SHOAL CREEK
WATERSHED ACTION PLAN

DRAFT

Prepared in cooperation with the Texas Commission on Environmental Quality
and the U.S. Environmental Protection Agency

May 20, 2020 - DRAFT

SHOAL CREEK CONSERVANCY

DOUCET & ASSOCIATES -27 years and counting-

The Meadows Center for Water and the Environment
Texas State University

Texas Commission on Environmental Quality

EPA United States Environmental Protection Agency

ACKNOWLEDGEMENTS

This document is a result of collaborative efforts between many stakeholders and partners. Each participant played an essential role in the Shoal Creek watershed planning process.

First, we wish to express our thanks to members of the Stakeholder Committee for their gracious investments of time and energy throughout the process. We greatly appreciate their contributions and support.

In particular, we would like to thank the Steering Committee for providing leadership and guidance to the stakeholders and project team during development of the plan. Steering Committee members include:

- Chris Herrington, COA Watershed Protection Department - Chair, Government Representative
- Louisa Brinsmade, Office of Austin City Council Member Leslie Pool - Government Representative
- Kasey Faust, University of Texas, Engineering School - Academic Representative
- Wendy Gordon, Vice Chair, Academic Representative
- Shannon Halley, Office of Austin Council Member Kathie Tovo - Government Representative
- Matt Harriss, Butler Family Interests - Business Representative
- Adam Haynes, Allandale Neighborhood Association - Neighborhood Representative
- Holland Jones, Whole Earth Provisions - Business Representative
- Ivey Kaiser, Shoal Creek Conservancy - Nonprofit Representative
- Linda McCoy - Neighborhood Representative
- Kazique Prince, Office of Austin Mayor Steve Adler - Government Representative
- Chris Randazzo, Real Estate Council of Austin - Business Representative
- Heath Riddles, Secretary, Pease Park Conservancy - Nonprofit Representative
- Janae Spence, COA Public Works Department - Government Representative
- D'Anne Williams, COA Parks and Recreation Department - Government Representative

The dedication of the Shoal Creek stakeholders throughout this process serves as testament to the deep community appreciation for Shoal Creek and commitment to participating in its stewardship for years to come. (Please see Appendix C for Stakeholder and Steering Committee information.)

We are especially grateful to the Texas Commission on Environmental Quality (TCEQ) and the U.S. Environmental Protection Agency (EPA) for providing the vision of a strong and influential stakeholder-led watershed planning process. These agencies provided funding through a Clean Water Act §319(h) grant and technical guidance that allowed us to establish a strong foundation for watershed stewardship in the Shoal Creek watershed.

Lastly, we extend our gratitude to our matching funding partners for making this project possible: The Still Water Foundation, The Jacob and Terese Hershey Foundation, and The Reese Foundation.

EXECUTIVE SUMMARY

Stretching from north to central Austin, Texas, the Shoal Creek watershed, segments 1429A and 1403J, encompasses 8,300 acres, extends 16 miles, and includes more than 30 miles of streams. This highly urban watershed drains into the Colorado River at Lady Bird Lake and is partially within the environmentally sensitive recharge zone of the Northern Segment of the Edwards Aquifer. Once home to popular swimming and fishing destinations, the creek suffers from poor water quality, severe flooding and erosion, reduced spring and baseflow, and loss of riparian and aquatic habitat.

One of the most significant issues facing Shoal Creek today is nonpoint source pollution. Since 2002, elevated bacteria concentrations have been observed in the Spicewood Tributary (Segment 1403J). This tributary is currently listed as impaired for bacteria and of concern for nitrate in the Draft 2020 Texas Integrated Report of Surface Water Quality. In 2012, TCEQ developed a Total Maximum Daily Load (TMDL) to address bacteria and to evaluate attainment of the contact recreation use in the Spicewood Tributary as well as in Waller Creek, Walnut Creek, and Taylor Slough South. TMDL compliance is based on maintaining bacteria mean concentrations below 126 MPN/100 mL (TCEQ, 2015). Water quality monitoring shows that bacteria in the Spicewood Tributary as well as other areas of Shoal Creek often exceed these levels. In addition, storm flows in Shoal Creek have high levels of nutrients, sediments, and other contaminants.

In addition to poor water quality, Shoal Creek faces significant flooding and erosion challenges. Shoal Creek has experienced several severe flood events throughout Austin's history, including the infamous 1981 Memorial Day Flood that destroyed numerous homes and businesses along the creek and claimed 13 lives. Lower Shoal Creek between 15th Street and Lady Bird Lake is currently the top-ranked creek flooding problem area in Austin, with 655 buildings and 54 roadways expected to be impacted in a 100-year flood event. Streambank erosion is also prevalent throughout the watershed. Since the early 1980s, the City of Austin (COA) has completed over 80 bank protection and stabilization projects. However, numerous erosion "hot spots" remain. This creek widening and downcutting, combined with reduced spring and baseflow, has negatively impacted riparian and aquatic habitat throughout the watershed.

The Shoal Creek watershed is highly urbanized with approximately 54% of the watershed surfaced in impervious cover. High levels of impervious cover cause increased flooding, reduced water quality and local groundwater recharge as well as other challenges. In addition, a majority of the development in Shoal Creek occurred prior to a modern understanding of the impact of development on watershed systems and before the COA required stormwater detention and water quality protection measures. This combination of issues presents special challenges and requires a multifaceted approach to restoring water quality and overall watershed health.

Past and Ongoing Efforts to Address Watershed Health

The COA Watershed Protection Department (WPD) manages the City's creeks, drainage systems and water quality programs. The WPD's focus is to reduce the impact of flooding, erosion, and poor water quality in Shoal Creek, and throughout Austin, through capital

projects as well as ongoing programs and services. Capital projects, also called Capital Improvement Program (CIP) projects, are typically large City-sponsored projects that construct, upgrade, or repair public infrastructure, including storm drain systems, low water crossings, and stream restoration. WPD's capital budget is funded by a combination of sources, including the Drainage Utility Fund (DUF), voter-approved bonds, and developer mitigation funds derived from the Regional Stormwater Management Program. The WPD has invested over $83 million in improvements to the Shoal Creek watershed since the 1970s. The City also provides numerous ongoing services and programs within the watershed aimed at improving water quality and overall creek health. This work is complimented by education and outreach efforts by nonprofit organizations such as Shoal Creek Conservancy (SCC), Pease Park Conservancy, Keep Austin Beautiful, and Austin Parks Foundation. Despite these significant investments, Shoal Creek remains impaired. (A full summary of activities within the watershed is located in the Watershed Characterization Report found in Appendix A.)

The Need for a Plan

Concerns about poor water quality and overall creek health coupled with stakeholder interest in stewardship of the creek led SCC, an Austin nonprofit organization, to pursue funding for the creation of a watershed action plan. The project was funded by the EPA through a Clean Water Act §319(h) grant that is administered by TCEQ in addition to funds from private foundations. SCC facilitated the Shoal Creek Watershed Action Plan (SCWAP) process and partnered closely with the COA and academic, business, and neighborhood stakeholders to develop this Plan.

The creation of this document was guided by vision and goal statements regarding the future of Shoal Creek developed by stakeholders during the SCWAP planning process.

The vision statement for the future of Shoal Creek is:

> *Shoal Creek is a model healthy and resilient urban watershed that benefits people and nature and is supported by a well-informed and engaged community.*

The stakeholder goal statement is as follows:

> *The Shoal Creek Watershed Action Plan (SCWAP) is a model urban watershed management program that implements measures to achieve contact recreation standards; promote baseflow enhancement; reduce nutrients, herbicides, and pesticides; and promote riparian and aquatic health. Additionally, the SCWAP supports the City of Austin in flood mitigation and planning. Measures are implemented by an engaged community working in partnership with the Shoal Creek Conservancy and the City of Austin. The SCWAP informs ongoing City of Austin policymaking across a variety of areas, such as land development, mobility, and parks, in order to continually maximize water quality protection and support a healthy Creek.*

Stakeholder Goals and Management Objectives:

To achieve the goal stated above, SCWAP stakeholders, informed by scientific analysis and best management practices, identified a suite of management measures to pursue using a phased approach. The measures included in the SCWAP consist of strategies focused on reducing bacteria load as well as holistic strategies that seek to achieve an overall increase in watershed health.

To address bacteria management goals as required by TCEQ, the SCWAP follows the model set by the COA TMDL for Five Watersheds that was approved by TCEQ in 2015. This TMDL includes the Spicewood Springs Tributary of Shoal Creek. Key measures in the TMDL that will be supplemented watershed wide by SCWAP activities include the COA Scoop the Poop Program and the installation of Grow Zones in parks and urban areas. Additional measures included in the SCWAP to address bacteria in the creek include the promotion of the COA's Rainwater and Grow Green programs. Further measures are explored in this document to address the holistic health of Shoal Creek.

The following table lists each of the stakeholder goals included within the "goal statement" and their associated problem indicators, causes and management objectives identified during the watershed planning process.

Stakeholder Goals	Problem Indicators	Cause or Source of Impact	Management Objective
Promote Baseflow Enhancement	Intermittent flow and dry creek sections a majority of the year	Watershed Impervious Cover >50%	Enhance local recharge in existing detention basins and through spring restoration, green infrastructure, and riparian restoration
Support COA in Flood Mitigation and Planning	655 buildings and multiple bridges and culverts impacted by flooding	Inadequate stormwater controls, inadequate road culverts and bridges, floodplain development, storm drain systems directly connect runoff from impervious cover to the creek	Minimize flooding impacts by improving peak and volume controls on urban sources, retrofitting inadequate road crossings, increasing flood preparedness and safety
Restore Aquatic Habitat	Eroded stream, limited aquatic life, poor physical integrity, fair water quality	Lack of consistent baseflow, erosion of natural stream, channelization, urban runoff	Reduce sediment and pollutant loads, enhance baseflow, slow runoff
Achieve Contact Recreation Standards	*E. coli* bacteria levels exceed state contact	Urban runoff, dog and wildlife waste, COA and private lateral/wastewater leakage	Reduce loads from parks, creekside properties, and urban

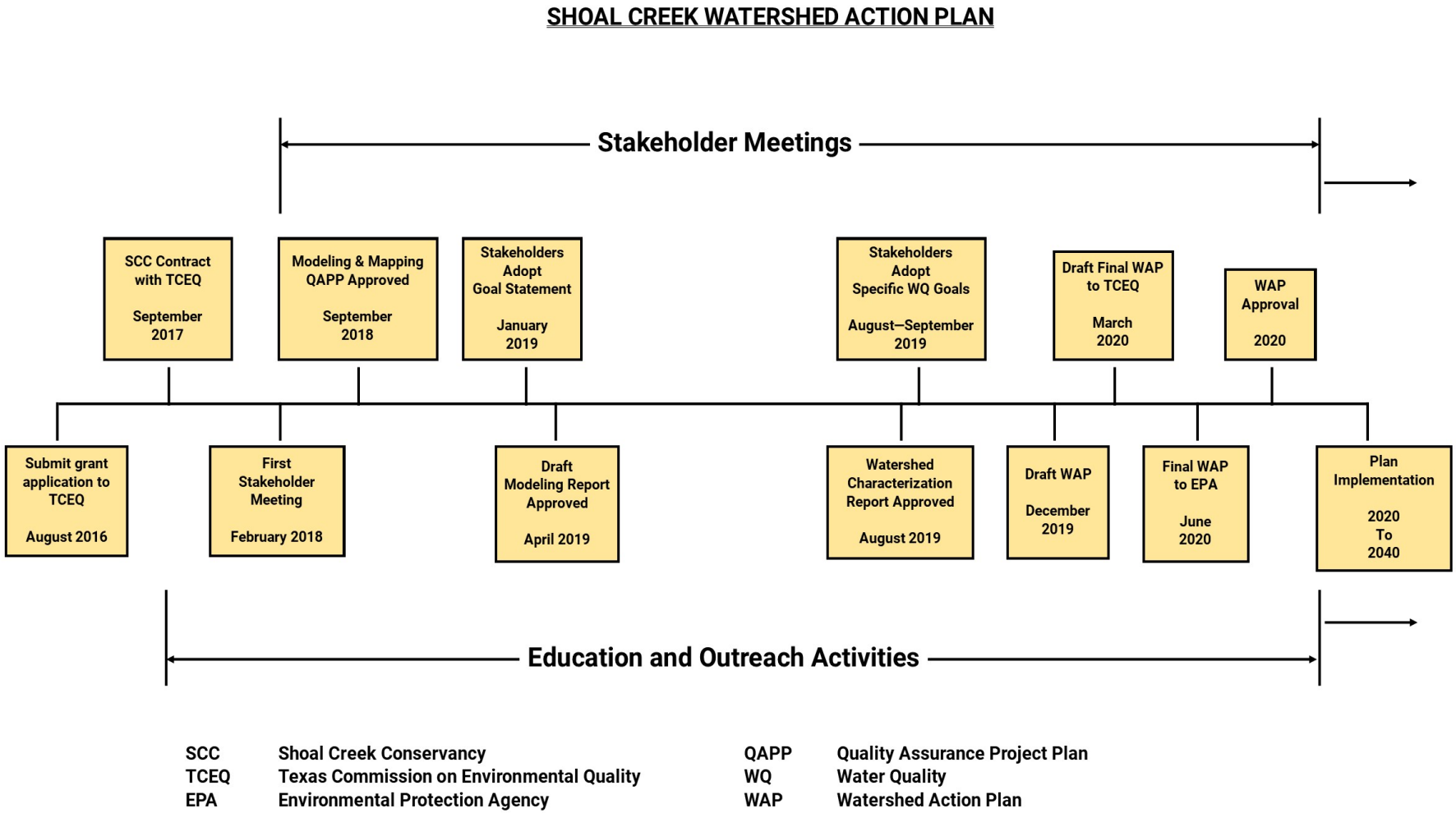
	recreation standards		sources such as leaking wastewater lines
Reduce Nutrients, Herbicides, and Pesticides	High pollutant loads	Urban runoff	Add stormwater controls; reduce use of herbicides, pesticides, and fertilizers
Promote Riparian Health	Minimal natural riparian areas	Urbanization, floodplain development, creekbank erosion	Enhance existing and initiate new grow zones and creek buffer zones

Technical and Financial Assistance, Monitoring, and Education/Outreach

This document also identifies technical and financial assistance opportunities, monitoring support, and a robust education and outreach effort. Technical and financial assistance opportunities to support implementation of the SCWAP are listed in Section 5.3, including the exploration of future partnerships with local, state, and federal entities. Monitoring support will continue from the COA, which provides Environmental Integrity Index (EII) data to help assess water quality improvements in comparison to the above goals, and volunteer monitoring efforts will be explored to enhance this data. Section 5.2 details the education and outreach plan that highlights opportunities to further involve residents in the Shoal Creek watershed and to involve them in protecting water quality, providing input, and obtaining funding.

Watershed Action Plan Timeline

The below diagram summarizes the timeline of key events during Shoal Creek Watershed Action Plan process.



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LIST OF ACRONYMS AND ABBREVIATIONS

ACC	Austin Community College
AISD	Austin Independent School District
APF	Austin Park Foundation
AWU	Austin Water Utility
AYRW	Austin Youth River Watch
BMP	Best Management Practice
BST	Bacterial Source Tracking
CIP	Capital Improvement Program
COA	City of Austin
COM	Commercial
CWA	Clean Water Act
DO	Dissolved Oxygen
DSD	Development Services Department, City of Austin
DUF	Drainage Utility Fund
E&O	Education and Outreach
E. coli	Escherichia coli
EII	Environmental Integrity Index
EPA	Environmental Protection Agency
ESAC	Environmental Stewardship Advisory Committee
HOA	Homeowners Association
HCP	Habitat Conservation Plan
KAB	Keep Austin Beautiful
LCRA	Lower Colorado River Authority
LDC	Load Duration Curve
LID	Low Impact Development
MPN	Most Probable Number
MS4	Municipal Separate Stormwater Sewer System
NA	Neighborhood Association
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source
NRCS	National Resource Conservation Service
PARD	Parks and Recreation Department, City of Austin
PID/BID	Public/Business Improvement District
PPC	Pease Park Conservancy
PSA	Public Service Announcement
QAPP	Quality Assurance Project Plan
SCC	Shoal Creek Conservancy
SCWAP	Shoal Creek Watershed Action Plan
SELECT	Systems Effectiveness and Life Cycle Costs Tool
SFH	Single Family Home
SIPES	Social Indicator Planning and Evaluation System
SSO	Sanitary Sewer Overflow
SVI	Social Vulnerability Index
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load

TN	Total Nitrogen
TNSMP	Texas Nonpoint Source Management Program
TP	Total Phosphorus
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSS	Total Suspended Solids
TST	Texas Stream Team
TWDB	Texas Water Development Board
TXDOT	Texas Department of Transportation
TWRI	Texas Water Resources Institute
USGS	United States Geological Survey
UT	University of Texas
WAP	Watershed Action Plan
WCR	Watershed Characterization Report
WPD	Watershed Protection Department, City of Austin

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NINE ELEMENT CROSSWALK

The EPA has identified nine key elements that are critical for achieving improvements in water quality. These nine elements are required by the EPA to be addressed in watershed plans funded with the incremental Clean Water Act §319(h) funds. (For more information on these elements, please refer to EPA's "Handbook for Developing Watershed Plans to Restore and Protect Our Waters".) The EPA reviews all watershed plans that serve as guidance for §319(h)-funded projects. To assist with this review, the following table provides a guide to locating these nine elements within the SCWAP.

A Guide to Finding the EPA Watershed Planning Elements in the Shoal Creek Watershed Action Plan

Element	Element Description	Watershed Action Plan Section	Page #
A	Identification of causes and sources of pollution that need to be controlled to achieve load reductions	Ch 1 Watershed Characterization Summary, Section 1.51 Watershed Health, Table 3	14-22
B	Estimation of load reductions expected from management strategies	Ch 5 Watershed Action Plan Implementation, Table 8a	45-59
C	Description of management strategies	Ch 4 Watershed Health Management Strategies; Ch 5 Watershed Action Plan Implementation	37-42; 45-59
D	Estimation of technical and financial assistance needed to implement the plan	Ch 5.3 Technical and Financial Assistance to Implement the Plan, Table 11	59-60
E	Information and education component used to enhance public understanding of the plan	Ch 5.2 Education and Outreach to Enhance Public Understanding of the Plan	53-56
F	Schedule for implementation of management strategies	Ch 5 Watershed Action Plan Implementation, Table 8a	46
G	Description of interim, management milestones for determining whether management strategies are being implemented	Ch 5 Watershed Action Plan Implementation, Table 8a; Ch 5.1 Plan Implementation	45, 46
H	Set of criteria that can be used to determine whether load reductions in (B) are being achieved	Ch. 5 Watershed Action Plan Implementation, Table 8a; Ch. 6.1 Tracking Load Reductions from Management Measures	46, 63
I	A monitoring component to evaluate the effectiveness of the implementation efforts over time	Ch. 6 Monitoring to Evaluate Implementation Effectiveness	63

1.0 INTRODUCTION

Shoal Creek is an 11-mile (13-square-mile) urban stream with 5 miles of contributing tributaries, which, due to its high degree of development, faces critical water quality impairment and degraded overall creek health. As a result, in 2017, SCC in partnership with the COA and local stakeholders commissioned the creation of the SCWAP to address the current and future needs of the creek and the surrounding community.

The Shoal Creek community is dependent upon the stream as an aesthetic, recreational, and functional part of the local ecosystem. Shoal Creek has provided in the past, and has the potential to provide in the future, essential ecosystem services to residents such as storm drainage, flood control, habitat for native species, and opportunities for swimming, fishing, and relaxation. For example, the Shoal Creek Trail, a recreational hike-and-bike trail, currently runs approximately four miles along the length of the creek with plans to extend the trail northward by nearly 9 miles. Shoal Creek also has the distinction of having the oldest trail in Austin, which was built by volunteers in the early 1960s (Wolaver, J., Cruz, J., Siff, T., 2013).

Shoal Creek once demarcated the western boundary of the City of Waterloo, now known as Austin, Texas (Figure 1). The creek was named by Edwin Waller circa 1839 around the time the town of Waterloo was established (Clark, 1954; PPC, n.d.). Shortly prior, Mirabeau B. Lamar stood on the banks of Shoal Creek and declared it the location of the new frontier where the capital of Texas should be placed, with the land west of the city considered Comanche territory (SSC, 2018). Presumably, Native Americans inhabited the Shoal Creek watershed 11,400 years ago, as scientists have found evidence of their existence in Central Texas at this time (PPC, n.d.). During the founding of Waterloo, Comanche “resisted private land ownership around...Shoal Creek, wanting to maintain access to the pristine waters” (PPC, n.d.).

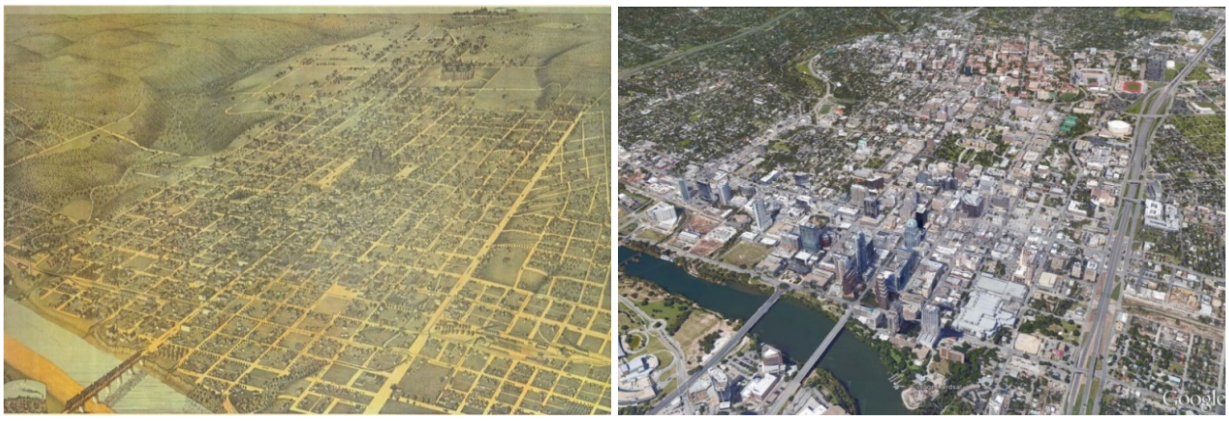

Figure 1 *- Austin circa 1887 and Austin 2016 (WCR, 2019).*

NOTE: Shoal Creek is shown on the left side of the images.

The Shoal Creek watershed is home to important historical neighborhoods and events, such as the Wood Street Settlement, a community of formerly enslaved African

Americans and Mexican and Mexican American families who were later pushed into East Austin as part of the 1928 city master plan (Flores, 2018). In addition, Wooldridge Square, also located near Shoal Creek, was home to major political events, including one featuring Booker T. Washington in 1911 (SCC, 2018). Other important markers along the creek include the West 6th Street bridge which, constructed in 1887, "opened the way for Austin's expansion westward" (SCC, 2018, p. 14).

1.1 Watershed Planning Approach

In response to ecological concerns in the Shoal Creek watershed, stakeholders in the community, led by SCC, commissioned Texas State University's Meadows Center for Water and the Environment (MCWE) and Doucet & Associates (Doucet) to help facilitate the creation of the SCWAP. This work was funded in part by Clean Water Act funding. The SCWAP uses the geographical area of the Shoal Creek watershed to set goals for addressing the health of the creek and the land and community within its bounds. A watershed is "the land area that drains water to a particular stream, river, or lake" (USGS, 2014). When it rains, water, pollutants, nutrients, and sediments move downhill to the watershed's common downstream point. The watershed approach to managing water resources is a holistic and flexible framework for meeting the varied challenges of conservation. This process typically involves three phases: (1) watershed characterization and planning, leading to the production of a watershed protection, or action, plan, (2) implementation, wherein the management measures selected during planning are executed by the community and responsible entities, and (3) evaluation, which occurs at intervals often in conjunction with implementation. While a document and plan are produced in the planning phase, the watershed approach is meant to be adaptive to changing circumstances and the SCWAP stakeholder group intends to meet for the foreseeable future.

The SCWAP also seeks to align with the philosophy of the One Water Approach, which has been adopted by select regional entities to guide future decision making. One Water takes a systems approach to water quality and quantity considerations, including the identification of projects and programs that address economic, environmental, and social implications of watershed protection. One Water embraces multi-faceted solutions that utilize emerging technologies in water conservation and meet other key goals such as ensuring safe places to swim and recreate, reducing flashiness in urban streams, creating healthy riparian corridors, protecting culturally significant features, providing flows to sustain native wildlife, and protecting water quality. As the SCWAP is implemented, stakeholders will explore One Water solutions with relevant partners in Shoal Creek. Such solutions might include rainwater harvesting demonstration projects, groundwater analysis, and flood control measures.

1.2 Stakeholder Process

The watershed planning approach provides stakeholders the opportunity to determine the trajectory of conservation activities in the Shoal Creek watershed. The watershed planning process uses "a series of cooperative, iterative steps to characterize existing conditions, identify and prioritize problems, define management objectives, develop protection or remediation strategies, and implement and adapt selected actions as necessary" (EPA, 2008). Over the course of two years, Shoal Creek stakeholders met

bimonthly at community centers located within the watershed. Through a series of collaborative discussions informed by science, the stakeholders identified issues contributing to the degradation of water quality and overall health of the watershed and made decisions about how to address them. This stakeholder process was facilitated by SCC.

1.3 Stakeholder Committee Organization and Structure

The SCWAP was developed by a stakeholder committee, four working groups, a steering committee, and facilitating entities (see Figure 2). The stakeholder committee is composed of a rotating group of 264 attendees, 40 on average per meeting, representing a range of interests in the watershed including business owners, real estate organizations, residents, researchers and educators, government representatives, and environmental nonprofit organizations. During the planning phase, the stakeholder committee periodically separated into four working groups for the purpose of designing best management practices (BMPs). The working groups were task- and issue-based and included the implementation, education and outreach, water, and land stewardship working groups. The steering committee is composed of individuals that represent organizations and governmental entities responsible for implementation of the plan. The steering committee was originally intended to be an active decision-making entity through the planning process. However, due to a high level of consensus among stakeholders, the steering committee played an informal role until the committee vote on the final draft of the SCWAP. The steering committee will continue to play a key role in future decision-making during the next phase of plan implementation.

The SCWAP is developed as part of the Texas Nonpoint Source Management Program and is monitored and funded in part by the EPA and TCEQ. Additional funding is also provided by private foundations including The Still Water Foundation, The Jacob and Terese Hershey Foundation, and The Reese Foundation. SCC and watershed stakeholders commissioned the MCWE and Doucet to assist with the planning process and to coordinate relevant research and watershed modeling (see Figure 2). The WPD also provided significant guidance and in-kind contributions throughout the process.

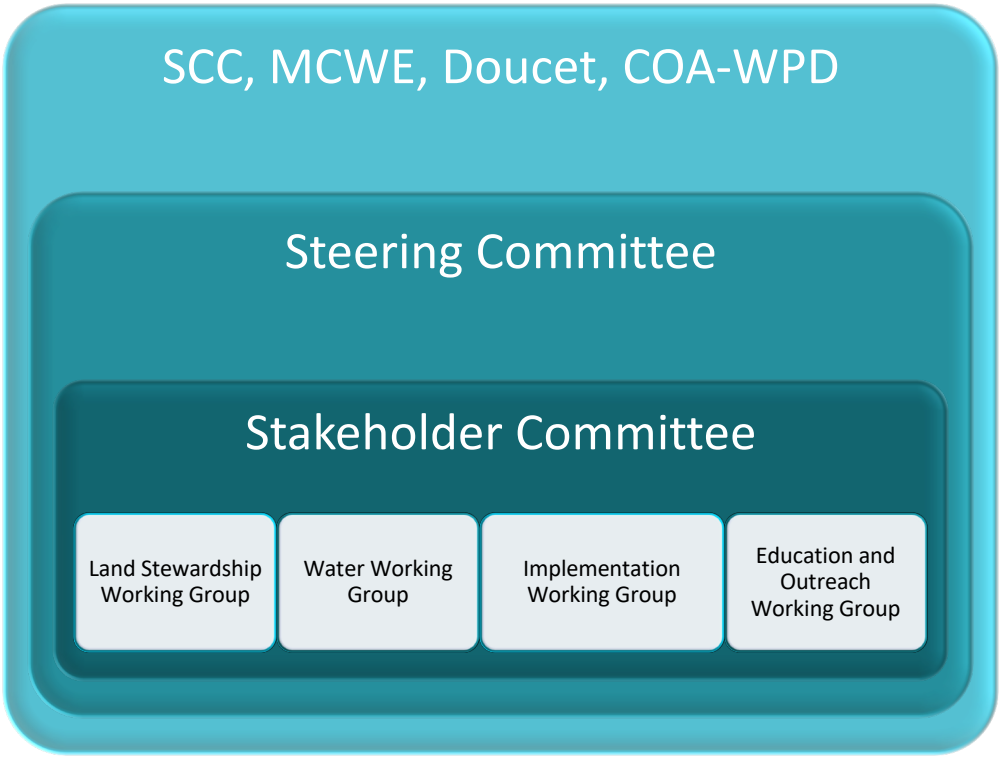

***Figure 2** - Stakeholder Composition of the SCWAP*

1.4 Stakeholder Goals

Stakeholders developed a vision and goals statement to guide the future of Shoal Creek as part of the SCWAP planning process.

The vision statement for the future of Shoal Creek is as follows:

> *Shoal Creek is a model healthy and resilient urban watershed that benefits people and nature and is supported by a well-informed and engaged community.*

The goal statement is as follows:

> *The Shoal Creek Watershed Action Plan (SCWAP) is a model urban watershed management program that implements measures to achieve contact recreation standards; promote baseflow enhancement; reduce nutrients, herbicides, and pesticides; and promote riparian and aquatic health. Additionally, the SCWAP supports the City of Austin in flood mitigation and planning. Measures are implemented by an engaged community working in partnership with the Shoal Creek Conservancy and the City of Austin. The SCWAP informs ongoing City of Austin policymaking across a variety of areas, such as land development, mobility, and parks, in order to continually maximize water quality protection and support a healthy creek.*

The following table lists each of the stakeholder goals included within the "goal statement" and their associated problem indicators, causes and management objectives identified during the watershed planning process.

***Table 1**- Stakeholder Goals, Impairment Causes, and Management Objectives*

Stakeholder Goals	Problem Indicators	Cause or Source of Impact	Management Objective
Promote Baseflow Enhancement	Intermittent flow and dry creek sections a majority of the year	Watershed Impervious Cover >50%	Enhance local recharge in existing detention basins and through spring restoration, green infrastructure and riparian restoration
Support COA in Flood Mitigation and Planning	655 buildings and multiple bridges and culverts impacted by flooding	Inadequate stormwater controls, inadequate road culverts and bridges, floodplain development, storm drain systems directly connect runoff from impervious cover to the creek	Minimize flooding impacts by improving peak and volume controls on urban sources, retrofitting inadequate road crossings, increasing flood preparedness and safety
Restore Aquatic Habitat	Eroded stream, limited aquatic life, poor physical integrity, fair water quality	Lack of consistent baseflow, erosion of natural stream, channelization, urban runoff	Reduce sediment and pollutant loads, enhance baseflow, slow runoff
Achieve Contact Recreation Standards	*E. coli* bacteria levels exceed state contact recreation standards	Urban runoff, dog and wildlife waste, COA and private lateral/wastewater leakage	Reduce loads from parks, creekside properties, and urban sources such as leaking wastewater lines
Reduce Nutrients, Herbicides, and Pesticides	High pollutant loads	Urban runoff	Add stormwater controls; reduce use of herbicides, pesticides, and fertilizers
Promote Riparian Health	Minimal natural riparian areas	Urbanization, floodplain development, creekbank erosion	Enhance existing and initiate new grow zones and creek buffer zones

Accomplishing Goals

The intention of the SCWAP is to improve baseflow, to reduce flooding and erosion, to enhance riparian and aquatic habitat, to protect groundwater resources, and to improve water quality for contact recreation. Monitoring and evaluation will be conducted during the implementation phase of the plan to assess the effectiveness of the adopted management measures using the EPA water quality standards and the COA's Environmental Integrity Index (EII).

The EII was developed by the WPD to monitor and assess the ecological integrity and degree of impairment of local creeks and streams. It is a multi-metric index that integrates information about the physical integrity, chemical, and biological conditions of a sampling location into a single score that reflects the overall ecological function of the creek. Water quality sampling occurs four times per year, and biological and habitat surveys occur once per year, for any given watershed in the city on a biennial basis. The EII assesses Shoal Creek at four discrete sampling points, which are then generalized to the study reaches, SH1, SH2, SH3, and SH4. Shoal Creek is currently rated having "Fair" water quality according to the most recent EII (for more information on the EII, see Section 2.3). The stakeholder adopted goal is to achieve at least "Good" water quality rating across the watershed according to the EII by 2030. Progress towards this goal will be used to evaluate the effectiveness of the management measures deployed.

1.5 Watershed Characterization Summary

The WPD prepared the Watershed Characterization Report (WCR), which summarizes the characteristics and overall health of Shoal Creek and identifies ongoing methods to address concerns. This report can be found in Appendix A and in the Resources section at this link https://shoalcreekconservancy.org/watershedplan/.

Table 2 summarizes the key characteristics of the Shoal Creek watershed. These characteristics are described in detail in the WCR.

Table 2 - Shoal Creek Watershed Characteristics

	Shoal Creek Watershed
Population (2019)	72,000
Projected Population (2040)	104,000
Population Density (persons per acre)	7.5
Creek Length (mi.)	16
Total Area (sq. mi.)	12.9
Receiving Water	Lady Bird Lake/Colorado River
Average Rainfall (in.)	34
Ecoregion	Transition Zone between Edwards Plateau and Blackland Prairie
Natural Features	Karst geology
Aquifer	Northern Segment of the Edwards Aquifer
Watershed in Recharge Zone (%)	27
Impervious Cover (%)	54
Tree Canopy Cover (%)	30
Endangered Species	Jollyville Plateau salamander
Undeveloped/Open Space (%)	5
Dominant Land Uses	Single Family and Commercial

Geographic Location

Shoal Creek begins near the junction of Loop 360 and Texas State Highway 1 (Mopac) and flows south until it empties into Lady Bird Lake between West Avenue and Nueces Street in downtown Austin, Texas. Shoal Creek has two major and two minor tributaries. Spicewood Springs is a small tributary in northwest Austin, named for a nearby spring. The Hancock Branch drains the area between Burnet Road and North Lamar Boulevard. These branches, along with the COA study reaches are shown in Figure 3. Minor tributaries include the Grover and Arroyo Seco, both of which extend from the Hancock Branch of Shoal Creek.

The study reaches in Figure 3 represent the EII reaches and indicate similarities in urbanization, land use, topography, and geology.

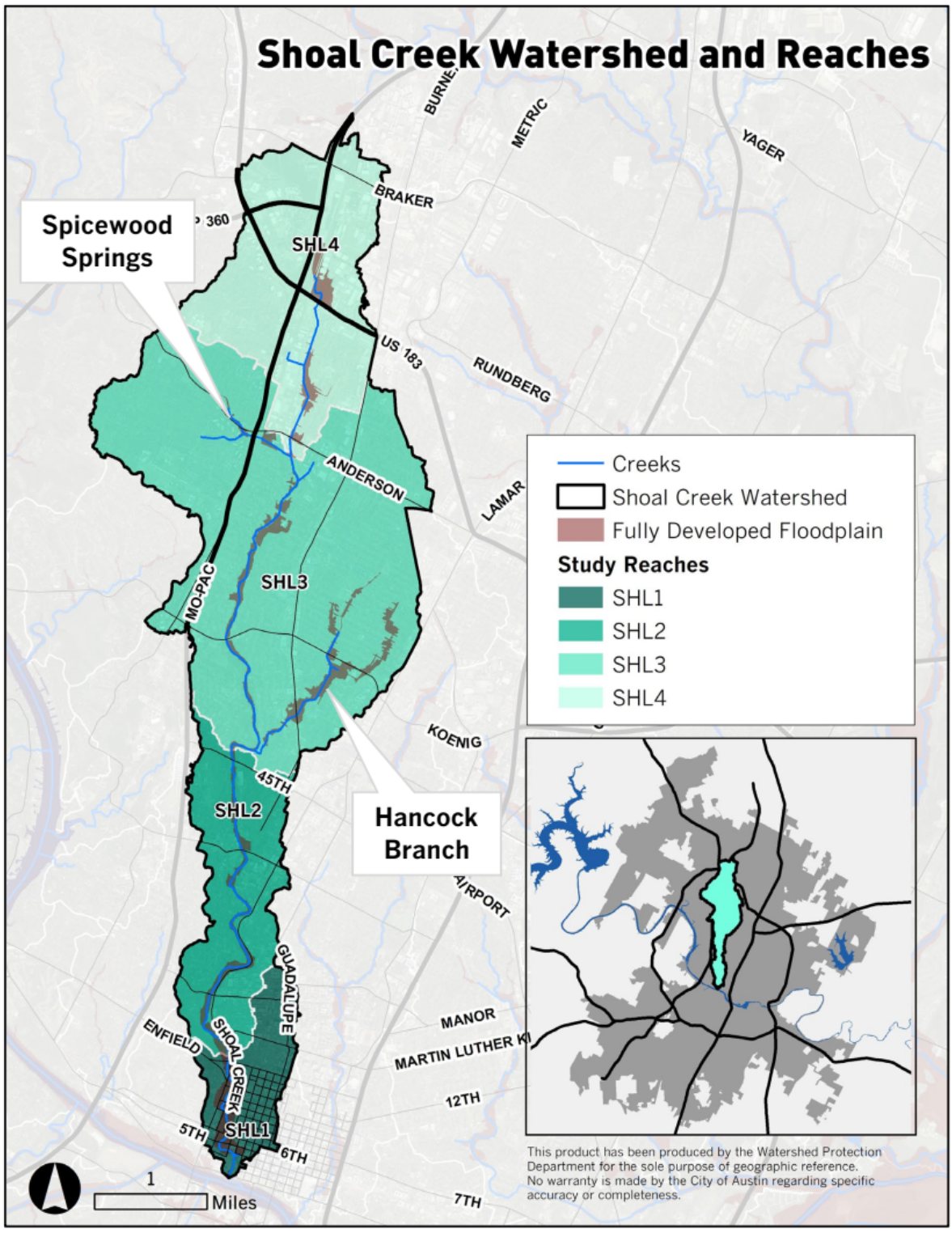

Figure 3 *- Shoal Creek Watershed and Reaches*

As the home to Shoal Creek, Austin is located within what the National Weather Service calls "Flash Flood Alley"—an area prone to intense rainfall events and flooding. Austin's rainfall patterns are influenced by its location along the Balcones Escarpment, which separates the Edwards Plateau ("Hill Country") from the Blackland Prairie to the east (WCR, 2019). Shoal Creek informally marks the division between these two ecoregions and is heavily impacted by these climatic features. Shoal Creek is a stream that is characterized by low base flow and high contributions of stormwater runoff. The primary concerns for the watershed are flooding, erosion, sedimentation, aquatic and riparian habitat health, and poor water quality.

Climate

Austin's climate is characterized by long, hot summers, short, mild winters, and warm spring and fall transitional periods. The City averages 34 inches of rainfall per year, with wide variation. May, September, and October are typically the wettest months. Climate change projections for the city include increases in annual average temperature, more frequent high temperature extremes, drought conditions in the summer, and extreme rainfall (Hayhoe, 2014). At the same time, the recent Atlas 14 report relates that with an increase in likelihood of increasing storms, the chances of flooding in the Shoal Creek watershed are now higher than in previous decades (NOAA, 2018).

Geology

One of Austin's defining natural features is its sensitive karst geology—portions of the city contribute to and directly recharge the Edwards Aquifer, a subsurface layer of porous limestone that stores and conveys water. The aquifer's recharge zone is where this limestone is exposed at the land surface, allowing water to flow directly into the aquifer. Because the limestone is close to the land's surface and there is little soil to filter out pollutants, the aquifer is particularly sensitive to pollutants from yards, roadways, and construction sites within its recharge zone. Approximately 27% of the Shoal Creek watershed is within the recharge zone of the Northern Segment of the Edwards Aquifer (COA-WPD, 2018).

The Shoal Creek watershed contains 30 identified natural seeps or springs. The two most notable springs are Seiders Spring and Spicewood Spring, the latter serving as habitat for the federally threatened Jollyville Plateau salamander. Because this species remains aquatic throughout its life, it depends on the quality and quantity of groundwater for its survival.

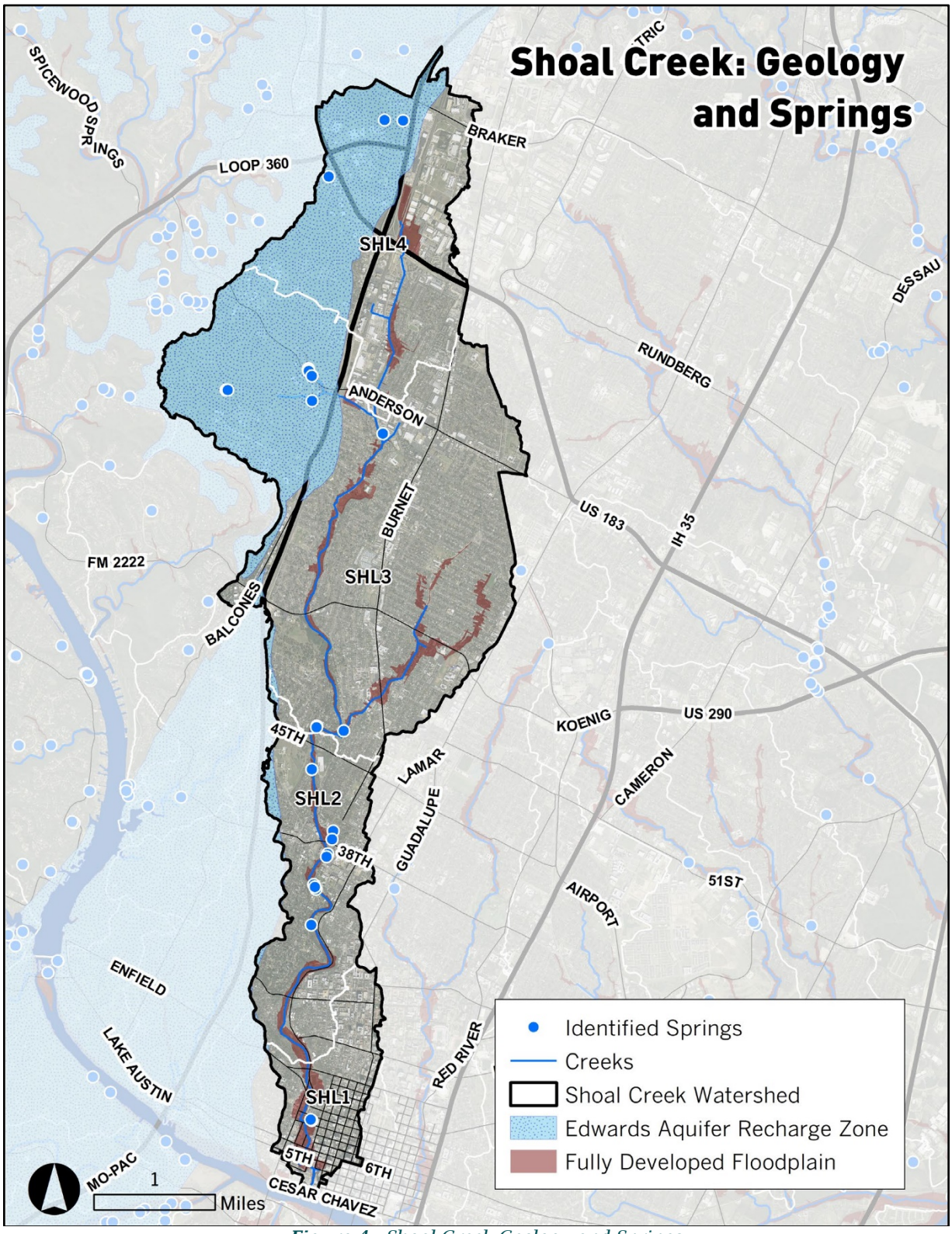

Figure 4 *- Shoal Creek Geology and Springs*

Demographics

The Shoal Creek watershed currently has a population of 72,000, with growth to 104,000 expected by 2040 (WCR, see Appendix A). Despite it being almost fully urbanized (only 5% remains undeveloped, see Figure 1), Shoal Creek continues to expect growth rates on par with the city of Austin and is currently the watershed with the 10th highest population density. As seen in Figure 5, the lower reaches of the watershed are expected to experience the greatest population increase over the next twenty years.

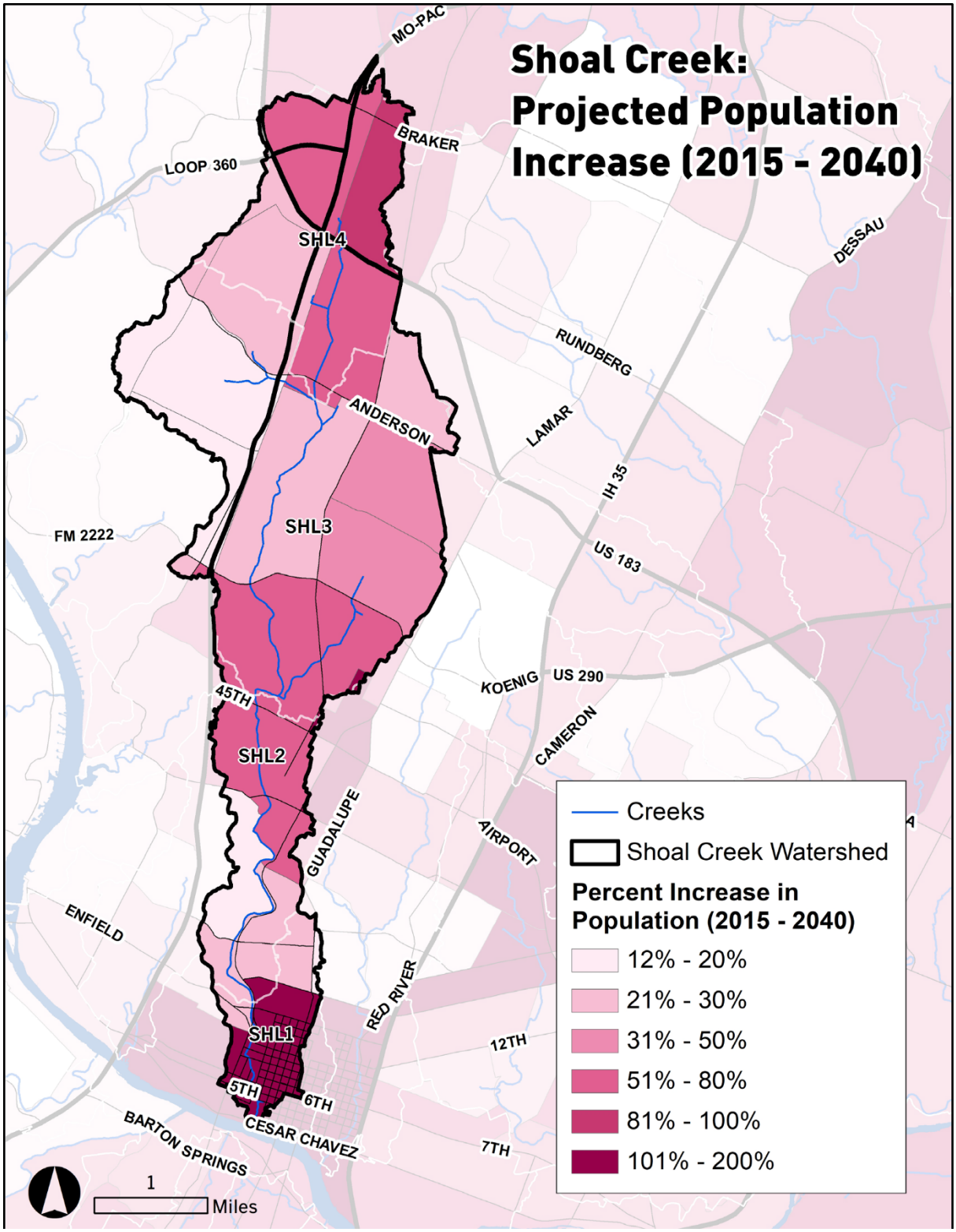

Figure 5 *- Projected Population Increase by Census Tract*

Impervious Cover

Due to the extent of its developed area, the Shoal Creek watershed has high rates of impervious cover, which can cause increased flooding and erosion and decreased water quality. Impervious cover is any surface that prevents the infiltration of water into the ground, such as roads, parking lots, and buildings. The Shoal Creek watershed is the fourth most impervious watershed in the city behind East Bouldin Creek, Waller Creek, and Buttermilk Branch, with 54% existing impervious cover. Based on a WPD analysis of impervious cover maximum buildout, Shoal Creek watershed could reach approximately 64% impervious cover if each site within the watershed developed to its impervious cover maximum (COA-WPD, 2018). It should be noted that proposed revisions to the City's Land Development Code related to increased density will not increase the amount of allowable impervious cover, as this is set at 64%.

1.5.1 Watershed Health

Throughout the SCWAP development process, stakeholders identified their primary concerns regarding the health and integrity of the stream and its surrounding watershed. Stakeholders agreed that the contact recreation Texas Surface Water Quality Standard (Title 30, Texas Administrative Code, Chapter 307), as established by TCEQ, should be the measure by which to attain water quality improvements in the stream, alongside a vision of a holistically healthy watershed. The characteristics of a healthy Shoal Creek watershed as defined by stakeholders include improved water quality, decreased flooding and erosion and improved riparian and aquatic habitat, increased baseflow, and the protection of groundwater sources. The WCR identifies problem areas in each of these categories and the corresponding causes and sources of the problems, as identified in COA assessments and data and modeled by Doucet. Table 3 summarizes the findings of the WCR in this regard. Please reference Figure 4 for the location of each subarea. For detailed descriptions of these issues please refer to the WCR. Definitions of terms used in the table can also be found in the Glossary (Appendix F).

***Table 3** – Shoal Creek Watershed Health Priority Areas by Impairment with Associated Likely Source*

Watershed Health Priority Areas							
Priority			Problem Area(s)				Source of Impairment
EII	Overall Rating: Fair		SHL1 – Lower watershed	SHL2 15th to 45th	SHL3 45th to Anderson	SHL4 – Upper Watershed	
			48 (Marginal)	59 (Fair)	65 (Good)	58 (Good)	
Water Quality							
	Water Chemistry						
		TSS	SHL1	SHL2			Impervious Cover; Aging secondary drainage infrastructure
		Conductivity	SHL1				Urbanization
	Nutrients						
		Nitrate	Spicewood Tributary				Fertilizer Application
		Ammonia	SHL1				Fertilizer Application
		Orthophosphorus	SHL1				Fertilizer Application
	Bacteria		SHL1	SHL4	Spicewood Tributary	Watershed-wide	Improper pet waste disposal; Aging wastewater infrastructure
	Illicit Discharges		SHL1	SHL2			High population density and urban activity
Priority			Problem Area(s)				Source of Impairment
Erosion			Grover Tributary	Arroyo Seco	Shoal Creek Mainstem - From W. 6th St to W. 15th Street		Development and urbanization close to the stream; Impervious cover
Flooding							
	Primary		9th St. Bridge	10th St. Bridge	Shoal Creek Blvd Bridge		Development and urbanization close to the stream; Impervious cover; Climatic and geological variables
	Secondary /Localized		Brentwood	Nueces	Burrell Dr.	Madison Ave.	Inadequate or failing secondary drainage infrastructure
Riparian and Aquatic Habitat			South of 15th St.	North of Anderson Lane			Development and urbanization close to the stream
Baseflow and Groundwater			Watershed -wide				Urbanization

2.0 WATER QUALITY MODELING SUMMARY

Water quality modeling was performed to estimate pollutant loads for bacteria, total suspended solids (TSS), total nitrogen (TN), and total phosphorus (TP). The models evaluate loads from the land surface and also in the creek to define the relationship between stormwater runoff and creek water quality. Modeling is necessary to identify the pollutant sources and location within the watershed. This information can then help define the appropriate water quality measures and their location to maximize water quality improvements. Modeling for flood management is not included in this project as it is outside the scope of the project and is being conducted by the COA as part of the Shoal Creek Risk Reduction effort from 15th Street to Lady Bird Lake.

The Final Modeling Report found in Appendix B presents the data sources, modeling approach, hydrologic data, computed loads, and load reductions for a potential management strategy to address the watershed challenges described in Section 1. Modeling was performed using the Water Research Foundation Systems Effectiveness and Life-cycle Evaluation of Costs Tool (SELECT) and Load Duration Curves (LDC) for constituents. The models were applied to existing and future land use conditions in the Shoal Creek watershed and will serve as key tools in evaluating water quality management strategies. Existing and future pollutant loads were modeled by SELECT for each of the 12 subareas (Figure 16) and are summarized in the report tables. Load duration curves were developed at the 12th Street stream gage where data were obtained from the United States Geological Survey (USGS) and the COA. The LDC tool is based on measured water quality and flow to help define creek health and serve as a basis to assess potential watershed improvements and resulting benefit to water quality.

LoadEST, a USGS program, was used to determine the total instream pollutant load for the watershed. Results from SELECT and LoadEST were used to calculate load reductions from Shoal Creek management measures. A source to stream (source:stream) ratio was calculated by dividing the total source load for the watershed by the total instream load. This factor was applied to load reductions from management measures that are not adjacent to the stream to account for the natural processes that occur on the land between the management measure and the waterbody.

SELECT Model

SELECT is a planning level spreadsheet tool with a focus on limiting the extent and complexity of input data needed to generate results for pollutant loadings and BMP effectiveness within a watershed area. The tool can be used in the early planning stage and model output can provide guidance on the impacts of new watershed development and retrofits/watershed programs to manage runoff quality. SELECT is an appropriate tool when making decisions/recommendations on the potential location and type of best management practices and when it is necessary to make an approximation.

Continuous hourly precipitation data from the National Climatic Data Center for the Austin Camp Mabry station were downloaded for approximately a ten-year period (10/2000 to 9/24/2010). Monthly evaporation rates were downloaded from the Texas Water Development Board (TWDB), and the average monthly evaporation from 2001 – 2011 was used in the model.

In the SELECT model, runoff coefficients translate rainfall into effective runoff. Initial abstraction is represented by depression storage, which is subject to evaporation between

rainfall events. When runoff occurs, the model tracks the volume and uses an event mean concentration for modeled pollutants to calculate pollutant loading. If BMPs are modeled, a water quality capture volume is used to determine how much of the runoff is routed through the BMP and how much is bypassed. Event mean concentrations are also used for BMP effluent calculations. SELECT is based on historical data and does not have the ability to project hydrologic changes from potential climate change.

Load Duration Curves

The LDC approach was selected as it is perhaps the simplest and most straightforward method of determining desired load reductions through the use of flow and load duration curve graphs. Where no water quality standard exists, screening criteria from TCEQ is used for threshold concentrations. LDCs are used for bacteria, TSS, and nutrients (nitrogen and phosphorus).

An LDC is developed from a flow duration curve (FDC). Flow data are multiplied by a threshold concentration, either a water quality standard or desired target concentration of a pollutant, producing a maximum allowable pollutant load for each flow in the period of record.

An FDC is a graph showing the percentage of time a stream exceeds various flow rates. Daily average stream flows over long periods are generally used in developing an FDC. If observed pollutant concentrations were available for each day, multiplying the pollutant concentration by the flow would result in a daily pollutant load over the flow period. Typically, observed data are available much less frequently than flow data, and a load regression curve is developed so that a pollutant concentration is calculated for each day of the flow record. The regression curve uses the assumption that the pollutant concentration is a function of stream flow. An LDC is developed by plotting this information on a graph to show the percentage of time a stream's pollutant load is exceeded. By choosing a constant "target" concentration for a pollutant, another line can be created on the LDC that allows a visual comparison of existing and "desired" loadings. A target could be a state water quality standard, or a stakeholder recommended goal.

Daily data mean flows were obtained from the USGS stream gauge for Shoal Creek flow at 12th Street. The data period obtained was from 01/09/1983 through 07/31/2018. Observed data for TP, TN, and TSS were obtained from the COA and USGS at sampling locations at or near 12th Street.

Since there were not a large amount of instream data, the LDC is based on infrequent data points. Additional monitoring could improve the assessment accuracy of pollutant loads in Shoal Creek.

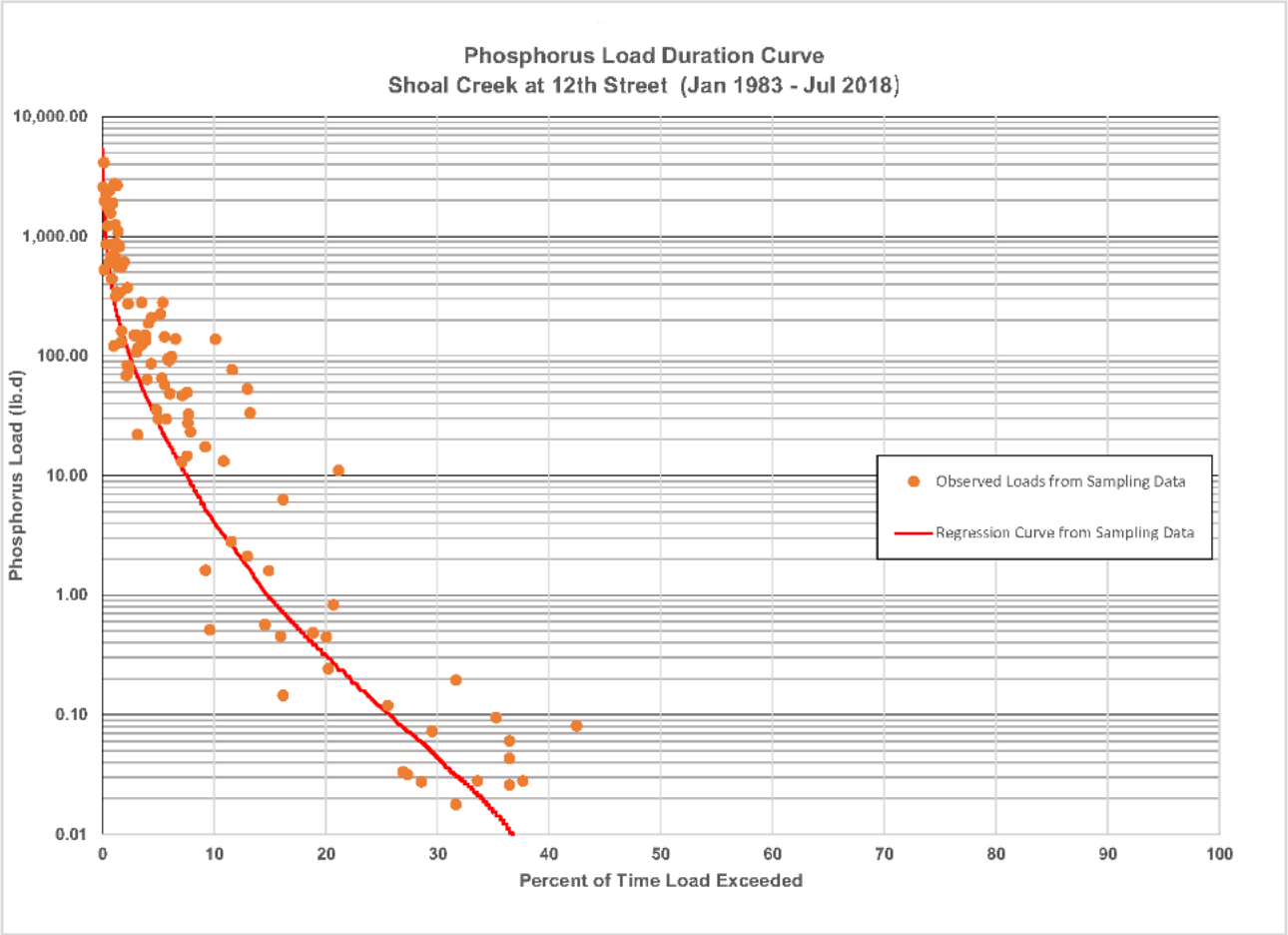

Figure 6 *- Phosphorous Load Duration Curve*

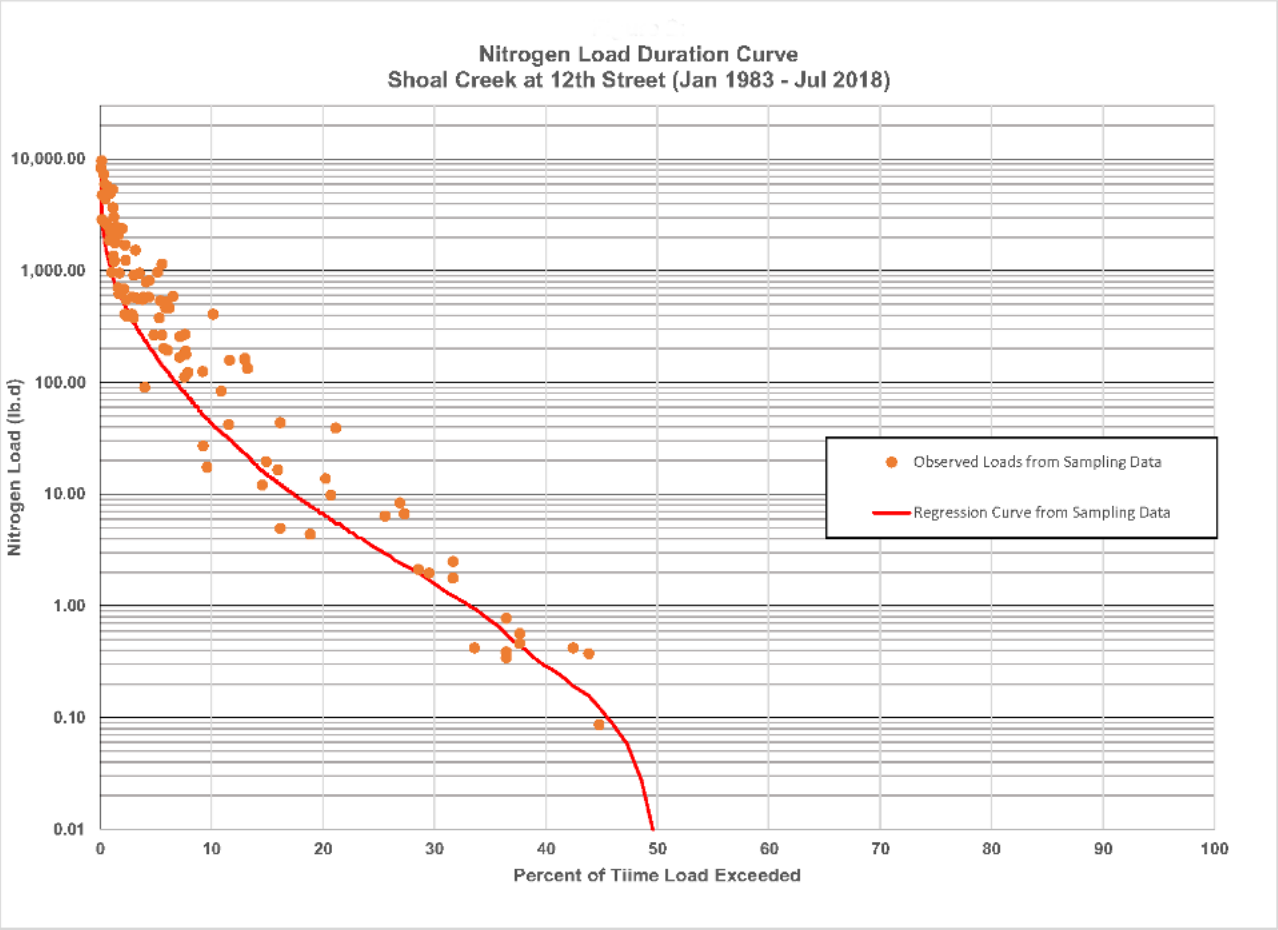

Figure 7 *- Nitrogen Load Duration Curve*

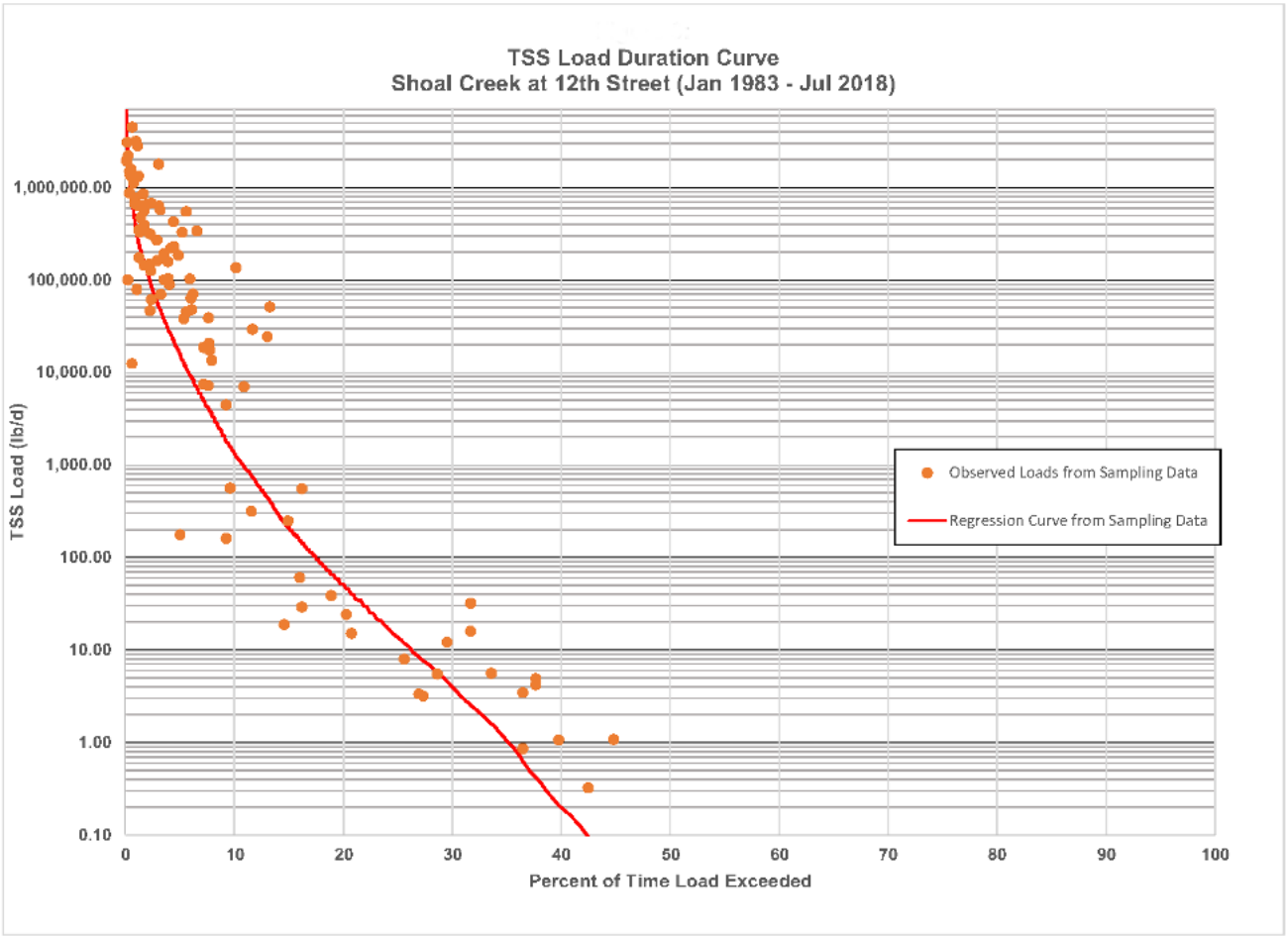

Figure 8 *- Total Suspended Solids (TSS) Load Duration Curve*

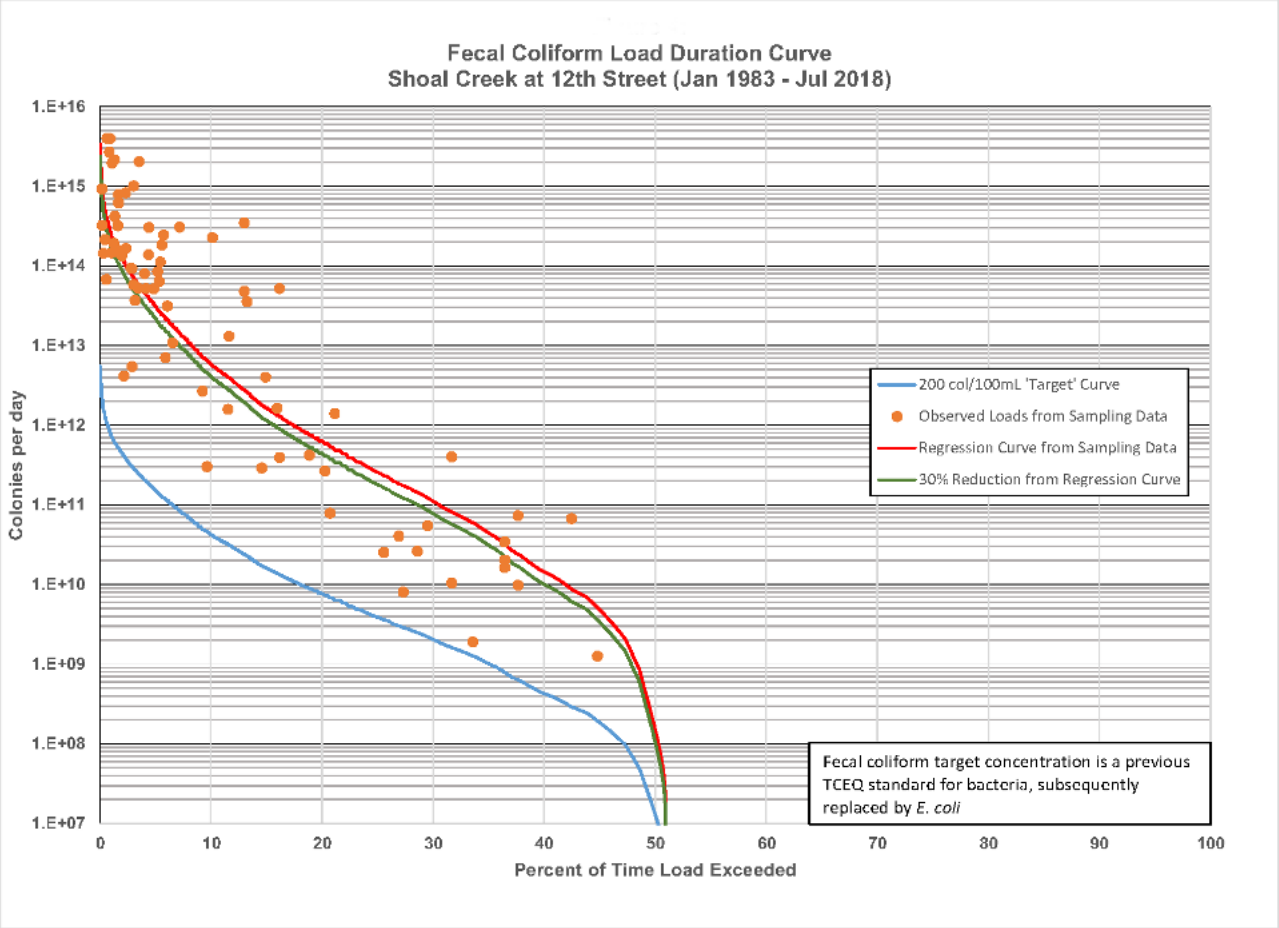

Figure 9 *- Fecal Coliform Load Duration Curve*

LoadEST

LoadEST is a USGS program for estimating constituent loads in streams and rivers. Given a time series of streamflow, additional data variables, and constituent concentration, LoadEST assists the user in developing a regression model for the estimation of constituent load. Flow and water quality data from the COA and USGS were used. For more information on LoadEST see the user guide located here: https://pubs.usgs.gov/tm/2005/tm4A5/pdf/508final.pdf

LoadEST was used to determine the instream daily load from the monitoring data. Then, a ratio of source load (watershed-wide modeling from SELECT) to instream load was computed to determine BMP effectiveness in managing pollutants. In other words, BMPs not located adjacent to the stream generate a lower instream load reduction. For bacteria, the source load to instream load ratio is 116. This was applied to the watershed BMPs to determine the load reduction in the stream. For example, a watershed BMP load reduction is determined to be X, then, that load reduction is divided by 116 to define the instream load reduction. The load reduction from all the recommended bacteria management BMPs is summed to achieve the target bacteria reduction to achieve compliance with contact recreation standards.

2.1 Existing Conditions

The Shoal Creek watershed was split into 12 sub-basins as shown in Table 4, which were individually modeled using the SELECT modeling program. The weighted land use breakdown of each sub-basin was used to model the load for each sub-basin using COA pollutant concentration data. The loads calculated in SELECT were used to estimate the percent reduction required for Shoal Creek to meet TCEQ state standards/screening criteria or other goals established by the stakeholder committee. Flow and LDCs were used to estimate existing load concentrations relative to flow data. Because Shoal Creek is an intermittent stream, flow at the 12th Street gauge largely occurs after rainfall events, thus, there are extended periods of time without flow in the creek. Water quality and flow data for Shoal Creek at the 12th Street monitoring gage were provided by the COA and the USGS.

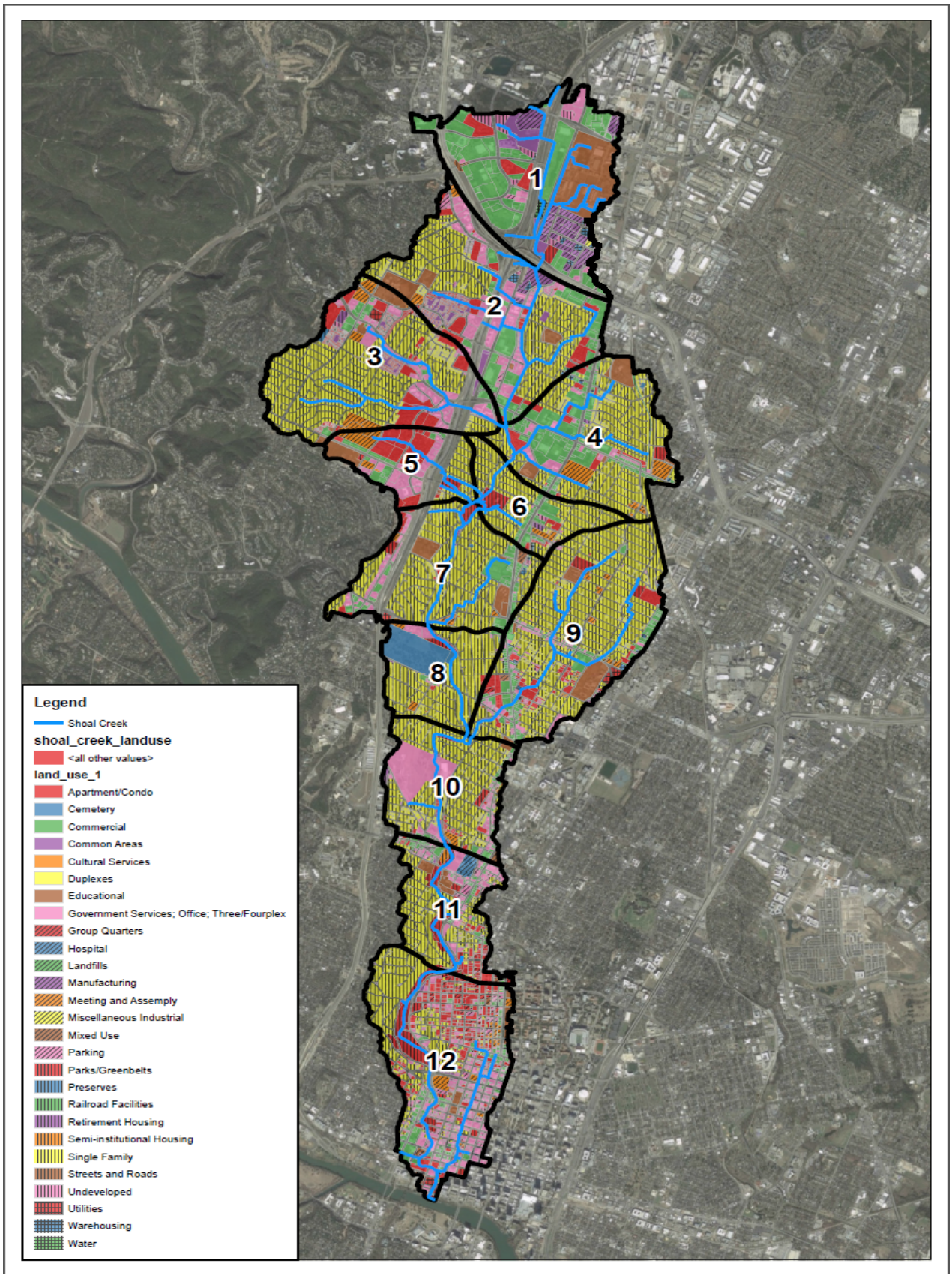

Figure 10 *- SELECT Model Subareas with Land Uses*

The results of the modeling show that the TCEQ contact recreation standard concentration for the bacteria *E. coli* is not met. The E. coli data is based on the City of Austin sampling of fecal coliform at the 12th Street Gage. The E. coli measurement in Most Probable Number (MPN) is obtained by multiplying the fecal coliform count by 0.63. Other constituents, TP, TN, and TSS are currently within acceptable levels to meet state requirements, but Shoal Creek's EII rating is still among the lowest performing watersheds within the Austin area, which was a significant concern to stakeholders.

A breakdown of each sub-area, including the weighted land use categories and the resulting load from each constituent are shown in Table 4. Table 4 shows which sub-areas are contributing the highest amounts of pollutants, and the characteristics of each sub-area: land area in acres, land use, impervious cover etc. This table highlights that pollutant loads are generated throughout the watershed, rather than concentrated in one area, due to the high levels of impervious cover and urban development. Typically, the higher the impervious cover percentage in a given sub-area, the greater the pollutant load.

Table 4 *- Existing Sub-area Land Use and Pollutant Loads*

Sub-area	Area (acres)	Impervious Cover (%)	General Location	Commercial Use	Residential Use	Undeveloped Land	TP (lbs/yr)	TN (lbs/yr)	TSS (lbs/yr)	*E. coli* (MPN/yr)
1	943	73%	Highway 183 to W Braker Ln	87%	9%	4%	1,424	8,157	637,275	05.86E+14
2	997	61%	Steck Ave to Highway 183	57%	40%	4%	1,357	7,672	583,561	05.59E+14
3	960	52%	N Hills Dr to Steck Ave	36%	61%	3%	1,115	6,299	478,148	04.59E+14
4	762	58%	Pasadena Dr to Ohlen Rd	48%	50%	2%	992	5,585	420,858	04.09E+14
5	339	60%	N Hills Dr to Greystone Dr	53%	43%	3%	446	2,518	191,409	01.83E+14
6	301	47%	Addison Ave to Whiteway Dr	30%	62%	8%	309	1,764	137,106	01.27E+14
7	700	55%	Northland Dr to Addison Ave	42%	55%	3%	853	4,814	365,019	03.51E+14
8	383	38%	Perry Ln to Northland Dr	21%	55%	24%	277	1,655	139,387	01.14E+14
9	1022	53%	47th St to Grover Ave	38%	60%	2%	1,225	6,897	520,571	05.04E+14
10	527	57%	W 38th St to W 48th St	46%	51%	3%	665	3,751	284,387	02.73E+14
11	433	55%	26th St to 35th street	49%	41%	10%	500	2,871	225,491	02.06E+14
12	932	59%	Lady Bird Lake to Ethridge Ave	57%	34%	9%	1,162	6,653	519,333	04.78E+14
						Total loads	10,324	58,637	4,502,546	4.25E+15

2.2 Future Land Use Conditions

Shoal Creek is classified as an urban watershed, consisting mainly of commercial and residential land uses and only 5% of land is currently undeveloped. Therefore, most of the construction that will occur will be re-development of older buildings and areas. The majority of development happened before the COA required on-site water quality treatment; thus, most of the developed area is not treated with stormwater controls. It is assumed that a large portion of redevelopment that will occur will have runoff treated to the same or better water quality than the previous conditions because all new development or redevelopment that adds more than 8,000 square feet of impervious cover must comply with the COA Urban Watershed Ordinance. This ordinance provides significant water quality benefits to Shoal Creek. It is anticipated that water quality will remain unchanged with future development as the stormwater management measures required by the COA Land Development Code treat runoff quality and regulate rapid runoff of small storms to minimize channel erosion. Thus, management measures detailed in the SCWAP are designed to manage existing runoff loads. The COA Land Development Code is currently in the revision process, and there is the potential for changes to current water quality requirements.

2.3 Comparison to Williamson and Bull Creeks

During the stakeholder process, reference watersheds were considered in order to define water quality improvement goals as stakeholders seek to improve creek water quality. Since Shoal Creek is rated as "fair" water quality by the City's EII, Williamson and Bull Creeks were selected as potential water quality targets, as Williamson has "good" water quality and Bull is rated as "very good" water quality per the EII. See Figure 7 for a comparison of EII scores across the City.

The EII is a tool developed by the COA to monitor creeks and provide perspectives on their aquatic health and water quality. The stakeholders supported the notion that the EII scores of Austin's creeks provide a basis for establishing a long-term water quality goal for Shoal Creek and an overall goal for future watershed health, including aquatic health. The EII was developed by the WPD to monitor and assess the ecological integrity and degree of impairment of local creeks and streams. The EII is a multi-metric index that integrates information about the physical integrity, chemical, and biological conditions of a sampling location into a single score that reflects the overall ecological function of a stream system. Water quality is sampled quarterly, and biological and habitat surveys are completed once per year. The EII has been on-going since 1996, and the sampling methodology is well described in COA documentation.

The LDC was used to define TSS, TN, and TP load reductions to meet "good" and "very good" water quality targets as defined by the EII. This modeling provided perspectives on load management across the watershed.

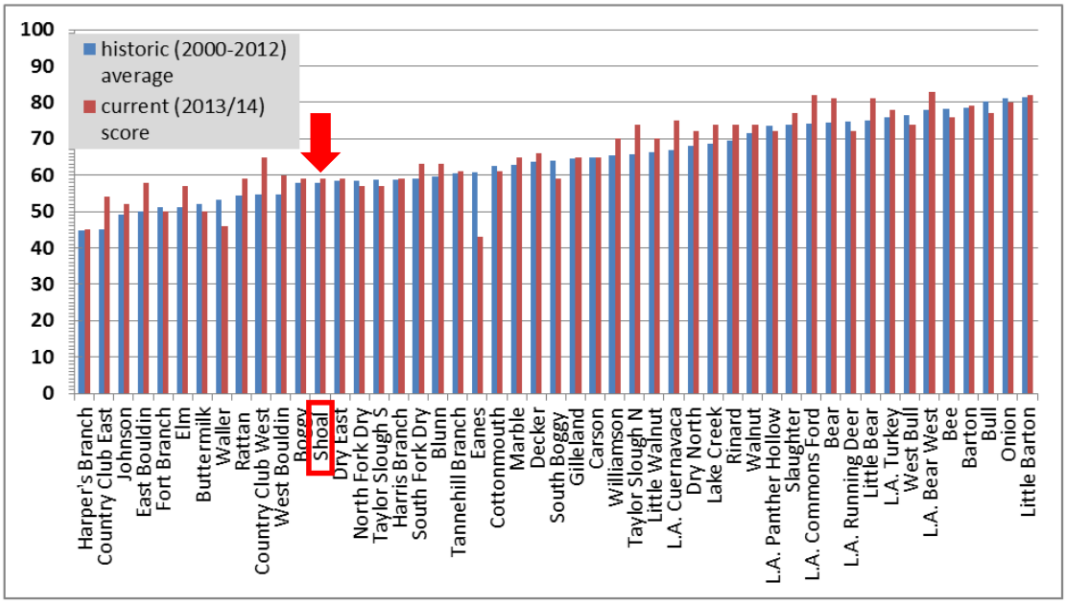

Figure 11 *- COA EII Scores (Aug. 2018 SCWAP meeting slides)*

To provide insight into TP, TN, and TSS load reductions to achieve the "good" to "very good" EII rating for Shoal Creek, the Williamson and Bull Creek water quality data were used as a comparison for the load reductions. It should be noted that Williamson and Bull Creek are suburban watersheds and have more water quality treatment measures currently in place than Shoal Creek.

To quantify these improvements for implementation, the load reductions per year needed to meet the Williamson (Good) and Bull (Very Good) were determined using COA monitoring data.

3.0 ESTIMATION OF LOAD REDUCTIONS (ELEMENT B)

Shoal Creek is classified as an urban watershed with several existing and emerging water quality issues. This SCWAP addresses the *E. coli* impairment and evaluates nutrients and sediment associated with the current and future growth and development. The existing and future loads for the watershed were determined through the SELECT model. The increase in pollutants under future conditions is preemptively "managed" by the Land Development Code.

Modeling results indicate that existing *E. coli* concentrations need to be reduced by about 98% in order to meet the state water quality standard (Table 12). It should be noted that most of the sampling occurred during either low or very low flow conditions, and extrapolation to the full range of flows adds uncertainty to the analysis. Additionally, these samples included data ranging back to the 1980s, which may not be representative of the current conditions for Shoal Creek. Thus, the expansion of the monitoring program to further define conditions is recommended.

***Table 5** - Load Reductions Necessary to Meet TCEQ Contact Recreation Standard*

Constituent	Watershed Annual Existing Load (SELECT model) (MPN/YR)	Average Concentration in sampling (MPN/mL)	State Standard (MPN/mL)	Meets Criteria (Y/N)	Instream load reduction to meet state criteria (LoadEST model) (MPN/day)
Bacteria (*E. coli*)	4.25E+15	1,915	126	N	9.820E+10

Table 5 summarizes the bacteria management requirements across the watershed to meet state contact recreation standards. Bacteria sources include wildlife, pets, wastewater leaks, human waste, and other sources. According to the modelling performed for this report, the mean yearly *E. coli* load (the average amount of *E. coli* bacteria generated in the Shoal Creek watershed per year) is 4.25E+15 MPN/year. MPN stands for most probable number and is used to measure the quantity of bacterial colony forming units in water. To reach the TCEQ contact recreation standard, a 98% reduction in *E. coli* is required. The management measures outlined in Section 5 indicate the estimated impact of each bacteria-related BMP on the stream per day, or how much the BMP is estimated to reduce or abate the pollutant each day. As detailed in Section 2, using the LoadEST model, a source to stream ratio is applied to the SELECT watershed model calculations to determine a total instream load, and applying a 98% reduction factor yields a required instream load reduction of 9.820E+10 MPN/day. The sum of all

SCC and partner implemented measures listed in the first part of Table 8a should reduce bacterial load on Shoal Creek by 9.820E+10 MPN/day to meet the state standard. Load reduction calculations were only provided for the water quality measures that the SCC believes it can implement over a 20-year period. The measures selected were designed to meet the load reduction standard. If other measures in addition to these are implemented in the future, then bacteria management can exceed the load reduction target.

Although Shoal Creek water quality already meets the TCEQ state screening criteria, stakeholders were interested in improving the EII rating to further address water quality concerns and promote aquatic health. Currently, TCEQ nutrient screening limits are not based on ecologically relevant thresholds, but distribution of data from Texas freshwater streams. The EII provides a more expansive measure of a healthy stream ecosystem. The stakeholders' goal is to improve the EII "fair" rating to "good" and potentially to "very good" in the long-term implementation of the plan. To accomplish those goals, the following load reductions would be necessary to achieve these goals. These are aspirational goals; thus, management measures are proposed to manage bacteria loading to satisfy State contact recreation standards. Load reductions are not proposed at this time for TSS, TN, and TP in the SCWAP.

***Table 6** - Load Reductions to Meet Stakeholder Aspirational Goals (TSS, TN, TP)*

Condition	Total Suspended Solids	Total Nitrogen	Total Phosphorus
Existing Condition Loads (lbs/yr)	4,502,546	58,637	10,324
Future Conditions Loads (lbs/yr)	4,746,285	62,215	10,995
Potential Watershed Ordinance Load Managed (lbs/yr)	243,738	3,579	671
Meets Criteria (Y/N)	Y	Y	Y
Load Reduction for Good Water Quality (%)	0	53	16
Load Reduction for Good Water Quality (lbs/yr)	0	31,019	1,662
Load Reduction for Very Good Water Quality (%)	83	87	68
Load Reduction for Very Good Water Quality (lbs/yr)	3,732,611	50,721	7,041

4.0 WATERSHED HEALTH MANAGEMENT STRATEGIES (ELEMENT C)

Through the Shoal Creek watershed action planning efforts, the Stakeholder Committee determined that initial implementation activities should focus on management strategies that reduce bacteria in Shoal Creek in order to meet the TCEQ contact recreation standard. The Committee agreed that these measures should also prioritize multifunctional solutions that address the group's stated goals of improving water quality, baseflow and protection of groundwater sources, riparian and aquatic health, and reducing erosion and flooding. These goals will be accomplished by enacting a phased implementation plan. Phase one includes education and outreach utilizing new and existing community programs; coordination with stakeholder groups and partners to install demonstration management measures and encourage the private utilization of incentive programs; and tracking and reporting of ongoing COA flood mitigation, infrastructure improvements, and stream restoration projects in the Shoal Creek watershed. Phase two will expand on these efforts based on a five-year report evaluating monitoring activities and measured milestones, conducted by the SCC. Phase three will incorporate further management measures based on evaluation, planning, and fundraising conducted during phases one and two.

4.1 Management Measures

This section provides a narrative description of the management measures suggested for immediate and future implementation to address stakeholder goals. See Appendix F for further BMP descriptions and photographs. Table 8a, Section 5 provides additional details about each management measure including effectiveness, location, measured milestones, responsible party, and potential partners. The estimation of bacterial load reductions of applicable management measures is also included in this table. The combined implementation of these measures over the next decades will improve the overall health of the watershed and meet the State criteria for bacteria. The multi-decade implementation program allows for a gradual improvement in water quality, and some measures will be adapted or removed as necessary.

Included in this list are measures identified by the COA, independent of the SCWAP, that relate to the Municipal Separate Storm Sewer System (MS4) Permit which the COA implements under the Texas Pollutant Discharge Elimination System (TPDES) requirements. These measures will supplement SCWAP activities and will be tracked and reported by the SCWAP Steering Committee to account for current and future impacts as they relate to Shoal Creek watershed health. Clean Water Act §319(h) grant funds will not be requested to fulfill TPDES requirements.

4.1.1 Phase One

Initial management measures to begin in the first 5 years of implementation include those that address the TCEQ contact recreation standard, which requires the reduction of *E. coli* bacteria in Shoal Creek. Though primarily focusing on bacteria, initial measures also address the holistic health of the Shoal Creek watershed. At year 5, the impact of

the executed management measures will be evaluated by the Steering Committee and communicated to stakeholders in a report, based on measured milestones. At that point in time, stakeholders will assess the effectiveness of the implemented measures and make recommendations for the next phase of implementation, with successful programs continuing.

The Steering Committee, facilitated by SCC, will work with potential SCWAP partners to improve outreach of new SCWAP programs and existing SCC and COA programs within the watershed. An SCWAP partner is defined as an organization or governmental entity responsible for some aspect of plan funding or implementation. Inclusion in the list of potential partners is non-binding, as watershed action planning activities are voluntary and non-regulatory. The Steering Committee will also coordinate the tracking and reporting of existing COA programs to measure their impact on watershed health. The SCWAP recognizes the importance of COA infrastructure-related projects in the Shoal Creek watershed and that the ongoing investments of the city into these programs will improve water quality and overall creek health.

Management measures to be implemented during phase one include:

Scoop the Poop Program – The existing COA Scoop the Poop Program educates residents on the importance of bagging and disposing of dog poop in an appropriate receptacle to reduce the quantity of *E. coli* in City streams. SCWAP partners will amplify the outreach and educational components of these programs to include but not be limited to working with partners and social media to inform and provide resources. Possible educational strategies to pursue include a Poop Bounty and brightly colored bags.

The COA, through the Scoop the Poop program, also provides pet waste stations to city parks and partnering programs for use on public land. These units dispense pet waste bags to the public and provide a receptacle for the disposal of waste. There are currently 21 pet waste dispensers in the watershed and stakeholders are requesting additional waste collection receptacles and servicing to discourage bags left behind on trails and in parkland within the watershed. These efforts should be volunteer-led, and the Steering Committee, facilitated by SCC, will work with partners to accomplish these goals. SCWAP partners will also work with large commercial landowners and academic institutions in the watershed to establish Scoop the Poop programs on their property. The goal of the SCWAP is to distribute 750 pet waste bags daily in order to achieve the pollution abatement, or load reduction, targets identified in Table 8a. In 2018 and 2019, the COA purchased 4,488,000 pet waste bags for city-maintained parks (Source: August 2019 TMDL Update https://www.tceq.texas.gov/waterquality/tmdl/101-austinbacteria#status). Assuming an even distribution per square mile throughout the city, with Shoal Creek watershed accounting for 4% of land in Austin, 246 bags were utilized per day in the watershed over this time period. In order to reach the goal of 750 bags per day, the Shoal Creek watershed would require an additional 64 dispensers to be installed over a 20-year period.

Rainwater Programs – Rainwater harvesting is the capture and storage of rainwater from roofs and other impervious surfaces for landscape, domestic, or other uses. A rain garden or rainscape is intended to be an aesthetically appealing and functional way to capture stormwater runoff temporarily in order to encourage infiltration and reduce

stormwater runoff. The COA encourages citizens to participate in rainscaping and rainwater harvesting through a number of programs. Austin Water Utility (AWU) offers the WaterWise Rainscape and Rainwater Harvesting Rebates for qualifying projects. The WPD administers the Stormwater Management Discount Program, which offers a discount on a residential or commercial property's drainage charge for rainwater harvesting systems, rain gardens, green roofs, and stormwater ponds that go above and beyond requirements for development. The Rain Catcher Pilot Program is testing the installation of several rainwater harvesting demonstration projects and educational incentives to determine if they will be offered city-wide. The estimated cost per residential system (rain garden & rainwater catchment) ranges between $6,000 to $8,000; however, with various rebate options, it is possible for the landowner to implement the system for about $1,500. SCWAP partners will amplify these rainwater programs in the Shoal Creek watershed through education and outreach and identify potential partners to construct demonstration projects. The *E. coli* load reduction estimation identified in Table 8a assumes a target of 250 single family properties implementing rainwater harvesting and rain gardens, for a total area managed of 50 acres.

Grow Zones – A grow zone is an effort to halt mowing along streams and allow the growth of more dense, diverse riparian vegetation. This strategy improves water quality, lessens erosion, increases wildlife habitat, and provides other ecosystem services. As of 2012, the COA managed 21 grow zones citywide. As of 2020, the COA managed the following five grow zones in the Shoal Creek watershed totaling approximately 25 acres.

Table 7 *- Grow Zone Locations and Sizes (Acre)*

Grow Zone Location	Acreage
Pease Park from 15th Street – Gaston Ave	19.6
Shoal Creek Greenbelt at 35th Street	1.2
Crestmont Drive	1.2
Shoal Creek Greenbelt Trail south of Allandale Road	3.6
NW District Park Pond	0.3

The WPD also provides assistance and advice to individuals, homeowners, and organizations interested in establishing private grow zones. A resource guide, Creekside Homeowners, A Guide for Creekside Residents, provides insights into how a grow zone or no-mow zone can be established. Working with partners, including Keep Austin Beautiful, Austin Youth River Watch, Austin Parks Foundation, educational entities, and local neighborhood associations, the SCWAP aims to enhance existing and initiate new grow zones in the watershed on both public and private lands along Shoal Creek. Special consideration will be given to balancing recreational uses and riparian restoration in parkland. To achieve load reduction targets identified in Table 8a, the SCWAP Steering Committee will work with partners and local residents to treat about 40 acres of parkland (80 acres of parkland and public lands currently exists) with new grow zones and 325 single family properties, or 19,500 linear feet, adjacent to the creek (out of about 1300 creekside properties), to implement grow zones at the creek's edge. Partnerships with large commercial properties will also be explored to supplement

residential grow zones. Due to the flood-prone nature of portions of Shoal Creek, it's important to be aware of the potential for grow zones to slightly affect floodplain elevations. The SCWAP will consider this aspect in the educational outreach effort.

Grow Green Program – The COA Grow Green program educates residents and businesses about the benefit of managing fertilizer, herbicide, and pesticide application and using native landscaping and integrated pest management to prevent and control pollutants. This program is vital to the health of the Shoal Creek watershed, and the Steering Committee, facilitated by SCC, will create a Shoal Creek-specific education and outreach campaign to promote this program to watershed residents.

4.1.2 Phase Two

Phase two of the SCWAP will begin in year 6 and will target holistic management measures to address bacteria, water quality, erosion, flooding, baseflow, groundwater sources, and aquatic and riparian health. During phase one, the Steering Committee will identify potential partners to assist with the execution of additional management measures during this second phase. Phase two will conclude at year 10 with a report that evaluates the effectiveness of management measures implemented to date based on monitoring and measured milestones. At this point, the continuation of these measures will be considered.

Management measures to be implemented during phase two include:

Stormwater Basin Additions and Retrofits – Stormwater basins detain stormwater following a rainfall event in order to increase infiltration into the ground. This increased infiltration in turn helps to prevent flooding by catching runoff and to filter pollutants prior to entering streams and waterways. The COA has existing requirements for stormwater infiltration during development. In phase two, alongside partners, the Steering Committee, facilitated by SCC, will explore the possibility of assisting landowners in identifying locations for additional stormwater basins and retrofitting aging basins to enhance the benefits these measures provide to the watershed. SCWAP partners will also track additions and retrofits as they occur from ongoing COA requirements and as communicated by the COA and measure the impact on the watershed.

COA Flood Management Partnership - Education and Outreach, Safety & Preparedness - SCWAP partners, coordinated by SCC, will increase public awareness of the flood risk along Shoal Creek, targeting areas with the greatest flood risk and highest population density such as the area of the watershed located below 15th Street. Possible activities could include promoting the use of ATX floods and other COA flood education and safety tools by Shoal Creek watershed residents; providing educational outreach materials to hotel, apartment and condominium managers to share with new residents along the creek; facilitating conversations about flood safety and preparedness BMPs among business owners in flood prone areas; and installing flood safety signage along the Shoal Creek Trail.

4.1.3 Phase Three – Potential Future Measures

Phase three of the SCWAP focuses on implementation of holistic management measures identified by the stakeholders. This phase will begin in year 11 and continue as needed. It is assumed that at this point, stakeholders will have an understanding of the effects of previous measures and will have secured the funding necessary for broader implementation measures.

Green Streets - A green street is a public street right-of-way that incorporates landscape features, engineered stormwater controls, and sustainability principles and practices to enhance non-motorized transportation options (e.g., walking and biking), mitigate the Urban Heat Island effect, improve water and air quality, and conserve ecological resources. The COA's Complete Streets policy affirms that all public streets and rights-of-way should include the aforementioned elements of Green Streets to the extent practicable given the many uses and functions of the public right-of-way (COA, 2015). Lamar Boulevard is an example of a street that could be modified as a Green Street to have a high impact on the health of Shoal Creek. SCWAP partners will identify and pursue opportunities for additional Green Street sites within the Shoal Creek watershed during this phase.

Groundwater Management & Spring Restoration – SCWAP stakeholders are interested in the development of future BMPs to increase baseflow and groundwater recharge as well as protect groundwater resources in the watershed. Potential ideas to explore further include establishing groundwater monitoring wells to track the impact of wells on private land; removal of impervious cover in key areas throughout the watershed; and a survey of existing springs within the watershed. Stakeholders also expressed a strong interest in pursuing spring restoration and identified Seiders Spring as a possible pilot project.

TXDOT Right-of-Way Treatment – TXDOT roadways comprise 5% of Shoal Creek's impervious cover (WCR, 2019). Treatment of these road rights-of-way with vegetated swales and detention basins can help to reduce flooding, erosion, and pollution by providing a means of stormwater infiltration.

In phase three, the Steering Committee, facilitated by SCC, will pursue a partnership with TXDOT and other entities to institute right-of-way treatments on highways including Loop 1 and 183. A potential starting point is for SCWAP stakeholders to explore the possibility of addressing such right-of-way treatments in the COA-TXDOT interlocal agreement.

Parking Lot Retrofits – Parking lot retrofits incorporate green design during the construction of parking areas. These green design measures can include various types of pervious surface technologies, rain gardens or stormwater basins, and increased vegetation. The Steering Committee, facilitated by SCC, will work with partners to identify locations for demonstration BMPs either on public or private land within the watershed. The Northcross Mall has been identified as a potential pilot area.

Emerging Technologies – As watershed management and restoration technologies advance, the Steering Committee will evaluate their potential application in the Shoal Creek watershed and incorporation into the SCWAP through the adaptive management process. New technologies discussed during the stakeholder process included integrating pervious grey infrastructure (i.e. pipes and pavement) into Green Streets,

which would enhance infiltration and reduce runoff into the creek. These ideas are captured in "The Gray & Green Stitch: Blending Green Infrastructure into Urban Transportation Right-Of-Ways," a report by Priya Mahendrabhai Patel presented to the Faculty of the Graduate School of The University of Texas at Austin.

Watershed-Specific Regulating Plan – A watershed-specific regulating plan would include a set of policies and incentives specific to Shoal Creek watershed, designed to achieve pollutant load reductions and advance other SCWAP goals. A set of policies such as these would be advanced separately from existing COA codes and ordinances and would direct future development and redevelopment and provide additional guidance to private property owners interested in stormwater and water quality management. The SCWAP Steering Committee will explore the potential for a watershed-specific regulating plan for Shoal Creek during this phase.

4.1.4 Reporting and Tracking of Ongoing City of Austin Programs

The following is a list of management measures currently performed by the COA within the Shoal Creek watershed. The majority of these measures relate to the COA's MS4 requirements under the TPDES program (listed in Table 8b). The management measures included in this section are examples of those that can be tracked by SCWAP partners to determine their impact on Shoal Creek watershed health.

Sanitary Sewer Overflow Response – A Sanitary Sewer Overflow (SSO) response plan presents a strategy to mobilize the resources required to correct any infrastructure failure that may cause or contribute to an un-permitted discharge from deteriorating sewer infrastructure, flooding, or other causes. An SSO is a wastewater overflow from a sanitary sewer system, often caused by a build-up of fats, oils, and greases. Austin Water Utility (AWU) manages SSO response, enforces requirements for grease traps for restaurants, and maintains a Special Billing Program to reimburse the City for expenses related to SSOs in the Shoal Creek watershed and throughout Austin.

Inspection of City and Private Water Quality Basins – COA's inspection of commercial water quality controls in the Shoal Creek watershed such as detention ponds and stormwater drainage systems can prevent nonpoint source pollution and control flooding by addressing the deterioration of aging systems. The Development Services Department (DSD) currently performs inspections on these controls for site plan reviews during the redevelopment of properties within the Shoal Creek watershed and in response to citizen complaints.

Private Wastewater Lateral Inspection and Repair - A private sewer lateral line is the segment of the sanitary sewer system located on private property that connects a residence or business to the City's sanitary sewer system. Inspection of private laterals can prevent sewage leakage into streams. Under the Private Lateral Program Ordinance in Austin City Code, private landowners are responsible for the maintenance of private wastewater laterals on their property. The City, guided by AWU wastewater service connection standards and the City's Plumbing Code, periodically tests the integrity of private laterals.

Wastewater Infrastructure Inspection and Repair – Renewing Austin is an ongoing program to replace and upgrade aging water and wastewater infrastructure. AWU was recently awarded $120 million in low-interest financing to complete a portion of some of these projects. AWU also works in collaboration with the COA Public Works Department which supervises construction. Increased emphasis on wastewater infrastructure inspection and repair prevents contaminants from reaching streams like Shoal Creek and improves water quality by removing the sources of current leaks. AWU also inspects and monitors industrial wastewater sources discharging to the City's wastewater collection system through the Pretreatment Program.

Construction Site Inspection – The Environmental Inspection Division of the DSD performs inspections on permitted site plans for temporary and permanent erosion controls, stormwater controls, critical environmental features, protection of trees and natural areas, landscape installation, and compliance with site plan requirements. The environmental inspectors also respond to citizen complaints of possible environmental violations related to active construction and initiate appropriate enforcement for noncompliant sites. Prior to construction, a pre-construction conference is held between contractors, developers and environmental inspectors to ensure controls are compliant. Inspections are conducted periodically during construction to ensure that temporary erosion controls are compliant, remain in place, and development is consistent with approved plans. A final environmental inspection is required before the site work is considered complete (Source: http://www.austintexas.gov). These inspections have been instrumental in the prevention (and identification) of pollution in the Shoal Creek watershed.

Streambank Restoration – The primary goal of the COA's Stream Restoration Program is the development of safe and stable stream systems that protect the Austin community from erosion and encourage the use and enjoyment of Austin's creeks and lakes. The Stream Restoration Program utilizes stream stabilization techniques such as reinforced earth bank reconstruction, limestone rock grade controls and rock weirs to protect structures and public infrastructure from erosion damage. Native materials and vegetation are used as much as possible to enhance the natural creek setting. The program is responsible for conducting erosion site assessments along Austin creeks, designing stream stabilization projects, overseeing construction, and monitoring repaired sites (Source: http://www.austintexas.gov). The recently completed Shoal Creek Restoration Project between 15th and 29th Streets is an example of a major success achieved through this program in the Shoal Creek watershed.

Inlet Retrofits for Trash and Sediment – Inlet protection devices restrain the movement of debris into secondary stormwater drainage infrastructure. As the COA incorporates new inlet retrofits into its current stormwater system, the Steering Committee will encourage, track, and help identify areas for the installation of these measures in the watershed and measure their impact on water quality in the Creek.

Lower Shoal Creek Flood Risk Reduction – 15th Street to Lady Bird Lake – The City of Austin initiated the Lower Shoal Creek Flood Risk Reduction Study in 2017. The study investigated the feasibility of a variety of options for flood risk reduction in the watershed including larger storm drain inlets, green infrastructure, additional detention basins, channel modifications, buyouts, underground conveyance/bypass, and community resilience. As these options are discussed over the next 10-15 years, the

SCWAP Steering Committee will track the impact of implemented measures on the health of the Creek.

Expanded Street Sweeping – The COA currently maintains a street sweeping schedule of six times per year for residential streets and once per month for major streets. Throughout implementation of the SCWAP, the Steering Committee, facilitated by SCC, will track and report the amount of debris prevented from entering the drainage system and explore opportunities for expanded street sweeping in the watershed.

End of Pipe Storm Drain Retrofits – End of pipe storm drain retrofits are those that are installed at the end of a pipe to prevent debris from entering the primary drainage system, Shoal Creek, as it leaves the secondary system, or the City's stormwater infrastructure. An end of pipe device can be a stormwater vault or more conventional BMP such as a rain garden, bioretention basin, sedimentation-filtration basin, or other similar measures. Upstream contributing drainage area plays a key role in defining the appropriate measure at a storm drain outfall. These retrofits decrease the amount of trash and other debris reaching Shoal Creek. Opportunities for additional retrofits will be explored by the SCWAP Steering Committee.

5.0 WATERSHED ACTION PLAN IMPLEMENTATION

This section addresses multiple elements required by TCEQ and EPA as part of a watershed action plan. These elements, when combined, outline the measures, the implementation schedule, interim milestones to determine whether control actions are being implemented, and a set of criteria that can be used to determine if substantial progress is being made toward plan implementation. Table 8a includes all proposed management measures and identifies their schedule of implementation, effectiveness, feasibility, target location, estimated pollution abatement (where applicable), relative cost estimates, key milestones and both responsible parties and potential partners. Table 8b is provided to identify ongoing programs supportive of SCWAP goals and managed by the COA in compliance with MS4 permit No. WQ0004705000.

Tables 8a and 8b address the following elements:

Element C – Management Measures
- Potential pollutant management effectiveness
- Priority areas
- Feasibility
- Relative cost

Element F – Implementation Schedule
- Years of implementation and completion dates
- Adaptive Management

Element G – Milestones
- Measurable
- Linked to overall implementation schedule
- Progress indicators

Element H – Load Reduction Criteria
- Measurable and quantifiable criteria

Table 8a below outlines the management measures that can be implemented in the Shoal Creek watershed by the SCC and its partners to improve water quality and achieve the bacteria management target to gain compliance with water quality standards. The load reductions are defined on in-stream reduction targets as previously noted based on the relationship of source load to instream load that was determined by the LoadEST model. An instream load was defined for the entire watershed for *E. coli.* Then, bacteria management measures were applied in a spreadsheet tool outside of SELECT to define the load managed for each recommended water quality measure. The parameters of each measure such as acreage, length, number, etc. were defined in the spreadsheet bacteria management calculations. The process functioned outside of the SELECT model since it only computes source loads. The requirement by TCEQ to define the water quality management plan based on instream loads necessitated this approach through the spreadsheet tool.

***Table** Error! Bookmark not defined.**a** - Proposed Management Measures, Schedule, Milestones, and Criteria by Potential SCWAP Implementation Partners*

Phase One: Implementation to Begin in Years 1-5																
Prioritization	Target: Bacteria-Focused Management Measures															
Management Measures	Effectiveness									Feasibility	Location	Measured Milestones	Total Potential Pollutant Abatement	Total Estimated Cost	Responsible Party	Potential Partners
	Bacteria	P	N	TSS	Baseflow	Aquatic Health	Erosion	Riparian Health	Flooding							
Scoop the Poop Program: Increase number and servicing of pet waste stations	H	-	-	-	L	H	-	M	-	H	Emphasis on creek side parks and trails, new kiosks, trash cans	3 pet waste stations installed per year; pounds of waste collected	*E. coli* 6.200E+10	$80/ Dispenser; $240/year	SCWAP Steering Committee, facilitated by SCC	NAs/ Academic Institutions/ Private landowners/ Friends of parks groups
Scoop the Poop Program: Watershed-wide education programs focused on pet waste management	H	-	-	-	L	H	-	-	-	H	Watershed-wide emphasis	Tracking of number of community surveys, web posts, social media, annual meetings, annual events, flyers	*E. coli* 9.921E+09	$5k/year for E&O materials	SCWAP Steering Committee, facilitated by SCC	NAs/Academic Institutions/ Private landowners/ Friends of parks groups
Rainwater Programs: Education and Outreach; Demonstration Projects (Modeled after the Waller Creek Program)	H	H	H	H	H	H	M	H	M	H	Watershed-wide; Austin Central Library; City buildings; ACC; Lamar Activity Center; SFHs	10 raingarden and rainwater harvesting installations per year, years 1-5; 20/yr, years 6-15, and resulting gallons of infiltration; rebates utilized per year, outreach events per year	*E. coli* 5.343E+07	$8k per residence; $5k/year for E&O	SCWAP Steering Committee, facilitated by SCC	NAs/HOAs/ Academic Institutions/ AYRW/ Private landowners/ COM
Grow Zones: Enhance existing and initiate new on parkland; Encourage new on private residential and commercial properties	H	H	H	H	L	H	H	H	M	M	Pease Park; Shoal Creek Trail; NW Park and other public lands; Private Property along Creek	Number of service groups contacted and engaged; Establish grow zones on about 2 acres of parkland/year and at 10 residences/year first 5 years, 20 per year in years 5-20 (total of at least 325 residences).	*E. coli* 3.044E+09 (park and public lands) 2.496E+10 (residential lots)	$600/acre for E&O	SCWAP Steering Committee, facilitated by SCC	NAs/ AYRW/ PPC/SFHs/ COM / KAB / APF

Prioritization	Target: Holistic Management Measures, including Water Quality, Baseflow, Aquatic Health, Erosion, Flooding, Riparian Health															
Grow Green Program: Education and Outreach	L	H	H	M	M	H	M	M	L	H	SHL2; SHL3; SHL4	Community surveys, web posts, social media, annual meetings and events, flyers	TBD	$5k/year	SCWAP Steering Committee, facilitated by SCC	NAs/HOAs/ Private landowners

Acronyms: ACC Austin Community College · **APF** Austin Parks Foundation · **AYRW** Austin Youth River Watch · **COM** Commercial Properties · **HOA** Homeowners Association · **KAB** Keep Austin Beautiful · **NA** Neighborhood Association · **PPC** Pease Park Conservancy · **SFH** Single Family Home

The bacteria management measures on the prior page achieve the reduction requirements to satisfy TCEQ standards, with total potential pollution abatement to reach 1E+11 MPN/day. Phase one measures are to begin implementation in years 1-5 but are expected to continue through year 20 of the plan. The management of dog waste is the priority program as there are an estimated 15,000 dogs in the watershed. Details are noted in management descriptions in Section 4.1.1.

Additional management measures to be implemented during phases two and three are included in the below table.

Phase Two: Implementation to Begin in Years 6-10																
Prioritization	Target: Holistic Management Measures, including Bacteria, Water Quality, Baseflow, Aquatic Health, Erosion, Flooding, Riparian Health															
Management Measures	Effectiveness									Feasibility	Location	Measured Milestones	Total Potential Pollutant Abatement	Total Estimated Cost	Responsible Party	Potential Partners
	Bacteria	P	N	TSS	Baseflow	Aquatic Health	Erosion	Riparian Health	Flooding							
Stormwater Basin Additions and Retrofits	M	M	M	M	L	M	H	H	H	L	SHL4	Identification of sites, complete preliminary and final plans, construction completion	TBD	$$$	SCWAP Steering Committee, facilitated by SCC	COM/ Private landowners
COA flood management partnership - education and outreach, safety	L	L	L	M	L	M	M	M	M	H	Watershed-Wide	Education events, outreach materials	TBD	$	SCWAP Steering Committee, facilitated by SCC	COM/ Private landowners

Acronyms: COM Commercial Properties

Phase Three: Potential Measures for Future Start Dates																
Prioritization	Target: Holistic Management Measures, including Bacteria, Water Quality, Baseflow, Aquatic Health, Erosion, Flooding, Riparian Health															
Management Measures	Effectiveness									Feasibility	Location	Measured Milestones	Total Potential Pollutant Abatement	Total Estimated Cost	Responsible Party	Potential Partners
	Bacteria	P	N	TSS	Baseflow	Aquatic Health	Erosion	Riparian Health	Flooding							
Green Streets	H	M	M	M	M	M	L	M	M	M	SHL1; SHL4	Identification of sites, complete preliminary and final plans, construction completion, number of miles converted	TBD	$$$	SCWAP Steering Committee, facilitated by SCC	TBD
Groundwater Management & Spring Restoration	L	L	L	L	H	M	L	M	L	M	SHL3, SHL4 - Area over the Edwards Aquifer Recharge Zone	TBD	TBD	$$$	SCWAP Steering Committee, facilitated by SCC	Travis County/ Private Landowners
TxDOT right-of-way treatment	L	M	M	M	L	M	M	M	M	L	Loop 1; US 183	Number of retrofits constructed	TBD	$$$	SCWAP Steering Committee, facilitated by SCC	TXDOT
Parking Lot Retrofits	L	M	M	M	M	M	M	M	M	M	SHL1, SHL3, SHL4	Number of square feet of retrofits constructed	TBD	$$$	SCWAP Steering Committee, facilitated by SCC	COM/Other public and private landowners
Emerging Technologies as available and appropriate	M	H	H	H	M	H	H	H	H	M	Watershed-wide	Identification of Emerging Technologies implemented	TBD	$-$$$	SCWAP Steering Committee, facilitated by SCC	TBD
Watershed-Specific Regulating Plan	H	M	M	H	M	M	H	M	H	H	Watershed-wide	Adoption by City Council, subsequent amendments	Manage runoff from new impervious cover, no increase in load	$$$	SCWAP Steering Committee, facilitated by SCC	TBD

Acronyms: COM Commercial Properties · **TXDOT** Texas Department of Transportation

Table 8b below is identifies ongoing programs supportive of Shoal Creek Watershed Action Plan goals and managed by the City of Austin in compliance with MS4 permit No. WQ0004705000.

***Table** Error! Bookmark not defined.**b** - COA MS4 Compliance Categories*

	Implementation to Begin in Years 1-5			
Prioritization	Target: Bacteria-Focused Management Measures			
Reporting and Tracking of COA MS4 Permit No. WQ0004705000	Location	Areas of Emphasis	Measured Milestones	Education Target
Sanitary Sewer Systems	Watershed-wide	Make improvements to sanitary sewers to reduce overflows; Address lift station inadequacies; improve reporting of overflows; strengthen sanitary sewer use requirements to reduce blockage from fats, oils, and grease	Annual reporting required on sub-goals and progress toward full implementation	Operations and maintenance staff and policy makers
Illicit Discharges and Dumping	Watershed-wide	Put in place additional effort to reduce waste sources of bacteria; for example, from septic systems, grease traps, grit traps, or other sources	Annual reporting required on sub-goals and progress toward full implementation	Operations and maintenance staff, stormwater staff, system owners, etc.
Animal Sources	Watershed-wide	Expand existing management programs to identify and target animal sources	Annual reporting required on sub-goals and progress toward full implementation	Code enforcement and zoning staff, policy
Residential Education	Watershed-wide	Bacteria discharging from residential sites either during rainfall runoff events or directly; Fats, oils, and grease clogging sanitary sewer lines and resulting overflows; Maintenance and operation of decorative ponds; and Proper disposal of pet waste	Annual reporting required on sub-goals and progress toward full implementation	Residents and potentially visitors

Clean Water Act §319(h) grant funds will not be used to perform activities in table 8b unless those activities are going above and beyond the permit requirements.

5.1 Plan Implementation

Elements for Successful Implementation

As noted in the document prepared for TCEQ entitled *Surviving and thriving: What makes watershed stakeholder groups successful in implementation?,* a number of elements are key to the effective implementation of watershed plans (Schwartz, 2016). These elements of success include, but are not limited to:

- Recognizing that significant time is needed to realize water quality improvements,
- Reaching a high level of agreement on what needs to be implemented prior to implementation,
- Securing adequate funding to support the group's infrastructure and implementation measures,
- Involving a broad group of stakeholders that can leverage access to funding and resources as well as broaden the knowledge base,
- Funding a facilitator or watershed coordinator to focus on obtaining funding,
- Ensuring strong leadership, particularly hiring a facilitator or coordinator,
- Developing institutional memory and redundancy in case of leadership turnover,
- Beginning with small projects to build momentum and setting clear goals in the plan,
- Involving skilled agency staff and elected officials that can provide information, authority and legitimacy,
- Embracing open communication and transparency among members and the public, and
- Allowing for flexibility to the implementation structure as needs change over time.

Framework and Leadership Structure for Implementation of the SCWAP

Keeping in mind the critical elements of success listed above, the stakeholders developed the following framework and leadership structure to guide the first 5 years of implementation. This structure should be reviewed every 5 years.

Similar to its role during SCWAP development, **Shoal Creek Conservancy** will **facilitate** the implementation of the SCWAP. SCC will be responsible for:

- Coordinating and facilitating Steering Committee meetings, including maintaining meeting records and managing relationships with stakeholders and potential partners,
- Pursuing a resolution supporting the SCWAP by the Austin City Council on behalf of the Steering Committee,
- Tracking the status of implementation of each management measure,
- Developing the brief annual report on the status of implementation of management measures and providing it to the Steering Committee,
- Supporting additional reviews of the SCWAP by the Steering Committee as described below,

- Spearheading public education and outreach regarding the SCWAP and its implementation, and
- Securing a portion of the funding necessary to implement the SCWAP on behalf of the Steering Committee and stakeholders.

The **Steering Committee** will **oversee and guide** the implementation of the SCWAP. The Steering Committee will be responsible for:

- Ensuring implementation of the SCWAP by the responsible parties,
- Reviewing the brief annual report on the status of implementation of management measures provided by SCC and recommending actions as necessary,
- Conducting additional reviews of the SCWAP as well as the implementation structure as described below,
- Assisting with identification of funding sources for implementation of the SCWAP and supporting funding requests by the entities responsible for implementing management measures,
- Ensuring diverse stakeholder involvement and opportunities for public input throughout the implementation process.

The Steering Committee will include representatives of responsible entities listed in the SCWAP as well as other key decision-making entities, whose participation is necessary for successful implementation. The Committee will include 8 to 10 members and representatives from the COA-WPD, the COA Parks and Recreation Department, the COA Public Works Department, and the COA City Council. It will also include a representative from academic, business, neighborhood, and nonprofit entities involved in implementation. The Steering Committee's activities will be guided by the Ground Rules established in the SCWAP Public Participation Plan, updated October 9, 2018 (Appendix D).

During the implementation phase, the Shoal Creek **Stakeholder Committee** will continue to **provide insight about public concerns and values** that help bridge scientific research and community-driven efforts. Diverse stakeholder involvement will remain an essential component of the SCWAP, and Shoal Creek watershed stakeholders will be broadly defined as anyone who lives, works, and/or shares an interest in protecting and restoring the Shoal Creek watershed. Similar to the planning process, the intent of the implementation process is to be inclusive, open and welcoming to all. There will be no limit on the number of participants on the Stakeholder Committee, and any member of the public is invited to participate. Similar to the plan development process, during the implementation phase, the Stakeholder Committee will be a non-voting entity. However, rather than holding stand-alone Stakeholder Committee meetings, the stakeholders will be invited to attend and provide input during Steering Committee meetings.

Austin City Council Resolution Supporting the SCWAP

Once the draft is finalized and submitted to TCEQ for approval, the Steering Committee, coordinated by SCC, will pursue support of the SCWAP by the Austin City Council. The resolution for support will include a clear pathway for implementation of the SCWAP, including formalizing SCC's role as facilitator of the SCWAP, the City's role as a key stakeholder and participant in monitoring for the SCWAP, and the Steering Committee's

role as an oversight entity. The Steering Committee will consider requesting letters of support from potential partners listed in the SCWAP as well as key stakeholders involved during Plan development.

Schedule for Plan Review

Annual Review - Annually, SCC, serving as the coordinating body, will conduct an informal survey of SCWAP partners and develop a brief report on the status of implementation of management measures. The first report will be completed one month after the first anniversary of acceptance by EPA. This report will be provided to the Steering Committee and will be used to determine any necessary action to ensure successful Plan implementation.

Biennial Review - As the EII conducts water quality sampling and biological and habitat surveys every two years in any given watershed, a water quality data analysis and review will be administered during the off year of EII monitoring and shared with the stakeholders. The COA provides EII data for Shoal Creek in odd years, therefore, the biennial review will begin in 2022, to be conducted in even-numbered years thereafter.

Five Year Review - The Steering Committee will conduct an in-depth review of the leadership framework, the progress of implementation including education and outreach, and EII data analysis every five years in order to adapt the SCWAP as needed. The initial steps of education and outreach evaluation will begin immediately upon EPA acceptance of the plan, with formal review and milestone reporting to occur with the five-year review (for more information, see Section 5.2.1).

Adaptive Management

The SCC will facilitate the stakeholders' effort to periodically assess the results of the planned activities and other sources of information to evaluate the effectiveness and efficiency of the SCWAP and post the relevant information on the SCC website. The stakeholders will evaluate several factors, such as the pace of implementation, the effectiveness of management measures, load reductions, and progress toward meeting water quality goals. The stakeholders will document the results of these evaluations and the rationale for maintaining or revising elements of the SCWAP. The SCWAP is a 20-year plan, with management measures scheduled for years 1 through 10. In preparation for year 10, and phase three, the Steering Committee will assess the need for additional management measures, identify these measures, and revise the plan accordingly.

Stakeholders will track the progress of the SCWAP using both implementation milestones and water quality indicators. These terms are defined as:

· **Implementation Tracking —** A measure of administrative actions undertaken to improve water quality and watershed health.

· **Water Quality Indicators** — Measures of water quality conditions for comparison to pre-existing conditions, constituent loadings, and water quality standards.

Some areas specifically noted by the Stakeholder Committee for future further exploration and consideration in implementation include:

- Baseflow and Groundwater measurement
- Riparian Health
- Aquatic Health
- Incidence of major erosion events
- Incidence and impact of major flooding events
- New and emerging technologies
- Watershed-specific regulations and incentives

Implementation Tracking

Implementation tracking provides information that can be used to determine if progress is being made toward meeting the SCWAP goals. Tracking also allows stakeholders to evaluate the actions taken, identify those actions which may not be working, and make any changes that may be necessary to move the plan forward. Schedules of implementation activities and milestones are included in the tables associated with the management measures (Table 8a). If yearly milestones are not being met, the Steering Committee will reevaluate their appropriateness for the plan at years 5 and 10.

Water Quality Indicator Tracking

Routine fecal indicator bacteria monitoring will occur within the watershed at the four EII monitoring locations. *E. coli* samples will be analyzed by an approved laboratory accredited by the National Environmental Laboratory Accreditation Program. As part of the EII, biological and habitat surveys are also conducted that address the holistic health of the creek and its surrounding ecosystem. These metrics will also be considered in the evaluation of management measures. If significant changes are made to the EII program, the Steering Committee will consider and implement changes as needed to the water quality indicator tracking methodology. If a decline in bacteria levels at the 10-year review is not indicated, the Steering Committee will reevaluate the water quality management plan.

5.2 Education and Outreach to Enhance Public Understanding of the Plan (Element E)

During the initial planning process, Shoal Creek stakeholders developed a public participation plan to garner interest in the SCWAP. Strategies included leveraging partnerships, utilizing SCC outlets, and media distribution of meetings and events. This plan helped to expand attendance at meetings and will serve the same purpose through implementation (see Appendix D, Public Participation Plan). Broad representation at meetings was a priority, and thus, meeting locations and times were alternated.

Future participation in the implementation phase should identify underrepresented groups and target outreach in these areas. As part of a demographic analysis of the Shoal Creek watershed, the WCR used the Social Vulnerability Index (SVI) to identify and map the communities that are most vulnerable to hazardous events such as flooding, erosion, and water quality degradation (Centers for Disease Control, 2016). Three geographic areas were identified that received moderate to high vulnerability rankings, including

areas surrounding the University of Texas, the Wooten neighborhood, and the area between Spicewood Springs Road and Far West Boulevard. Similarly, the Shoal Creek watershed is dominated by areas in the lowest quartile for the race and language sub-index, with higher concentrations of people of color and/or low English-language proficiency in the Wooten neighborhood (Centers for Disease Control, 2016; WCR, 2019).

Education and Outreach Plan

The stakeholders of the Shoal Creek watershed view environmental education and outreach as a chief conservation strategy, and they plan to leverage partnerships, broaden audiences, and promote individual impact in support of the SCWAP. The purpose of this Education and Outreach (E&O) Plan is to define the E&O goals and objectives for the SCWAP as well as to identify specific activities.

The Education and Outreach Working Group developed five primary E&O goals that will drive watershed protection forward. Plan goals and target audiences are shown in Table 9.

***Table 8** – E&O Plan Goals and Audience*

E&O Plan Goals	E&O Plan Target Audiences
Increase Watershed Awareness	Watershed Neighbors and General Public
Encourage Positive Interactions	General Public, Recreators
Promote Individual Impact	NGOs, Government and General Public
Share the Watershed Action Plan with the Community	Watershed Neighbors and General Public
Coordinate Efforts with Community Partners	NGOs, Government, and Watershed Partners

These goals will require implementation partners to reach new audiences, establish authentic relationships, and build trust with underserved communities. The activities outlined in this plan are designed to bring the community together around creek conservation and establish an ethic of land stewardship within the community. These efforts will be guided by the following stakeholder-developed principles:

- **Identification:** This plan will identify gaps in our audience and work to establish new relationships
- **Intentionality:** Each of the measures listed in this plan are intentional and designed to expand the circle of supporters and advocates for the SCWAP.
- **Inclusion:** This E&O Plan seeks to establish authentic relationships with every member of our community and will actively recruit leaders with diverse backgrounds to ensure that all members of our community know they are included.
- **Individual:** The SCWAP will require the support of thousands of individuals working together to support the ecological health of the creek. This plan will highlight individual efforts and foster individual connections.

The E&O Plan activities and their associated measures of success are listed below in Table 10. Commitments to the projects and programs listed are dependent on available

funding as well as the ability to further strengthen relationships with potential partners listed in the table.

***Table 9** - E&O Implementation Plan Activities*

Please note that commitments to the following projects and programs are dependent on available funds. Estimated costs include program supplies only and are not inclusive of staff time.

E&O Topic	Potential Partners	Number Implemented in Years 1-5	Number Implemented in Years 6-10	Estimated Cost, Years 1-10
A. Events and Outreach Programs				
Workshops	SCC, MCWE, Texas Water Resources Institute	5	5	$5,000
Steering Committee Meetings	SCC	20	20	$5,000
Educational Tours and Programs	SCC and Partners	50	50	$50,000
Austin Independent School District (AISD) Educational Events	Environmental Stewardship Advisory Committee (ESAC), AISD Outdoor Learning Specialist, SCC	3	3	$1,000
Texas Stream Team Citizen Science Trainings	MCWE	2	1	$600
Community Cleanups	Keep Austin Beautiful, SCC, Austin Parks Foundation	60+	60+	$120,000
E&O Topic	**Potential Partners**	**Number Implemented in Years 1-5**	**Number Implemented in Years 6-10**	**Estimated Cost, Years 1-10**
B. Print Materials and Website				
Website	SCC	Ongoing	Ongoing	$50,000
New and existing brochures and printed	SCC	As needed	As needed	$20,000

materials (including printing costs)				
Branded "Scoop the Poop" Dog Bags	SCC	1 new design	As needed	$2,000
Watershed Tours and supporting materials (volunteer led and self-guided)	SCC and partners	Ongoing	Ongoing	$5,000
Public Service Announcements (PSAs)	SCC	3	3	$6,000
E&O Topic	**Potential Partners**	**Number Implemented in Years 1-5**	**Number Implemented in Years 6-10**	**Estimated Cost, Years 1-10**
C. Physical Outreach Tools and Campaigns				
"Get Involved" PSA	SCC, KUT	2	2	N/A
Banners and signage about nonpoint source pollution (to be installed along the creek, and possibly at House Park Stadium)	SCC, Austin Parks Foundation, AISD	3	As needed	$10,000
Large Art Installation	Art Alliance, SCC, Art in Public Places, The Contemporary	1	Replacement as needed	$20,000
Watershed Wise Business Campaign	Shoal Creek Conservancy	Ongoing (after year 3)	Ongoing	$50,000

5.2.1 Description of Activities

The E&O Plan activities included in Table 10 are described in detail below.

Events

Workshops

Half- to full-day workshops will focus on topics such as:

- Water quality protection and monitoring
- Xeriscaping, Grow Green, yard wise
- BMPs for homeowner associations and apartment management
- Groundwater protection strategy (land conservation, water well plugging)
- Texas Watershed Steward Program
- Low Impact Development (LID) for homeowners

- Texas Well Owner Network
- Texas Stream and Riparian Education Program

Press releases, newspaper notices, and direct communications will be used to attract interested individuals to the workshops. These workshops will be conducted by the MCWE and SCC.

Steering Committee Meetings - The SCWAP Steering and Stakeholder Committees will continue to meet quarterly during implementation. Meetings will be announced via email and through the project website. These meetings will be open to the public and will be an opportunity for collaboration and updates. The meetings will focus on implementation project status updates, issues to resolve, and new ideas for collaboration. They will be facilitated by SCC.

Educational Tours and Programs - SCC in partnership with other organizations will host regular educational tours and programs that focus on riparian health and highlight the importance of watershed protection. These programs will be open to the general public but an effort to engage with watershed neighbors will be made.

AISD Educational Events - Working directly with the Environmental Stewardship Advisory Committee, the AISD Outdoor Learning Specialist, and the public schools in the watershed, SCC will host educational events that focus on students of AISD. These events may include citizen science workshops, service-learning opportunities, nonpoint source pollution demonstration activities, or creek hikes.

Texas Stream Team Trainings - The Texas Stream Team (TST), an MCWE program, will host "Core Kit" Water Quality Trainings and certify area residents as water quality monitors. This program will empower watershed leaders and help SCC monitor water quality parameters that will affect ecological health.

Community Cleanups - SCC will host monthly creek cleanups and will expand at least one monthly cleanup per year into a watershed-wide cleanup event. Possible partners include Keep Austin Beautiful, WPD, and the organizers of The Great Texas River Cleanup and It's My Park Day.

Printed Material and Website

Website - SCC will keep the SCWAP website updated and it will link to other local, state and federal stormwater resources. Information on TST activities, BMPs, watershed tours, brochures, PSAs, and volunteer outreach events will be included.

Brochures - Working with the partners, SCC will develop relevant literature for distribution within the watershed. These brochures will highlight the importance of limiting NPS pollution and provide insight on ecofriendly alternatives to pesticides and herbicides.

Branded "Scoop the Poop" Pet Waste Bags - SCC will develop branded "scoop the poop" Pet Waste Bags that not only encourage people to use them but highlight the SCWAP and the work of SCC.

PSAs - SCC will develop several PSAs that highlight the SCWAP, how watershed neighbors can get involved, and advertise upcoming watershed events.

Banner and Signage - SCC will work with partners to create and install signage about nonpoint source pollution along the creek. One creative idea to explore further is signage at House Park. This multipurpose stadium is used by dozens of local area schools and will provide an opportunity for indirect engagement with watershed neighbors encouraging them to get involved in the process.

Physical Outreach Tools and Campaigns

Large Scale Art Installation - Working with community partners, Austin Art Alliance, and Art in Public Places, SCC will actively solicit proposals for a large-scale art instillation in Duncan Park or other creekside parkland. SCC will also explore the possibility of partnering with The Contemporary on this project.

Watershed Wise Business Campaign - An outreach program targeting local retail and service businesses in the watershed will be designed to complement the Green Business Certification program. Businesses that choose to receive educational information, display information about protecting water quality, and participate in nonpoint source pollution prevention programs, such as litter-preventing patio guards, will receive recognition as being Watershed Wise. SCC will explore a partnership with the Austin Chamber of Commerce and other local business associations.

Evaluating Effectiveness of Education & Outreach

Management milestones will be tracked and reported for all measures implemented as part of the SCWAP E&O Plan. Metrics such as the number of events, number of participants, how many individuals have accessed the website, and the types of materials printed will be reported in the five-year implementation plan review process. Informal surveys will be distributed at workshops and events to gauge educational outcomes.

Additionally, the Social Indicator Planning & Evaluation System (SIPES) will be explored as a project evaluation tool. SIPES is a seven-step process that uses social indicators to help plan, implement, and evaluate nonpoint source management projects. This system is being explored by Shoal Creek Conservancy for use as an evaluative metric to determine the effectiveness of education and outreach practices on water quality improvements.

This evaluation begins with a review of project plans and then guides projects through a process to collect, analyze, and use social indicator data at the beginning and end of a nonpoint source project (Genskow and Prokopy, 2011). The SIPES Handbook was developed by the Great Lakes Regional Social Indicators Team with collaboration from US EPA Region 5, state water quality agencies, and numerous stakeholders in Region 5.

This Handbook outlines the following seven steps:

1. Review project plan
2. Collect and enter pre-project survey data

3. Review data and refine social outcomes
4. Monitor social data throughout project
5. Collect and enter additional post project data
6. Collect and enter post-project survey data
7. Review data and use results

Water quality problems have accumulated over many decades and may take decades to amend (Genskow and Prokopy, 2011). Confirming that awareness and attitudes are changing, and conservation-related behaviors are being adopted in a watershed is one way that projects can demonstrate progress toward water quality goals. Monitoring social indicators, like monitoring environmental indicators, will provide valuable information about how well management strategies are working.

5.3 Technical and Financial Assistance to Implement the Plan (Element D)

The SCWAP will coordinate and build upon existing watershed projects and programs instituted by the COA, SCC, and other relevant entities. In addition, new activities and projects will be pursued to meet stakeholder goals related to water quality and overall health.

Throughout the multi-year planning effort, the SCWAP Stakeholder Committee worked together with governmental and nongovernmental organizations to investigate potential commitments for implementing SCWAP activities. Formal financial agreements may be necessary. The funding agreements could include SCC, COA, Texas State University, TCEQ, and other partner's pledges to commit and seek additional funding required to implement the plan.

The Steering Committee, facilitated by SCC, will apply for additional funding to implement Plan components and will solicit technical support on an ongoing basis. Potential funding sources and grants available for SCWAP implementation activities, including federal, state and private funds. Sources of potential additional technical assistance are listed in Table 11. It will be determined during plan implementation which entities will apply for funding.

***Table 10** - Potential Funding Sources for SCWAP Implementation Activities*

Program	Focus Area	Organization	Additional Information
STATE			
Outdoor Recreation, Parks Grants	Recreation, open spaces, and parks	TPWD	http://tpwd.texas.gov/business/grants/recreation-grants/grant-programs, https://tpwd.texas.gov/business/grants/recreation-grants/#coop
Texas Capital Fund Main Street Improvements Program, Texas Capital Fund Infrastructure Development Program	Development, infrastructure, and green infrastructure	Texas Dept. of Agriculture (TDA) and the Texas Department of Rural Affairs	https://www.texasagriculture.gov/GrantsServices/RuralEconomicDevelopment/RuralCommunityDevelopmentBlockGrant(CDBG)/SmallTownsEnvironmentalProgram.aspx, https://www.texasagriculture.gov/GrantsServices/RuralEconomicDevelopment/TexasCapitalFund/MainStreetImprovementProgram.aspx,https://texasagriculture.gov/GrantsServices/RuralEconomicDevelopment/TexasCapitalFund.aspx
Clean Waters State revolving funds, low interest loan	Nonpoint source pollution control and stormwater mitigation	TWDB	https://www.twdb.texas.gov/financial/programs/CWSRF/
Texas Water Development Board State Flood Planning Grants	Flood planning	TWDB	http://www.twdb.texas.gov/about/contract_admin/request/RFA-Flood/index.asp
Texas Water Development Board: FEMA Flood Mitigation Assistance Grant Program	Flood mitigation	TWDB	http://www.twdb.texas.gov/flood/grant/fma.asp
FEDERAL			
Environmental Quality Incentives Program	Watershed protection and flood prevention	NRCS)/ United States Department of Agriculture (USDA)	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/
Watershed Action Plan Implementation – Clean Water Act § 319(h) Grant	Watershed protection and nonpoint source pollution	EPA	https://www.epa.gov/nps/319-grant-program-states-and-territories

OTHER			
Environmental Education Grants (Public and Private)	Environmental E&O	Multiple (EPA, National Environmental Education Foundation, etc.)	https://www.epa.gov/education/environmental-education-ee-grants, https://www.neefusa.org/grants
Private, Foundation Funding and Grants	Water quality, watershed protection, restoration, water conservation, land management and conservation, and implementation of SCWAP activities	Multiple (Meadows Foundation, Mitchell Foundation Still Water Foundation, etc.)	--
Specific Implementation, Management Measure Funding	Water quality, watershed protection, restoration, water conservation, land management and conservation, and implementation of SCWAP activities	Corporate, NGOs (The Nature Conservancy, etc.)	--
Environmental Impact Bonds	This bond model matches investors interested in green infrastructure with municipalities implementing stormwater controls	"Impact Investors"	https://www.quantifiedventures.com/, https://www.cbf.org/how-we-save-the-bay/programs-initiatives/environmental-impact-bonds.html
COA Great Streets Development Fund	Greening Streets	COA	https://www.austintexas.gov/department/great-streets-program
Public Improvement District Business Improvement District	A business improvement district (BID) or public improvement district (PID) is a defined area within which businesses pay an additional tax in order to fund projects within the district's boundaries. The majority of taxpayers within a proposed BID/PID must petition the local government to form a BID/PID.	COA	
LCRA: Community Grant program for capital improvements	Capital improvements up to $50,000	LCRA	https://www.lcra.org/community-services/Pages/community-grant-program.aspx

***Table 11** - Potential Technical Assistance for SCWAP Implementation Activities*

Organization	Focus/Management Area
National Center for Appropriate Technology, EPA, Texas State University (facilities, Environmental Health, Safety and Risk Management), and Edwards Aquifer Habitat Conservation Plan Implementation Committee	Green infrastructure, LID, stormwater retrofits, riparian buffers, and BMP installation
Texas Department of Transportation	Various BMPs for highway projects
The Nature Conservancy	E&O; data collection; land-owner assistance; land, riparian, and habitat management activities; land and watershed protection. Lessons learned in Waller Creek
Texas State University, MCWE, TCEQ, and Texas Water Resources Institute	Technical, water quality modeling
Austin Water Utility	Water conservation strategies
EPA, Smart Growth Network	Compact development and site-specific development
TWDB, Federal Emergency Management Agency, EPA	Flooding and stormwater management
Barton Springs Edwards Aquifer Conservation District	Groundwater management planning
Lower Colorado River Authority	Colorado River Watch Network
U.S. Geological Survey Texas Water Science Center	Technical, water resources data

6.0 MONITORING PLAN (ELEMENT I)

Tracking of the implementation of the SCWAP through instream water quality monitoring is a critical component of demonstrating progress towards achieving the goals of the plan. Water quality monitoring allows the Steering Committee and stakeholders to evaluate the success of the management measures and utilize adaptive management to modify management measures if progress is not observed. Available water quality monitoring data will be used to track water quality conditions, overall creek health and progress towards goals identified in the SCWAP.

The Steering Committee, facilitated by SCC, will track progress and success of each management measure using data available from the COA. For example, the City records the volume of wastewater recovered after sanitary sewer overflow events via its SSO response program. The Steering Committee will use this data to communicate progress in pollution load prevention to watershed stakeholders. Data for each management measure will be incorporated into the biennial plan review to be conducted by Steering Committee.

6.1 Tracking Load Reductions from Management Measures

Efforts to measure the effectiveness of program implementation will follow the Implementation Schedule (Element F), modeled or calculated outcomes of measures (Element B) and identified management objectives (Element C) described in this document. Monitoring will be coordinated by SCWAP partners, recorded, and reported on SCC and/or COA websites.

Adaptive management guided by the results of water quality analyses will determine future implementation strategies. By tracking water quality trends and responses to both environmental factors and SCWAP activities, stakeholders will be able to evaluate whether SCWAP implementation is successful and to determine the need for additional actions or refocusing of existing efforts. This adaptive approach relies on frequent input of watershed information and the comparison of current conditions to the water quality targets and goals.

***Table 12** - Monitoring efforts and data to be included in the monitoring plan*

Party	Monitoring Activities	Notes
City of Austin	Water quality, EII, flow	Per City scheduled activities
USGS	Monitoring of discharge at 12th Street.	Data are available on website
SCWAP Steering Committee, facilitated by SCC	Monitoring implementation activities	Will track throughout the implementation period

Individual management measures will be implemented at different times throughout the watershed, with some requiring more time, coordination, planning, and funding. Reductions in pollutant loads are likely to be gradual and results will occur temporally and spatially at varying rates across the watershed until implementation is complete and institutionally integrated. Water quality targets will serve as benchmarks of SCWAP progress and are a tool to facilitate decision-making for prioritizing future implementation activities.

Project partners will coordinate all ongoing water quality monitoring in the watershed. All acquired data will be compiled in accordance with best practices.

6.2 City of Austin Monitoring and Analyses

Monitoring in Shoal Creek conducted by the COA as part of their EII will be used to provide water quality monitoring for the SCWAP. The COA EII will be a key tool for monitoring overall water quality health and will be used to define progress towards the stakeholders' "good" water quality goal and to assess bacteria reductions. The COA could provide EII training to SCC or others to enhance the frequency of monitoring. Additional monitoring sites utilizing Texas State University's TST program and network will be explored.

Water quality monitoring conducted and funded by the COA for the SCWAP will follow COA Quality Assurance Project Plan requirements. If funds from TCEQ or the Clean Water Act §319(h) grant are used, the monitoring will adhere to Texas Commission on Environmental Quality standards for quality assurance and quality control and will be submitted to the Texas Commission on Environmental Quality for Clean Water Act Section 303(d) assessment.

6.3 Supplemental Surface Water Monitoring

Supplemental monitoring activities in the watershed not currently in effect may provide useful information and allow for more in depth understanding of surface water quality data, especially at the sub-basin or site-specific level. Additional water quality and quantity monitoring efforts are likely to arise throughout the long-term implementation of the Plan and may be of considerable value. Partner examples include Austin Youth Works, TST, and the Colorado River Watch Network.

6.4 Monitoring of Management Measures

Management measures implemented early in the implementation phase may be monitored for effectiveness of mitigating pollution entering Shoal Creek. Management measures that are working effectively will be presented to the community and encouraged for further deployment where appropriate across the watershed.

6.5 Bacterial Source Tracking

Monitoring for bacteria alone shows the concentration present at a sample site and provides no information as to the source of the pollutant. Bacterial source tracking (BST) identifies sources of fecal matter allowing targeted management strategies. Identification and assessment of sources are key components for effective abatement programs. Additionally, BST can provide information about potential water quality impacts from the permitted discharges in the watershed. A project for BST may be implemented if funding is found.

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APPENDIX A – WATERSHED CHARACTERIZATION REPORT

View online at
https://shoalcreekconservancy.org/watershedplan/shoal_characterization_report_aug2019_web/

APPENDIX B – FINAL WATER QUALITY MODELING REPORT

View online at https://shoalcreekconservancy.org/wp-content/uploads/2020/04/Final-Shoal-Creek-WPP-modeling-report.pdf

APPENDIX C – STAKEHOLDER MEETING INFORMATION

Shoal Creek Watershed Action Plan meeting schedules and materials can be found at https://shoalcreekconservancy.org/watershedplan/.

The following two tables include a list of Steering Committee members and a list of groups and organization represented on the Stakeholder Committee, respectively.

Steering Committee Members				
First Name	**Last Name**	**Affiliation**	**Role**	**Alternate**
Linda	McCoy	Neighborhood	Neighborhood Rep	
Chris	Randazzo	RECA	Business Rep	
Chris	Herrington	COA Watershed Protection	Government Rep, Chair	
Janae	Spence	COA Public Works	Government Rep	Ana Seivert
Shannon	Halley	COA City Council, Tovo	Government Rep	
Kasey	Faust	University of Texas, Engineering School	Academic Rep	
D'Anne	Williams	COA Parks and Recreation	Government Rep	Patrick Beyer
Ivey	Kaiser	Shoal Creek Conservancy	Nonprofit Rep	Ted Siff
Louisa	Brinsmade	COA City Council, Pool	Government Rep	
Heath	Riddles	Pease Park Conservancy	Nonprofit Rep, Secretary	
Holland	Jones	Whole Earth Provisions	Business Rep	
Adam	Haynes	Property owner and Allandale Neighborhood Association	Neighborhood Rep & Property Owner	
Kazique	Prince	Mayor's Office	Government Rep	
Wendy	Gordon	Various	Academic Rep, Vice Chair	
Matt	Harriss	Butler Family Interests	Business Rep & Property Owner	

Groups and Organizations Represented by the Stakeholder Committee	
3D PARS	Hill Country Alliance
ADAPT	Hill Country Conservancy
AECOM	Keep Austin Beautiful
Alamo Draft House	Knight Construction
Allandale Neighborhood Association	Lamar Middle School
AMC Company	Long Family
Arbor Walk/Simon Property Group	Lower Colorado River Authority
Aspen Heights (Independent)	Lucy-Read Pre-K
Austin B-Cycle	Mayor Adler's Office
Austin Community College	McCann Adams Studio
Austin Energy	Meadows Center
Austin History Center	Method Architecture
Austin Metro Trails and Greenways	Morningside Consulting
Austin Parks Foundation	National Wildlife Federation
Austin Ridge Riders	Pease Park Conservancy
Austin Water Forward, Meadows Center	Real Estate Council of Austin
Austin Water Forward, Mitchell Foundation	Riverside Resources (5th and West)
Austin Water Forward, Sierra Club	Save Our Springs
Austin Youth River Watch	Schlosser Development
Balcones Resource Inc.	Seton Hospital
Baldridge Architects	Shield-Ayres Foundation Trustees
Barton Springs Edwards Aquifer Conservation District	Shoal Creek Ambassadors
Bat Conservation International	Shoal Creek Conservancy
Bicycle Sport Shop	Shoal Creek Saloon
Black + Vernooy Architects	Sierra Club
Brentwood Elementary	Siglo Group
Brentwood Neighborhood Planning Area	Silicon Labs
Brykerwoods Elementary School	St. Andrews Episcopal School
Cajas Digital Agency (maybe Hispanic Chamber?)	St. Andrews Lower School
Cap Metro	St. David's Foundation
Capital Metro Authority	St. David’s Hospital
Chamber of Commerce	State of Texas, Library
Cirrus Logic	Still Water Foundation
City Council	SunPower
City of Austin Watershed Protection Department	Sustainable Food Center

City of Austin, Watershed Protection	T3
Clean Water Action	TCEQ
COA PARD	Texas Archives Commission, Library Commission
COA Public Works	Texas Department of Transportation
COA Watershed Protection	Texas Floodplain Management Association
COA Watershed Protection, Education	Texas Water Conservation Association
Congregation Beth Israel	Texas Water Development Board
Constructive Ventures	Texas Water Foundation
Council Member Alter's Office	The Nature Conservancy
Council Member Leslie Pool's Office	Tier Riet
Council Member Tovo's Office	Trammell Crow Company
Covenant Presbyterian Church	Travis Audubon
Doucet & Associates	Travis County Historical Commission
Downtown Austin Alliance	Travis County Natural Resources
ECHO	Tree Folks
Edwards Aquifer Research & Data Center at Texas State	U.S. Geological Survey Texas Water Science Center
Endeavor	University of Texas
Endeavor (Domain)	Urban Space Realty
Evolve Austin Partners	US geological Survey: Texas Water Science Center
Families in Nature	UT
Fermata, Inc.	UT Department of Civil, Architectural and Environmental Engineering, Cockrell School of Engineering
Friends of the Forest	UT Pickle Research Center
Google	UT, Real Estate Office
GSD&M	UT, Sustainability Office
Gullett Elementary School	Walker Partners/Bowman Consulting
Halff Associates	Waller Creek Conservancy
HDR Inc	Water Environment Association of Texas
Headwaters School	Whole Earth Provisions
Highland Park/ West Balcones Neighborhood Association	Whole Foods Market

APPENDIX D – PUBLIC PARTICIPATION PLAN

Public Participation Plan
Shoal Creek Watershed Action Plan
Updated by the Steering Committee October 9, 2018

Overview

This Public Participation Plan details the strategy for engaging the public and stakeholders in the watershed planning process for the Shoal Creek Watershed in Austin, Texas. It is a living document that will be regularly visited and updated during the stakeholder process.

The goal of the Shoal Creek Watershed planning process is **to identify creative, cooperative solutions to address Shoal Creek's challenges and create a resilient, healthy and safe creek** through the development of Shoal Creek's first Watershed Action Plan (WAP). The Shoal Creek watershed suffers from numerous and interconnected water-related challenges, including devastating flood events, poor water quality, erosion, loss of native habitat, and loss of productive spring flow.

The Shoal Creek Conservancy (SCC) will serve as the WAP project facilitator and is leading a coalition of public and private groups, including the City of Austin (COA), The Meadows Center for Water and the Environment (Meadows), and other local community organizations, to develop and implement solutions to these pressing issues through a Watershed Action Plan. This cooperative project is funded in part by the Texas Commission on Environmental Quality (TCEQ) through a United States Environmental Protection Agency (EPA) grant and the Still Water Foundation.

Stakeholder involvement is an essential component of the Shoal Creek WAP. It enhances cooperation, collaboration, and community participation. Stakeholders provide insight about public concerns and values that help bridge scientific research and community-driven efforts.

A Shoal Creek Watershed stakeholder is anyone who lives, works and shares an interest in protecting and restoring the Shoal Creek watershed. Diverse stakeholder representation is key to the success of the Shoal Creek Watershed Action Plan. The intent of this planning process is to be inclusive, open and welcoming to all.

Stakeholder Group Structure

Shoal Creek Watershed Stakeholder Committee (Stakeholder Committee) - General

- Anyone who lives, works and shares an interest in protecting and restoring the Shoal Creek watershed is invited to participate in the Stakeholder Committee.
- The Stakeholder Committee will be open to all and welcoming in nature.
- There will be no limit on the number of participants in the Stakeholder Committee.
- The Stakeholder Committee will be a non-voting entity.

Stakeholder Committee - Ground Rules

- All Stakeholder Committee members agree to be open to new concepts and respectful to other points of view.
- No audio or visual recordings of Stakeholder Committee meetings. Instead minutes of the meetings will provide a brief overview of the topics discussed and will be placed on the Shoal Creek Watershed Action Plan webpage.
- All meetings of the Stakeholder Committee will be open to the public with an opportunity for public comments at the end of each meeting.

Shoal Creek Watershed Steering Committee (Steering Committee) - General

- The Steering Committee will include representatives expected to include 8-10 key decision-making entities, whose buy-in is necessary for successful implementation.
- Steering Committee decisions and actions will be shared with the full Stakeholder Committee.
- Representation on the the Steering Committee will include:
    - COA, Watershed Protection Department representative
    - COA, Parks and Recreation Department representative
    - COA, Public Works Department representative
    - Academic Representative
    - Business Representative
    - Neighborhood Representative
    - Nonprofit Representative
    - City Council Representative

Steering Committee - By Laws

- As the project facilitator, SCC will work with partners to appoint a minimum of seven representatives to an inaugural Steering Committee.
- As the project facilitator, SCC will appoint its Executive Director to serve as member of the Steering Committee.
- Steering Committee members agree to make an effort to attend all meetings. If unable to attend, they will notify the project facilitator.
- A quorum of the Steering Committee, defined as more than fifty percent of the Steering Committee members, is required in order to take action on matters before the Steering Committee.
- The Steering Committee will seek officer nominations and will elect, by majority vote, a chair, vice-chair and secretary. Steering Committee officers will be elected to a term not to exceed 12-months. There are no term restrictions.
- The Steering Committee Chair will preside over all official decisions made by the Steering Committee. If the Steering Committee Chair is unable to preside over an official decision due to absence or recusal, the Vice-Chair shall serve as the presiding officer.
- The Steering Committee Secretary will serve as the presiding officer due to absence or recusal of both the Chair and Vice-Chair. The Steering Committee Secretary is responsible for documenting the minutes of official Steering Committee meetings. Draft minutes will be posted on the project website within 30 days and approved on or before the next scheduled meeting of the Steering Committee.
- Steering Committee officer elections will be held annually in October.

- Steering Committee members may request agenda items no later than two weeks prior to the next scheduled meeting of the Steering Committee. The project facilitator will work with the Steering Committee Chair to finalize the agenda. Best efforts will be made to post the agenda as soon as it is available.
- Any Steering Committee member may nominate a new member to serve on the Steering Committee by notifying the project facilitator and Steering Committee Chair of the nomination at least two weeks prior to the next scheduled meeting of the Steering Committee. The nomination will be considered valid and placed on the agenda of the next scheduled meeting of the Steering Committee if the new member nomination is:
    - Approved by the Steering Committee Chair
    - Seconded in writing or by email by another sitting Steering Committee member

  New Steering Committee members must be approved by a majority vote of the Steering Committee.
- From time to time it may be also necessary to conduct a vote to remove a member of the Steering Committee. A ⅔ majority vote of the Steering Committee is required to remove a sitting member of the Steering Committee. Any Steering Committee member may request a vote to remove another sitting Steering Committee member by notifying the project facilitator and Steering Committee Chair of the removal request in writing at least three weeks prior to the next scheduled meeting of the Steering Committee. **The removal request must include the signatures of two sitting Steering Committee members to be considered valid.** If the removal request is deemed to be valid, it shall be placed on the official agenda of the next scheduled meeting of the Steering Committee. The Steering Committee member subject to the removal request must be officially notified in writing by the project facilitator and/or the Steering Committee Chair at least two weeks prior to the Steering Committee meeting that will consider the removal request. Both the Steering Committee member that initiated the removal request and the Steering Committee member subject to the removal request will be given up to 10 minutes to speak on the agenda item. Other Steering Committee members may also be allowed to speak on the removal request prior to any vote being taken.
- While the Steering Committee is expected to include representation from 8 to 10 key decision-making entities, there is no limit to the number of individuals that may serve on the Steering Committee at any point in time.
- Steering Committee members agree to be open to new concepts and respectful to other points of view.
- All meetings will be open to the public with an opportunity for public comments at the end of each meeting.
- Steering Committee voting may be conducted by email on time sensitive matters. A quorum of the Steering Committee members must participate for the vote to be considered valid.
- The goal is for decisions by the Steering Committee, other than membership and officer election procedures directly specified above, to be made by consensus. If consensus cannot be reached, recommendations, including the amendment of Steering Committee Ground Rules will be decided by ⅔ majority vote of Steering Committee members.

Working Groups

- The working groups are small groups that delve into particular topics in detail.
- There will be no limit to the number of members in each working group; they will be open and welcoming.
- Working groups will provide summaries of meetings to the full Watershed Committee and Steering Committee.
- Working groups will make recommendations based on the information gathered and input from other stakeholders.
- Each working group will select a leader and a notetaker.
- Each group will facilitate, schedule and recruit members for their working group.
- The working groups will include:

    - **Water Working Group -** Includes flood, base flow, and water quality (combined to recognize interconnected nature)
    - **Land Stewardship Working Group -** Includes public and private property in upland and floodplain areas (consider combining with the Water Working Group at later date)
    - **Education and Outreach Working Group**
    - **Implementation Working Group -** Includes policies, funding and metrics
- The specific goals of each working group will be defined at the first working group meeting, but will include to:
    - Set long-term goals
    - Identify areas of concern
    - Identify causes/sources of the problem
    - Identify standards in place and areas for improvement
    - Identify and recommend best management practices that can be implemented

Stakeholder Meetings - Tentative Schedule and Topics

- **Tuesday, February 13, 2018 (Lunch, Downtown)-** Stakeholder Committee Meeting
    - **Topics:** Overview of Shoal Creek challenges, watershed planning basics, role of stakeholders
- **Saturday May 19, 2018 (Morning, Downtown) -** Stakeholder Committee Meeting Site Visit
    - **Topics:** First-hand tour of Shoal Creek challenges and opportunities
- **Tuesday, July 10, 2018 (Morning, Downtown) -** Steering Committee Meeting with Stakeholder Committee
    - **Topics:** Overview of project, discuss public participation plan, steering committee role and ground rules, technical update and discussion
- **Wednesday, August 29, 2018 (Lunch, Mid-Watershed) -** Stakeholder Committee Meeting with Educational Forum.
    - **Topics:** Project update led by Steering Committee, water quality educational presentation and discussion
- **Tuesday, October 9, 2018 (Lunch, Downtown/Mid-Watershed) -** Stakeholder Committee Meeting (11 to 12 noon) with possible Working Group Meetings prior. Followed by Texas Watershed Steward Workshop with Texas A&M AgriLife (12:30 to 4:30).
- **Wednesday, December 5, 2018 (Morning, Mid-Watershed)-** Steering Committee Meeting
- **Wednesday, January 30, 2019 (Evening, Downtown)-** Stakeholder Committee Meeting with Working Group Meetings prior. Include Educational Forum.
- **Tuesday, April 9, 2019 (Evening, Upper or Mid-Watershed)-** Stakeholder Committee Meeting. Possibly with Shoal Creek Tour.
- **Wednesday, April 24, 2019 (Lunch, Downtown) -** Working Group Meetings
- **Tuesday, June 11, 2019 (Morning, Downtown)-** Steering Committee Meeting
- **Wednesday, August 7, 2019 (Evening, Downtown) -** Stakeholder Committee Meeting with Educational Forum and Working Group meetings prior.
- **Tuesday, October 8, 2019 (Evening, Mid-Watershed) -** Stakeholder Committee Meeting with Working Groups
- **Wednesday, December 14, 2019 (Lunch, Downtown) -** Steering Committee Meeting

Targeted Outreach Plan

The project partners will employ the following strategies to increase public participation in the process and at meetings:

- Leveraging Partnership:
    - Email partner nonprofits and businesses to inform them of the meetings and ask them to assist with promotion through newsletter articles, facebook posts and other outlets
    - Send targeted emails to identified stakeholders asking them to attend committee meetings and participate in working groups
    - Ask stakeholder committee members to assist in identifying additional participants and spreading the word
    - Email neighborhood association presidents and/or newsletter contacts within the watershed to ask them to share information on nextdoor, through listservs and in newsletters
    - Request assistance from Council Members Pool, Alter and Tovo in promoting the meetings
    - Partner closely with the City of Austin Public Information Office to promote all meetings
- Utilizing Shoal Creek Conservancy Outlets:
    - Maintain a watershed action plan "microsite" on the Conservancy website
    - Promote the workshops on the Conservancy website homepage and events pages, blog posts
    - Post on Conservancy social media platforms including: Facebook, Instagram, Twitter
    - Include information in the Conservancy's e-newsletter each month, list includes over 1,500 email addresses with an open rate of 30%
    - Sent e-blasts to Conservancy's email lists of over 1,500 stakeholders
- Additional Strategies:
    - Consider hosting meetings in different locations within the watershed to increase geographic representation
    - Secure food donations to encourage attendance
    - Post meeting details on various Austin online calendars, including the Austin Chronicle, Eventbrite, do512, Austin Monthly, EcoNetwork, Community Impact, and Austin360
    - Distribute media advisories to all Austin media outlets prior to the meetings
    - Consider posting "yard signs" with information along Shoal Creek

APPENDIX E – SHOAL CREEK ONGOING PROJECTS AND PROGRAMS

Water-Related Management Plans that Intersect with the Shoal Creek Watershed Action Plan

The following list is not exhaustive but provides a picture of the primary plans related to the Shoal Creek watershed.

Note: Habitat Conservation Plans (HCP) for the Southern and Barton Springs Segments of the Edwards Aquifer do not apply to the Northern Segment, for which Shoal Creek is a part. The threatened Jollyville Plateau Salamander residing in some Shoal Creek springs does not yet have an HCP.

Austin Water Forward: Integrated Water Resource Plan (AWU) – Austin Water Forward is a water use and conservation plan catalyzed by AWU for implementation within the COA. The primary management measures included in Austin Water Forward that intersect with the SCWAP regard rainwater harvesting and water reuse. Others involve infiltrative measures such as a proposed Landscape Transformation Ordinance which would require single family homes to limit turf-grass (and potentially enhance grow zones). For more information on this document, visit http://austintexas.gov/sites/default/files/files/Water/WaterForward/Water_Forward_Plan_Report_-_A_Water_Plan_for_the_Next_100_Years.pdf

COA Watershed Protection Master Plan – The WPD's Master Plan details how the WPD fulfills its mission to "protect the lives, property, and environment of our community by reducing the impact of flooding, erosion, and water pollution." The Master Plan was completed and approved by City Council in 2001 and was updated in 2016. Solutions to problems existing in Austin watersheds are divided into three categories: capital project solutions, operating programs, and regulations. Under this plan, large portions of Shoal Creek are prioritized as problem areas, including study areas SHL1 and SHL2 for creek flooding, erosion control, and water quality, and parts of SHL3 for local flooding, creek flooding, and erosion control. Please refer to the Master Plan for details on the vast number of suggested solutions, many of which overlap with the management measures listed in this SCWAP (https://www.austintexas.gov/watershed_protection/publications/document.cfm?id=261630&id2=%20).

Imagine Austin – Imagine Austin, adopted in 2012 and most recently updated in 2016, is the COA's comprehensive plan for a vibrant, livable, and connected city. Within this plan, the sustainable management of water resources is prioritized, and extensive actions are recommended that combine elements from multiple water-, conservation-, and climate-related plans throughout the city such as Austin Water Forward and the Watershed Protection Master Plan. To access the Imagine Austin plan, visit https://plans.bloomfire.com/posts/2693110-imagine-austin-comprehensive-plan.

Pease Park Master Plan – The Pease Park Master Plan, finalized in 2014, encompasses a large extent of natural area, trails, and parkland along Shoal Creek, from W 15th Street to

W 31st Street (Wallace, Roberts, & Todd, Siglo Group, Clayton & Little Architects; 2014). The project area includes 84 acres of the Shoal Creek watershed and 2.1 miles of the stream. Many of the recommendations proposed in the Pease Park Master Plan for natural resource management intersect with Shoal Creek management measures including riparian restoration and grow zones, erosion control, and native plant restoration. Pease Park, SCC, and the COA will continue to work together on large project planning such as stormwater controls related to infiltration such as those proposed in this Master Plan for Lamar Boulevard.

Region K Water Plan - Region K (the Lower Colorado Regional Water Planning Area) is one of sixteen regional water planning groups in Texas. The TWDB coordinates this water planning effort which is primarily focused on water use. The Region K Water Plan manages water use and groundwater withdrawal in the Lower Colorado River Watershed, which encompasses Shoal Creek and the Northern Segment of the Edwards Aquifer. The COA is a partner in this planning effort and COA management strategies relevant to Shoal Creek listed in this plan include rainwater harvesting, water conservation, a direct use water reclamation initiative, and decentralized reuse (graywater, etc.). Through this agreement with the TWDB, the City commits a number of acre-feet per year to each measure, with incremental increases through 2070. For details, visit https://www.regionk.org/planning-documents/2016-region-k-water-plan/.

Shoal Creek Trail: Vision to Action Plan – The Shoal Creek Trail Plan represents a community-led strategy to connect neighborhoods with nature, envisioning a city accessible by foot or bike. The proposed trail extends the existing 3.9 miles of Shoal Creek Trail by 9 miles, ultimately connecting to a 30-mile urban hike and bike loop encompassing the city of Austin. The Shoal Creek Trail Plan is an opportunity to educate its users on the value and function of the watershed for the city and to enhance the health of the creek and its communities through ecosystem-related recreational services. This plan's Natural Resources and Ecology Guiding Principle is to "identify and integrate best practices in environmental stewardship, sustainability, and resiliency," with two primary goals that intersect with the SCWAP: the restoration of plant communities and the improvement of ecological function in the Shoal Creek Corridor. For more information, see https://shoalcreekconservancy.org/wp-content/uploads/2018/11/ShoalCreekTrailVisionToActionPlan_2018.11.07_small.pdf.

Spicewood Tributary TMDL and Implementation Plan (I-Plan) – The documents, *Five Total Maximum Daily Loads for Indicator Bacteria in Four Austin Streams* and *Implementation Plan for Five Total Maximum Daily Loads for Bacteria in Four Austin Streams,* both approved by the EPA in 2015 and collectively called the TMDL in this document, outline pollution abatement measures for the Spicewood Tributary to Shoal Creek, Segment 1403J, and segments of Taylor Slough South, Walnut Creek, and Walnut Creek. The TMDL provides the basis for water quality modelling and management measure recommendations in the SCWAP. For more information, please visit https://www.tceq.texas.gov/waterquality/tmdl/101-austinbacteria#plan.

Travis County Land, Water, and Transportation Plan – Though the majority of management measures in the Travis County Land, Water, and Transportation Plan address issues that occur outside of Austin city limits, and thus outside of the boundaries of Shoal Creek watershed, SCWAP stakeholders recognize the

interconnectedness of waterways and ecosystems, and that Shoal Creek is part of the greater Lower Colorado River watershed, which encompasses Travis County. While most projects in this plan do not directly impact Shoal Creek, the Water Availability Rule is one that could potentially affect baseflow in the stream. The Water Availability rule manages groundwater pumping from the Trinity Aquifer in western Travis County, which contributes water as recharge to the Edwards Aquifer (source: https://www.edwardsaquifer.net/trinity.html). For more information on this plan, visit:https://www.traviscountytx.gov/images/tnr/Docs/lwtp-Summary_of_Select_Plans_Ordinances_and_Rules.pdf.

Stormwater-Related COA Capital Improvement Projects in the Shoal Creek Watershed

From the COA Capital Projects Explorer, data updated September 30, 2019: https://capitalprojects.austintexas.gov/projects

5th St to Ladybird Lake Stream Restoration - Project ID: 5282.052 - Multiple stream restoration projects were constructed in lower Shoal Creek including independent Watershed Protection Department projects as well as cost-sharing with other City Departments. Completed Summer 2018.

Landslide Repair near 2500 Block of N Lamar - Project ID: 6039.116 - Emergency project to restore flood capacity and repair damaged infrastructure in Shoal Creek, including a wastewater line and trails. Project will stabilize and remove material blocking the creek, reroute a storm drain, and restore the streambank. Completion anticipated Fall 2020.

Little Shoal Creek Tunnel Stormdrain Improvements Study - Project ID: 5789.093 - The Little Shoal Creek Tunnel does not have the capacity necessary to serve the contributing drainage area and needs improvements. This Project will determine vertical and horizontal alignment of the proposed replacement storm drain system. Project Location: Nueces St from W Martin Luther King Jr Blvd to Lady Bird Lake. Project completion TBD.

Lower Shoal Creek Flood Risk Reduction Study - Project ID: 5754.076 - An updated feasibility assessment was conducted to evaluate flood risk reduction solutions to address flooding along the mainstem of Shoal Creek from 15th St to Lady Bird Lake. Project completion TBD.

Northwest Park Dam Maintenance and Modernization - Project ID: 7492.032 - Inspections identified deficiencies in the pond and the need for modernization of the dam. Phase 1 and 2, completed in 2014 and 2016, identified 8 different improvements for the pond/dam. Phase 3 will be the implantation of improvements as necessary. Project Location: Located inside Beverly S Sheffield Northwest District Park, 7000 Ardath St. The earthen embankment dam is located on the west side of the park along the main stem of Shoal Creek. Project completion TBD.

Wooldridge Drive Emergency Storm Drain Reroute - Project ID: 5789.135 - Wooldridge Drive & Gaston Ave Emergency Storm Drain Reroute is needed to divert storm water from an existing 15" storm drain outfall directed to the location of 2018 Shoal Creek Bank failure. Project Location: Approximately from 2421 Woolridge Dr to the intersection with Gaston Avenue. Project completion anticipated winter 2019-20.

APPENDIX F – GLOSSARY

Baseflow – Baseflow is the flow of water derived from the seepage of groundwater or the standard contribution of inflow into a stream. In periods of drought, baseflow represents the majority of stream flow in a waterway. (Source: https://www.encyclopedia.com/earth-and-environment/ecology-and-environmentalism/environmental-studies/baseflow). As environmental conditions change, including those related to urban land development, average baseflow levels may increase or decrease accordingly. As watershed managers and stakeholders attempt to address baseflow, groundwater, and runoff, it may be important to understand historical baseflow if it is desirable to attempt a return to pre-development instream conditions.

Best management practice (BMP) - Nonpoint source BMPs are activities, practices, and procedures undertaken to prevent or reduce water pollution (TCEQ and TSSWCB, 2017). BMPs are a menu of options for which entities within a watershed can choose to implement in order to achieve benchmarks and goals through water conservation. Best management practices are voluntary measures that can be implemented within a specified timeframe (https://www.twdb.texas.gov/conservation/BMPs/index.asp). The "best" BMP to use depends on the particular needs or purposes to be addressed and the specific site characteristics (TCEQ and TSSWCB, 2017).

Channelization - Channelization involves the straightening and deepening of streams so water will move faster. It is a method of flood control that disturbs fish and wildlife habitats and can interfere with a water body's ability to assimilate waste (TCEQ, 2009).

Conductivity - A measure of the amount of salts in water and a good indicator of a range of urban pollutants.

Contact recreation standards - Two standards are listed for recreational water quality designation under the Texas Surface Water Quality Standards (Title 30, Chapter 307 of the Texas Administrative Code), contact recreation and non-contact recreation. According to this standard, "water bodies in Texas are presumed to have contact recreation except where specifically proven otherwise by a use-attainability analysis" (TCEQ, 2007). *E. coli* is used as the indicator bacteria to determine recreational status in freshwater bodies in the state. To achieve contact recreation designation, freshwater bodies of water must maintain an *E. coli* geometric mean of less than 126 MPN per 100mL.

Edwards Aquifer Recharge Zone – The Edwards Aquifer is an aquifer, or geological formation containing water, that extends southwest from Williamson County toward San Antonio, then west to Kinney County. The Edwards is a karst aquifer, meaning its karstic limestone is highly permeable and responsive to rainfall and drought. The Recharge Zone is the area of land where water enters the Aquifer where Edwards Limestone is exposed at the ground surface (Source: https://www.edwardsaquifer.org/science-maps/about-the-edwards-aquifer/). Water flowing over land and into streams throughout the Recharge Zone is especially sensitive to pollution, as a karstic system does not contain sand like other aquifers, with which to filter contaminants. Approximately 27% of the Shoal Creek watershed is in the Edwards Aquifer Recharge Zone.

Eutrophication – Eutrophication is the process in a body of water by which excessive nutrients stimulate algae growth, which decreases the amount of oxygen available for other living organisms (Source: https://oceanservice.noaa.gov/facts/nutpollution.html).

Flashiness – A flashy stream is one that has a tendency toward "flash floods," or abrupt flooding during heavy rainfall events. Intermittent, urban streams often have increased flashiness because of the lack of pervious cover resulting from development that might otherwise slow the movement of runoff into a stream during a storm.

Illicit discharges - Common discharges include petroleum products (e.g., motor oil, gasoline, diesel fuel), sewage, soaps and detergents, sediment (e.g., silt, mud), antifreeze, latex and oil-based paints, solvents, trash and debris, restaurant grease, and fertilizers and pesticides. Discharges may occur through illicit plumbing connections to the City's storm sewer system, wastewater overflows, deliberate dumping, or accidental spills (Source: http://www.austintexas.gov).

Intermittent Stream – An intermittent stream is one that largely flows seasonally and/or during heavy rainfall events as opposed to a perennial stream which derives the majority of its baseflow from groundwater seepage in the form of springs.

Localized flooding - A term used when flooding occurs away from creeks in a concentrated area due to problems with the secondary drainage system.

Primary drainage system - The primary drainage system is comprised of the streams to which the engineered, or secondary, drainage system channels stormwater.

QAPP - The quality assurance project plan, or QAPP, is a document that outlines the procedures that those who conduct environmental data operations will take to ensure that the data they collect and analyze meets project requirements. It is an invaluable planning and operating tool that outlines the project's methods of data collection, storage and analysis (EPA, 1996). The City of Austin has its own QAPP that is used to monitor water quality in local streams.

Riparian zone - The area adjacent to a waterway that serves as the transition zone between the upland and aquatic ecosystems. A healthy riparian zone typically contains dense native vegetation that filters contaminants from runoff and slows the flow of stormwater.

Secondary drainage system - The secondary, or engineered drainage system is composed of pipes, curb inlets, manholes, minor channels, roadside ditches, and culverts.

Total Maximum Daily Load (TMDL) - A TMDL is a determination made by TCEQ of the quantity that a pollutant must be reduced for a watershed to no longer be impaired.

Total suspended solids (TSS) - Total suspended solids are either organic or inorganic particles that are suspended in water. High levels of TSS prevent sunlight and oxygen from reaching aquatic life and increase pollutants, as contaminants adhere to particles.

APPENDIX G – BMP GLOSSARY

BMP Descriptions **Note:** Descriptions taken from the Texas Nonpoint Source Management Program's BMP Finder unless otherwise noted	Corresponding SCWAP Potential Management Measures
Animal Waste Collection - Animal wastes can be controlled through ordinances requiring collection and removal of the waste from curbsides, yards, parks, roadways and other areas where the waste can be washed directly into receiving waters. The ordinances should include guidance on proper disposal of animal wastes.	Scoop the Poop Educational Program
	Install additional Pet Waste Bag Dispensers in Parks and along trails
	Expand Pet Waste Measures to Private Dog Parks/Facilities
Extended Detention Basin - Basin that temporarily stores a portion of storm water runoff following a storm event. It is used to remove particulate pollutants and to reduce maximum runoff rates associated with development to their pre-development levels.	Extended Detention/ Sedimentation Pond
	Retrofit Existing Structures/Stormwater Detention Basins
	Inspect City and Private Water Quality Basins

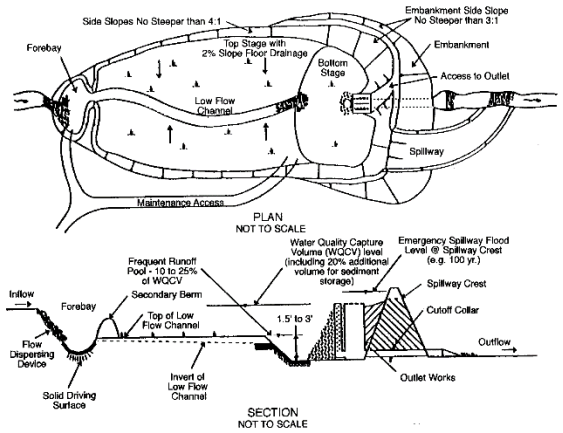


Figure 12- *Extended Detention Basin (TCEQ, 2005)*

See also Retention Ponds

Figure 13 *- LCRA Extended Detention Basin (Source: Google Maps)*

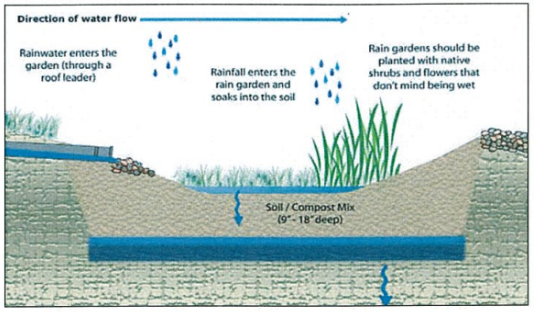
Filter Strip, Vegetated (VFS) - *Also known as vegetated buffer strip.* An area of vegetation that filters solids from overland sheet flow between pollutant source areas and a receiving water or channel. VFSs can be natural or planted, should have relatively flat slopes, and should be vegetated with dense-culmed, herbaceous, erosion-resistant plant species, usually grass.

Expansion of Grow Zones on private and public lands

Figure 14 *– Filter Strips (BRWM, n.d.)*

Infiltration Device - Structure to facilitate the entry of storm water into the soil to remove pollutants and to recharge or replenish the ground water. Infiltration devices, also called exfiltration devices, include *infiltration basins*, *infiltration trenches* and *dry wells*. Properly designed infiltration devices can closely reproduce the water balance that existed pre-development, providing ground water recharge, control of peak flows from storm water and protection of streambanks from erosion due to high flows. Infiltration devices can remove a significant amount of pollutants through adsorption onto soil particles, and biological and chemical conversion in the soil. Some infiltration devices (*infiltration trenches*, *dry wells*, and *catch basins*) can be constructed underground, under parking lots or roads, taking very little land from other uses. Locating smaller infiltration devices is fairly easy so that large downstream devices can be replaced with a number of small structures upstream and still achieve the same control of storm water. Infiltration devices require permeable soils and reasonably deep-water tables. Smaller infiltration devices such as dry wells or basins can be located near buildings to capture the runoff from roofs and other impervious surfaces.	Strategies for increasing infiltration through redevelopment and other efforts

Inlet Protection Devices – "proprietary devices that are installed at inlets to manage trash and/or improve water quality depending upon selected device" (from the City of New Braunfels Edwards Aquifer Habitat Conservation Plan) - **Block and Gravel** - A temporary sediment control barrier formed around a storm drain inlet by the use of standard concrete block and gravel, to filter sediment from storm water entering the inlet prior to stabilization of the contributing area soils, while allowing use of the inlet for storm water conveyance. - **Excavated** - A temporary excavated area around a storm drain drop inlet or curb inlet designed to trap sediment prior to discharge into the inlet. - **Fabric** - A temporary fabric barrier placed around a drop inlet or curb inlet to help prevent sediment from entering storm drains during construction operations, while allowing use of the inlet for storm water conveyance. - **Sod** - A permanent grass sod sediment filter area around a storm drain drop inlet for use once the contributing area soils are stabilized. This application is well-suited for lawns adjacent to large buildings.	 ***Figure 15** - Clogged inlet (COA, n.d. Green Stormwater Infrastructure Maintenance Manual)*
Landscaping and Lawn Maintenance Controls - Significant amounts of fertilizers and pesticides enter the water from lawn maintenance and landscaping activities. Professional services may overapply fertilizers and pesticides to better please customers, and homeowners may not know the proper amounts of fertilizer and pesticides to use. Both groups may apply lawn-care chemicals too near water bodies. Requirements can be established through landscaping ordinances for business and industry to use native,	COA Avoid Weed & Feed Program

<table>
<tr>
<td>hardy perennial species which require less fertilizer and water than common landscape varieties. Professional landscaping services can be required to minimize fertilizer and pesticide use and restrict application to the growing season. Integrated Pest Management, a well-established system to minimize the amount and toxicity of pesticides released to the environment, is a recommended landscape and lawn maintenance BMP. Particular attention should be paid to certain areas of high-intensity landscaping, such as cemeteries and golf courses, which may contribute large amounts of excess fertilizer and pesticides to runoff. Homeowners should be informed about the proper use of lawn and garden chemicals.</td>
<td>Grow Green Lawn/Landscape Program(s)
 

DESCRIPTION: Soil additives, or amendments, can be used to minimize development impacts on native soils by restoring their infiltration capacity and chemical characteristics. After soils have been amended their improved physical, biological and hydrological characteristics will make them more effective agents of stormwater management.
Figure 16 - Soil Amendments (BRWM, n.d.)</td>
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<tr>
<td rowspan="2">Porous Pavement - An alternative to conventional pavement intended to reduce imperviousness and consequently minimize surface runoff.
 

Figure 17 – Porous pavement (BRWM, n.d.)</td>
<td>Parking Lot Retrofits</td>
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<td>Permeable Pavement Incentives, Code, etc. residential and commercial</td>
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<td>Rain Garden - Gardens to treat storm water runoff from parking lots, roadways, or driveways through temporary collection of the water before infiltration. Also known as bioretention. They are slightly depressed areas</td>
<td>WaterWise Rainscape Rebate Program</td>
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<td>into which storm water runoff is channeled by pipes, curb openings, or gravity.

 
Figure 18 – Raingarden (BRWM, n.d.)</td>
<td>COA Stormwater Discount</td>
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<td rowspan="2">Rainwater Harvesting[1] - (See Retention/Irrigation Systems) Capture and storage of rainwater from roofs and other impervious surfaces for landscape, domestic, or other consumptive uses. This can mitigate or eliminate the increased runoff volume and velocity due to additions of impervious cover, reducing the required capacity for down-slope retention and sediment control BMPs.

 
Figure 19 - Rainwater Harvesting (COA, n.d., Rainwater Harvesting)</td>
<td>WaterWise Rainwater Harvesting Rebate Program</td>
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<td>COA Stormwater Discount</td>
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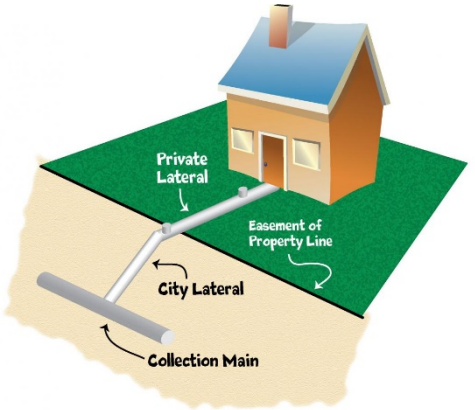
Retention Pond, Dry - Ponds or basins that temporarily detain a portion of storm water runoff for a specified length of time, releasing it slowly to reduce flooding and remove a limited amount of pollutants through settling. Also called *dry detention basin or device or dry pond*. **Retention Pond, Wet-** Also called *wet detention basins or wet basins or ponds*, these structures maintain a permanent pool of water in addition to temporarily detaining storm water. Wet ponds are one of the most effective and reliable devices for removing pollutants from storm water, particularly dissolved nutrients. The permanent pool of water enhances the removal of many pollutants.	 ***Figure 20*** *- Retention Pond (BRWM, n.d.)*
Street Sweeping Operations -Mechanical collection of debris, silt, and dirt from paved outdoor surfaces including streets and parking lots. High-efficiency systems increase the elimination of pollutants on pavement exposed to runoff. Street cleaning can reduce pollutants in runoff if it is performed regularly. Another benefit of street cleaning is that pipes and outlets in detention structures and ponds are less likely to become clogged.	"Residential streets are swept six times a year, while major streets are swept once a month. This schedule allows for the regular sweeping of many of the City's prized bicycle facilities, located both on residential and major streets. Austin Resource Recovery cannot sweep streets without curbs, but litter is periodically picked up by hand from these streets. The street sweeping system is designed to clean the gutters and prevent automotive fluids and other contaminants from polluting Austin's creeks and waterways." http://www.austintexas.gov/department/street-sweeping

Swale - A shallow, gentle depression in the ground which serves as a drainage course. Swales are most commonly grass-lined except where runoff flow or inundation is particularly frequent or intense. In such cases, *rip-rap* or other rock lining may be used. They may serve as diversions or conveyances for storm water. *See Diversion and Grassed Channel or Swale.* **Grassed Channel or Swale** [1] - *Also called grassy swale.* An earthen channel or swale vegetated with grass, which is dry except following storms and serves to convey specified concentrated storm water runoff volumes, without resulting in erosion, to disposal locations. They require shallow slopes and soils that drain well. Typical uses include roadside swales, highway medians, outlets for road culverts or runoff diversions, construction storm water routing, and drainage of low areas.	 ***Figure 21****- Bio-Swales (BRWM, n.d.)*
Review/Revise Stormwater payment-in-lieu policies The COA has a fee in-lieu of water quality controls option that allows developers to pay a fee in exchange for an exemption from impervious cover limits. The application is found in Appendix T of the Environmental Criteria Manual.	"The new code will ask all developments to contribute their fair share to solutions that address threats to public safety and property. This could be achieved through a variety of options including on-site detention, off-site conveyance improvements, and payment-in lieu of drainage improvements." http://www.austintexas.gov/faq/how-will-new-code-address-flooding
Green Roofs – A green roof cover is a veneer of vegetation that is grown on and covers an otherwise flat or pitched roof, endowing the roof with hydrologic characteristics that more closely match surface vegetation than the roof. (from Bexar Regional Watershed Management: Low Impact Sustainability Techniques)	COA Stormwater Discount  ***Figure 22*** *- Green Roofs (BRWM, n.d.)*

Land Conservation – - **Natural area preservation** – conservation of natural areas within development sites to retain predevelopment runoff quantity and quality characteristics - **Conservation easements** – the purchase of property adjacent to a stream for the purpose of preservation and/or public access	 ***Figure 23****- An example of conservation easements on the Rappahannock River, Virginia, where the City of Fredericksburg has purchased 4200 acres of riverfront property (COF, n.d.)*
Green Streets - A green street is a stormwater management approach that incorporates vegetation (perennials, shrubs, trees), soil, and engineered systems (e.g., permeable pavements) to slow, filter, and cleanse stormwater runoff from impervious surfaces (e.g., streets, sidewalks). Green streets are designed to capture rainwater at its source, where rain falls. Whereas, a traditional street is designed to direct stormwater runoff from impervious surfaces into storm sewer systems (gutters, drains, pipes) that discharge directly into surface waters, rivers, and streams. (from https://www.epa.gov/G3/learn-about-green-streets)	 ***Figure 24*** *- Green Street, before and after (BRWM, n.d.)*

Private Lateral Inspection – A private lateral is the segment of the sanitary sewer system located on private property that connects a residence or business to the City's sanitary sewer system (from Austin City Code 15-11-2). Inspection of private laterals can prevent sewage leakage into streams.	Private Lateral Program Ordinance  ***Figure 25** – Private Sewer Lateral Line (COA, n.d., Private Lateral Program)*
Storm drain Retrofits - Stormwater vaults, inlet systems, and on-line measures that are installed to retain pollutants, sediment and trash. There are many different types and vendors available to provide the devices and information on installation and maintenance. These types of retrofits require consistent and scheduled maintenance to ensure performance and prevention of local flooding issues.	
End of Pipe Storm Drain Retrofits - An end of pipe device can be a stormwater vault or more conventional BMP such as a rain garden, bioretention basin, sedimentation- filtration basin, or other similar measures. Upstream contributing drainage area plays a key role in defining the appropriate measure at a storm drain outfall.	

Sanitary Sewer Overflow Response - Sanitary sewer overflows (SSOs) are releases of untreated sewage into the environment from deteriorating sewer infrastructure, flooding, or other causes (from https://www.epa.gov/sites/production/files/2015-10/documents/sso_casestudy_control.pdf). An SSO response plan presents a strategy to mobilize the labor, materials, tools and equipment required to correct/repair any infrastructure failure which may cause or contribute to an un-permitted discharge. Being prepared to respond to system failures lessens the chances that an overflow will adversely impact surface waters, land, or buildings (from https://www.epa.gov/sites/production/files/2014-03/documents/april_22_2011_exhibit_c_water_works.pdf)	

Bank Stabilization Projects – Measures used to reduce erosion in problematic areas, potentially to include but not limited to:
- Gabions - Traditionally, wire mesh boxes, baskets or cages filled with small rocks. They are wired together as building blocks in the construction of hardened stream-bank protections.
-Live Cribwall - A hollow, box-like interlocking arrangement of untreated log or timber members, this structure is filled with suitable backfill material and layers of live branch cuttings, which root inside the crib structure and extend into the slope.
- Live Staking - A form of soil bioengineering involving the planting of live cuttings from hydrophytic shrubs or trees along the stream bank. *Also known as woody cuttings, posts, poles, or stubs.* As cuttings develop, they protect streambanks from erosion, minimizing sediment and associated nutrient impacts downstream. Established cuttings also moderate bank and water temperatures facilitate colonization of other species and provide forage.
- Mattress - A form of soil bioengineering which uses a blanket woven of live green cuttings and biodegradable fiber, geotextile, or wire, laid into a slight excavated depression in the bank, anchored with live or wooden stakes, and often punched through with live stakings. It is then covered with soil and watered repeatedly to fill voids with soil and to facilitate sprouting.
- **Revetment, Composite** - Tiering of any number of materials up bank slopes, such as cement burlap bags, stone, gravel, wire mesh blanketing, *gabions*, biodegradable fabrics, geotextile fabrics, *tree revetments*, and *live staking* of hydrophytic vegetation, matched to the erosive potential of the vertical stream-bank zones, for the purpose of reducing stream-bank erosion and associated sediment and nutrient impacts downstream.
-Revetment, Tree - A form of soil bioengineering which uses uprooted, live trees laid on their sides and secured to the bases of banks along eroded stream segments, tops pointed downstream and overlapped about 30 percent. Species used are those with abundant, dense branching to promote sediment trapping, and those which are decay resistant.
- **Riprap** - A layer of loose angular stone designed to protect and stabilize channels or other areas subject to erosion from concentrated flows, or to protect slopes subject to seepage or areas with poor soil structure. Riprap is used on slopes where vegetation cannot be established, channel slopes and

***Figure 26** – Cribwall above washout behind hike & bike trail upstream of 6th St. Bridge, looking downstream, 1997. (Hegemier, T. 2016))*

***Figure 27** - Damaged gabion mattress, downstream of 9th St., Shoal Creek (Hegemier, T., 2016)*

bottoms, storm water structure inlets and outlets, slope drains, streambanks, and shorelines.

Figure 28 *- New gabion along west bank looking upstream from 10th St. Bridge, 1997 (Hegemier, T.., 2016)*

Sediment Removal BMP Design and Implementation Sediment removal is an option for accessible parts of a stream that have collected large amounts of debris due to long-term runoff and erosion.	 ***Figure 29*** *– 5th Street Bridge, East Span, Shoal Creek, Looking Downstream (Hegemier, T., 2016)*
Natural Channel Design Natural channel design involves the restoration of streams to reflect pre-development conditions.	 ***Figure 30*** *- Natural Channel Design (BRWM, n.d.)*

Grow Zones
Native vegetation established along the creek's edge to filter stormwater runoff to reduce pollutants from reaching the creek. Other benefits include:

- Minimize stream bank erosion
- Cool air and water temperatures
- Absorb water/promote baseflow
- Provide habitat
- Reduce mowing and maintenance
- Creates a greenbelt woodland
- Reduce the City's carbon footprint

"Creekside Homeowners, A Guide for Creekside Residents":
http://www.austintexas.gov/sites/default/files/files/Watershed/growgreen/creekside_design.pdf

Figure 31 *- A streambank prior to restoration*

Figure 32 *- Streambank after grow zone established*