a variety of City ROW locations, including medians, roundabouts, vegetated edges, curbs and gutters, pedestrian/bike paths, cul-de-sacs, parking lots, and courtyards/patios. Note, though, that designs should be site-specific and consider suitability factors such as topography and slope, infiltration rate, drainage area, locations of utilities, property ownership, driveway access needs and curb cuts, etc. Section 3 further discusses general design considerations.

Please Share!

The factsheets in this section can be excerpted as "cut sheets" to convey information concisely to City departments and staff. Private developers and engineers can use the information as a reference for road redesign and reconstruction projects, redevelopment and urban renewal/revitalization, streetscape design, and maintenance of roadways and landscaping.

Green Infrastructure Factsheet: BIORETENTION SYSTEM

A **bioretention system** is a shallow landscape depression sited at a low point and designed to collect, treat and sometimes infiltrate stormwater runoff. Bioretention is an aesthetically pleasing, sustainable landscaping element within a roadway setting as well as a functional infrastructure element. It provides multiple benefits to the surrounding human and natural environments.

Bioretention systems can:

- Infiltrate stormwater and recharge the aquifer.
- Reduce pollutants delivered to receiving waters.
- Reduce the need for potable water sources for landscape irrigation.

Bioretention practices are typically designed for water quality treatment through filtration, biological uptake, and microbial activity. With adequate space, they can provide some flood storage. They can also be designed for double duty as roadway bump-outs that provide traffic calming and improve pedestrian safety by reducing the length of cross-walks.

BENEFITS

- ☑ Recharges groundwater.
- ☑ Reduces long-term irrigation needs and potable water dependency.
- ☑ Reduces pollutants and improves water quality.
- ☑ Improves aesthetics.
- ☑ Prevents surface ponding during small rain events, but should include an overflow mechanism to accommodate heavy rainfall.
- ☑ Provides carbon sequestration.
- ☑ Provides shade and reduces urban heat island effects.
- ☑ Improves air quality.
- ☑ Increases value of the surrounding area.

A small bioretention system at the intersection of Espinacitas and Hopewell streets in Santa Fe, constructed in 2016 through the retrofit of an existing vacant curb median. Photo: Santa Fe Watershed Association

DESIGN CONSIDERATIONS

Planning-Level Costs

- Low cost/acre for rural applications ($–$$). Can be moderate to high for urban locations ($$$).

Physical Site Characteristics

- Bioretention is challenging on streets with steeper slopes. Incorporate diversion berms, check dams or terraces so the bottom is relatively flat (1 to 5 percent grade).
- Consider if the site has shallow bedrock or high groundwater. Use in areas where porous underground material (i.e., tuff) is at least 18 inches below the bottom of the system.
- Avoid groundwater contamination by separating the system from the groundwater table; a distance of 2 feet is recommended between the bottom of the excavated bioretention area and the seasonally high groundwater table.
- Consider potential groundwater contamination. Consider using other solutions for drainage areas with gas stations, chemical storage areas and other areas that could have hazardous spills.
- Consider the drainage area. Bioretention can serve a highly impervious area smaller than 2 acres, and the surface area of the practice should be about 3 to 6 percent of the contributing drainage area. The sediment trap or forebay should be sized to contain at least 5 percent of the total detention volume.

Design Elements

- The top elevation of the sediment trap interior wall should be at least 4 inches below the gutter inlet elevation.
- Interior walls within the planting area should be at most 4 inches below gutter inlet elevation.
- Consider the amount of nearby pedestrian activity; install walkways or bridges across the system if needed.
- Design to avoid conflicts with subsurface utilities.

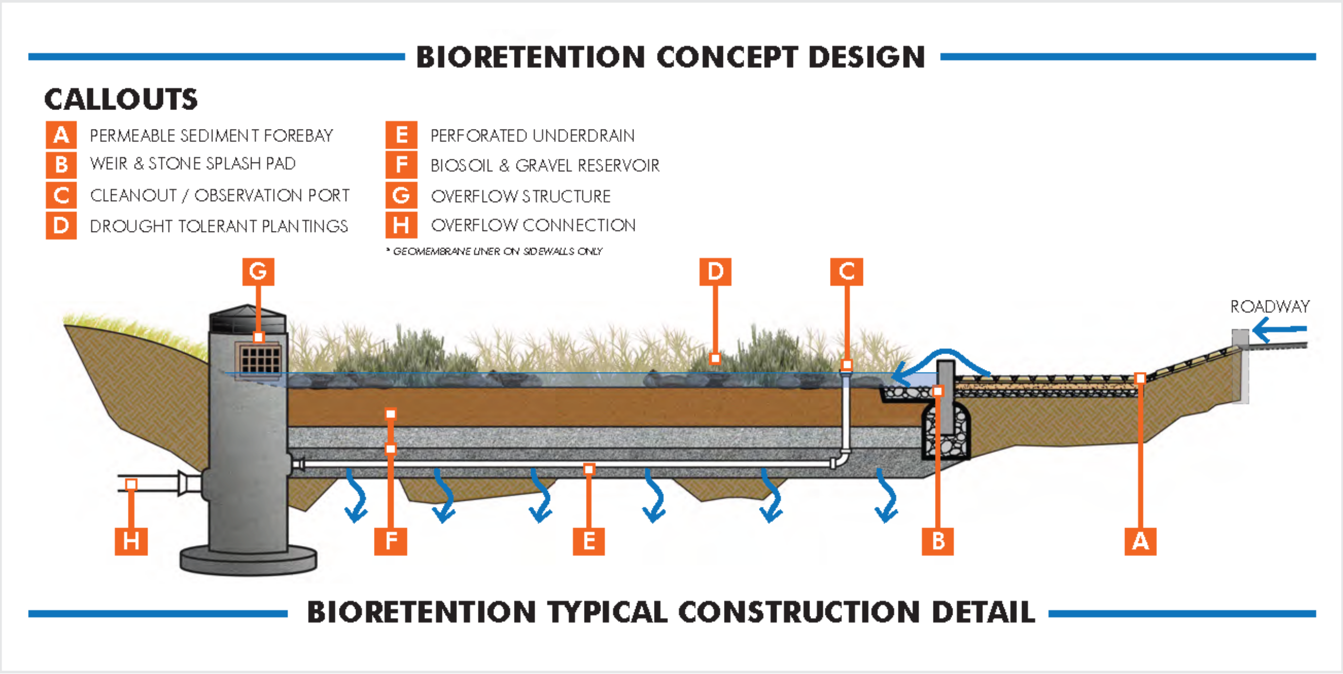
Pretreatment

- Sediment forebay/sediment trap, gravel, or stone diaphragm.

Soils

- Soils should have a suitable infiltration rate. If the infiltration rate is below 0.5 inches/hour, consider amending soils, including an underdrain to allow filtration before overflow, or installing a sand layer at least 12 inches thick under the basin.
- Reduce soil compaction by either mixing the soil with amendments or replacing it with structural soils or other suitable soil media.
- Soils should be suitable to sustain the selected plantings. In general, tree soils need more moisture-holding capacity than soils that support herbaceous plants or xeriscape.

Banner photo in the previous page: West Alameda rain garden near Sicomoro Street in Santa Fe. Photo: Santa Fe Watershed Association



Bioretention system with underdrain and infiltration into the subsurface. Diagram: Horsley Witten Group

Vegetation

- Vegetation should be drought-tolerant, able to withstand periodic inundation, and salt-tolerant.
- The planting zone should be stabilized with a 3-inch depth of shredded hardwood or rock mulch (crushed rock, pea gravel, or small stones).

CONSTRUCTION CONSIDERATIONS

- Where relying on existing soils for infiltration, do not over-compact basin soils. Compaction can reduce infiltration rates by increasing bulk density of the soil.
- Identify appropriate materials and hold points for inspection and approval.
- Ensure that design and construction incorporate maintenance access.

MAINTENANCE

- Inspect for the following at least annually, and repair as needed: adequate perennial vegetation coverage; erosion; degradation of check dams and other structures; debris, trash and sediment accumulations; and runoff flow through the full length of the system.
- Prune trees and shrubs, remove dead vegetation, and remove plantings as needed to avoid overcrowding.
- Check for and remove invasive species.
- Do not mow vegetation.
- Remove sediment from the forebay regularly.
- Remove trash and dead vegetation regularly.
- Stabilize any areas to prevent erosion.
- If soils become compacted, turn or till soils.

Green Infrastructure Factsheet:
TREE TRENCH

A **tree trench** is a type of infiltration trench containing one or more trees, located in a street ROW typically between the street and the sidewalk. It combines the benefits of a street tree with the efficiency of a stormwater infrastructure element, improving the surrounding human and natural environments using only minimal surface space. Most importantly, tree trenches provide an opportunity to infiltrate and evapotranspire stormwater, recharge the aquifer, reduce pollutants delivered to receiving waters, and reduce the burden that landscaping can have on potable water sources for irrigation. Tree trenches are typically designed for water quality treatment and to promote healthier tree growth. With adequate space, the practice can provide modest flood reduction benefits. In a ROW, stormwater runoff enters the trench through one or more catch basins, passes through crushed stone, is conveyed through an underdrain to one or more tree plantings, and fills void space. Larger storms overflow back through the catch basin.

BENEFITS

- ☑ Recharges groundwater.
- ☑ Reduces pollutants/improves water quality.
- ☑ Improves aesthetics.
- ☑ Increases habitat value.
- ☑ Provides shade/reduces urban heat island effects
- ☑ Provides carbon sequestration.
- ☑ Improves air quality.
- ☑ Reduces long-term irrigation needs/potable water dependency.
- ☑ Uses minimal surface space.

Applications

- Roadway medians.
- Roundabouts.
- Rights-of-way/vegetated roadway edges.
- Curb and gutter roadways.
- Pedestrian, bike and multi-use paths.
- “Complete” streets for multi-modal transportation.
- Parking lot islands/edges.
- Cul-de-sacs.
- Courtyards/patios.

Curb inlets to tree trench pavilions in an Albuquerque parking lot. Photo: Tess Houle

DESIGN CONSIDERATIONS

Planning-Level Costs

- Moderate cost/acre ($$).

Physical Site Characteristics

- Tree trenches are challenging to design on steep slopes. If slopes are greater than 4 or 5 percent, consider a terraced approach.
- Consider if the site has shallow bedrock or high groundwater. A separation distance of 3 feet is recommended between the bottom of the trench and the seasonally high groundwater table to avoid groundwater contamination.

Design Elements

- Center the tree trench about 4 to 6 feet behind the back of the curb to preserve the step-out zone on the curb side of the trees and the sidewalk on the other.
- The soil medium is typically 3 to 4 feet wide, 6 to 8 feet long, and up to 4 feet deep. When combined with a stone storage reservoir, cobbles, or synthetic media, this typically gives tree roots enough space to grow and expand. Proper sizing will help prevent sidewalk upheaval from root growth.
- Permeable pavement is an option above the tree trench to intercept more stormwater and help provide oxygen to the roots of the tree.
- Tree trench sections can be constructed back to back for any length desired. However, 1 inlet and water control structure are recommended for every 3 trees.

Pretreatment

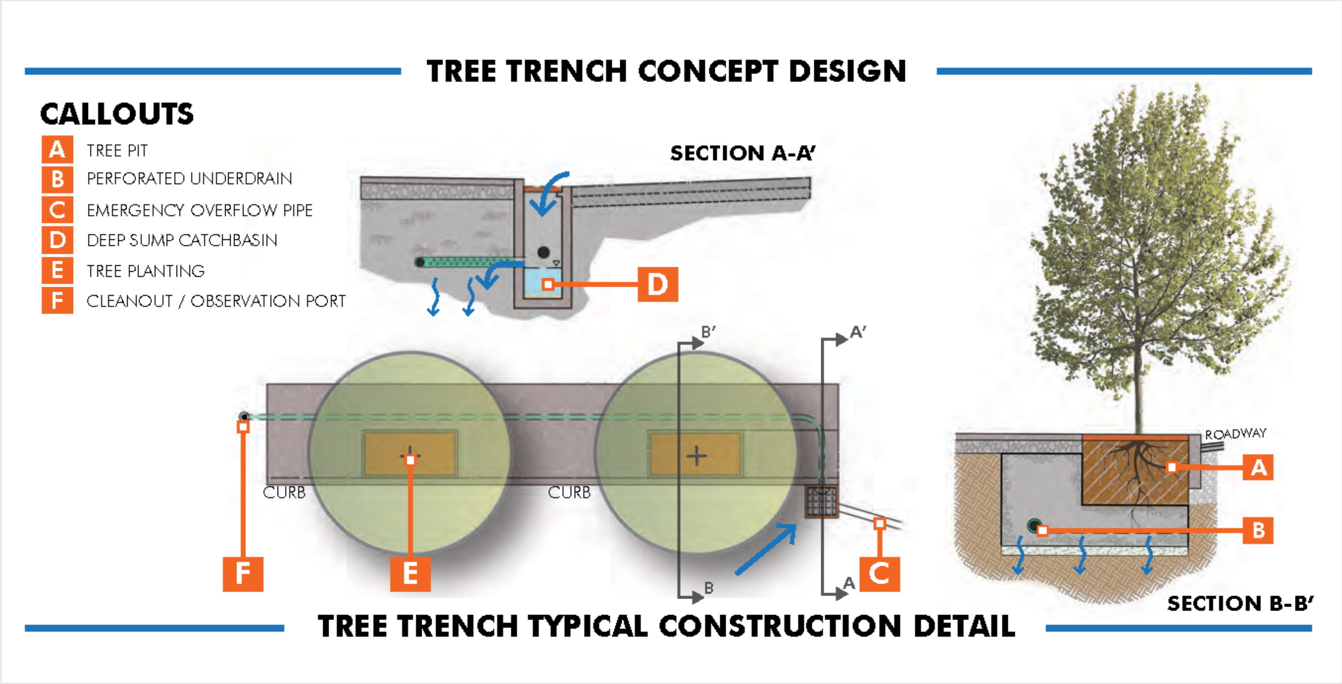
- Pretreatment filter designed with media (e.g., pea gravel).

Soils

- Soil infiltration rates must be enough to prevent tree roots from drowning. An overflow mechanism may be needed for larger rain events.

Vegetation

- Aboveground or subsurface utilities can provide challenges. Choose trees with maximum growth potential less than the height of the utility (usually about 30 feet). Factor in enough space to protect underground utilities from roots and water.
- The chosen trees should be well suited to the trench size and the distance to adjacent structures to avoid conflicts or restrictions on root growth.
- Use xeriscaping. Xeriscaping uses vegetation compatible with the New Mexico environment and offers cooling and habitat while using less water than other vegetation types.
- Water for trees should be applied as efficiently as possible and only when necessary. Drip, bubbler, and micro-spray systems or soaker hoses are appropriate for trees.



Example tree trench design. Diagram: Horsley Witten Group

CONSTRUCTION CONSIDERATIONS

- Do not over-compact soil while delivering plants to the planting locations, digging planting holes, and installing plants. Compaction can reduce infiltration rates by increasing bulk density of the soil.
- Examine the surface grades and soil conditions. Only plant when weather and soil conditions are suitable, in accordance with locally accepted practices.
- When possible, plant trees before other plants.

MAINTENANCE

- Remove sediment and trash from the catch basin and remove trash and dead vegetation from the tree trench.
- Upkeep of vegetation includes occasional weeding, pruning and removal of invasive species/ pests.
- If mulch is used, check whether it needs to be replaced.
- Turn or till soil if compaction occurs.
- Check for signs of erosion and improper root growth.
- Check that the irrigation system is functioning properly; adjust automatic irrigation systems as the seasons change.
- Inspect the underdrain for obstructions.

Green Infrastructure Factsheet:
PERMEABLE PAVEMENT

Permeable pavement is any paving material that allows rainwater and snowmelt to infiltrate where it falls, including permeable pavers, porous asphalt, pervious concrete, and reinforced gravel/aggregate soils. It provides the benefits of green infrastructure without losing the functionality of traditional pavement. Most importantly, it provides an opportunity to infiltrate/retain stormwater, recharge the aquifer, and reduce pollutants delivered to receiving waters. The porous paving materials are underlain by a designed sub-base that allows stormwater to percolate through the sub-strata for temporary storage and/or infiltration. Examples include porous asphalt, pervious concrete, pervious pavers, permeable interlocking concrete pavement, and concrete grid pavement.

Applications

- Roadways.
- Pedestrian, bike, and multi-use paths.
- Parking lots.
- Cul-de-sacs.
- Courtyards/patios.
- Areas with light traffic within commercial and residential sites.

BENEFITS

- ☑ Recharges groundwater.
- ☑ Reduces pollutants/improves water quality.
- ☑ Prevents surface ponding during small rain events.
- ☑ Reduces runoff temperatures.
- ☑ Uses minimal surface space.
- ☑ Reduces road noise.
- ☑ Reduces roadway splash and spray, as well as pollutant wash-off from auto undercarriages.
- ☑ Improves safety by reducing hydroplaning.

Permeable pavement used in a low-volume parking lot. Photos: Los Alamos National Laboratory, 2017

DESIGN CONSIDERATIONS

Planning-Level Costs

- Moderate cost/acre ($$).

Physical Site Characteristics

- Permeable pavement is only recommended for gentle slopes (below 5 percent). The bottom of the infiltration bed should be level or near level. Consider terracing if needed.
- Consider potential groundwater contamination and depth to water table. Consider other solutions for drainage areas with gas stations, chemical storage areas, and other areas that could have hazardous spills.
- Appropriate for use in light traffic areas where heavy loads are limited, due to the lower resistance to stress than traditional pavement.

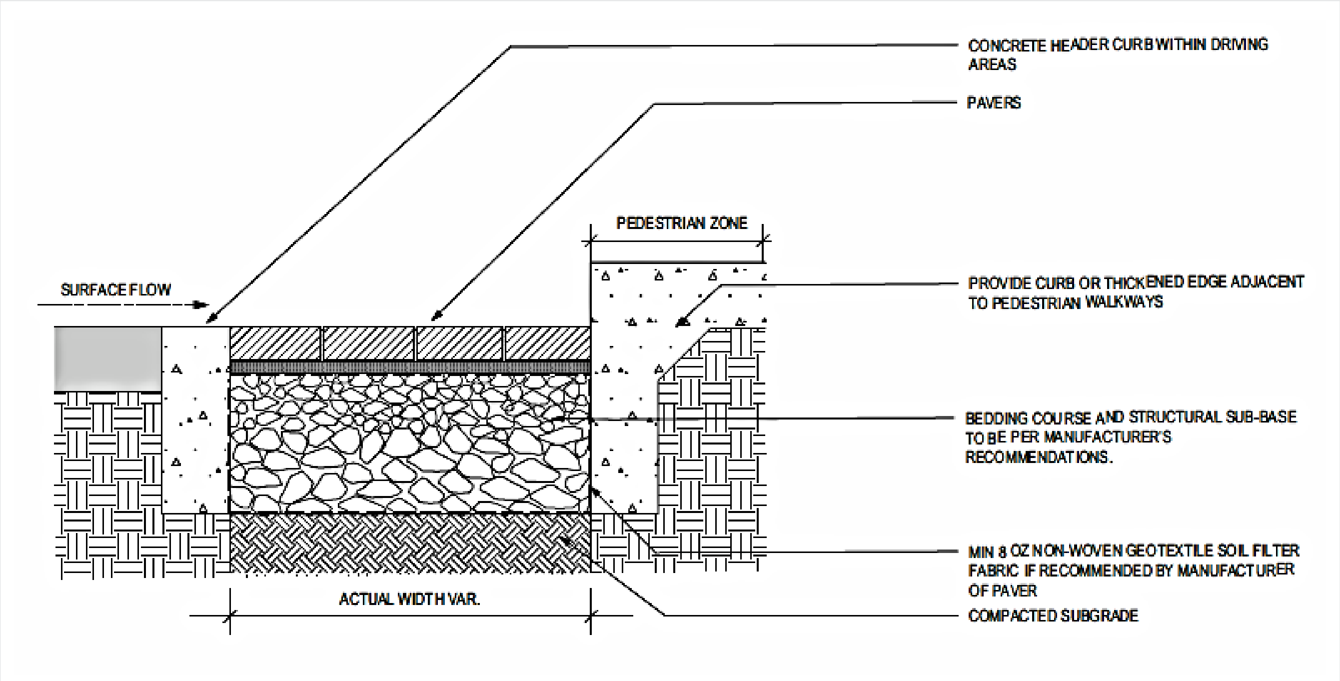
Design Elements

- All permeable pavements have a similar structure: a surface pavement layer, an underlying stone aggregate reservoir layer, optional underdrains, and geotextile over uncompacted soil subgrade. Details may vary, though. Design per manufacturer recommendation.
- Consider snow management. Avoid applying sand for traction, since it can clog the surface material. Do not use permeable pavement as a storage area for plowed snow.
- Permeable pavement is appropriate for infiltrating the precipitation that falls directly on it. Accumulated runoff from adjacent impervious areas can carry sediment and organics that can clog the system and reduce infiltration capacity; directing this runoff onto permeable pavement is not recommended. If this approach is taken, first consider runoff ratios and the types of source area in the drainage area. The directed runoff should be pretreated to remove sediments and other pollutants that can clog the system. For installations next to traditional pavement, consider elevating the permeable areas to avoid run-on.
- Runoff from adjacent vegetated areas can carry sediment, which can clog the system. Stabilize adjacent vegetated areas to limit sediment transport.

Soils

- Suitable soil infiltration rates are required. An overflow mechanism may be needed for larger rain events. Amend or replace soils to improve permeability. For storms beyond the infiltration/storage capabilities of the pavement, the design should ensure that the excess runoff does not harm downstream water bodies.
- Consider designs to address clay soils with high shrink-swell capacity. Increase the sub-base depth and/or add geogrids to provide additional support.

Banner photo in the previous page: Allston Way in Berkeley, California, was completely renovated with permeable interlocking concrete pavers. Photo: Clean Water Program



Cross section of permeable pavement installation. Source: Los Alamos National Laboratory, 2017

MAINTENANCE

- Sweep or vacuum the roadway with a vacuum sweeper to ensure that clogging does not occur.
- Inspect for proper drainage and to identify any deterioration, cracks, and settling.
- Inspect adjacent areas for sources of sediment (e.g., erosion of uphill areas) and vegetation management activities that could affect performance (e.g., grass clippings).
- Pervious pavements can reduce winter maintenance needs. Do not use sand for winter maintenance; use deicers only as needed. Icing is rare, because water infiltrates instead of ponding and freezing.
- Plow snow with care to prevent chipping of pavement. Do not store snow piles on the surface. They generally contain sediment and debris that will clog the system as the snow melts.

CONSTRUCTION CONSIDERATIONS

- Do not over-compact basin soils where relying on existing soils for infiltration. Compaction can reduce infiltration rates by increasing bulk density of the soil.
- Ensure that subgrades are properly installed to prevent the finish surface from becoming uneven over time.
- Identify appropriate materials and hold points for inspection and approval. Failure to follow the recommendations will likely cause premature structural failure.

Green Infrastructure Factsheet: BIOSWALE

Bioswales are broad, shallow, vegetated depressions designed to convey, treat, and infiltrate stormwater runoff. They serve as both an attractive, sustainable landscaping element in a roadway setting and a stormwater infrastructure element, and they provide multiple benefits to the surrounding human and natural environments. Most importantly, they provide an opportunity to infiltrate stormwater, and recharge the aquifer, reduce pollutants delivered to receiving waters, and reduce the burden of landscaping on potable water sources for irrigation. They are similar in function to bioretention systems except that they are linear and provide some conveyance of runoff. A swale can be designed with a hard edge to promote linear conveyance of stormwater runoff from impervious surfaces to localized basins. Check dams incorporated into the swale design allow water to pool and infiltrate into the underlying soil or engineered media, thus increasing the volume of water treated, especially in areas with steeper slopes.

BENEFITS

- ☑ Recharges groundwater.
- ☑ Reduces runoff rate and volume.
- ☑ Reduces pollutants/improves water quality.
- ☑ Prevents surface ponding during small rain events.
- ☑ Improves aesthetics.
- ☑ Increases value of the surrounding area.
- ☑ Provides shade/reduces urban heat island effects.
- ☑ Provides carbon sequestration.

Applications

- Roadway medians.
- ROWs/vegetated roadway edges.
- Curb and gutter roadways.
- Pedestrian, bike and multi-use paths.
- "Complete" streets for multi-modal transportation.
- Parking lot islands/edges.

A bioswale with bioretention/bioinfiltration taking stormwater from a parking lot. Photo: Arid LID Coalition

DESIGN CONSIDERATIONS

Planning-Level Costs

- Low to moderate cost/acre ($$). Potentially less expensive installation than traditional curb and gutter systems.

Physical Site Characteristics

- Challenging on steep slopes. Make longitudinal slope as flat as possible, not greater than 5 percent. Check dams or V-weirs can be incorporated for steeper settings to prevent erosion by reducing flow velocity. Check dams or weirs can also enhance treatment by increasing the volume of water retained and increasing the contact time between soil or media and runoff water.
- Consider if the site has shallow bedrock or high groundwater. Avoid groundwater contamination by separating the system from the groundwater table. A separation of 3 feet is recommended between the bottom of the excavated bioretention area and the seasonally high ground water table.
- Consider using other solutions for drainage areas with gas stations, chemical storage areas, and other areas that could have hazardous spills.

Design Elements

- Consider the amount of nearby pedestrian activity and provide walkways or bridges across the practice if needed.
- Design to avoid conflicts with subsurface utilities.
- Install appropriate erosion and flow dissipaters at the entry and exit points of the swale.

Pretreatment

- Pretreatment can be provided by sediment forebays, vegetated filter strips/side slopes, and/or water quality inlets.
- Bioswales can also serve as pretreatment to a bioretention or bioinfiltration system.

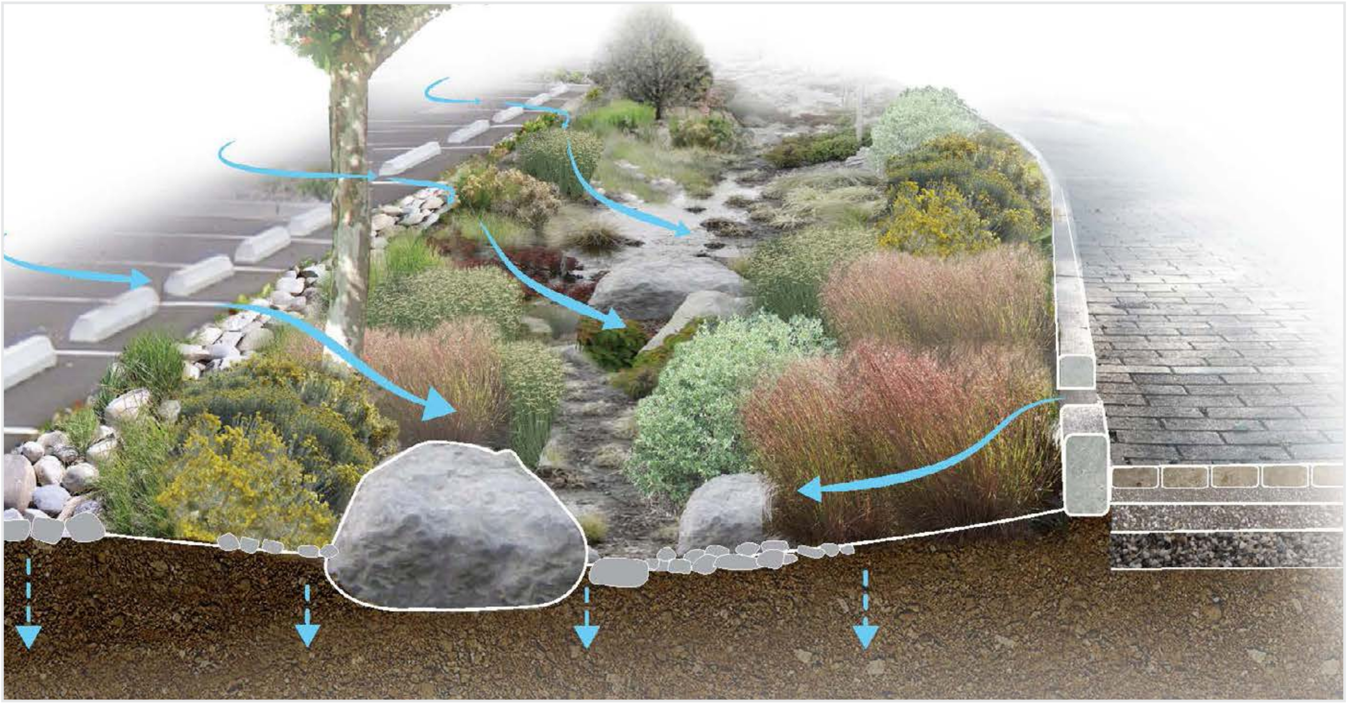
Soils

- Soils should have a suitable infiltration rate. If the infiltration rate is below 0.5 inches/hour, consider including a perforated underdrain connected to the drainage network to reduce overflows and increase safety. Other alternatives include amending soils, installing a minimum 12-inch sand layer under the basin, or using a dry swale with engineering media instead.
- Not suitable for highly erodible soils.
- Soils should be native or amended soils suitable to sustain the selected vegetation.

Vegetation

- Vegetation should be native, drought-tolerant, salt-tolerant, and able to withstand periodic inundation.

Banner photo in the previous page: Impervious surface in a parking lot replaced by a landscaped infiltration facility. Credit: Los Alamos National Laboratory, 2017



Example design of a vegetated swale/bioswale. Source: Surroundings

CONSTRUCTION CONSIDERATIONS

- Do not over-compact basin soils where relying on existing soils for infiltration. Compaction can reduce infiltration rates by increasing bulk density of the soil. Avoid using heavy equipment directly on bioswale soils during site preparation and construction.
- Identify appropriate materials and specify times for inspection and approval.
- During construction, use sediment and erosion control measures to prevent sedimentation from upgradient construction activities. When practical, complete upgradient work before swale installation.

MAINTENANCE

- Inspect at least annually for adequate perennial vegetation coverage, erosion, and degradation of side slopes.
- Remove sediment, trash, and dead vegetation at inlets and outlets to avoid clogging.
- Manage vegetation by regular weeding, pruning, removing invasive species, and revegetating as needed.

Green Infrastructure Factsheet: IMPERVIOUS PAVEMENT REDUCTION

Impervious pavement reduction is the retrofitting of an existing property or revising the design before new construction to reduce the volume of stormwater runoff generated at a site. It is an effective way to preserve a site's predevelopment stormwater runoff characteristics. Through pavement reduction, remaining pervious areas on a site can absorb and infiltrate stormwater runoff.

Impervious areas—such as roads, parking lots, building surfaces, walkways, and driveways—increase stormwater runoff volumes and can contribute to flooding and streambank erosion. Impervious surfaces also facilitate the wash-off and transport of pollutants like oil, grease, nutrients, and sediment into downstream rivers, lakes, and wetlands. A practical, simple, cost-effective approach is to identify and remove unnecessary pavement in the design phase of a new development or during the retrofit of a redeveloped site. Pavement reduction limits the size of streets, sidewalks, driveways, parking spaces, and other impervious surfaces by designing them efficiently to avoid excess unnecessary paved areas. Pavement reduction is also frequently used to improve roadway safety through road diets and other efforts. Replacement surface treatment may include hydroseeding, artificial turf, planting beds, washed gravel, pavement and pavers, or vegetated stormwater management.

By helping protect or restore the natural hydrological conditions of a site, impervious pavement reduction can also reduce stress on downstream waters.

Applications

- Roadway medians.
- Roundabouts.
- Rights-of-way/vegetated roadway edges.
- Curb and gutter roadways.
- Pedestrian, bike and multi-use paths.
- "Complete" streets for multi-modal transportation.
- Parking lot islands/edges.
- Cul-de-sacs.
- Courtyards/patios.

BENEFITS

- ☑ Recharges groundwater.
- ☑ Reduces runoff rate and volume.
- ☑ Reduces pollutants/improves water quality.
- ☑ Improves aesthetics.
- ☑ Reduces the burden on/size of downstream stormwater management systems.
- ☑ Increases habitat value.
- ☑ Improves public safety.

DESIGN CONSIDERATIONS

Planning-Level Costs

- Low cost/acre ($), especially for incorporating this approach into the initial design rather than removing pavement after construction. If the natural, pervious surface is retained during design, costs are lower than if an existing impervious surface is removed and revegetated.

Physical Site Characteristics

- Shifts excess area for parking and travel lanes to other functions.

Right-Sized Streets

- Reduce street widths and improve traffic safety where feasible by eliminating underused on-street parking or reducing lane width.
- Largely applicable in residential neighborhood roads.
- Local public works, police and fire departments, and residents who fear losing parking spaces and accessibility may object to narrower streets. Permeable pavement could be used as an alternative for parking and other areas to address this concern.

Right-Sized Cul-de-Sacs

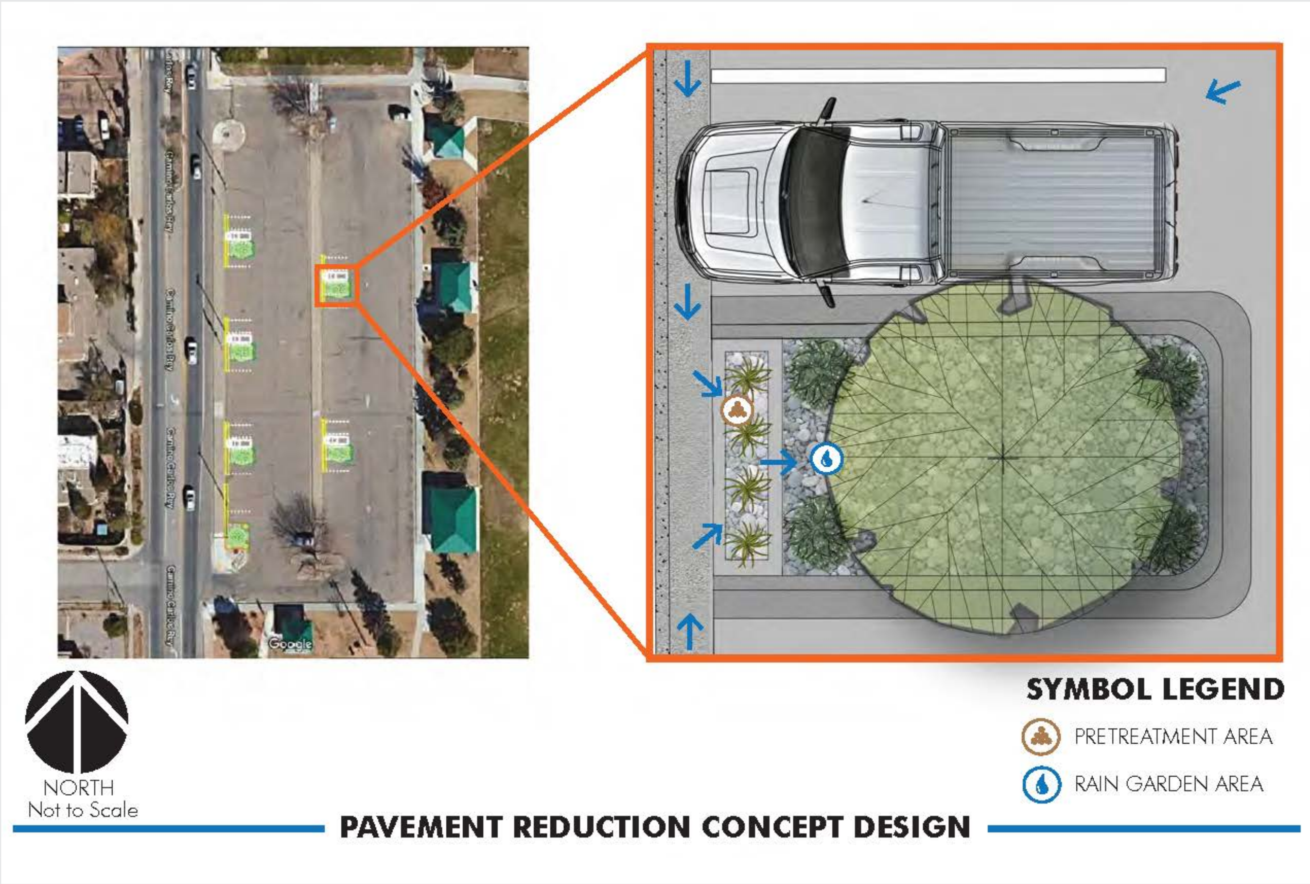
- Minimize the diameter of residential street cul-de-sacs. Consider hammerhead turnarounds or loop roads and/or incorporate landscaped islands.

Right-Sized Parking Lots

- When evaluating parking requirements, consider average demand as well as peak demand.
- Consider smaller parking stalls and/or compact parking spaces.
- Analyze parking lot layout to evaluate the applicability of narrowed traffic lanes and slanted parking stalls.
- Where appropriate, minimize impervious parking area by using overflow parking areas constructed of pervious paving materials.
- Encourage shared parking arrangements with adjacent land uses.
- Enable owners/developers to provide adequate parking while constructing only those spaces they show are necessary.

Slimmer Sidewalks

- Consider if sidewalks can be installed on one side of the street or combined with multi-use paths in backyard easements or natural areas where suitable to meet pedestrian needs. Ensure that designs comply with any Americans with Disabilities Act requirements. Whenever possible, build these paths from pervious materials.
- Use alternative development designs, such as cluster development, to reduce the length of roads, sidewalks, and other impervious areas.



Pavement from underused parking spaces being removed in General Miles Park in Santa Fe and replaced with rain gardens to promote infiltration. Source: Southwest Urban Hydrology, produced for use by Santa Fe Watershed Association

MAINTENANCE

- Specific maintenance practices are dependent on the type of pervious surface installed.
- Example maintenance includes periodic sweeping to remove accumulated debris, pruning vegetation, mowing turf, sweeping gravel, and inspecting drainage paths to ensure that adjacent conveyance structures are operable.

Photo by MBucka (Wikimedia CC)

7. References and Resources

This document cites several resources and references. The list below includes these, as well as others related to the design and implementation of green infrastructure practices such as those referenced in the factsheets. Some of these resources provide specific references to implementation in arid landscapes. This list can act as a starting point for those in Santa Fe looking to further research green infrastructure implementation.

Albuquerque Bernalillo County Water Utility Authority. (n.d.). Xeriscaping: The complete how-to guide. Retrieved from https://rrnm.gov/DocumentCenter/View/63083/Xeriscaping-How-to-Guide?bidId=.

AridLID Coalition. (2018). Low impact development in a high desert climate: Green stormwater infrastructure practices and case studies. Retrieved from https://landandwatersummit.org/blog/land-water-summit-blog-1/post/2018-aridlid-booklet-22.

Bernalillo County Commission. (n.d.). Bernalillo County green stormwater infrastructure: Low impact design strategies for desert communities. Retrieved from https://www.bernco.gov/uploads/FileLinks/590808d5c7dd4e0cbfaf3009cf1affb9/Green_Infrastructure_and_Low_Impact_Design_Guide_1.pdf.

Center for Watershed Protection. (2007). National Pollutant Removal Performance Database. Version 3. Retrieved from https://owl.cwp.org/mdocs-posts/fraley-mcneall-_national_pollutant_removal_perf_v3/.

City and County of Denver. (2016). Ultra-urban green infrastructure guidelines. Retrieved from https://www.denvergov.org/content/dam/denvergov/Portals/705/documents/ultra-urban-green-infrastructure-guidelines.pdf.

City of Portland Environmental Services. (2017). Green street stewards maintenance guide. Retrieved from https://www.portlandoregon.gov/bes/article/319879.

EPA (U.S. Environmental Protection Agency). (2015). Estimating predevelopment hydrology for urbanized areas in New Mexico. (EPA Publication No. 832-R-15-009). Retrieved from https://www.env.nm.gov/wp-content/uploads/2018/05/EPA-NM-MS4-Pre-Development-Hydrology-March2015.pdf.

EPA. (2016). Green infrastructure and climate change: Collaborating to improve community resiliency. (EPA Publication No. 832-R-16-004). Retrieved from https://www.epa.gov/sites/production/files/2016-08/documents/gi_climate_charrettes_final_508_2.pdf.

Horsley Witten Group. (2011). Tools and methodologies for tracking/reducing impervious cover. EPA Region 1 MS4 Stormwater General Permits and LID

Training Clinic. Presented June 3, 2011, Dean College, Franklin, MA. Retrieved from https://www3.epa.gov/region1/npdes/stormwater/presentations/20110603FranklinDCIA.pdf.

Jiang, Y., Yuan, Y. and Piza, H. (2015). A review of applicability and effectiveness of low impact development/green infrastructure practices in arid/semi-arid United States. Environments (2). 221–249.

Los Alamos National Laboratory. (2017). Low impact development standards. Document No. LA-UR-17-27538. Retrieved from https://engstandards.lanl.gov/esm/civil/LID-Standards.pdf.

Massachusetts Department of Environmental Protection. (2008). Massachusetts stormwater handbook and stormwater standards. Retrieved from https://www.mass.gov/guides/massachusetts-stormwater-handbook-and-stormwater-standards.

Minnesota Pollution Control Agency. (2018a). Minnesota stormwater manual. Retrieved from https://stormwater.pca.state.mn.us/index.php?title=Main_Page.

Minnesota Pollution Control Agency. (2018b). Case studies for tree trenches and tree boxes. In: Minnesota stormwater manual. Retrieved from https://stormwater.pca.state.mn.us/index.php?title=Case_studies_for_tree_trenches_and_tree_boxes.

NMDOT (New Mexico Department of Transportation). 2014. Functional classification guidance manual. Retrieved from http://dot.state.nm.us/content/dam/nmdot/planning/NMDOT_FC_Guide.pdf.

NMDOT. 2018. Drainage design manual. Retrieved from http://dot.state.nm.us/content/dam/nmdot/Infrastructure/Drain_Design_Manual.pdf.

Pennsylvania Department of Environmental Protection. (2006). Chapter 5: Non-structural BMPs. In: Pennsylvania stormwater best BMP manual. Retrieved from http://pecpa.org/wp-content/uploads/Stormwater-BMP-Manual.pdf.

Santa Fe MPO (Metropolitan Planning Organization). (2015). Metropolitan Transportation Plan 2015–2040. Retrieved from http://santafempo.org/wp-content/uploads/2015/09/Santa-Fe-MPO-MTP_FINAL_Electronic.pdf.

SSF (Sustainable Santa Fe). (2015). Sustainability benchmarks report 2015. Retrieved from https://www.santafenm.gov/media/files/Sustainable_SF_Commission/Sustainable_SF_Commission_Benchmarks_Final.pdf.

UNHSC (University of New Hampshire Stormwater Center). (2009). UNHSC design specifications for porous asphalt pavement and infiltration beds. Retrieved from https://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/pubs_specs_info/unhsc_pa_spec_10_09.pdf.

Virginia Department of Conservation and Recreation. (2011). Virginia DCR stormwater design specification no. 7: Permeable pavement. Version 1.7. Retrieved from https://www.vwrrc.vt.edu/swc/april_22_2010_update/DCR_BMP_Spec_No_7_PERMEABLE_PAVEMENT_Final_Draft_v1-7_03082010.htm.

Virginia Department of Conservation and Recreation. (2013). Virginia DCR stormwater design specification no. 9: Bioretention. Version 2.0. Retrieved from http://chesapeakestormwater.net/wp-content/uploads/downloads/2014/03/VA_BMP_Spec_No_9_BIORETENTION_FINAL_Draft_v2-0_06Nov2013.pdf.

Appendix A

Example Design Concepts for Santa Fe Sites

The following four designs show how the green infrastructure practices described in this guide can be integrated into various roadway settings in Santa Fe. Though they are only intended to be illustrative, they describe four real projects (in various stages of design when this guide was published):

- A rain garden bump-out at the General Miles Park parking lot.
- Bioretention at the proposed Camino Entrada roundabout.
- Tree trenches at the proposed Camino Entrada roundabout.
- Tree trenches with overflows and crowned road design on Guadalupe Avenue.

GENERAL MILES PARK RAIN GARDEN BUMP-OUT

DESIGN NARRATIVE

There is merit for both new development and retrofit efforts for this application. With respect to retrofitting an existing parking lot, the process begins by identifying under utilized space. Taking initiative to reduce pavement and adding multi-purpose green space improves the parks sense of place while reducing environmental impacts. For new development projects, integrating green infrastructure early in the process often results in a more successful installation. Discussing maintenace expectations and capabilities, while also using green infrastructure features as an educational amentity, or to reinforce sight lines, or even as a buffer for incompatible uses. Often times green infrastructure is value-engineered out of public improvements projects for a multitude of reasons. Including stakeholders and community members within the design process by outlining the benefits may increase the likelihood of funding beautiful, successful, and high-performing landscape features.

BENEFITS

- Reduces Under Utilized Pavement
- Provides Canopy Cover
- May Reduce Heat Island Effect
- Potential for Education
- Provides Wildlife Habitat
- Captures and Infiltrates Runoff On-site
- Straight Forward Maintenance Access
- Improves Aesthetics
- Softens Park Entrance

CONSIDERATIONS

- Ornamental grasses require additional water and care
- Cool season grasses require deep, root watering weekly
- Sediment traps should be designed for easy maintenance
- Provide sediment protection during construction
- Remove silt from surface to improve drainage

RAIN GARDEN BUMP OUT CONCEPT DESIGN

Potentilla fruticosa - Potentilla

Spiraea japonica - Spiraea 'Goldflame'

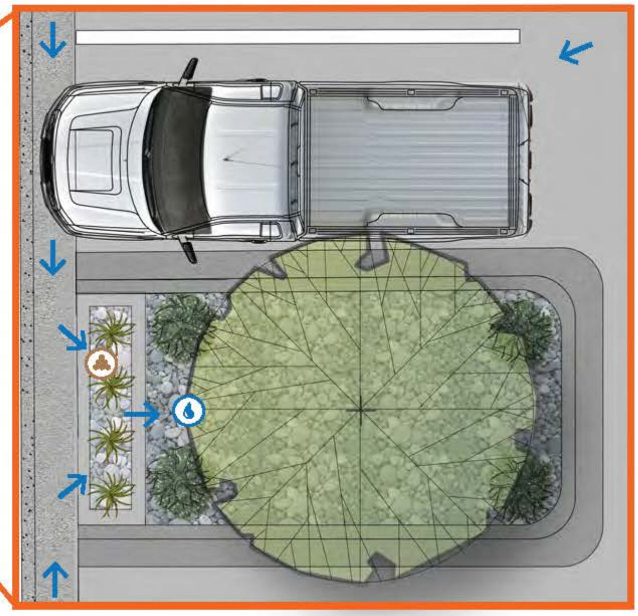
Juniperus sabina - Buffalo Juniper

Festuca ovina 'Glauca' - Blue Fescue

Calamagrostis x acutiflora - Feather Reed

Helictotrichon semperirens - Blue Oatgrass

SUGGESTED RAIN GARDEN PLANTING PALETTE



NORTH
Not to Scale

SYMBOL LEGEND

- PRETREATMENT AREA
- RAIN GARDEN AREA

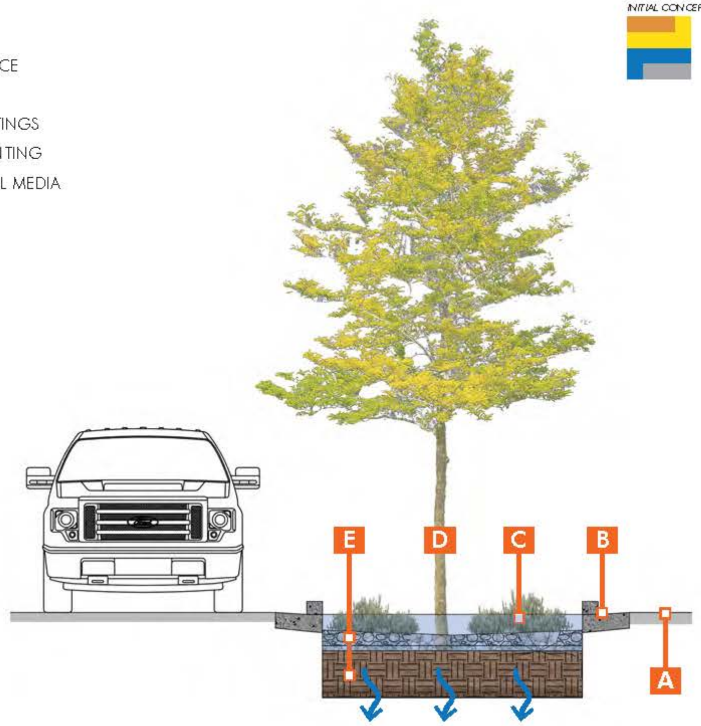
PAVEMENT REDUCTION CONCEPT DESIGN

CALLOUTS

- **A** PARKING / ROADWAY SURFACE
- **B** CURB BORDER
- **C** DROUGHT TOLERANT PLANTINGS
- **D** URBAN TOLERANT TREE PLANTING
- **E** STONE COVER & SANDY SOIL MEDIA

* GEOMEMBRANE LINER ON SIDEWALLS ONLY

INITIAL CONCEPT PLANS WERE PRODUCED BY:
Southwest UrbanHydrology



RAIN GARDEN BUMP OUT TYPICAL CONSTRUCTION DETAIL

BIORETENTION ROUNDABOUT AT CAMINO ENTRADA

DESIGN NARRATIVE

Locating a bioretention area within a roundabout's center circle requires raising the roundabout to drain toward the center. Three inlets on the inner edge drain runoff from the roadway into individual sediment forebays. All three forebay areas provide adequate shoulder space and surface area for maintenance access. The flat forebay should be designed with a hard, porous surface that can be easily cleared of debris. A weir structure detains the first flush of runoff to trap trash and debris. Runoff is then conveyed over the weir and into the bioretention area. Bioretention areas should be planted with drought-tolerant, native species that can also tolerate temporary inundation. For public safety, this concept includes a perforated underdrain and high-flow outlet structure to avoid flooding and convey excess runoff to the drainage network. This is particularly applicable for the City of Santa Fe, as Santa Fe can receive large amounts of rainfall over short periods of time.

BENEFITS

Improves Aesthetics
Creates Wildlife Habitat
Emergency Overflow Connections
Lower Comparative Install Call
Potential for Education
Activates Under Utilized Space
May Reduce Flooding
Maintenance Access Via Turnout Bays
May Provide Canopy Cover

CONSIDERATIONS

Requires Traffic Safety Evolutions
Higher Comparative Maintenance Cost & Effort
Concentrates Runoff to One Location
Cost Varies Depending on Material Selection
May Interfere with Subsurface Utilities

BIORETENTION CONCEPT DESIGN

Nolina microcarpa - Beargrass

Nassella tenuissima - Threadgrass

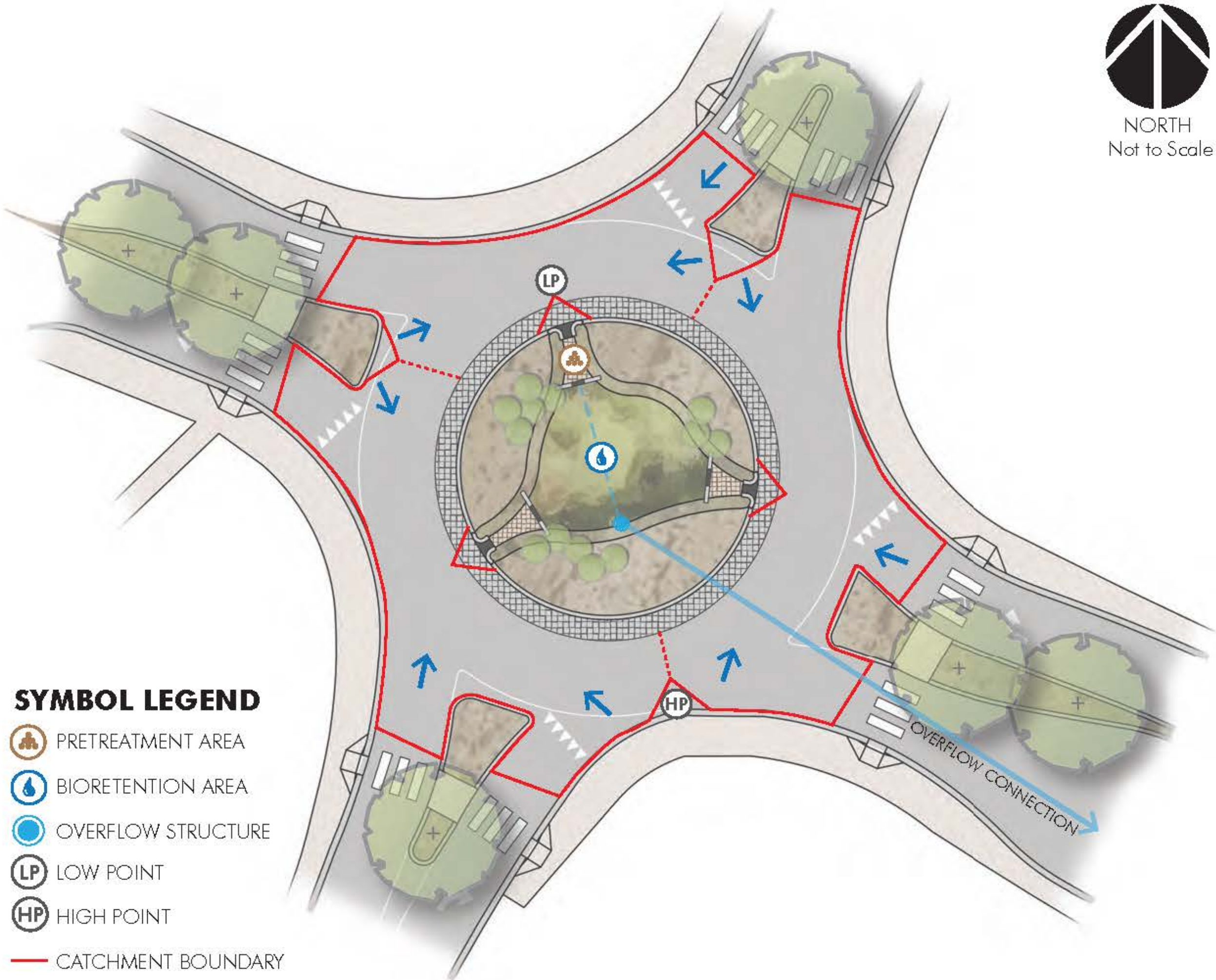
Fallugia paradoxa - Apache Plume

Dasylirion wheeleri - Sotol

Ericameria nauseosa - Chamisa

Hesperaloe parviflora - Red Yucca

SUGGESTED BIORETENTION PLANTING PALETTE

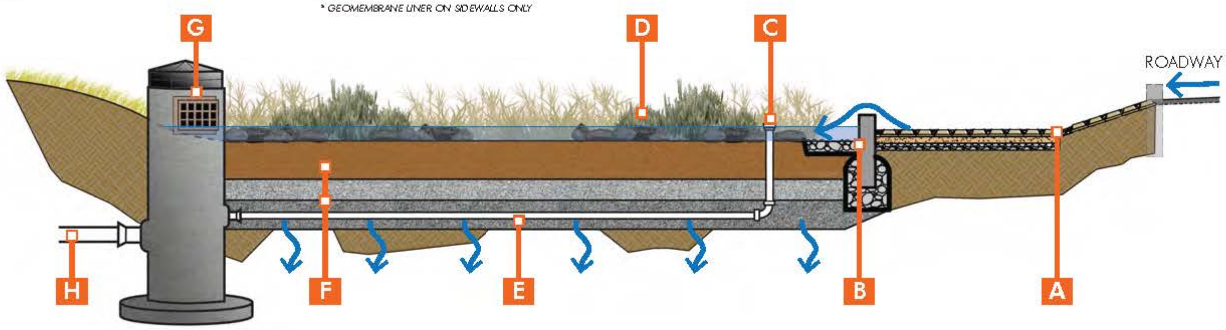


BIORETENTION CONCEPT DESIGN

CALLOUTS

- A PERMEABLE SEDIMENT FOREBAY
- B WEIR & STONE SPLASH PAD
- C CLEANOUT / OBSERVATION PORT
- D DROUGHT TOLERANT PLANTINGS
- E PERFORATED UNDERDRAIN
- F BIOSOIL & GRAVEL RESERVOIR
- G OVERFLOW STRUCTURE
- H OVERFLOW CONNECTION

* GEOMEMBRANE LINER ON SIDEWALLS ONLY



BIORETENTION TYPICAL CONSTRUCTION DETAIL

TREE TRENCH ROUNDABOUT AT CAMINO ENTRADA

DESIGN NARRATIVE

Utilizing tree trenches encourages smaller subcatchments. This eliminates the concentration of runoff to one collection area, unlike the bioretention concept. Tree trenches require pretreatment which is graphically shown as a deep sump catchbasin. Frequent sediment cleanout is required to maintain performance. A deep sump catchbasin is a small footprint, pretreatment option. Landscape maintenance is also simplified which may include pruning, removal of dead branches, and weeding at the base. Similar to the bioretention concept, each tree trench includes a perforated underdrain for emergency overflow situations to increase public safety during extreme storm events. Small rain events will enter the trench, irrigate the root zone and infiltrate downward through the filter media.

BENEFITS

- Provides Canopy Cover
- May Reduce Heat Island Effect
- Distributes Runoff Load
- Potential for Overflow Connections
- Lower Comparative Maintenance Cost

CONSIDERATIONS

- May Impede Sight Lines
- Higher Comparative Installation Cost
- Easy Maintenance with Vactor Truck
- May Interfere with Subsurface Utilities

TREE TRENCH CONCEPT DESIGN

Quercus macrocarpa - Bur Oak

Ulmus carpinifolia x parvifolia 'Frontier' - Elm

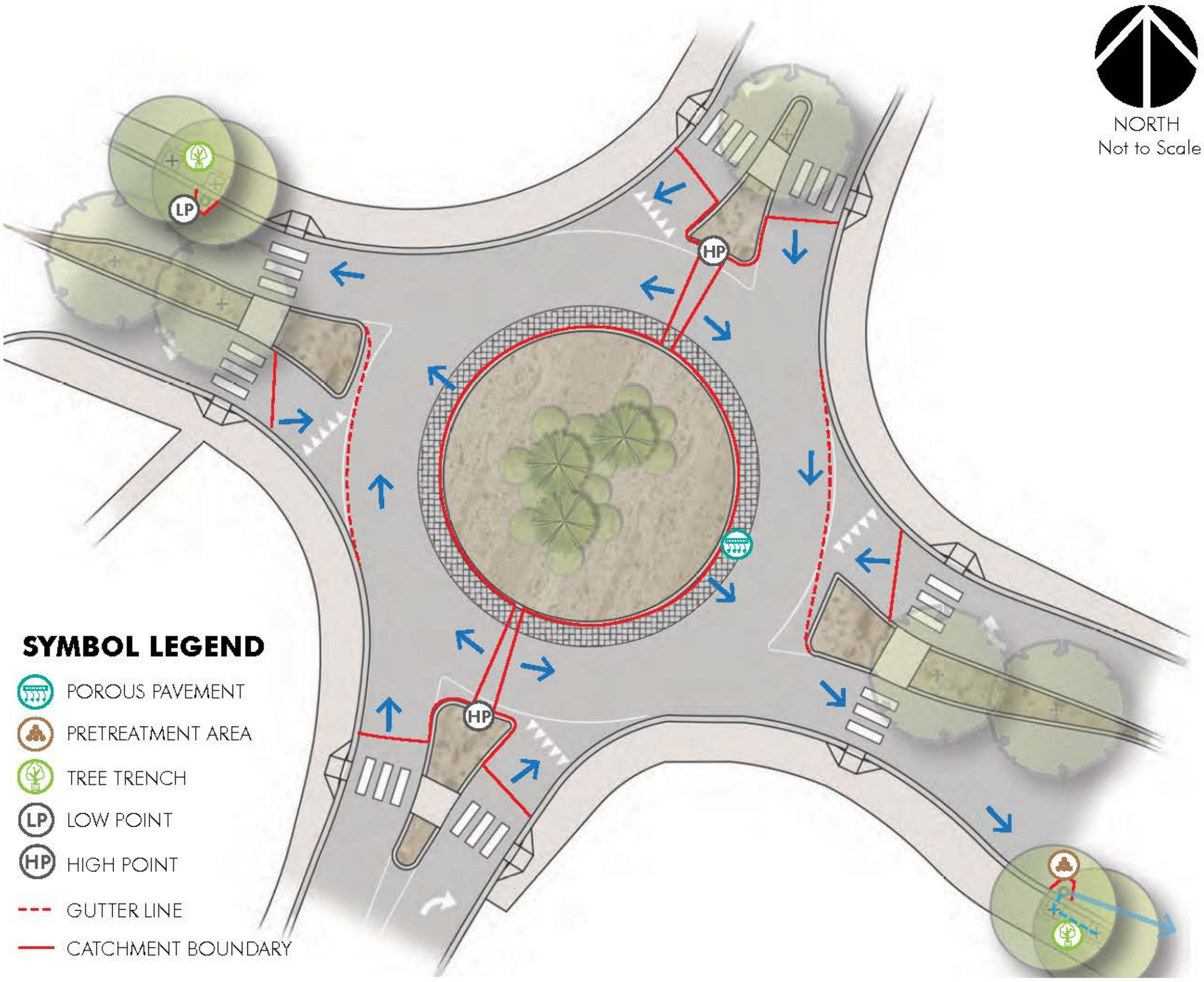
Gingko biloba - Maidenhair Gingko

Celtis occidentalis - Common Hackberry

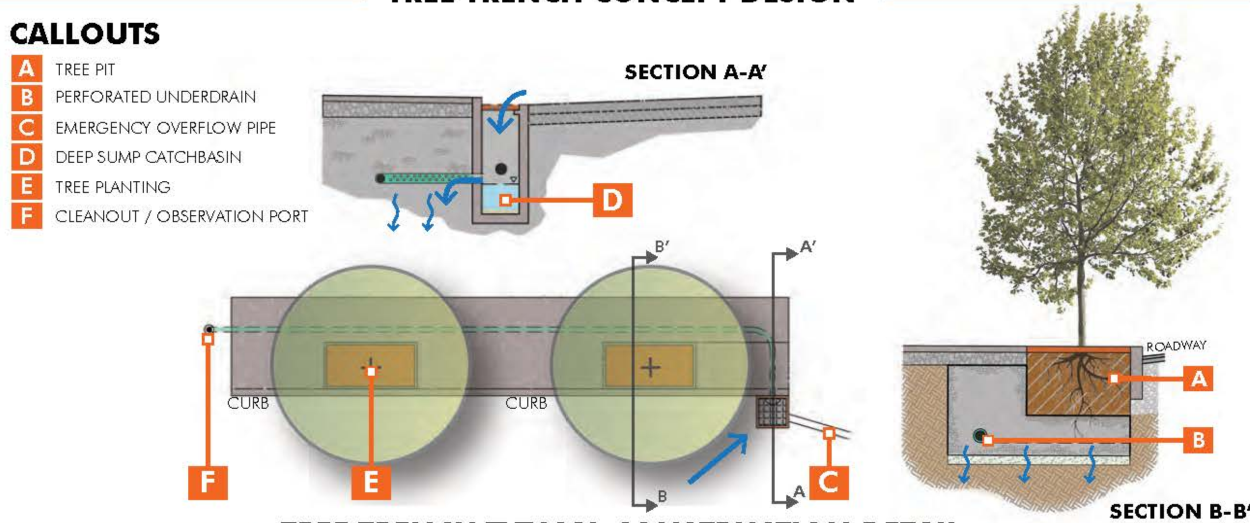
Fraxinus americana 'Autumn Purple' - Ash

Gleditsia triacanthos - Honeylocust

SUGGESTED TREE TRENCH SPECIES



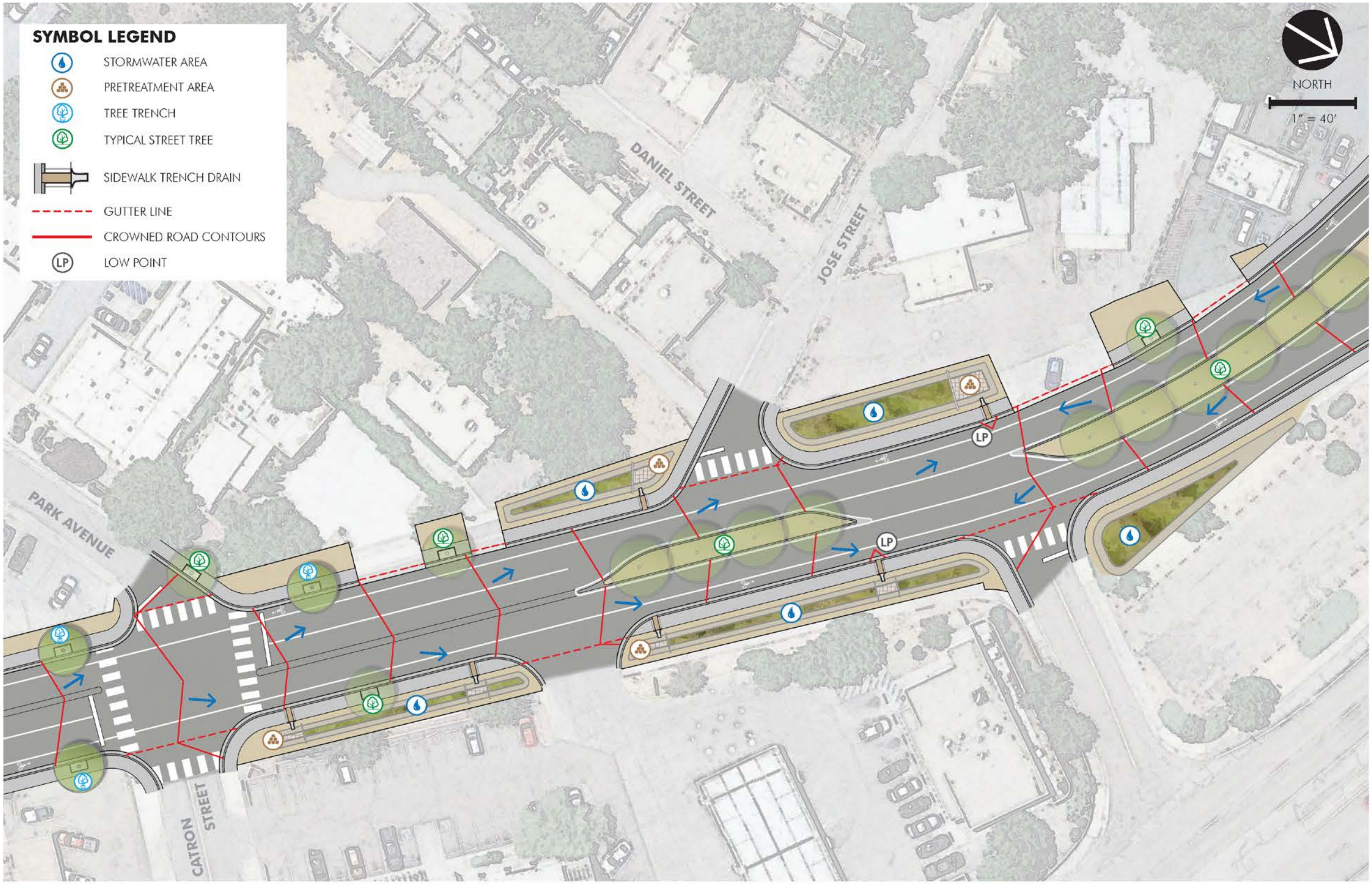
TREE TRENCH CONCEPT DESIGN



TREE TRENCH TYPICAL CONSTRUCTION DETAIL

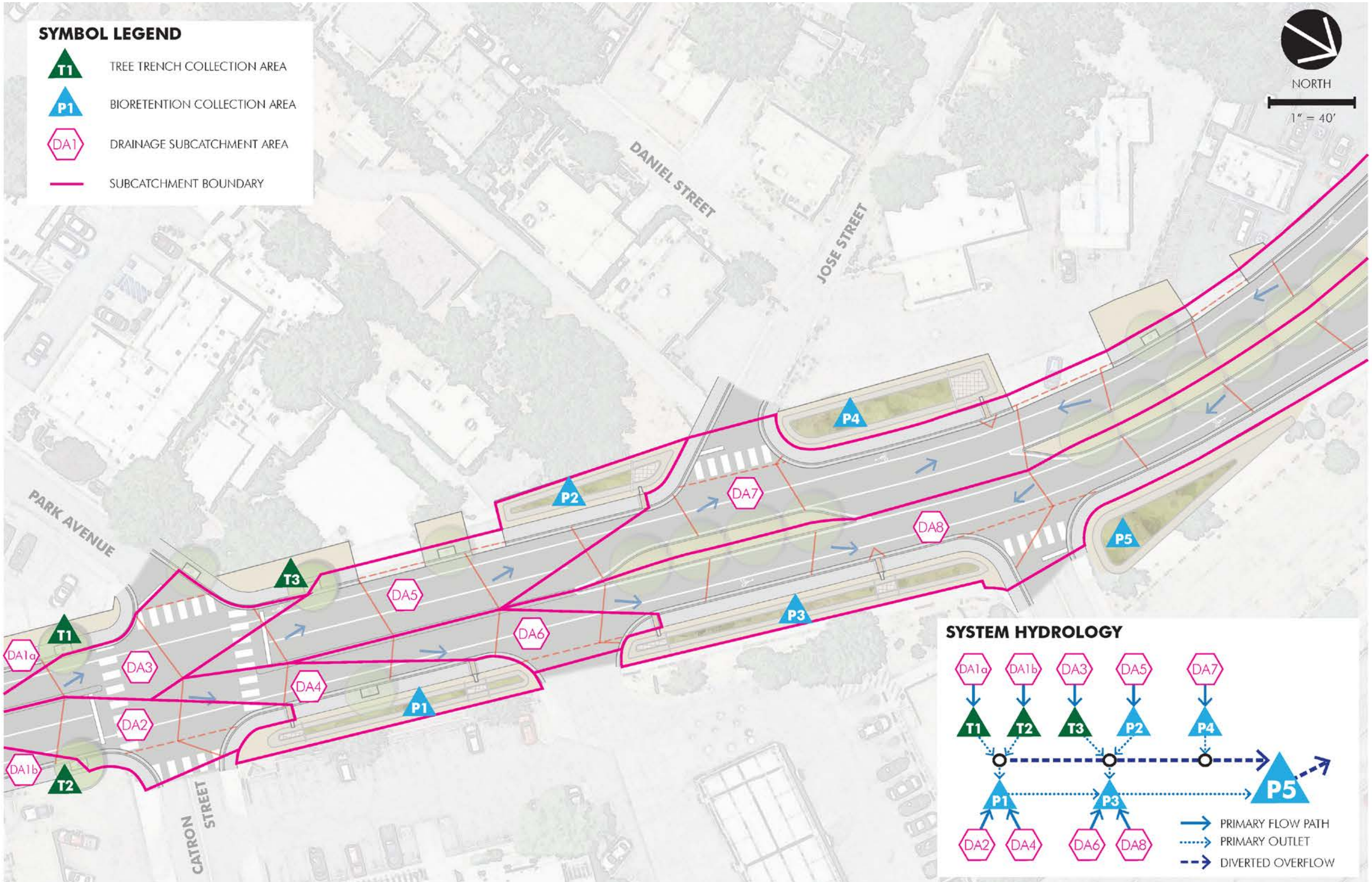
NORTH GUADALUPE STREET

The reconstruction of North Guadalupe Street presents many opportunities to incorporate green infrastructure within the right-of-way corridor as an alternative stormwater treatment and management solution. The goal of green infrastructure is to manage runoff at the source using nature-based solutions. This three-part concept design illustrates how the road might be re-graded to direct stormwater runoff into distributed small green infrastructure elements, and where these elements should be located. Pretreatment forebays are included at each inlet location to facilitate regular maintenance. The second diagram illustrates how closed pipe infrastructure and structural elements play a role to connect the entire system. The piping conveys and distributes stormwater through the treatment train during smaller storms and also provides a higher factor of safety to drain water off the street during more extreme storms. The third diagram illustrates each catchment drainage area and the dedicated stormwater area associated with each drainage area. With each drainage area subdivided and impervious cover reduced, each green infrastructure element can be designed to effectively treat and infiltrate the water quality volume from all storms.



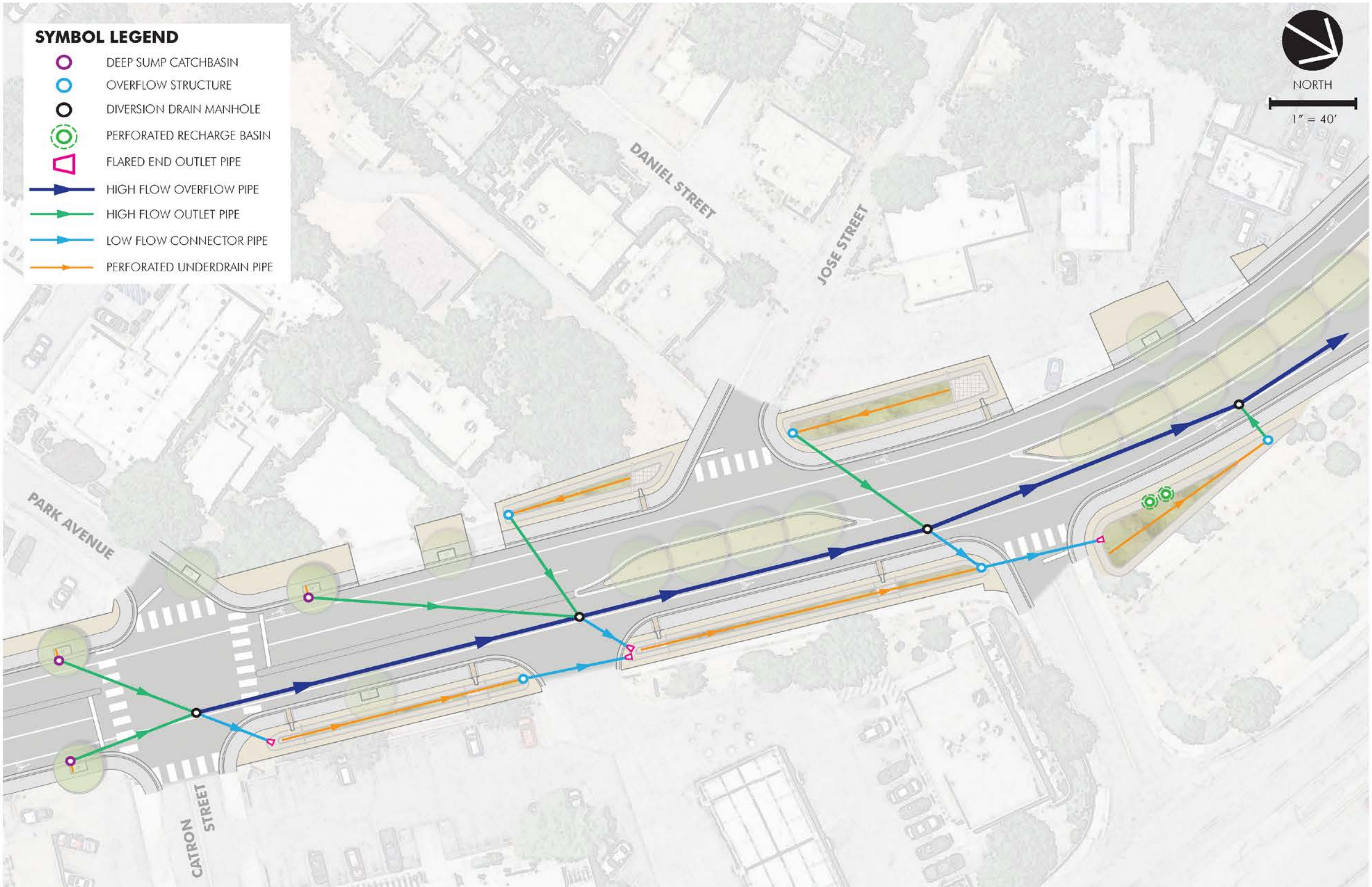
Initial concept design image provided by Surroundings©

CONCEPTUAL GREEN INFRASTRUCTURE DESIGN



CONCEPTUAL DRAINAGE AREAS

Initial concept design image provided by Surroundings©



CONCEPTUAL DRAINAGE NETWORK

Initial concept design image provided by Surroundings©