United States Environmental Protection Agency

Pueblo de Cochiti Green Infrastructure Concept Design

Improving Stormwater Management and Water Quality in the Community while Preserving Cultural History

SEPTEMBER 2016
EPA 832-R-16-008

About the Green Infrastructure Technical Assistance Program

Stormwater runoff is a major cause of water pollution in urban areas. When rain falls in undeveloped areas, soil and plants absorb and filter the water. When rain falls on our roofs, streets, and parking lots, however, the water cannot soak into the ground. In most urban areas, stormwater is drained through engineered collection systems and discharged into nearby water bodies. The stormwater carries trash, bacteria, heavy metals, and other pollutants from the urban landscape, polluting the receiving waters. Higher flows also can cause erosion and flooding in urban streams, damaging habitat, property, and infrastructure.

Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, *green infrastructure* refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site, *green infrastructure* refers to stormwater management systems that mimic nature by soaking up and storing water. Green infrastructure can be a cost-effective approach for improving water quality and helping communities stretch their infrastructure investments further by providing multiple environmental, economic, and community benefits. This multibenefit approach creates sustainable and resilient water infrastructure that supports and revitalizes urban communities.

The U.S. Environmental Protection Agency (EPA) encourages communities to use green infrastructure to help manage stormwater runoff, reduce sewer overflows, and improve water quality. EPA recognizes the value of working collaboratively with communities to support broader adoption of green infrastructure approaches. Technical assistance is a key component to accelerating the implementation of green infrastructure across the nation and aligns with EPA's commitment to provide community-focused outreach and support in the President's Priority Agenda Enhancing the Climate Resilience of America's Natural Resources. Creating more resilient systems will become increasingly important in the face of climate change. As more intense weather events or dwindling water supplies stress the performance of the nation's water infrastructure, green infrastructure offers an approach to increase resiliency and adaptability.

For more information, visit *http://www.epa.gov/greeninfrastructure*.

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This report was developed under EPA Contract No. EP-C-11-009 as part of the 2014 EPA Green Infrastructure Technical Assistance Program.

Cover illustration by Tetra Tech.

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1 Executive Summary

Pueblo de Cochiti is a federally recognized Native American tribal entity located 55 miles north of Albuquerque, New Mexico, along the Rio Grande, that lies within 53,779 acres of reservation land. Cochiti is located in the heart of the tribe's traditional homeland with a strong desire to preserve the community's culture and traditions.

Unfortunately, the community faces significant water quality problems. Monitoring indicates that water quality issues occur in areas both upstream and downstream from Cochiti and include both point and nonpoint sources of pollution. Cochiti has experienced catastrophic flooding resulting from the loss of vegetation due to recent wildfire activities as well as localized flooding and erosion scour from excessive stormwater runoff. In addition, there has been an increase in total impervious area and an overall reduction in native vegetation.

As part of EPA's Green Infrastructure Technical Assistance Program, green infrastructure conceptual designs were developed working with the Pueblo leaders and community members to address these water quality issues. The conceptual designs will serve to introduce green infrastructure practices to the tribal community. The project will provide evidence of the feasibility and functionality of green infrastructure practices in areas with an arid climate and limited regulation of stormwater management. Cochiti hopes that through the implementation of green infrastructure practices, they will be able to better manage stormwater in low areas, especially the central Plaza, and reduce runoff throughout other areas where flooding and erosion have been problematic. Using green infrastructure principles and techniques also can reduce contributions of pollutants from Cochiti's impervious areas to the Rio Grande.

Finding the balance between encouraging appropriate green infrastructure approaches and respecting the traditions and culture of Cochiti was of primary importance in the development of the concept designs. The project had three main objectives:

- Develop a green street design that can be applied to several upcoming road rehabilitation projects, including Turquoise Street and Roadrunner Road.
- Develop a design that incorporates green infrastructure features into the Cochiti Plaza area, the central gathering place for the Pueblo.
- Identify green infrastructure solutions to address poor drainage and erosion issues in a newer residential neighborhood.

This project has the support of the Pueblo leadership, staff, and community members and will provide a vision for integrating cultural and traditional knowledge with green infrastructure practices. Support was gained by involving the community in the design process through activities including a charrette presentation at the Pueblo with students in the native language program and a multigenerational group of community members. Together the groups contributed to the discussion and provided direct input for the designs.

The conceptual designs in the report include the development of rain gardens, a *green street*, and the use of cisterns to manage stormwater runoff. The selection of vegetation prioritized native and historically significant plants. An emphasis was put on using materials that are locally available and community approved. The recommendations and conceptual designs included in this report incorporate the input of the Pueblo leadership and community members to provide practical and realistic green infrastructure approaches tailored to the needs of this culturally rich Desert Southwest community.

2 Introduction

Pueblo de Cochiti is a federally recognized Native American tribal entity that was added to the New Mexico Register of Cultural Properties in 1972 and the National Register of Historic Places in 1974. Cochiti is located 55 miles north of Albuquerque along the Rio Grande and lies within 53,779 acres of reservation land. According to the 2010 Census, the population of Cochiti is 528, with 95.1 percent being American Indian. Principal land uses include farming, livestock, recreation, housing, and administration facilities. Figure 2-1 shows an aerial view of Cochiti and the surrounding lands.

Source: Google Maps

Figure 2-1. Regional map showing location of Pueblo de Cochiti, New Mexico.

As a sovereign nation, Cochiti has a centuries-old, traditional form of government. The people of Cochiti continue to speak their native language of Keres. They maintain their cultural practices and have instituted programs dedicated to teaching and educating the younger generation about Pueblo traditions, cultural practices, and the native language. Like the other Pueblo communities in the Desert Southwest, Cochiti celebrates an annual feast day on July 14 associated with the patron saint of the community, San Buenaventura.

Of primary importance to Pueblo de Cochiti are the natural resources (land, air, and water) on the reservation, which is the lifeline of Pueblo traditions and culture. The Pueblo is located in the heart of the tribe's traditional homeland and maintaining the environmental quality there is critical to preserving the community's culture and traditions.

2.1 Water Quality Issues and Goals

Pueblo de Cochiti lies within the Rio Grande watershed—at the bottom of the Upper Rio Grande watershed and the top of the Middle Rio Grande watershed, with Cochiti Reservoir serving as the transition point between the two (see Figure 2-2). The Pueblo monitors water quality on Pueblo lands, but also faces water quality issues in both upstream and downstream areas. The New Mexico Environment Department completed stream assessments in both the Upper and Middle Rio Grande watersheds and concluded that the designated uses of the Rio Grande are not being attained. Impairments in the Upper and Middle Rio Grande watersheds include E. coli bacteria, gross alpha (adjusted), polychlorinated biphenyls (PCB) in fish tissue and in the water column, turbidity, acute aquatic toxicity, and dissolved oxygen. Sources of these impairments include both point and nonpoint sources, such as runoff. The state prepared a total maximum daily load (TMDL) document in 2010 (WQCC 2010).

Photo credit: Tetra Tech, Inc.

Figure 2-2. The Pueblo sits along the Rio Grande.

In recent years, the Pueblo also has experienced catastrophic flooding. This is due in part to the Las Conchas wildfire that burned over 150,000 acres of forest in the Jemez Mountains during the summer of 2011, including a large area in the upper watershed of Peralta Creek. With the upland vegetation removed, precipitation is much less likely to infiltrate the soils and instead quickly runs off to downslope areas. The Pueblo's reservation lands are located at the terminus of the watershed, and most of the Pueblo's population and economic activities are concentrated along the creek near its confluence with the Rio Grande (USACE 2012).

Subsequent severe storms have caused increased stormwater runoff, resulting in floods at the Pueblo from postfire conditions in the upper areas of the watershed.

Within the Pueblo, historic architecture and construction practices have yielded to more modern building materials and methods in recent decades. This has resulted in an increase in total impervious area and coincided with an overall reduction in vegetation, as once-common native tree and plant species have died off. In some locations, less desirable invasive species such as Russian olive and Chinese elm have replaced native species. As a result, the Pueblo has experienced an increase in localized flooding and erosion scour from excessive stormwater runoff.

The people of the Pueblo hope that through the implementation of green infrastructure practices, they can better manage stormwater within low areas such as the central Plaza and reduce runoff throughout other areas where flooding and erosion have been problematic. The application of green infrastructure principles and techniques also can reduce the transfer of pollutants from the Pueblo's impervious areas to the Rio Grande.

2.2 Project Overview and Goals

This project had three main objectives:

- Develop a green street design that can be applied to several upcoming road rehabilitation projects, including Turquoise Street and Roadrunner Road.
- Develop a design that incorporates green infrastructure features into the Cochiti Plaza area, the central gathering place for the Pueblo.
- Identify green infrastructure solutions to address poor drainage and erosion issues in a newer residential neighborhood.

These green infrastructure designs identified ways to integrate water resource management with cultural and historic preservation. For example, Pueblo leadership and planning staff will be able to preserve critical cultural and historic buildings and roads, and use native plant species for stormwater swales and other green infrastructure features to increase walkability throughout the Village.

2.3 Project Benefits

Over the years, as western living concepts were introduced, the historic Pueblo living concepts were set aside for the "modern way of life" diminishing the traditions, culture, and language of Cochiti. The reconnection of the people and the land will help to preserve, maintain, and continue the traditions, culture, and language of the Cochiti people. The Pueblo has become more aware of flood hazard and water quality and quantity issues and the project will begin to address those concerns. Cultural and historic preservation initiatives already have begun in the Village housing area. One ongoing initiative is the development of a Plaza Revitalization Plan. The Plaza is a critical cultural element of the Village. The plan will include mapping out a self-determined preservation and rehabilitation approach that will guide management of the Plaza in the coming decades.

This project has support from the Pueblo leadership, staff, and community members and will provide a vision for integrating cultural and traditional ecological knowledge with green infrastructure practices. Future tribal infrastructure funds, tribal transportation program funds, and water quality and watershed management funds will be used to leverage additional funds to begin and continue the implementation of green infrastructure. The results could be a model for tribal communities locally, regionally, and nationally.

2.4 Local Challenges

The project and any subsequent implementation efforts must preserve and respect the cultural history of the Pueblo by developing designs that incorporate features sensitive to the culture and supported by the Pueblo's residents. Traditional building materials and native plants should be selected to maintain the authentic look of the Pueblo.

There are currently no design standards for the community, so standards from nearby communities will be considered and adapted as appropriate. Design elements also must be able to function effectively in the hot, arid climate of the region. Long periods of drought followed by intense rainfall can present challenges for implementing green infrastructure practices that incorporate vegetation.

Working on tribal lands also could require adherence to specific federal statutes and regulations that restrict certain design elements.

3 Site Conditions

Located in the heart of the tribe's traditional homeland, much of Pueblo de Cochiti exhibits the traditional elements of a historic southwest pueblo. The Pueblo needs infrastructure improvements that are culturally and environmentally appropriate and that focus on traditional needs of the community. This section describes each of the three project sites.

3.1 Cochiti Plaza

Cochiti Plaza is the heart of the Pueblo. It is the location of social and ceremonial gatherings with great historic and traditional significance. The Plaza center is a large open area with dirt cover and little vegetation. It is surrounded on all sides by single-story, historic adobe structures. Original features include flat, grass-vegetated rooftops; canales (scupper drains) for rooftop drainage; and hornos (outdoor bread ovens). Reconstructed structures use traditional designs to minimize any deviation from the pueblo style.

There is very little pavement on the Plaza and very limited stormwater control of either paved or nonpaved areas. Water drains from canales directly onto the ground with no way to capture or store the rainwater. The majority of the roads are dirt and provide some infiltration of rainwater and drainage. During the rainy season and winter months, however, much of the drainage flows to the center of the Plaza and forms a large shallow pool (see Figure 3-1). That phenomenon has positive associations for many community members who grew up near the Plaza and played in the pool.

Photo credit: Tetra Tech, Inc.

Figure 3-1. Runoff collected in Plaza center.

Outside of the Plaza center, the primary stormwater-related issue is erosion along building foundations resulting from rooftop runoff. Figure 3-2 shows a modern design with a gutter and downspout, which the community does not prefer. Discussions with Pueblo residents indicated a perception that runoff volumes from rooftop surfaces might have increased with the recent adoption of modern roofing materials such as impermeable membrane roofs. Historically, adobe roofing structures were topped with a layer of soil that could have retained some portion of each storm event rather than directly discharging runoff like a modern roofing system; however, a search of published literature could not confirm that practice.

Photo credit: Tetra Tech, Inc.

Figure 3-2. Rooftop runoff results in scour along building foundations.

3.2 Turquoise Street

Turquoise Street is a two-lane road connecting Pueblo Route 85 and Plaza Street. It serves as a primary route between the Plaza and the remainder of the Pueblo. Turquoise Street is located within a 40–60-foot- (ft-) wide corridor between adjacent residential areas and is paved its entire 1,800-ft length. Single-family homes, in the traditional adobe and pueblo styles, are located on both sides of the street. There are no sidewalks or other pedestrian access along the street. Most homes have mature trees and some local vegetation on their properties. Fences surrounding the homes limit pedestrian access through the community. See Figure 3-3 for a view of Turquoise Street.

Photo credit: Tetra Tech, Inc.

Figure 3-3. Existing conditions on Turquoise Street.

The lack of active stormwater management along Turquoise Street is believed to be a source of significant erosion problems, including issues in the area where Turquoise Street meets Cochiti Plaza. A site visit revealed the most severe erosion to be along the fence at the Plaza end of the street, shown in Figure 3-4.

Photo credit: Tetra Tech, Inc.

Figure 3-4. Erosion near the intersection of Turquoise and Plaza Streets.

Stormwater runoff throughout the Pueblo generally flows in a southeast direction. In addition to the area of Turquoise Street near the Plaza, other locations including the area east of the Plaza near a former fill site show signs of significant erosion and sediment deposition (see Figure 3-5). Conditions such as these emphasize how greatly a stormwater management plan could benefit Pueblo de Cochiti.

Photo credit: Tetra Tech, Inc.

Figure 3-5. Stormwater impacts downslope of the Pueblo.

3.3 Robin Street

Robin Street is part of a residential development of single-family homes in the western portion of the community, across Pueblo Route 85 from Cochiti Plaza. The Robin Street neighborhood was constructed in the late 1970s on an area of alluvial deposits from the Peralta Creek watershed. During construction, the street network was excavated several feet below the ground surface to provide surface drainage away from the residences. In that manner, the roadway network served as the drainage conveyance system for the neighborhood. Runoff collected in the ditches is ultimately routed into one of several infiltration basins constructed adjacent to the streets. As a result, there is no off-site discharge of stormwater from the neighborhood. There still, however, are several localized issues resulting from stormwater runoff. The excavation of the road network resulted in sloped driveways and other areas adjacent to the street that often exhibit evidence of scour, as well as sediment deposition on the roadway itself (see Figure 3-6, Figure 3-7, and Figure 3-8). Some residents have attempted to direct rooftop runoff into vegetated areas to minimize flow into the road. But drainage from driveways and other impervious surfaces at many houses along Robin Street contributes to the burden on the stormwater drainage system, including sediment deposition into the infiltration basins, which are poorly maintained and being filled in due to the erosion occurring in upland areas.

Photo credit: Tetra Tech, Inc.

Figure 3-6. Deposited sediment from upland areas often plugs infiltration basin inlets.

Photo credit: Tetra Tech, Inc.

Figure 3-7. Residences, landscaping, and road conditions on Robin Street.

Photo credit: Tetra Tech, Inc.

Figure 3-8. Example of stormwater erosion on Robin Street.

The roadway network within the Robin Street neighborhood exhibits characteristics typical of roadways of its age. Surface cracks are common on the pavement surface; many appear to have been repaired with an appropriate sealer. Weeds and other vegetation have grown between the paved surface and the curb, and sediment accumulates in the gutter, especially near the curb cuts leading to infiltration basins. Roadway widths range from 20 to 34 ft, which might be excessive given the lack of observed street parking within the neighborhood.

4 Design Approach

4.1 Stormwater Standards

At present, Pueblo de Cochiti is not regulated by a National Pollutant Discharge Elimination System municipal separate storm sewer system (MS4) permit and no local standards exist for stormwater management. To determine appropriate and applicable stormwater standards upon which to base the green infrastructure design, a review of other New Mexico communities was conducted.

Managing stormwater to predevelopment hydrological conditions for newly developed and redeveloped sites is a goal of the existing Phase I Albuquerque MS4 permit and the Middle Rio Grande watershed MS4 permit to improve water quality. Those permits use a percentile storm event approach as a surrogate that mimics predevelopment hydrology. The Phase I Albuquerque permit requires treatment of the 90th percentile storm event (0.62 inch) for new development and treatment of the 80th percentile storm event (0.44 inch) for redevelopment. The proposed Middle Rio Grande watershed MS4 permit contains a similar standard.

The *City of Albuquerque Development Process Manual*, Chapter 22, Section 2, Part A (City of Albuquerque 2016) outlines procedures for determining the appropriate design storm, runoff volume, and peak discharge rate for projects with drainage areas smaller than and larger than 40 acres. The principal design storm is the 100-year, 6-hour event as defined by NOAA Atlas 2 (Miller et. al 1973). It is noted that "for design of retention or detention ponds, storms of 24-hour or longer duration may be required." Part B details the calculations for time of concentration, lag time, and time to peak. Section 9 of the chapter defines the water quality storm event as 0.6 inches of precipitation within a 6-hour period, which is approximately equivalent to the average annual precipitation event and the 80th percentile rainfall event.

Per City of Santa Fe Ordinance No. 2011-37 (Chapter 14, Section 8.2 part D.4.b), "the stormwater runoff peak flow rate discharged from a site shall not exceed pre-development conditions for any frequency storm event up to the one percent chance, twenty-four-hour storm event at each discharge point." The ordinance also describes acceptable runoff control measures as including detention and retention basins, water harvesting, swales, berms, check dams, vegetative ground cover, permeable pavement, tree wells, dry wells, cisterns, and "other techniques appropriate for retaining and infiltrating water on site." The ordinance goes on to describe specific standards for individual practices.[1]

4.2 Soil Conditions

Soils in the Pueblo are predominantly of the type Waumac-Bamac association, which is characterized by 1–7-percent slopes and classified as hydrologic soil group (HSG) A (USDA 2014). Waumac-Bamac soils are typical of valley floors and alluvial fans, are well-drained-to-excessively drained, and have depths to water tables greater than 80 inches. They are typically composed of loamy sand and sandy loam soils with some gravel. Group A soils have a high infiltration rate and low runoff potential.

Geotechnical investigations conducted as part of planned roadway improvements for Coyote Street (two blocks south of Turquoise Street) provide more specific information on subsurface soil conditions, which might be representative of the Pueblo at large (Terracon 2014). Since the soil borings were conducted in support of roadway design, they do not directly provide the full suite of information that might be necessary for the final design of green infrastructure practices; for example, the data do not contain permeability/infiltration rates of subsoil layers. The investigations do, however, provide general information on soil texture and classification, which give an indication of these critical features. The two borings were advanced to a depth of 6.5 ft at disparate locations along Coyote Road. Poorly graded sand with silt (SP-SM) with fines constituting approximately 10 percent dominate the subsoil conditions at both locations. At one of the boring locations, a surface layer of silty sand (SM) extends to a depth of 2 ft. Neither boring location exhibited ground water, showing no indication of a seasonally high water table.

The sand-based textural classification, limited fines content, and absence of observed ground water indicate that subsoils in the project area are well within the typical characteristics for infiltration-based green infrastructure practices, which makes these practices appropriate for the Pueblo.

[1] *http://clerkshq.com/default.ashx?clientsite=Santafe-nm*.

4.3 Community Charrette

To integrate green infrastructure successfully into a traditional community such as Pueblo de Cochiti, it will be essential to obtain feedback from the community. This community perspective and historic context will clearly influence the concept design approach. A communitywide charrette took place the evening of July 16, 2014, to present the green infrastructure concept and provide a format for community input into the development of the green infrastructure plan for the Pueblo. Prior to the charrette, a discussion was held with a group of students who were participating in the summer native language program. As part of the discussion, the students were asked to provide sketches of how green infrastructure practices could be integrated into Pueblo de Cochiti (see Figure 4-1 and Figure 4-2).

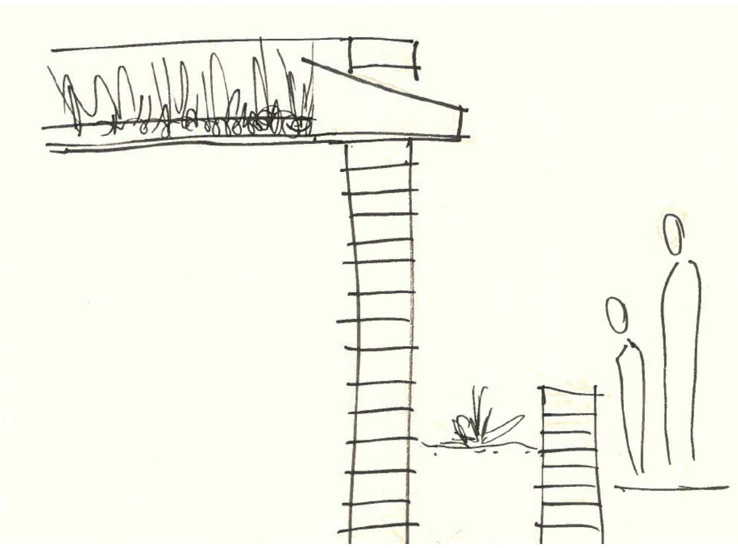


Figure 4-1. Student sketch of raingarden in Pueblo setting.

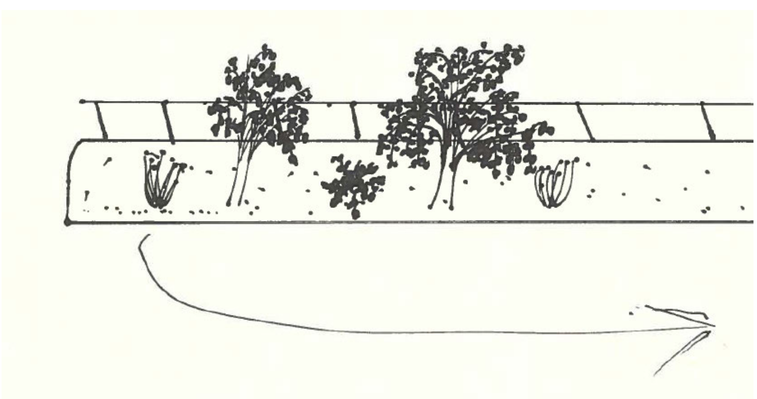


Figure 4-2. Student sketch of roadside swale.

After meeting with the students, a larger group participated in the evening charrette. Attendance at the evening charrette was high with a multigenerational group of community members. The discussion was lively and the residents appreciated the opportunity to contribute to the development process.

The discussion touched on several areas of potential green infrastructure activities. As a guiding principle, the group agreed that the modern look of the recently redeveloped Cochiti Street was not appealing or consistent with the Pueblo style (see Figure 4-3). Specific complaints about Cochiti Street included the concrete, large curbs, speed bumps, and dark asphalt. Instead, the community preferred designs that include gentle curbing, no pavement, and more natural-looking roads. Participants agreed that preserving the traditional look of the community was very important.

Figure 4-3. View of Cochiti Street, including the heavy infrastructure features that Pueblo members expressed a desire to avoid.

Much of the discussion during the charrette centered on ideas for green infrastructure improvements along Turquoise Street. Turquoise Street residents were very vocal and were able to provide information on the history of the road. For example, the residents spoke about why the road was fenced at the Plaza end and how construction on the adjoining road has impacted them by limiting access to their properties.

Ideas for Turquoise Street included removing the pavement entirely and using a more appropriately colored pavement (e.g., tan) that would blend in with the natural surroundings. Other ideas included:

- An unpaved walking trail along the north side of the street leading to the Plaza area, with shade from fruit trees and native plants.
- Providing access to yards and keeping pedestrians out of the street.

- Removing the existing fencing in the Pueblo area to return to a more traditional open space. Replacement of only some fences with more natural looking coyote (latilla) fencing would contain pets.
- The student group expressed interest in adding a feature at the historic windmill near the entrance to Turquoise Street (e.g., a fitness trail or native trees and plants) that would make better use of the space, provide for some bioretention, and preserve the character of the land.
- Planting fruit trees such as apple, apricot, cherry, and pear, as well as native trees (e.g., cottonwood and aspen) along the street was met with agreement. Future costs for maintenance of trees and vegetation, however, were raised as a concern.

Existing issues in the Plaza area also were discussed during the charrette. Ice formation in the winter and exposed tree roots were considered problematic. Community members stated that any green infrastructure projects proposed for the Plaza area must be consistent with the social and ceremonial uses of that area and must be coordinated with the Plaza revitalization group and tribal specialists.

4.4 Stormwater Toolbox

The Pueblo de Cochiti community is sensitive to aesthetics and does not wish to deviate from historical vegetation species or construction practices. Community acceptance is among the most significant factors in evaluating potential stormwater management options. This section describes green infrastructure practices that have been identified as appropriate for the community.

4.4.1 Rain Gardens

A *rain garden*, also known as bioretention or a bioretention cell, is a shallow, vegetated basin that collects and infiltrates runoff from rooftops, streets, sidewalks, and other impervious surfaces (USEPA 2014). Rain gardens should be sited to capture runoff from as much impervious area as possible and sized to provide a volume of soil storage that is appropriate for the extent of the drainage area. Rain gardens are typically planted with deep-rooted native plants and grasses to maximize stormwater infiltration (see Figure 4-4). Excavation might be required to increase soil storage and accommodate plant roots, and soil amendments might be necessary to increase soil water retention and maintain healthy plants (USEPA 2010).

Due to the limited rainfall and water supply in arid and semiarid regions, careful attention must be given to selecting appropriate plant species. Unlike conventional gardens, rain gardens are designed to receive most or all of their water needs from precipitation, making them an attractive option where water conservation is a concern (USEPA 2010). When properly designed, rain gardens mimic natural hydrology and are able to withstand moisture extremes, which makes them an ideal green infrastructure practice for arid regions.

Stormwater runoff is conveyed to rain gardens via sheet flow or can be directed from a downspout, driveway, or sump pump. By infiltrating and temporarily storing runoff water, rain gardens not only remove pollutants but also can reduce a site's overall runoff volume and help to maintain the predevelopment peak discharge rate and timing (a key component of many stormwater program requirements).

Source: University of Arizona Cooperative Extension

Figure 4-4. Typical rain garden design.

4.4.2 Green Street

Green streets typically integrate multiple green infrastructure elements into the street or alley design to store, infiltrate, and evapotranspire stormwater. Common green street/green alley elements include permeable pavement, vegetated swales or bioswales, planter boxes, street trees, vegetated curb extensions, and landscaped medians (USEPA 2009, 2014). See Figure 4-5 for an example design. Typical benefits of green streets include reduced stormwater flow, urban heating, and carbon footprints; and improved water quality, pedestrian safety, and neighborhood aesthetics. Residential streets often offer excellent opportunities for green street designs because they tend to have lower vehicle speeds and traffic volumes and frequently already incorporate landscape elements (USEPA 2009).

One of the key green infrastructure practices proposed as part of the green street design for Pueblo de Cochiti is the use of infiltration swales. These long, shallow vegetated depressions are slightly sloped to convey stormwater. Swales are different from rain gardens in that they are linear in geometry and are designed to allow water to travel downslope. Stormwater flow through the swale is reduced as it encounters plants and soil, which allows for the settling of sediment and pollutants. Water is absorbed into the soil and taken up by plants; it can infiltrate fully if native soil conditions permit (USEPA 2009, 2010). As with rain gardens, vegetation selection is critically important for swale design in arid and semiarid climates.

Other proposed green street design elements for Turquoise Street include the planting of fruit trees and resurfacing the street with a new colored asphalt pavement.

Source: Tetra Tech, Inc.

Figure 4-5. Example green street design incorporating curb cuts leading to roadside infiltration swales.

4.4.3 Cisterns and Rain Barrels

Cisterns are a type of rainwater harvesting system that enables the collection and storage of rainfall for later use. When properly designed, they slow and reduce runoff and can provide an alternate source of water for irrigation or other uses. That feature is of particular interest in arid regions such as the Southwest, where water recycling can reduce demands on limited water supplies (USEPA 2014). Cisterns can be constructed both above and below ground from a variety of materials including concrete, metal, wood, and plastic (see Figure 4-6). Storage volumes typically range from several hundred to several thousand gallons, an appropriate size for concurrent use by multiple single-family residences. Cisterns can be designed to store stormwater for irrigation or infiltration between storms, or to slowly release water through a permanently open outlet. To maximize storage and hydrologic performance, systems should drain fully between rain events, ideally via slow release into another green infrastructure practice or landscaped area for irrigation and treatment. An overflow structure also is necessary for cases in which the volume of stormwater exceeds the cistern's capacity. Overflow can then be routed to another green infrastructure practice or to the conventional stormwater drainage system.

On a smaller scale, *rain barrels* typically store less than 100 gallons and are generally appropriate for use by individual residences (see Figure 4-7). To maximize hydrologic benefit, however, rain barrels either must be appropriately sized or multiple units must be used to fully capture runoff from the contributing roof area.

These systems are typically placed near roof downspouts so that flows can be easily diverted into the cistern or rain barrel. The State of New Mexico's rainwater harvest guide contains detailed information on cistern design procedures that are appropriate for the Pueblo de Cochiti region (OSE 2009).

Source: Santa Fe Children's Museum, Santa Fe, NM

Figure 4-6. Decorative cistern.

Source: Tijeras Rain Barrels, Albuquerque, NM

Figure 4-7. Example rain barrel installations.

4.4.4 Vegetation Selection

Several species of native trees and plants were considered for the conceptual designs. Fruit trees including apple, apricot, cherry, and pear will provide additional resources to the community and are historically significant for the area. Other trees such as cottonwoods, aspen, and willow are naturally found along the flood plains of nearby rivers and streams. Those riparian plant species are well-integrated into the local hydrologic system, provide important wildlife habitat, and help to regulate overall water temperature fluctuation and nutrient levels. Additionally, they stabilize stream banks and prevent erosion. Piñon and juniper trees, found further upland, can provide an economic resource for the community.

Many native trees and plants are historically significant to the Pueblo and reintroducing them has been recommended as an effort to restore or enhance their role in the traditional way of life. These species include tea plants, the yucca, and the Rocky Mountain Bee Plant (*Cleome serrulata*). Several varieties of herbs and tea plants have historical, ceremonial, and economic significance for the Pueblo (see Figure 4-8 for an example planting). The concept of reintroducing native and ceremonial herbs and teas around the Pueblo, such as in garden areas, was well received by community members. Yucca plants are both culturally and economically significant in the Southwest and to the Pueblo community. Yucca plants come in several varieties, are widespread on a variety of landforms on the Pueblo lands, and can provide browse and cover for animals.

Photo credit: Tetra Tech, Inc.

Figure 4-8. Growth of Greenthread, a native plant used for tea in Pueblo de Cochiti.

Rocky Mountain Bee Plant is a pink-blossomed wildflower often found along dry roadsides (see Figure 4-9). This annual herb can grow up to 4 ft tall, has a long blooming season, and has blossoms that attract a diverse array of pollinators, including bees, butterflies, and wasps. The Bee Plant is an important cultural plant; in the past, it has been used as a potherb or medicinally as a tea for fevers and other ailments. The seeds also were ground and used to make gruel or bread. A concentrated form of dye made from boiling the plant into a thick black resin is used to paint designs on pottery or for decorating baskets.

Photo credit: Tetra Tech, Inc.

Figure 4-9. Rocky Mountain Bee Plant observed in the community.

Tribal specialists can provide additional guidance and recommendations for planting native plants that are historically significant to the tribe. An online resource for the Pueblo is the Southwest Yard and Garden Plant Advisor (New Mexico State University 2016). This resource includes a large database of xeriscaping plants, as well as helpful tips and advice for landscaping in New Mexico.

5 Concept Design

As mentioned above, a principal consideration when selecting and designing green infrastructure practices for use in Pueblo de Cochiti is community acceptance, with an emphasis on using locally available and community-approved materials. Furthermore, the practices and their design configurations must be appropriate for local climate conditions. The conceptual green infrastructure designs detailed in this section address the stormwater management concerns in each of the three project areas. The information obtained in the community charrette heavily influenced the green infrastructure practices proposed for each area. Specifically, typical practice configurations applicable to the Desert Southwest urban environment were modified to preserve historical pueblo aesthetics. Furthermore, the concept designs were selected and configured to enable local community members to use local resources to implement and maintain the practices, ensuring that they are sustainable and successful in the long term.

5.1 Cochiti Plaza

Under the existing conditions, roof runoff that accumulates during rainfall events causes scour and erosion around building foundations in the community (see Figure 5-1). Residents have emphasized that any green infrastructure practices proposed for Cochiti Plaza should avoid digging and grading. To address those conditions, two green infrastructure practice types—cisterns and rain gardens—are recommended for consideration.

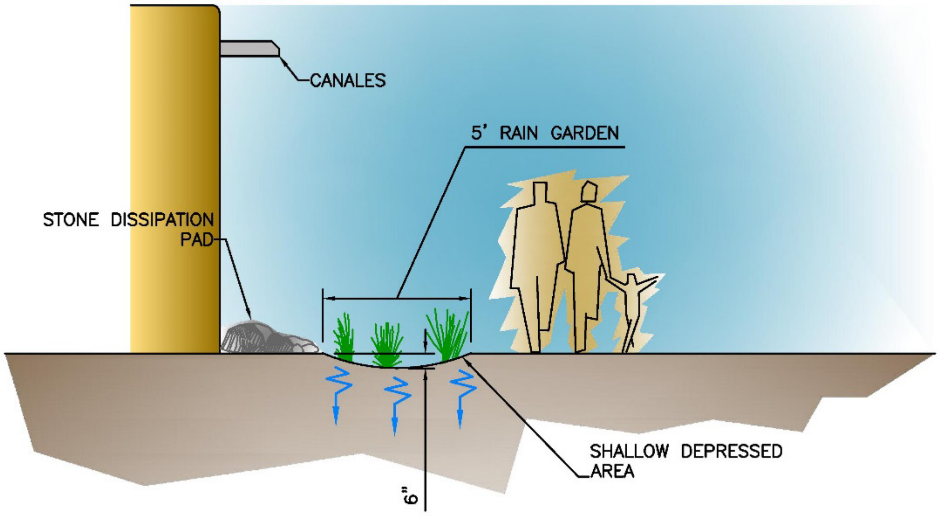
Photo credit: Tetra Tech, Inc.

Figure 5-1. Photos illustrating scour and erosion at adobe foundations under a canales.

Cisterns and rain barrels are technologically appropriate solutions for the stormwater issues in Cochiti Plaza. During charrette discussions, however, members of the community expressed reservations about the use of the practice within the Plaza area. The design of cistern or rain barrel systems for the Plaza would have to consider the community's preference for historical aesthetics. Figure 4-7 illustrates examples of rain barrels in New Mexico communities that are constructed of materials designed to blend in with regional buildings and landscapes. Pueblo residents determined that those applications were inconsistent with the desired aesthetics of the Pueblo. As a result, the conceptual design for the Plaza area does not include cisterns or rain barrels. Additional discussions with the community are necessary to determine potentially acceptable materials and locations for the water harvesting systems and whether they can be implemented as part of future green infrastructure initiatives.

Small-scale rain gardens were more warmly received by residents as a potential green infrastructure practice within the Plaza area. The rain gardens would consist of shallow depressions adjacent to the building into which rooftop runoff from canales would collect and infiltrate (see Figure 5-2).

Materials such as native stones should be placed under the canales to dissipate energy and route runoff into the rain garden. The rain gardens would be planted with locally and culturally significant vegetation species (such as those described in section 4.4.4).



Source: Tetra Tech, Inc.

Figure 5-2. Rain garden schematic.

Many structures are slightly elevated relative to surrounding roadways and pathways, possibly a result of long-term erosion. In those instances, implementation of a rain garden could require a retaining wall system to provide a transition in elevation and protect the rain garden from erosion (Figure 5-3).

Retaining walls consisting of large timbers are used elsewhere in the Pueblo but are not preferred by the community. To address those concerns, the conceptual design proposes to construct the retaining wall of adobe brick and plaster consistent with building construction throughout the Pueblo. Adobe brick is emphasized as the community's preferred material. An additional benefit of adobe is that the community has a skilled adobe maker within the Pueblo and is actively building the capacity to conduct regular maintenance of adobe walls using community resources. In the construction of adobe brick retaining walls and implementation of rain gardens adjacent to existing buildings, the potential for implications to structural stability of the buildings and other infrastructure should be considered.

Therefore, it is recommended that, prior to installation of these practices, a local engineer be consulted to ensure that construction will not endanger structural stability and that retaining wall size is appropriate for site conditions.

Source: Tetra Tech, Inc.

Figure 5-3. An artist's rendering of a rain garden incorporating an adobe retaining wall.

In retrofit scenarios such as the Plaza and throughout the rest of Pueblo de Cochiti, the sizing of any green infrastructure device depends on the space available and the presence of other infrastructure. As such, any rain garden installation should attempt to take advantage of site conditions and not be constrained by a strict sizing guidance. To provide a guide for potential rain garden sizing, an assessment of Pueblo rooftop size contributing to each rain garden was conducted. Since most rain garden retrofits would treat runoff from a single canal, this scenario was the basis for the analysis. The assessment revealed that contributing rooftop area for most buildings generally ranges from 100 to 400 square feet (sq ft). That range of contributory area was used to determine the rain garden size necessary to retain the 0.62 inch rainfall that Pueblo receives annually (Table 5-1). This information provides a general guide for rain garden sizing, but rain garden designers could construct rain gardens that vary from these guidelines to suit site conditions.

Table 5-1 Rain garden sizing guide to retain 0.6-inch storm

Rooftop Drainage Area (sq ft)	Runoff Volume for Storm (cu ft)	Suggested Rain Garden Footprint (sq ft)	Suggested Rain Garden Dimension (ft)
100	5	12	3 X 4
150	7.5	18	4 X 4.5
200	10	24	4.8 X 5
250	12.5	30	5 X 6
300	15	36	5 X 7.2
350	17.5	42	5 X 8.4
400	20	48	5 X 9.6

Note: cu ft = cubic feet.

The use of rain gardens for stormwater management will help to alleviate some of Pueblo de Cochiti's stormwater issues, while also addressing their desire to bring more vegetation into the community.

5.2 Turquoise Street

Pueblo de Cochiti residents expressed overwhelming disapproval of a recent roadway improvement project on Cochiti Street that included the installation of asphalt pavement, curbs, speed bumps, and other design features that are not commensurate with the historical and cultural character of the community. The proposed green infrastructure design for Turquoise Street (included in Appendix A) incorporates roadside infiltration swales planted with fruit trees along both sides of the street and a walking path on one side of the street. The proposed design includes the use of coarse local stone for the roadside swales and native stone for the walking path surface. The aging asphalt road surface would be resurfaced with a new asphalt material dyed to match the native soil color to preserve historic aesthetics.

The stone walking path will improve pedestrian safety and address a key concern raised in the community charrette regarding residents walking in the street. Planting fruit trees along the new street design will provide additional opportunities for stormwater infiltration and evapotranspiration, improved aesthetics and shading, and a potential food resource for the community. All of these practices together will respect residents' preference for historically and culturally significant vegetation and neighborhood aesthetics, while helping to reach the community's goal of increasing the amount of vegetation and shade.

Figure 5-4 shows a current view of Turquoise Street and the projected view after implementation of the proposed green street design. Figure 5-5 presents a cross section of the proposed green street design.

Photo credit: Tetra Tech, Inc.

Figure 5-4. *Top*, view of Turquoise Street near Pueblo Route 85 facing southeast; *bottom*, artist's rendering of green street design.

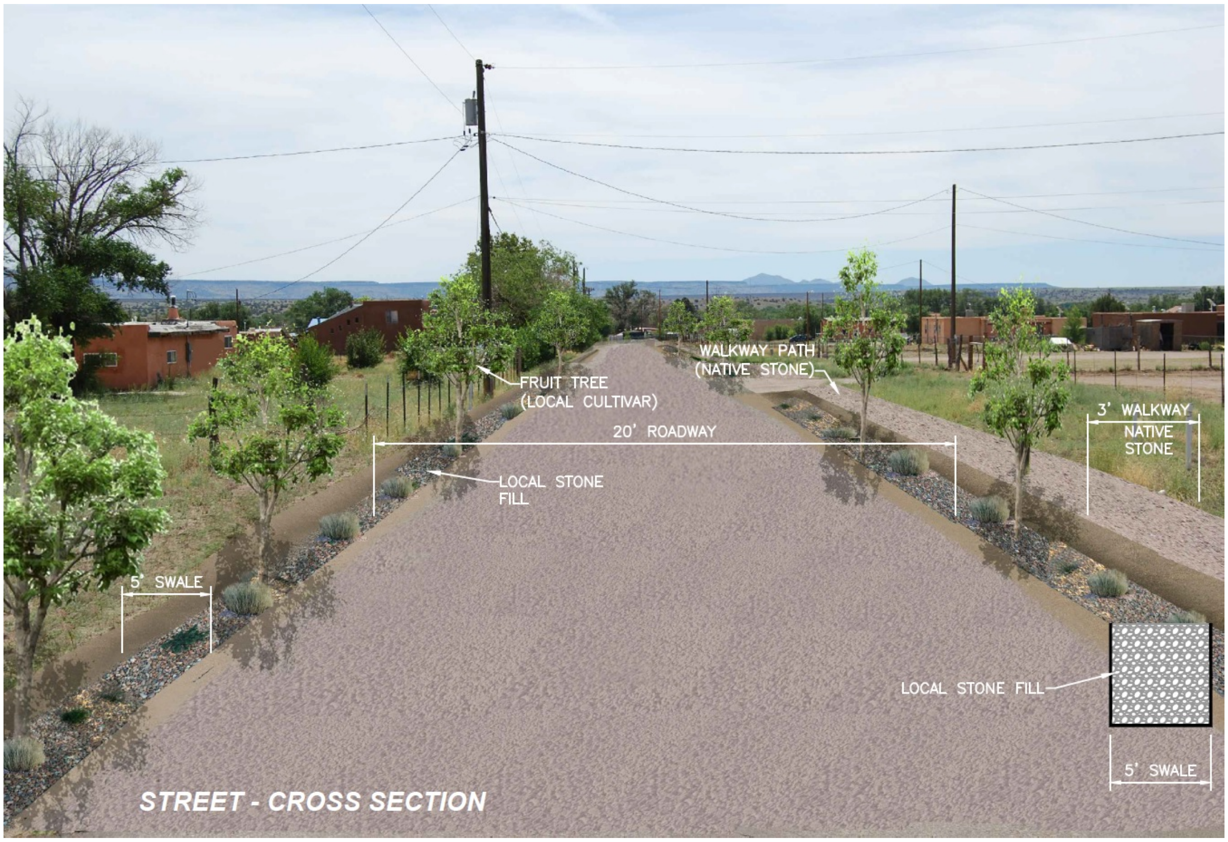


Figure 5-5. Proposed green street concept design cross section for Turquoise Street.

The City of Albuquerque's stormwater design guidance was used as a preliminary reference for calculating the volume of stormwater storage required by the proposed infiltration swales. As noted in section 4.1, the Albuquerque MS4 permit requires treatment of the 90th percentile storm, which is equivalent to a rainfall depth of 0.62 inch. That criterion was used to provide preliminary sizing, summarized in Table 5-2.

Table 5-2. Summary of infiltration swale geometry and retention volume for Turquoise Street design

Project Area	Green Infrastructure BMP Type	Approx. Contributing Area (acre)	Design BMP Width (ft)[a]	Design BMP Length (ft)	Storage Volume Provided (ft^3)
Turquoise Street	Infiltration Swale	1.65	10	255	3,311

Notes:
ft3 = cubic feet
a. Infiltration swales of 5-ft width are recommended for both sides of the street, totaling 10-ft width.

The Turquoise Street conceptual design, once implemented, also could serve as a template for future roadway improvement projects such as the other connecting streets along Pueblo Route 85 and streets within the Robin Street neighborhood (discussed in section 5.3).

5.3 Robin Street

The existing stormwater management system serving the Robin Street neighborhood is beset by problems of scour in upland areas and associated sediment deposition along streets and infiltration basins. Despite preventing the discharge of stormwater from the neighborhood, the current management approach results in unsightly conditions, eroding landscapes, and potentially hazardous roadway surfaces. Based on observed site conditions, it was determined that the Pueblo should consider a suite of green infrastructure solutions that can be implemented at a variety of temporal and spatial scales, constituting a long-term green infrastructure plan for the Robin Street neighborhood.

5.3.1 Residential Green Infrastructure Solutions

A central tenet of the green infrastructure plan for the Robin Street neighborhood is to manage stormwater at its source within the upland residential areas. Management at this scale can be accomplished through both nonstructural and structural approaches.

Nonstructural solutions recommended for this neighborhood include a reduction in sloped areas dedicated to driveways by replacing them with vegetation to increase stormwater infiltration and improve soil stability. Many driveways in the Robin Street area are excessively wide, resulting in vehicular traffic along a large area of sloped ground. The width of those areas should be limited to only what is necessary to provide access to residences and parking space for vehicles. That can be accomplished through either targeted planting of vegetation or placement of aesthetic stone or timber barriers that can blend into the landscape. Such vegetation reestablishment also is recommended for areas outside of existing driveways, which also could be denuded of vegetation or impacted by historic compaction or other activities. Figure 5-6 shows an example of aesthetically desirable landscaping at a Robin Street home that exhibits good vegetative cover and limits driveway width.

Photo credit: Tetra Tech, Inc.

Figure 5-6. Desirable landscaping elements at a Robin Street home.

The structural green infrastructure practices of rain gardens and cisterns were identified as suitable for use within this neighborhood based on observed conditions and community preferences. Both practices can result in a net reduction in runoff volumes while encouraging (if not enhancing) the amount of vegetation surrounding residential structures. The application and design guidance for rain gardens detailed in section 5.1 for the Plaza area also is applicable to the Robin Street neighborhood. The list of plant species, however, could be expanded beyond historically or culturally relevant species to include others that are desirable to individual residents. Cisterns should be considered as an alternative practice to rain gardens where dedicated use of captured rainwater is desired by residents. Cistern design should be customized for each contributing rooftop and associated use based on locally relevant design criteria, such as the City of Albuquerque rainwater harvest guide (City of Albuquerque 1999).

5.3.2 Roadway Green Infrastructure Solutions

While rooftops and eroding driveways were observed to be a primary source of stormwater issues observed within the neighborhood, the roadway network itself constitutes the majority of impervious surface in this area of the Pueblo. In addition, observation of the number of vehicles using on-street parking suggest that roadway widths are likely excessive relative to the current needs of the community. As the current roadways require maintenance and ultimately replacement, the Pueblo could consider reducing the overall roadway width where appropriate, specifically on Jackrabbit, Broken Arrow, and Robin streets where widths exceed 20 ft (the minimum generally necessary for emergency services access). Such roadway reduction would directly reduce the amount of impervious surface contributing to stormwater runoff within the area and have the added benefit of reducing roadway replacement and, by extension, maintenance costs. The resulting space left over from roadway reduction activities might provide opportunities for incorporating green infrastructure elements such as those prescribed for the Turquoise Street conceptual design.

6 Conclusion

A wide variety of green infrastructure stormwater solutions have been developed for application in urbanized areas throughout the country and are generally suited to communities that follow typical urban development practices. But for traditional Pueblo communities of the arid Southwest such as Pueblo de Cochiti, standard green infrastructure practices, design geometries, and construction materials often conflict with the traditional development patterns and cultural needs of the community.

Nonetheless, the broader green infrastructure principles of reduced impervious surface, management of stormwater at its source, and incorporation of vegetation can easily be adapted to the Pueblo setting. The conceptual designs recommended for Pueblo de Cochiti adapt regionally appropriate green infrastructure practices using appropriate construction materials and vegetation and provide a plan for integrating green infrastructure into current and future Plaza revitalization and Pueblo development. The plan enables the Pueblo to use an adaptive approach to green infrastructure implementation along its roadways and to learn from initial projects which designs, materials, and vegetation are most suitable for long-term success and community acceptance.

7 References

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Appendix A: Turquoise Street Concept Design

PUEBLO DE COCHITI, NEW MEXICO
GREEN INFRASTRUCTURE CONCEPTUAL PLAN
SITE: TURQUOISE STREET

Site Location			
Date of Field Visit	7/16/2014	Latitude	35° 36' 33" N
Field Visit Personnel	J. Smith, K. Dors	Longitude	106° 20' 59" W
Major Watershed	Rio Grande River	Landowner	Pueblo de Cochiti
Street Address	Turquoise Street		

Drainage Area Characteristics	
Drainage Area, acres	1.65
Hydrologic Soil Group	A
Existing use	Roadway
Design Storm Event, in	0.62

Proposed Characteristics*	
Proposed BMPs	SS, ST
Total Detention Vol., ft^3	3,524
Swale Area, ft^2	2,711

Existing Site Description: The proposed project site consists of Turquoise Street, a two lane residential road connecting Pueblo Route 85 with the Plaza Street. The road is currently paved with an aging asphalt surface approximately 18 feet wide within a 40-60 ft' wide corridor. The corridor is bordered by private residences served by vehicular driveways. Shallow swales run along both sides of the road providing surface drainage of roadway runoff which flows southeast towards Plaza St.

Proposed Green Infrastructure Description: Proposed improvements to the roadway will include incorporation of infiltration swales along both sides of the roadway designed to capture and infiltrate roadway runoff. The swales will be partially filled with local native stone and planted with local fruit tree cultivars to utilize the captured runoff. A 3 ft wide stone walking path will be included on the southern side of the roadway.

SS = Stormwater Swale, ST = Street Trees

*Green Infrastructure characteristics are based on field observations and GIS data resources available at the time of conceptual design analysis. Note that final design characteristics will be dependent on a detailed site survey and could vary slightly from conceptual design characteristics.

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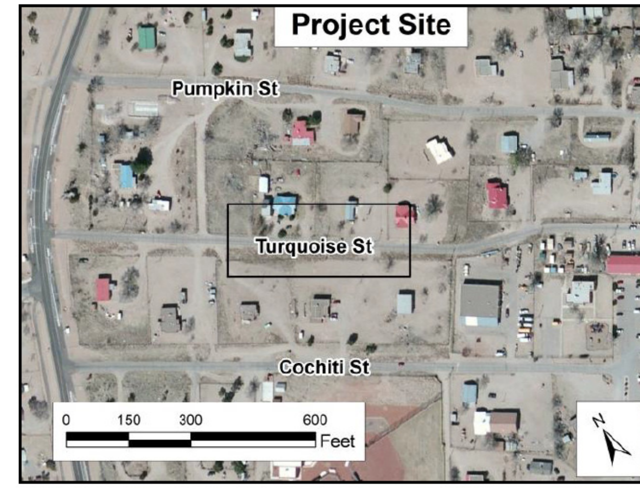

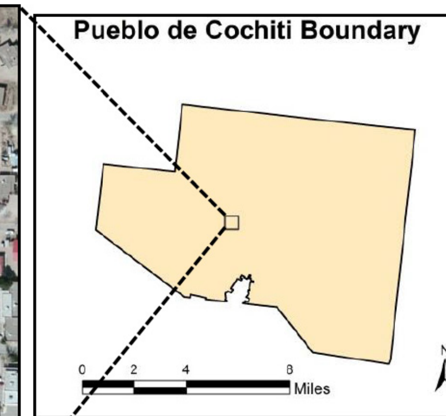

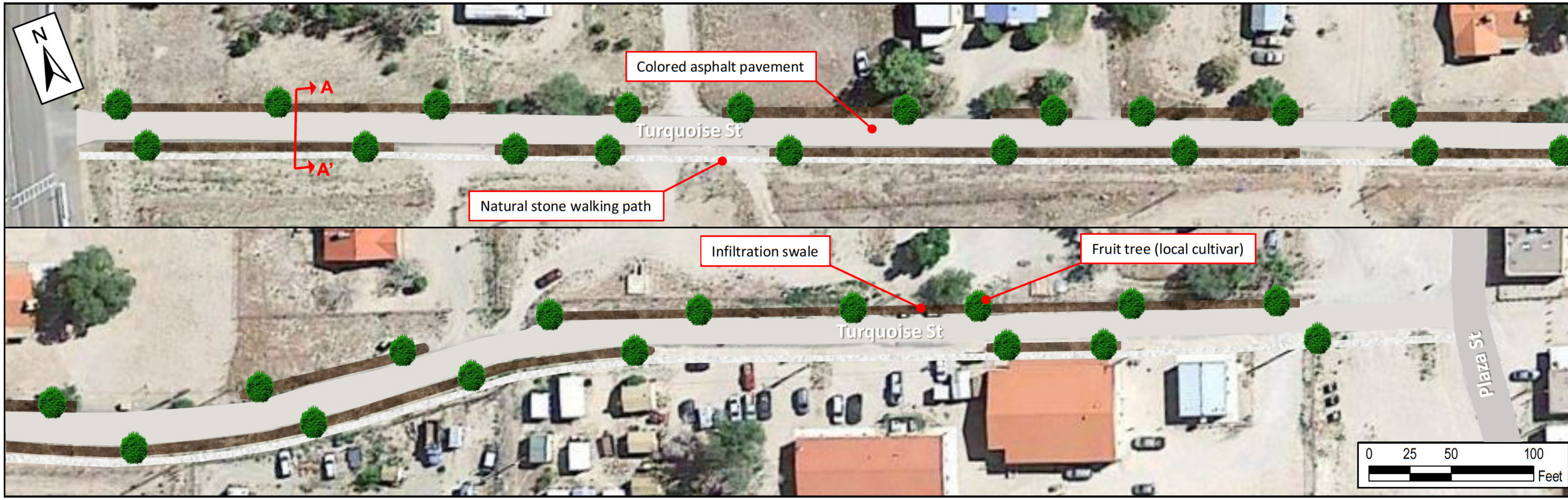

Current Street View (Facing Southeast)

Conceptual Green Street Rendering (Facing Southeast)