Final Report: Cypress Creek Watershed Protection Plan (WPP) Implementation

TCEQ Contract No. 582-16-60282 funded through a Clean Water Act 319(h) grant from the Environmental Protection Agency

CYPRESS CREEK

Let's keep it clean, clear & flowing

United States Environmental Protection Agency

The Meadows Center for Water and the Environment
Texas State University

Texas Commission on Environmental Quality

Meadows Center Report 2020-01

February 2020

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Introduction

In June 2009, Stakeholders from the communities in the Cypress Creek watershed, with the assistance of The Meadows Center for Water and the Environment at Texas State University (MCWE), formed the Cypress Creek Stakeholder Committee which sought to develop a management strategy to keep Cypress Creek clean, clear, and flowing. This committee developed the Cypress Creek Watershed Protection Plan (CCWPP) which describes best management practices (BMPs) and other actions to attain, maintain, and ultimately improve water quality in the creek and its tributaries. For more information on the CCWPP, visit www.CypressCreekProject.net.

Executive Summary

Throughout the implementation of the CCWPP contract period, August 2016 – February 2020, MCWE has led a variety of projects that support the vision of ensuring a clean, clear, and flowing Cypress Creek for the Wimberley Valley region. Each project represents a unique, collaborative effort with local partners and stakeholders. Highlights of this three year effort include hosting or participating in twenty informative public workshops and events to educate local stakeholders on ways to prevent non-point source pollution, collaborating with local communities to establish revised ordinances protective of water quality, developing guidance documents for planning and development professionals as well as the public, installing green stormwater infrastructure (GSI) BMPs throughout the watershed and performing water quality monitoring in accordance with a Quality Assurance Project Plan (QAPP) associated with the project. Adaptive management strategies to protect both water quality and quantity enabled the MCWE and our partners to conduct additional research on the sources and causes of elevated *E. coli* bacteria levels in the lower section of Cypress Creek, develop an online, a 360 degree virtual tour of the entire perennial section of Cypress Creek and to engage the community and local school district to establish the first 'One Water' school in Texas, Wimberley Independent School District's (WISD) new Blue Hole Primary School.

Implementation of the CCWPP began to take shape in 2016 and 2017 with MCWE serving as the watershed coordinator for quarterly stakeholder meetings, education and outreach programming, website development, hiring an engineering contractor, developing a QAPP, and conducting quarterly water quality monitoring at 6 locations along Cypress Creek in coordination with Clean Rivers Program (CRP) partners, Wimberley Valley Watershed Association (WVWA), and the Guadalupe-Blanco River Authority (GBRA).

From August 2017 to October 2017, MCWE, in conjunction with the City of Wimberley and Texas A&M University, conducted a 3-month Bacterial Source Tracking (BST) study to determine the source(s) of elevated *E. coli* bacteria discovered in Cypress Creek near downtown Wimberley. Results from the BST were varied, sources identified in the analysis included livestock, wildlife, and human. Although the BST study was not funded through the Clean Water Act (CWA) 319(h) project, based on the findings, two sites were determined as ideal locations for implementation of BMPs to be installed using the CWA 319(h) project funds.

MCWE also hosted several workshops and meetings in 2017 for local stakeholders, including the Blanco River/Onion Creek Water Forum where over 100 attendees who live in the area gathered to find common ground and discuss resolutions for current and future water issues in the watershed. The Texas Well Owner Network, a program run by Texas A&M AgriLife Extension, also hosted a "Well Educated" workshop to educate Wimberley residents about managing household wells, improving and protecting water resources, septic system maintenance, well maintenance and construction, and water quality treatment.

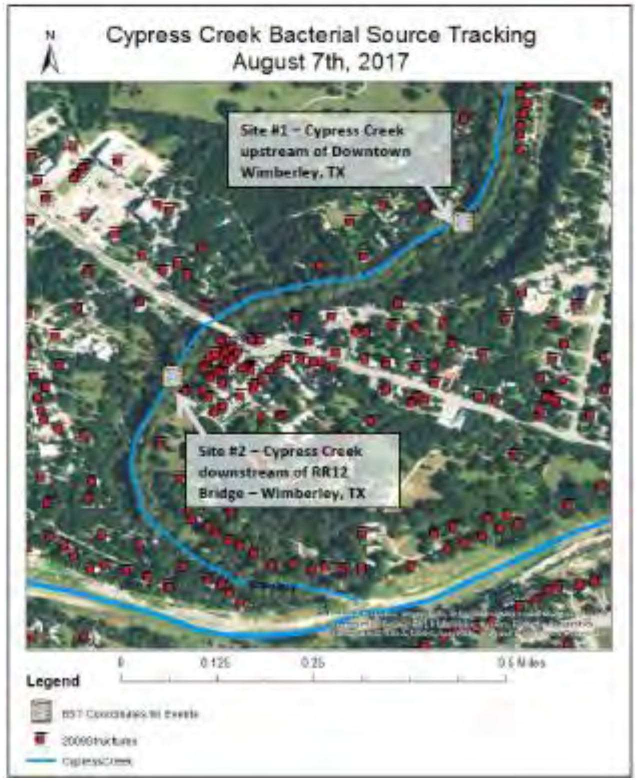

Figure 1. Map of 2017 Bacterial Source Tracking Study

Figure 2. Blanco River/Onion Creek Forum

MCWE continued CRP monitoring efforts throughout 2018 and took steps to include water quality sampling from 2 monitoring wells understood to have hydrologic connection to Jacob's Well Spring, the source of perennial flows in Cypress Creek. Five workshops were hosted for stakeholders, including the Soil for Water workshop where attendees learned about soil and range management techniques, riparian restoration techniques, and riparian ecosystem monitoring. Participants learned how to improve the condition of their land, store more water on-site, increase biodiversity and productivity, and how to reduce the effects of drought and flooding. The newly created Central Texas Feral Hog Task Force also led a workshop where attendees learned about how feral hogs can degrade waterways and different management techniques. The first of many GSI BMPs was also completed in 2018, a rainwater harvesting system at the Patsy Glenn Wildlife Refuge was installed as part of a Low Impact Development workshop for the public.

Figure 3. Rainwater Harvesting Systems installed at the Patsy Glenn Wildlife Refuge

In 2019, MCWE efforts turned to completing the remaining GSI deliverables in the Cypress Creek watershed and multiple focused efforts with CCWPP partners including: maintenance agreements for GSI projects; local cost share for water quality monitoring; the development of multiple technical reports for developers, planners and the public; adoption of water quality ordinances for Wimberley and Woodcreek; a partnership with WVWA and WISD to design and build the first 'One Water' school in Texas; partnering once again with WVWA to develop a 360 degree virtual tour of Cypress Creek; and participation in a broad stakeholder effort to recommend new rules for the Hays Trinity Groundwater Conservation District (HTGCD) that would establish a Jacob's Well Groundwater Management Zone (JWGMZ). Quarterly CRP water quality monitoring continued through 2019 along with the addition of two monitoring wells. Rainwater harvesting systems (4 sites), permeable pavers (3 sites), and a rain garden (1 site) were installed at highly visible locations throughout the watershed. Three more educational workshops for local stakeholders were also held in 2019.

Figure 4. Rainwater Harvesting System installed at WVWA Headquarters

Figure 5. Permeable Paver parking lot in Downtown Wimberley

Figure 7. Permeable paver sidewalk at Blue Hole Regional Park

Figure 6. Rain garden at Woodcreek Community Golf Course just after completion, pre-plant

The work toward water quality ordinances for Wimberley and Woodcreek together with the effort to establish a JWGMZ made 2019 a banner year for the CCWPP; however, it was breaking ground on Wimberley's new Blue Hole Primary School, the first 'One Water' school in Texas, that made the biggest headlines locally and across the state. MCWE partnered with WVWA to spearhead the design for a school that would use 90 percent less water than traditional development standards. The design also includes GSI features that support the CCWPP mission of keeping Cypress Creek clean, clear, and flowing. The design was ratified through a Memorandum of Understanding between MCWE, WVWA, and WISD and was unanimously approved by WISD's Board of Trustees. Construction for the new campus began in July 2019. Although this effort was not funded through the CWA 319(h) project or identified in the CCWPP, this innovative approach to protecting water quality and conserving water resources will have a direct impact on the watershed and will be used as a model for future development projects throughout the Texas Hill Country.

LOCAL

Wimberley school to make history as first 'One Water' school in Texas

A 'One Water' school means it will use 90 percent less groundwater than a typical school of this size.

Author: Shawna Reding
Published: 8:04 AM CST December 3, 2018
Updated: 11:06 AM CST December 3, 2018

Figure 8. Austin American Statesman, December 3, 2018

As the CWA 319(h) contract neared completion in 2020, MCWE wrapped up several projects: the last GSI BMP to be completed - a hybrid vegetated filter strip/raingarden at the WVWA headquarters – as well as educational signage for all the other projects (including Spanish translations); a self-guided, informative tour of all BMPs in the watershed to be viewed on a mobile device or desktop was published; the City of Wimberley formally adopted a significantly improved water quality protection ordinance with the City of Woodcreek poised to follow suit; and, all technical reports were completed and submitted.

CCWPP Implementation Years 4 through 6 has been selected for funding under CWA 319 (h) grant funds with a focus on transitions to more local ownership and sustainability of the plan. An 'Sustainability Plan' reinforced through an interlocal agreement among key stakeholders will be sought to ensure technical and financial resources are in place to continue water quality monitoring and BMP implementation. A 'One Water' approach to watershed management will remain the critical, long-term strategy for a clean, clear, and flowing Cypress Creek.

Project Significance and Background

The Cypress Creek watershed is home to a unique set of rural and urban communities, ecosystems, and a long-standing reliance on groundwater for both drinking supply and recreational uses. Cypress Creek flows through unincorporated portions of Hays County and the cities of Wimberley and Woodcreek. It meets the Blanco River near the Wimberley town center. Nearly five and a half miles upstream of the confluence, near the City of Woodcreek, is Jacob's Well Spring, the headwaters of the perennial Cypress Creek. Jacob's Well is an expression of underground water stored in the Trinity Aquifer that discharges at the land surface. The artesian spring perennially feeds water to the lower third of the creek. Above the artesian headwaters, flows in the Cypress Creek (Dry Cypress) are driven by rain events. Once the water is in the creek bed, part of it flows back underground into the aquifer. Flow between land surface and the subsurface creates a complex interaction between groundwater and surface water in Cypress Creek.

Although water quality in the Cypress Creek is primarily meeting water quality standards, data reveal both spatial and temporal trends that may be due to climate variability, nonpoint source pollution, and changes in land use and/or management in the watershed. Water quality parameters vary considerably from site to site throughout the perennial part of the stream. In general, the five upper most water quality monitoring sites (Jacob's Well, Camp Young Judea, Woodcreek Drive, RR12 north, and Blue Hole) tend to be highly influenced by inflow of groundwater in terms of their water chemistry, while the lower two sites (RR12 downtown[1] and the Blanco confluence) tend to cluster closer together and show more of an influence of local stream conditions and runoff from contributing subwatersheds. Issues of concern include excess sediment in the creek, high bacteria concentrations, particularly in the lower two sites, depressed dissolved oxygen, and occasionally very high nutrient levels which are exacerbated by low flows.

Methods

Task 1: Project Administration

OBJECTIVE: To effectively administer, coordinate, and monitor all work performed under this project including technical and financial supervision and preparation of status reports.

Deliverables under this task included:

- Quarterly Progress Reports (QPRs)
- Reimbursement Forms
- Contract communication meeting notes
- Contract closeout strategy
- Annual report article

[1] GBRA monitored CRP site

Task 2: Quality Assurance and Data Acquisition

OBJECTIVE: Document and implement data quality objectives (DQOs) and quality assurance/control (QA/QC) activities that ensure data of known and acceptable quality are used in and generated by this project. Data collected for this project will be used for monitoring, modeling and mapping activities undertaken to improve community decision makers' abilities to identify sources of, as well as, prevent and mitigate NPS pollution from urbanization and development.

<u>Deliverables under this task included:</u>

- QAPP Planning Meeting Notes
- Draft and Final Monitoring/Data Acquisition QAPP
- QAPP Annual Reviews and Revisions
- Draft and Final Monitoring/Data Acquisition QAPP Amendment

Task 3: Monitoring

OBJECTIVE: Conduct additional monitoring and coordinate with monitoring performed by its partners during this project.

Surface Water Quality Monitoring

Routine surface water quality monitoring was conducted approximately quarterly at six CRP sites by MCWE (Figure 9 and Table 1). All water samples were collected under the TCEQ-approved QAPP and adhered to the TCEQ Surface Water Quality Monitoring Program Procedures. Eight monitoring events were conducted between September 2016 and August 2018 for previous contracts, Phases 1 and 2, and five monitoring events were conducted between December 2018 and December 2019 to meet the contractual obligations of the current contract (Phase 3). A total of thirteen events were conducted in the Cypress Creek Watershed Protection Plan Implementation project for Phases 1-3 between September 2016 and December 2019. Field measurements collected *in situ* included water temperature, specific conductance, pH, dissolved oxygen, and stream flow. Water samples were collected and analyzed by the Guadalupe-Blanco River Authority Laboratory. Samples were analyzed for total suspended solids (TSS), total nitrate-nitrogen, ammonia-nitrogen, total phosphorous, and *E. coli* bacteria.

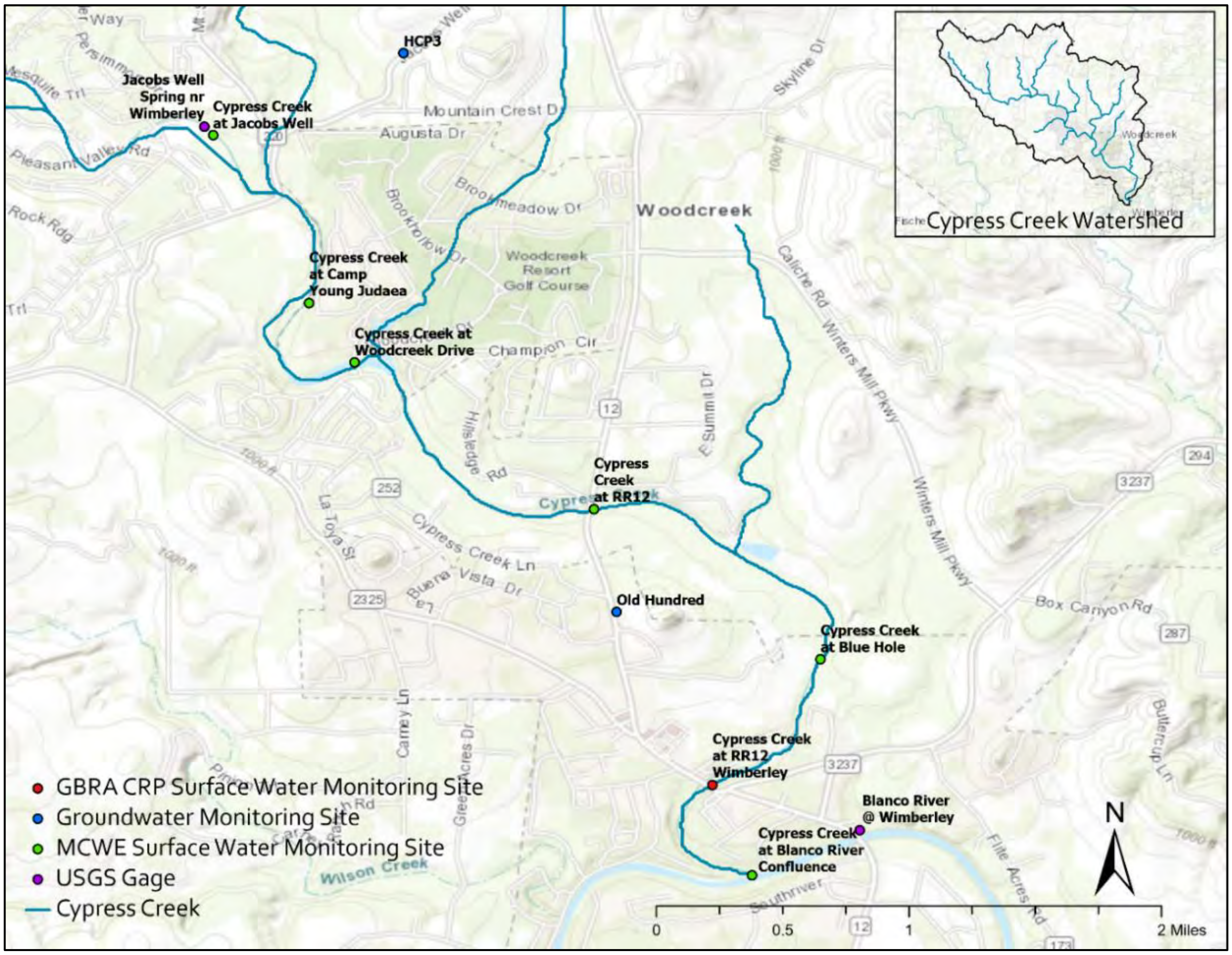

Figure 9. Cypress Creek watershed and monitoring sites

Table 1. Clean Rivers Program Monitoring Sites

Site ID	Site Description	Number of Events: Sept. 2016 – Dec. 2019
12677	Cypress Creek @Jacob's Well	13
22109	Cypress Creek @ Camp Young Judea	5
22110	Cypress Creek @ Woodcreek Drive	5
12676	Cypress Creek @ RR12	13
12675*	Cypress Creek @ Blue Hole	13
12673*	Cypress Creek @ Blanco River confluence	13

*24-hour dissolved oxygen monitoring occurred at these sites

Twenty-four hour dissolved oxygen monitoring occurred at two sites within the Cypress Creek watershed (Table 1). Four 24-hour monitoring events were conducted in April and September 2019 for Phase 3.

Groundwater Quality Monitoring

Two groundwater wells were sampled between November 2019 and January 2020 for Phase 3 within the Cypress Creek watershed. The two groundwater wells included the HCP3 (#5764718), sampled three times, and Old Hundred (#5764721), sampled twice (Fig. 1). Field measurements were conducted in a bucket with sample water from the well and water samples were collected from the well for laboratory analyses. The same parameters were measured for field and laboratory samples as described above for routine surface water quality monitoring.

Acquired Data

Primary sources of acquired data under separate QAPPs include:

- GBRA (CRP monitoring at 12674 – Cypress Creek at FM12 at Wimberley)
- Texas Stream Team (citizen science data collection)
- United States Geological Survey (stream discharge data)
- HTGCD (well data)

Appendix I provides a comprehensive analysis and details of all monitoring activities covered under this project.

<u>Deliverables under this task included:</u>

- Documentation of monitoring activities, in QPRs
- Data Submittals to SWQMIS
- Annual acquired and collected water quality data summary report, including analyses

Task 4: Installation of BMPs at Highly Visible Sites

OBJECTIVE: To install functioning NPS pollutant control technologies which will educate stakeholders concerning the pollution reduction and water conservation benefits of simple, relatively inexpensive management measures.

Subtask 4.1: Rainwater Cisterns at City and County Properties

- Woodcreek Golf Course – 5,000-gallon system utilized for washing golf carts
- Blue Hole Regional Park – 3,453-gallon system utilized for flushing toilets
- Hays County Precinct 3 – 1,000-gallon system utilized for landscape irrigation
- WVWA Headquarters – 30,000-gallon system utilized for indoor potable use
    - WVWA provided the funds to convert the system to indoor potable use.

Subtask 4.2: Rain Garden/Equivalent BMP Sites

- Woodcreek Golf Course – Raingarden designed to divert 160,000 gallons of stormwater and 108 pounds of pollutants annually
- WVWA – Vegetated filter strips designed to divert 280,000 gallons of stormwater and 45 pounds of pollutants annually

- Blue Hole Regional Park #1 – Permeable sidewalk designed to divert 5,000 gallons of stormwater and 6 pounds of pollutants annually
- Blue Hole Regional Park #2 – Permeable trail designed to divert 30,000 gallons of stormwater and 37 pounds of pollutants annually
- Blue Hole Regional Park #3 – Permeable ADA parking spaces designed to divert 17,000 gallons of stormwater and 20 pounds of pollutants annually

Subtask 4.3: Stormwater BMP

- Downtown Wimberley – Permeable parking spaces designed to divert 70,000 gallons of stormwater and 117 pounds of pollutants annually

Appendix II, III and IV to this report provide more extensive analysis to work completed under Task 4.

<u>Deliverables under this task included:</u>

- Advertised and approved bid for supplying equipment and installing rainwater harvesting systems and demonstration BMPs (Subtasks 4.1, 4.2, and 4.3)
- Contract/subcontracts for design and construction including site plans for rain gardens and other demonstration BMPs (Subtasks 4.1, 4.2, and 4.3)
- Final Design Reports for all BMPs (Subtasks 4.1, 4.2, and 4.3)
- Estimated site/area pollutant loadings and BMP load reductions report (Subtasks 4.1, 4.2, and 4.3)
- Technical resource guides created for developers and engineers (Subtasks 4.1, 4.2, and 4.3)
- Technical resource guides for the general public (Subtasks 4.1, 4.2, and 4.3)
- Literature about exhibits created for a self-guided public tour (Subtasks 4.1, 4.2 and 4.3)
- Photo-documentation of four cisterns installed (Subtask 4.1)
- Photo-documentation of five rain gardens/equivalent BMPs, installed (Subtask 4.2)
- Documentation of at least seven signs designed, manufactured and installed, including photo documentation – one sign may be used to provide information about multiple BMPs at a single site (Subtask 4.1 and 4.2) – See Ex. **Figure 10**
- Photo-documentation of a stormwater BMP near Wimberley Central Business District (Subtask 4.3)
- Documentation of one sign designed, manufactured and installed, including photo documentation (Subtask 4.3)

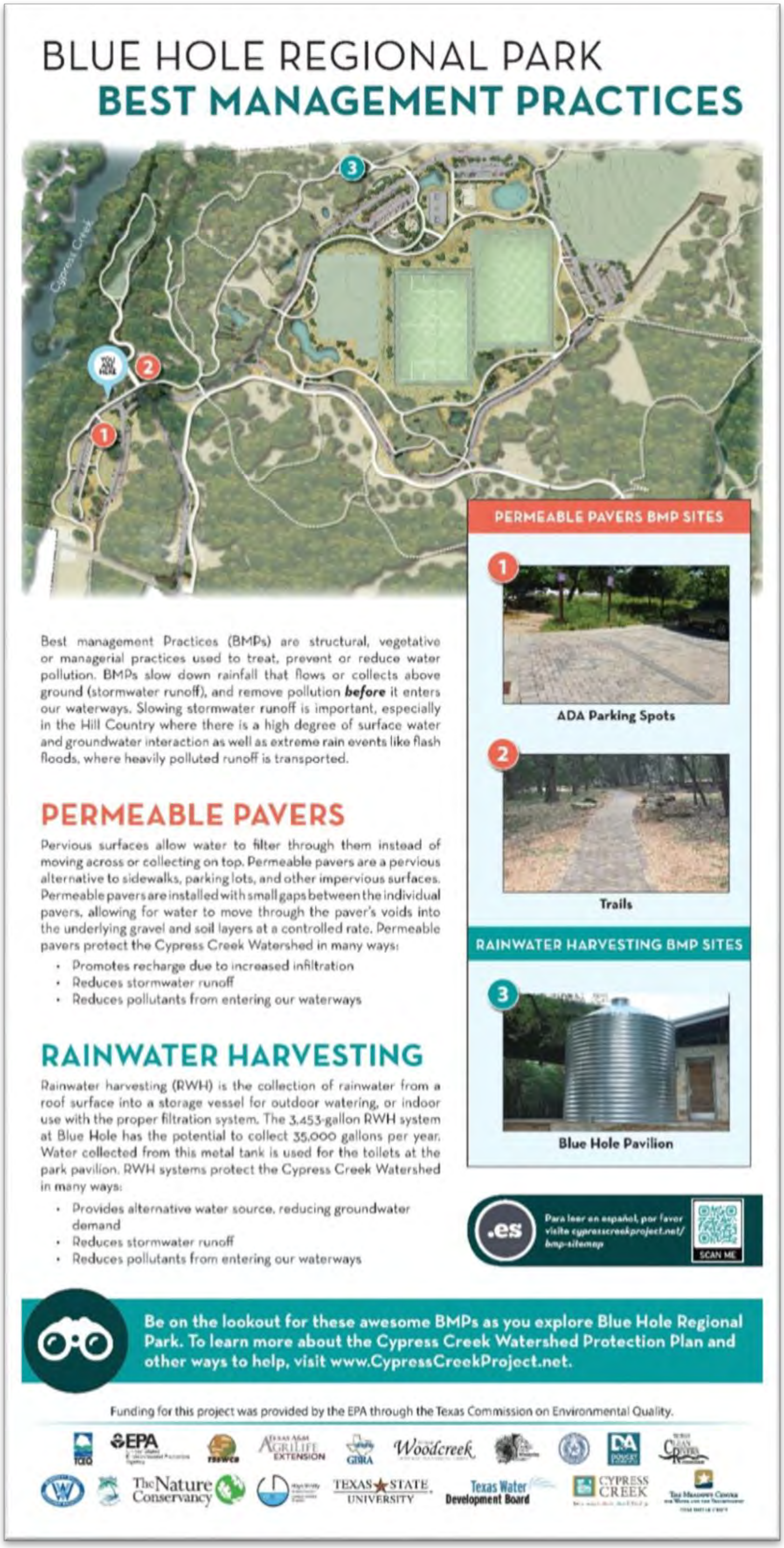

Figure 10. Blue Hole Regional Park Best Management Practices

Task 5: Education, Outreach and Community Support

OBJECTIVE: Enhance the implementation of the WPP through the engagement of the community in education and outreach activities, including meetings, events, workshops, print materials, website and signage.

Subtask 5.1: Watershed Coordination

MCWE has:

- Served as the primary conduit for interaction with landowners, citizens, and other entities;
- Facilitated the implementation of the CCWPP;
- Sought additional funding, coordinated complementary activities in the basin; and
- Tracked WPP implementation progress.

Subtask 5.2: Education and Outreach Website, Print Materials, and Signage

MCWE utilized existing outreach material and resources adapted to local circumstances and developed new content to execute the following:

- *Quarterly stakeholder meetings*
- *Regular updates of the project website including a clearing house of information, up-to-date calendar and significant value-added website components developed through this project and as a result of new partnerships (see Subtask 5.1)*
- *Electronic distribution of standardized biannual newsletters*
- *Distribution of "Inside Cypress Creek Watershed Environmentally Sensitive Area" road signs (see Ex.* ***Figure 11****)*
- *Development of a WPP Executive Summary (****Appendix V****)*
- *Development of an NPS Prevention Resource Guide (****Appendix VI****).*

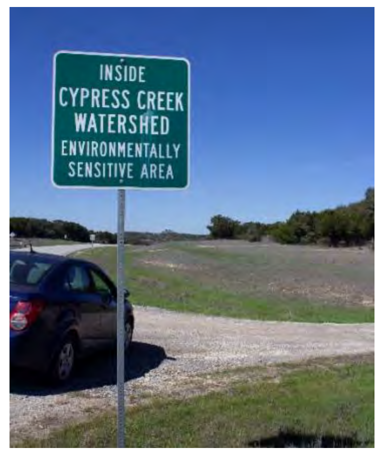

Figure 111. Inside Cypress Creek Watershed Road Sign

Appendix V and VI to this report provide more extensive analysis to work completed under Subtask 5.2.

Subtask 5.3: Refined WPP

Appendix VII to this report provides an addendum to the CCWPP.

Subtask 5.4: Events and Workshops

MCWE coordinated, advertised and documented 20 workshops and events over the course of this project with topics including:

- Water Quality Protection
- Riparian Design, Restoration and Management
- LID demonstration
- Rural Landowners

MCWE further participated with a booth and informational materials for community events, coordinated youth events, conducted watershed model demonstrations and a speaker series on water related topics to inform community members and decision makers about key issues in the watershed. **Table 3. Cypress Creek Watershed Protection Plan Workshop and Events** provides workshop and event details.

Subtask 5.5: Ordinance Review and Design Plan Review Process for Fast-tracking Development Proposals

MCWE and Doucet and Associates, Inc. facilitated a comprehensive review of the relevant city and county ordinances that affect Cypress Creek's water quality. The purpose of the review was to assess the region's effectiveness at mitigating NPS pollution via watershed protection ordinances and regulations, identify potential redundancies and potential improvements, and work closely with key decision makers and stakeholders to establish new approaches that can implement sustainable drainage design.

Multiple deliverables under Subtask 5.5 were incorporated into two separate documents included in the appendices of this report:

- **Appendix III: Cypress Creek WPP - Technical Resource Guide for Developers and Engineers, Green Infrastructure Plan Review Guide, and Fast Track Review Process**
- **Appendix VIII: Cypress Creek WPP - NPS Assessment and Water Quality Ordinance Report**

Subtask 5.6: DSS

MCWE and Doucet and Associates, Inc. completed a feasibility study regarding potential updates and improvements in function of the 2009 DSS developed based on input from a subcommittee of CCWPP Stakeholder Committee members. The DSS requires updates to incorporate current and proposed future land use patterns and available groundwater data and to increase functionality and usability.

Appendix IX to this report provides a summary of the CCWPP Decision Support System.

Deliverables under this task included:

- Quarterly stakeholder meetings held and documented through announcements, agendas, attendance, presentation materials, and minutes
- Website maintained at least monthly (documentation of website updates included in all QPRs)
- Water quality database and dashboard added to website
- Biannual newsletter published
- WPP Executive Summary in a community friendly format published
- NPS Prevention Resource Guide
- Photo documentation of three installed "Inside Cypress Creek Watershed Environmentally Sensitive Area" signs
- Update or addendum to the WPP prepared
- Materials from three hosted workshops (water quality protection, riparian areas, and LID) documented by announcements and presentation materials
- Three Annual Rural Landowner workshops convened and documented by announcements and presentation materials
- Attendance at two community events documented by agendas
- Three youth events documented by announcements and presentation materials
- Three watershed model demonstrations held and documented through announcements

- Speaker series on water related topics held and documented by agendas (at least five organized by project staff and partners)
- Report with review of relevant city, river authority, and county ordinances, assessment of potential water quality ordinance enhancements, potential reductions in NPS contributions from future development and recommendations compiled and published
- Fast Track Review Process Report detailing the design plan review process and the plan for "fast tracking" developer proposals. The report includes:
  - An explanation of the basis for the fast track review
  - The process utilized
  - Issues encountered and solutions
  - Recommended future activities
  - Technical assistance for cities and the county to fast-track development proposals with significant LID and green infrastructure components
- NPS Assessment Report that summarizes existing studies by the City of Woodcreek, Hays County and the City of Wimberley to provide recommendations on future potential water quality retrofit options and locations, partnering opportunities with other projects, and connecting flood management criteria with water quality incentives
- One Green Infrastructure Plan Review Guide for developers and engineers compiled and published to assist users in navigating regulatory review procedures, incorporating LID and green infrastructure into development plans, and facilitating permitting from local authorities. This document will complement existing and updated city/county design manuals
- Nine proposals reviewed via fast-track process (two small and one large for each city and county)[2]
- One stakeholder (cities, county) meeting to determine desired inputs, functionality and outputs for updated DSS documented by meeting notes and notices[3]
- Report published detailing DSS review, feasibility of and recommended changes in functionality, data to be incorporated, and other recommendations

Task 6: Final Report

OBJECTIVE: Produce a Final Report summarizing all activities completed and conclusions reached during the project. The Final Report will describe project activities and identify and discuss the extent to which project goals and purposes are achieved, and the amount of funds actually spent on the project. The Final Report will emphasize successes, failures, lessons learned, and include specific water quality data demonstrating water quality improvements where possible. The Final Report will summarize all the Task Reports in either the text or as appendices.

<u>Deliverables under this task included:</u>

- Draft Final Report
- Address TCEQ/EPA comments
- Final Report

[2] No official plan reviews were performed or requested by the City of Wimberley or the City of Woodcreek

[3] No official meeting held for this deliverable

Results and Observations

Task 1: Project Administration

OBJECTIVE: To effectively administer, coordinate, and monitor all work performed under this project including technical and financial supervision and preparation of status reports.

Observations

MCWE executed all project oversight and administration of deliverables including hiring of personnel, securing subcontractors and project billing and reporting.

Contract Amendment No. 1 was executed in July 2018 resulting in the following changes to the original contract:

1. Updated signature page
2. Expiration date changed to 2/28/2020
3. Scope of Work replaced in entirety
4. Schedule of Deliverables replaced in entirety
5. Cost Budget – Matching Funds updated

Contract Amendment No. 2 was executed in October 2018 resulting in the following changes to the amended contract:

1. Update Subtask 2.2: QAPP for Monitoring and Data Acquisition
2. Update Subtask 3.1: Monitoring to be conducted by the Performing Party
    a. Routine surface water quality monitoring for six sites (4 historic, 2 new)
    b. Groundwater quality monitoring in partnership with HTGCD

MCWE utilized communication with QPRs to update due dates and ensure deliverable tracking, completed three approved budget revision requests, conducted quarterly update calls, provided call notes and submitted an article for the 2019 Annual Report.

Results

- Quarterly Progress Reports (QPRs) - COMPLETE, on file with TCEQ
- Reimbursement Forms - COMPLETE, on file with TCEQ
- Contract communication meeting notes - COMPLETE, on file with TCEQ
- Contract closeout strategy – COMPLETE[4]
- Annual report article – COMPLETE[5]

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[4] no formal contract closeout strategy was completed, however, communication with project manager and budget revision ensured TCEQ approval of final project spending and deliverables

[5] 2019 Annual Report

Task 2: Quality Assurance and Data Acquisition

OBJECTIVE: Document and implement data quality objectives (DQOs) and quality assurance/control (QA/QC) activities that ensure data of known and acceptable quality are used in and generated by this project. Data collected for this project will be used for monitoring, modeling and mapping activities undertaken to improve community decision makers' abilities to identify sources of, as well as, prevent and mitigate NPS pollution from urbanization and development.

Observations

Cypress Creek Watershed Protection Plan Implementation Water Quality Monitoring and Data Acquisition QAPP was approved in November 2018 with amendments executed in May 2019 and August 2019. The primary effect of the QAPP amendments were to address difficulties with identifying and gaining access to two monitoring wells, revise calculation method for load reductions and updates for personnel changes. A nonconformance report and corrective action plan was issued in August 2019 due to the inability to sample a monitoring well due to lack of power at the well site.

Results

- QAPP Planning Meeting Notes - COMPLETE, on file with TCEQ
- Draft and Final Monitoring/Data Acquisition QAPP – COMPLETE, on file with TCEQ
- QAPP Annual Reviews and Revisions - COMPLETE, on file with TCEQ
- Draft and Final Monitoring/Data Acquisition QAPP Amendment - COMPLETE, on file with TCEQ

Task 3: Monitoring

OBJECTIVE: Conduct additional monitoring and coordinate with monitoring performed by its partners during this project.

Observations

Surface Water Quality Monitoring (See **Appendix I: Cypress Creek WPP - Surface and Groundwater Monitoring Results** for more extensive analysis)

<u>Data summary for 7 CRP Surface Water Sites</u>

- Water temperature values for all sites ranged from 12.0 to 28.8°C with all values falling below the TCEQ water quality criterion (30°C) (Fig. 2). The site with the least variability was Jacob's Well (12677) which is influenced predominantly by artesian spring water from the Trinity Aquifer.
- Conductivity values for all sites ranged from 512 to 652 µS/cm (Fig. 3). Most sites had conductivity values in exceedance of the water quality criterion (615 µS/cm), except the RR12 Wimberley site.
- DO values for all sites ranged from 1.0 to 10.9 mg/L (Fig. 4). Most values for all sites were above the grab minimum water quality criterion (4.0 mg/L). Two outliers, one each at RR12 Cottages (12676) and Blue Hole (12675), fell below the 4.0 mg/L criterion.
- The pH values for all sites ranged from 6.5 to 8.1 s.u. and were at or within the high and low water quality criteria (Fig. 5).

- *E. coli* values ranged from 1 to 2400 MPN/100 mL (Fig. 6). The RR12 Wimberley and Blanco Confluence sites exceeded the water quality geometric mean criterion (126 CFU/100mL) for most events.
- TSS for all sites ranged from 0.5 to 144 mg/L (Fig. 7). All sites had values below the Cypress Creek WPP water quality target (5.0 mg/L) except for RR12 Wimberley. This site had two outliers above the water quality target established in the Cypress Creek WPP.
- The range of nitrate-nitrogen values for all sites was from 0.05 to 0.67 (Fig. 8), well below the Cypress Creek WPP water quality target (1.65 mg/L).
- The 24-hour DO monitoring results exceeded both the average and minimum criteria at Blue Hole in September 2019 (Table 4). The remaining events at both sites met all criteria.

Groundwater Quality Monitoring (See **Appendix I: Cypress Creek WPP - Surface and Groundwater Monitoring Results** for more extensive analysis)

<u>Data summary for 2 monitoring wells</u>

- Non-detects resulted for all samples at both sites for ammonia-nitrogen, total phosphorus, *E. coli*, and TSS.
- Nitrate-nitrogen results varied, with about half non-detects and half reportable values.
- All non-detects for nitrate-nitrogen were from Old Hundred and all reportable values from HCP3 which ranged from .98 mg/L to 1.10 mg/L.

Acquired Data (See **Appendix I: Cypress Creek WPP - Surface and Groundwater Monitoring Results** for more extensive analysis)

Primary sources of acquired data under separate QAPPs include:

- GBRA (CRP monitoring at 12674 – Cypress Creek at FM12 at Wimberley)
- Texas Stream Team (citizen science data collection)
- United States Geological Survey (stream discharge data)
- HTGCD (well data)

<u>Results</u>

- Documentation of monitoring activities, in QPRs – COMPLETE, on file with TCEQ
- Data Submittals to SWQMIS - COMPLETE, on file with TCEQ
- Annual acquired and collected water quality data summary report, including analyses – COMPLETE, see **Appendix I**

Task 4: Installation of BMPs at Highly Visible Sites

OBJECTIVE: To install functioning NPS pollutant control technologies which will educate stakeholders concerning the pollution reduction and water conservation benefits of simple, relatively inexpensive management measures.

Observations

Table 2. Green Stormwater Infrastructure BMP Summary Table

Location and BMP Type	Approx. Treatment p[-Area	Cost ($)	Runoff Storage Volume	Avg. Annual TSS Removal (lbs)	Cost per Lb. TSS Managed ($)	Avg. Annual Water Supply (gallons)
Rainwater Harvesting						**Water usage**
Hays County Precinct 3 Office	4,200 SF roof	9,157	1,000 gal	58	158	18,000
City of Wimberley Blue Hole Regional Park	2,200 SF roof	14,992	3,453 gal	51	294	35,000
Wimberley Valley Watershed Association Offices	3,400 SF roof	14,800	29,173 gal	78	190	55,000
City of Woodcreek Golf Course Maintenance Shed	2,700 SF roof	14,990	5,000 gal	62	242	45,000
Permeable Pavement						**Infiltration**
City of Wimberley Blue Hole Park Bathhouse	250 SF surface	3,312	38 cu ft	6	552	5,000
City of Wimberley Blue Hole Park Trail	1,500 SF surface	19,875	225 cu ft	37	537	30,000
City of Wimberley Blue Hole Park ADA Parking	840 SF surface	13,020	126 cu ft	20	651	17,000
Rain Gardens and Vegetated Filter Strip						**Infiltration**
City of Woodcreek Golf Course Clubhouse Rain Garden	0.40 acres	14,100	540 cu ft	108	130	160,000
Wimberley Valley Watershed Association Offices Vegetated Filter Infiltration Strip	1.8 acres	20,000	12,500 cu ft	450	45	280,000
Wimberley Central Business District Stormwater BMP						**Infiltration**
Square Permeable Pavement	2,400 SF	24,500	560 cu ft	117	210	70,000

Results

- Advertised and approved bid for supplying equipment and installing rainwater harvesting systems and demonstration BMPs (Subtasks 4.1, 4.2, and 4.3) - COMPLETE, on file with TCEQ
- Contract/subcontracts for design and construction including site plans for rain gardens and other demonstration BMPs (Subtasks 4.1, 4.2, and 4.3) - COMPLETE, on file with TCEQ
- Final Design Reports for all BMPs (Subtasks 4.1, 4.2, and 4.3) – COMPLETE, see **Appendix II**
- Estimated site/area pollutant loadings and BMP load reductions report (Subtasks 4.1, 4.2, and 4.3) – COMPLETE, see **Appendix II**
- Technical resource guides created for developers and engineers (Subtasks 4.1, 4.2, and 4.3) – COMPLETE, see **Appendix III**
- Technical resource guides for the general public (Subtasks 4.1, 4.2, and 4.3) – COMPLETE, see **Appendix IV**
- Literature about exhibits created for a self-guided public tour (Subtasks 4.1, 4.2 and 4.3) – COMPLETE, see "The Cypress Creek Watershed Best Management Practices Tour" http://www.cypresscreekproject.net/different-bmps-1
- Photo-documentation of four cisterns installed (Subtask 4.1) – COMPLETE, see **Appendix II**
- Photo-documentation of five rain gardens/equivalent BMPs, installed (Subtask 4.2) - COMPLETE, see **Appendix II**
- Documentation of at least seven signs designed, manufactured and installed, including photo documentation – one sign may be used to provide information about multiple BMPs at a single site (Subtask 4.1 and 4.2) – COMPLETE, see Ex. **Figure 10**
- Photo-documentation of a stormwater BMP near Wimberley Central Business District (Subtask 4.3) - COMPLETE, see **Appendix II**
- Documentation of one sign designed, manufactured and installed, including photo documentation (Subtask 4.3) - COMPLETE, see Ex. **Figure 10**

Task 5: Education, Outreach and Community Support

OBJECTIVE: Enhance the implementation of the WPP through the engagement of the community in education and outreach activities, including meetings, events, workshops, print materials, website and signage.

Observations

Subtask 5.1: Watershed Coordination

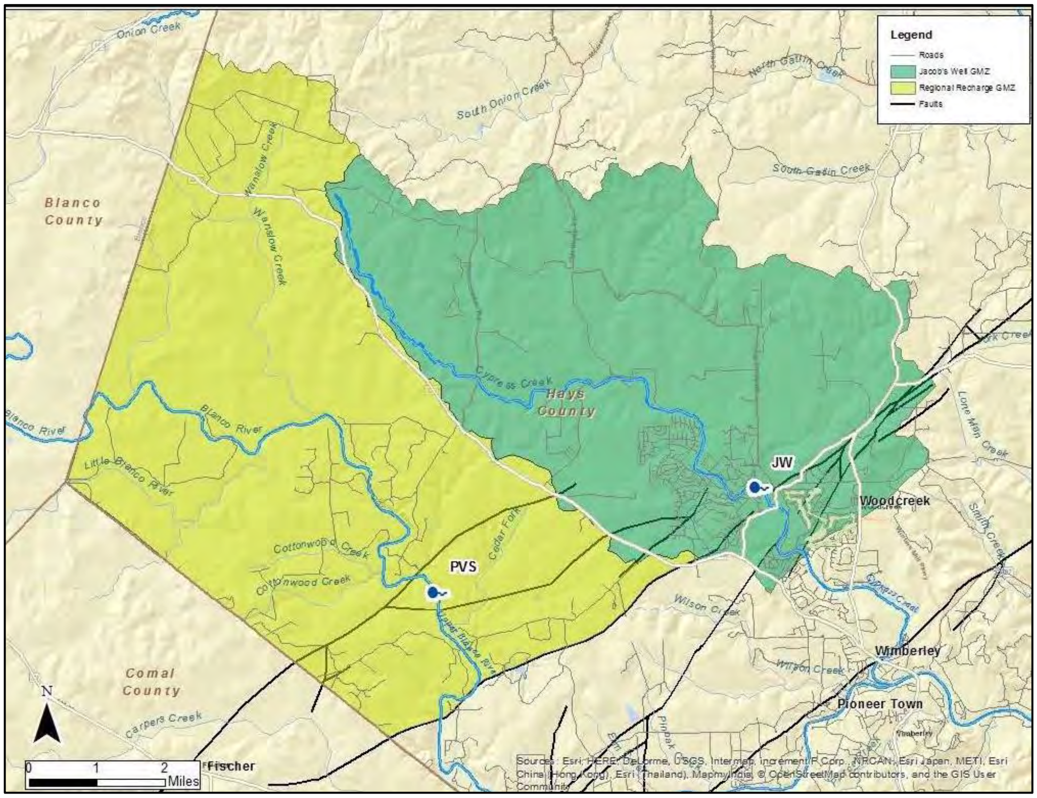
MCWE has worked to develop trusted relationships with a broad network of CCWPP stakeholders. This has enabled both the completion of project deliverables and the development of new partnerships and funding to bring additional projects and set the table for long-term sustainability of the CCWPP. MCWE has:

- Served as the primary conduit for interaction with landowners, citizens, and other entities;
- Facilitated the implementation of the CCWPP;
- Sought additional funding, coordinated complementary activities in the basin; and
- Tracked WPP implementation progress.

In addition to project funded deliverables, effective CCWPP Coordination by MCWE has led to:

- BST study of Cypress Creek in partnership with the City of Wimberley and Texas A&M University
- BMP maintenance agreements with project partners
- Commitments from project partners to cover water quality monitoring costs (laboratory analysis) with local/organizational funds. Financial partners include: City of Wimberley, City of Woodcreek, WVWA, HTGCD
- An MOU among WISD, WVWA, and MCWE to design and construct the first 'One Water' School in Texas backed by an additional $250,000 pledge from the Willett Foundation to WVWA
- A partnership with WVWA and FishViews to develop a 360-degree virtual tour of Cypress Creek from Jacob's Well Spring to the Cypress Creek confluence with the Blanco River. The virtual tour uses an ArcGIS platform with links to water quality monitoring locations along the creek and can be accessed from the CCWPP website or by a direct link: https://arcgis.earthviews.com/public/cypress-creek#351
- The development of a committee to generate input from a broad base of Wimberley Valley stakeholders and technical experts to establish the JWGMZ (HTGCD Rule 15 - pending) and a larger Regional Recharge Study Zone (HTGCD Rule 16 – Approved 11/8/2019). See **Figure 12**. Links to these rules, the stakeholder committee report and technical presentations may be accessed through the HTGCD website: http://haysgroundwater.com/
  - The JWGMZ (Rule 15) would restrict new permits in the designated zone, disallowing any new Tier 2 or Tier 3 wells in the Middle Trinity Aquifer and develops a framework for mandatory pumping curtailments on HTGCD permit holders in the JWGMZ based on springflow as measured by a 10-day running average of the USGS flow meter at Jacob's Well Spring.
  - The Regional Recharge Study Zone (Rule 16) – Study will monitor recharge, discharge, spring flow, water quality and aquifer levels for a 5-year study (Jan. 1, 2020 to Dec. 31, 2025) and invokes a moratorium on new operating permits exceeding 10 acre feet annually during the study period.

Figure 122. Map of Proposed Jacob's Well Groundwater Management Zone and Regional Recharge Study Zone



Left (yellow) – Regional Recharge Study Zone featuring Pleasant Valley Spring and the Blanco River – Rule 16 approved 11/8/2019.

Right (green) – Jacob's Well Groundwater Management Zone featuring Jacob's Well Spring, Cypress Creek and Tom Creek Fault Zone (eastern boundary) – Rule 15 still pending

Subtask 5.2: Education and Outreach Website, Print Materials, and Signage

Significant care has been taken to develop an extensive outreach and education platform for the CCWPP. Quarterly stakeholder meetings have been complemented by regular updates of the project website including a clearing house of information, up-to-date calendar and significant value-added website components developed through this project and as a result of new partnerships (see Subtask 5.1). Biannual newsletters updating stakeholders on CCWPP progress and local events have highlighted milestones and impactful projects led by MCWE and our partners. Hays County staff worked with MCWE to install five new "Inside Cypress Creek Watershed Environmentally Sensitive Area" road signs and redeploy three existing signs throughout the watershed (see Ex. **Figure 11**). MCWE also developed a WPP Executive Summary (**Appendix V**) and an NPS Prevention Resource Guide (**Appendix VI**).

Subtask 5.3: Refined WPP

MCWE has developed an Addendum to the CCWPP that demonstrates the value of One Water as the critical management approach to long-term economic health and ecological sustainability of the Cypress Creek watershed. The CCWPP Addendum highlights WISD's new Blue Hole Primary School as a case study in innovation, collaboration and conservation (**Appendix VII**).

Subtask 5.4: Events and Workshops

728 stakeholders attended 20 workshops and events held in completion of project deliverables as described in **Table 3. Cypress Creek Watershed Protection Plan Workshops and Events**.

Table 3. Cypress Creek Watershed Protection Plan Workshops and Events

Date	Event	No. Attendees
11/15/2016	Blue Hole Field Trip Day	100
6/1/2017	Riparian & Stream Ecosystem Workshop	85
7/13/2017	The Blanco River/ Onion Creek Water Forum	100
7/27/2017	"Well Educated" Workshop by Texas Well Owner Network	48
10/21/2017	Rainwater Harvesting Demonstration	10
3/3/2018	Soil for Water Workshop	45
3/16/2018	Aquatic WILD Workshop	21
6/23/2018	Cypress Creek Quarterly Series	40
8/15/2018	Hays County Feral Hog Workshop	16
9/1/2018	Wimberley Lions Club Chapter Meeting	60
10/19/2018	Core Citizen Scientist Water Quality Monitoring Youth Training Event	10
11/18/2018	"Unsticking Conversations" a Wimberley Community Event	10
12/19/2018	Hays Trinity Groundwater Conservation District Meeting	10
2/7/2019	Healthy Lawn & Healthy Waters Program	40
4/23/2019	Wimberley - 8th Annual Earth Day Celebration	45
8/27/2019	Latest and Greatest Feral Hog Updates Webinar	19
8/28/2019	Aerial Control of Feral Hogs Webinar	14
8/30/2019	Ortiz Game Management Webinar	15
9/4/2019	Cypress Creek Project: Riparian Design Workshop	30
10/9/2019	Free Family Fun Day: We Love Water!	10

Subtask 5.5: Ordinance Review and Design Plan Review Process for Fast-tracking Development Proposals

An effort led by MCWE and Doucet and Associates, Inc., resulted in revised water quality ordinances for the cities of Wimberley and Woodcreek to enhance water quality protection and promote aquatic health. The ordinance updates created a set of rules and criteria that are consistent with the TCEQ Optional Enhanced Measures that were determined by the United States Fish and Wildlife Service to be protective of threatened and endangered species.

Appendix VIII: Cypress Creek WPP - NPS Assessment and Water Quality Ordinance Report

It was anticipated that MCWE and Doucet and Associates, Inc. would have the opportunity to evaluate nine proposals via the fast-track process in cooperation with partners, Hays County, Wimberley and Woodcreek. While development guidance was provided to the City of Wimberley for two potential projects in the very early stages of planning, no official plan reviews were performed or requested by Hays County or the cities of Wimberley or Woodcreek over the course of this project.

Appendix III: Cypress Creek WPP - Technical Resource Guide for Developers and Engineers, Green Infrastructure Plan Review Guide and Fast Track Review Process

Subtask 5.6: DSS

As this CCWPP implementation progressed, it became apparent to local government staff and officials that they did not have the resources, (software, hardware, staff availability) to implement and operate a DSS for the Cypress Creek watershed. While it may be of interest to track in a geographic information system (GIS) the location of a new development, a new project would be subject to the local water quality and drainage regulations, thus, mitigating potential adverse water quality impacts.

Appendix IX: Cypress Creek WPP – DSS Evaluation Report

Results

- Quarterly stakeholder meetings held and documented through announcements, agendas, attendance, presentation materials, and minutes – COMPLETE, see http://www.cypresscreekproject.net/project-documents
- Website maintained at least monthly (documentation of website updates included in all QPRs) – COMPLETE, on file with TCEQ
- Water quality database and dashboard added to website – COMPLETE, see http://www.cypresscreekproject.net/main-water-quality#jacobswell
- Biannual newsletter published – COMPLETE, see http://www.cypresscreekproject.net/project-documents
- WPP Executive Summary in a community friendly format published – COMPLETE, see **Appendix V**
- NPS Prevention Resource Guide – COMPLETE, see **Appendix VI**
- Photo documentation of three installed "Inside Cypress Creek Watershed Environmentally Sensitive Area" signs – COMPLETE, see Ex. **Figure 11**
- Update or addendum to the WPP prepared – COMPLETE, see **Appendix VII**
- Materials from three hosted workshops (water quality protection, riparian areas, and LID) documented by announcements and presentation materials – COMPLETE, see **Table 3**
- Three Annual Rural Landowner workshops convened and documented by announcements and presentation materials – COMPLETE, see **Table 3**
- Attendance at two community events documented by agendas – COMPLETE, see **Table 3**
- Three youth events documented by announcements and presentation materials – COMPLETE, see **Table 3**
- Three watershed model demonstrations held and documented through announcements – COMPLETE, see **Table 3**
- Speaker series on water related topics held and documented by agendas (at least five organized by project staff and partners) – COMPLETE, see **Table 3**
- Report with review of relevant city, river authority, and county ordinances, assessment of potential water quality ordinance enhancements, potential reductions in NPS contributions from future development and recommendations compiled and published – COMPLETE, see **Appendix VIII**
- Fast Track Review Process Report detailing the design plan review process and the plan for "fast tracking" developer proposals – COMPLETE, included in **Appendix III**

- An explanation of the basis for the fast track review
- The process utilized
- Issues encountered and solutions
- Recommended future activities
- Technical assistance for cities and the county to fast-track development proposals with significant LID and green infrastructure components

- NPS Assessment Report that summarizes existing studies by the City of Woodcreek, Hays County and the City of Wimberley to provide recommendations on future potential water quality retrofit options and locations, partnering opportunities with other projects, and connecting flood management criteria with water quality incentives – COMPLETE, see **Appendix VIII**
- One Green Infrastructure Plan Review Guide for developers and engineers compiled and published to assist users in navigating regulatory review procedures, incorporating LID and green infrastructure into development plans, and facilitating permitting from local authorities. This document will complement existing and updated city/county design manuals – COMPLETE, included in **Appendix III**
- Nine proposals reviewed via fast-track process (two small and one large for each city and county) - INCOMPLETE[6]
- One stakeholder (cities, county) meeting to determine desired inputs, functionality and outputs for updated DSS documented by meeting notes and notices – INCOMPLETE[7], see **Appendix IX**
- Report published detailing DSS review, feasibility of and recommended changes in functionality, data to be incorporated, and other recommendations – COMPLETE, see **Appendix IX**

Task 6: Final Report

OBJECTIVE: Produce a Final Report summarizing all activities completed and conclusions reached during the project. The Final Report will describe project activities and identify and discuss the extent to which project goals and purposes are achieved, and the amount of funds actually spent on the project. The Final Report will emphasize successes, failures, lessons learned, and include specific water quality data demonstrating water quality improvements where possible. The Final Report will summarize all the Task Reports in either the text or as appendices.

<u>Deliverables under this task included:</u>

- Draft Final Report – COMPLETE, on file with TCEQ
- Address TCEQ/EPA comments – COMPLETE
- Final Report - COMPLETE

[6] Two informal review for the City of Wimberley. No official plan reviews were performed or requested by Hays County, the City of Wimberley or the City of Woodcreek. Funds reallocated to water quality ordinance development.

[7] No official meeting held for this deliverable

Discussion

Task 1: Project Administration

MCWE managed project administration including contract management, personnel, contractors, project updates and financial reporting. Two contract amendments were executed over the course of this project to adjust for on-the-ground modifications to the project's scope of work and a reallocation of funds to complete project deliverables.

This project was awarded a substantial sum of federal funds which also required significant non-federal matching funds to be acquired and documented. Toward this purpose a "Partner Match" spreadsheet was created to keep track of both "in-kind" support and financial contributions from project partners. Quarterly communication with partners on project progress and requests for partner match worked effectively to ensure sufficient matching funds were available each quarter.

Total federal funds for this project = $804,843

Total matching funds for this project = $536,562

Project total = $1,341,405

Matching funds received from the following partners:

- ✓ BARTON SPRINGS/EDWARDS AQUIFER CONSERVATION DISTRICT
- ✓ FRIENDS OF BLUE HOLE
- ✓ GUADALUPE-BLANCO RIVER AUTHORITY – USGS GAUGE/STAFF TIME
- ✓ HAYS COUNTY – STAFF TIME/BMPS
- ✓ WIMBERLEY COMMUNITY CENTER – MEETING SPACE
- ✓ CCWPP STAKEHOLDER COMMITTEE PARTICIPATION
- ✓ THE NATURE CONSERVANCY
- ✓ TREEFOLKS
- ✓ TEXAS STATE UNIVERSITY – EQUIPMENT, SUPPLIES, STAFF TIME, WAIVED IDC
- ✓ WIMBERLEY LIONS CLUB - WATER SPEAKER SERIES
- ✓ CITY OF WIMBERLEY - STAFF TIME, WATER QUALITY MONITORING
- ✓ HAYS TRINITY GROUNDWATER CONSERVATION DISTRICT – STAFF TIME
- ✓ CITY OF WOODCREEK – STAFF TIME
- ✓ WIMBERLEY VALLEY WATERSHED ASSOCIATION - OFFICE SPACE, STAFF TIME, SUPPLIES
- ✓ TEXAS MASTER NATURALISTS - HAYS CHAPTER

- ✓ ROBERT CURRIE - VIDEO SERVICES
- ✓ CITIZENS ALLIANCE FOR RESPONSIBLE DEVELOPMENT (CARD)
- ✓ WIMBERLEY OUTDOOR EDUCATORS
- ✓ RESTORATION RANGERS
- ✓ WIMBERLEY BIRDING SOCIETY
- ✓ HILL COUNTRY ALLIANCE (HCA) – STAFF TIME

Ultimately, when working closely with local governments and regulatory entities like groundwater districts, river authorities, etc., political changes can result in unforeseen circumstances. This places a premium on effective trust-building, coordination, communication, partner retention and accountability. As the political winds blew and changed throughout the Wimberley Valley from time of initial project proposal to project completion, the successful completion of CCWPP implementation project deliverables under this contract along with the extensive list of contributing partners is a testament to effective project coordination and administration. All project funds were expended and deliverables achieved with very little modification over the final two years of this project.

Total Project Administrative Cost[8] = $367,476

Task 2: Quality Assurance and Data Acquisition

Cypress Creek Watershed Protection Plan Implementation Water Quality Monitoring and Data Acquisition QAPP was approved in November 2018 with amendments executed in May 2019 and August 2019. The primary effect of the QAPP amendments were to address difficulties with identifying and gaining access to two monitoring wells, revise calculation method for load reductions and updates for personnel changes.

Expanded surface water quality monitoring and acquired data were managed consistently with all monitoring, data acquisition and quality assurance goals achieved.

It was envisioned with the initiation of the first Project Amendment and associated QAPP amendment, that groundwater monitoring could be conducted in conjunction with surface water quality monitoring during six quarters. The broad nature of this project along with staff turnover, delays in receiving the first QAPP amendment and then a change in monitoring well location resulted in a modification of Task 3 goals associated groundwater quality monitoring as the QAPP covering the final monitoring wells was only in effect for three quarters. It was also discovered that no power to pump water existed at one of the wells during the first covered sampling event. A nonconformance report and corrective action plan was issued in August 2019 due to the inability to sample this well.

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[8] Includes federal funds associated with salary, fringe and supplies. Includes all federal and non-federal indirect costs (IDC).

Through great effort of MCWE staff to acquire a generator from Texas State University and subsequently coordinate with HTGCD staff the groundwater monitoring component of this project was finally achieved over the last two quarters with plans to continue into the next round of implementation.

Total Quality Assurance and Data Acquisition Cost[9] = $33,547

Task 3: Monitoring

Surface water quality in Cypress Creek has historically been "good." Early proponents of the Cypress Creek WPP foresaw the increasing urbanization in the watershed and chose to be proactive in the development of the WPP. Recent results of the TCEQ's Texas Integrated Reports, both the 2018 and Draft 2020, are beginning to identify concerns and impairments in Cypress Creek using data that covers a longer period of record than is reported here. Results of both the collected and acquired surface and groundwater data from this project reveal similar concerns.

The conductivity criterion (615 µS/cm) is designed for surface water streams, not groundwater from springs. Cypress Creek is predominantly a spring-fed creek. Although the conductivity surface water quality criterion was exceeded by most sites sampled for this project, the RR12 Wimberley site (12674) did not exceed the criterion. In addition, the regression analysis using flow as an independent variable only explained a minimal source of the variability at RR12 Wimberley. These preliminary results may suggest a local water source influencing this site relative to the remaining sites sampled for this project.

Almost half of all impaired waters on the Texas Integrated Report (IR) 303(d) List are from exceedances of the *E. coli* bacteria geometric mean criterion (126 CFU/100 mL). Exceedance of the bacteria criterion results in numerous impairments of the contact recreation use state-wide. Two sites, RR12 Wimberley (12674) and Blanco Confluence (12675), within the Cypress Creek watershed exhibited exceedances of the contact recreation bacteria criterion for this project. Cypress Creek is not currently listed for an impairment of the contact recreation use, however given the proximity of the urbanization to the sites exceeding the bacteria criterion, coupled with the use of on-site septic facilities (OSSFs) and the inference of local source water to this area of the stream stated previously, it is prudent to continue water quality monitoring and analysis, and implementation of management measures to address bacteria water quality.

Cypress Creek is on the Draft 2020 IR 303(d) List for depressed dissolved oxygen. Findings presented in this report for DO grab sampling resulted in only two outliers exceeding the DO criterion. However, the 24-hour DO monitoring conducted at Blue Hole (12675) on September 4-5, 2019, resulted in exceedances of both the average and absolute minimum DO criteria. Many variables affect dissolved oxygen measurements. Rainfall, flow, temperature, time of year/day, and decomposition of organic matter are some of the variables that impact DO measurements. Additional data is needed to determine the best management strategies to address the DO impairment.

[9] Includes federal cost related to salary, fringe and supplies.

With the exception of reduced groundwater monitoring events noted previously in Task 2 discussion, all monitoring tasks were executed effectively. Further, following the council and/or board actions of CCWPP partners the City of Wimberley, the City of Woodcreek, WVWA and HTGCD, all laboratory analysis costs associated with surface and groundwater monitoring in the Cypress Creek watershed have been covered by non-federal funds since 2018. This is a tremendous step toward local ownership and sustainability of CCWPP implementation.

Total Monitoring Costs[10] = $130,546

Task 4: Installation of BMPs at Highly Visible Sites

While federal funds covered the design and installation cost of GSI BMPs, gaining operation and maintenance commitments from project partners along with the necessary partner staff time to collaborate on the design, placement and construction schedule took considerable effort on the part of MCWE and Doucet and Associates, Inc.

Ultimately, all operation and maintenance agreements were achieved and all goals and deliverables associated with Task 4 were completed. The water conserving, ecological, and aesthetic benefits of the BMPs have been further complemented by technical and non-technical guides, resources and even a self-guided tour. **Table 2** provides additional information on the installed BMPs, including the cost per pound of sediment treated annually.

The January 2020, Cypress Creek stakeholder meeting was held in the field enabling partners to see, first-hand, how the BMPs are working to both reduce pollutant loading in the Cypress Creek watershed and educate the Wimberley Valley community as well as its many visitors on the value of GSI and smart growth in the Texas Hill Country.

Total Installation of BMPs at Highly Visible Sites Costs[11] = $292,746

Task 5: Education, Outreach and Community Support

By far Education, Outreach and Community Support represents the largest investment of time and resources associated with this project. Task 5 was extensive from workshops and events, public meetings, smaller, more focused meetings with community opinion leaders, presentations, electronic communications, website updates, unforeseen opportunities, and the list goes on.

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[10] Includes federal cost related to salary, fringe, travel and supplies. Non-federal monitoring costs include GBRA operation of the USGS gauge at Jacob's Well Spring and laboratory costs covered by project partners.

[11] Includes federal cost related to salary, fringe, travel, supplies, contractual and other. Non-federal costs include a cash contribution from Hays County and in-kind support from project partners.

Stakeholder contact time, innovative engagement, planning tools and guides including policy improvements like the formal adoption of revised water quality ordinances by cities of Wimberley and Woodcreek far exceeded Task 5 goals and expectations. **Appendices III, V, VI, VII, VIII** and **IX** along with a clearing house of information and a virtual tour of the watershed now on the project website further demonstrate the creative resources and effectiveness of CCWPP Education, Outreach and Community Support generated through this project.

From **Appendix VIII: Cypress Creek WPP - NPS Assessment and Water Quality Ordinance Report**

These updated ordinances can be considered to significantly protect water quality during and after the development process, essentially achieving a non-degradation standard. From that perspective, the lower one-third of the watershed in a full-build out 2040 condition will essentially experience the same pollutant loads as the existing condition. Thus, the water quality ordinance revisions are the single most important measure enacted by this project to provide long-term protection of water quality and aquatic habitat. The ordinance revisions, applied to a large land area, manage pollutant loads for generations and place the maintenance burden on the development community and not local and state government operations.

Additionally, Hays County is considering the adoption of a Drainage Criteria Manual in 2020. If adopted as currently drafted, version 7, stream buffers will be implemented in creeks with drainage areas greater than 64 acres to provide floodplain risk reduction and water quality benefits. This will extend water quality protection beyond the cities of Wimberley and Woodcreek.

The results of outreach and education are often difficult to quantify, particularly in the short-term; however, they should be viewed as the essential component for developing conditions that will enable local watershed stakeholders to achieve successful implementation of the CCWPP. A prime example of enabling conditions was on full display as Cypress Creek stakeholders built a coalition of support for the One Water approach to WISD's new primary school, set to be the first ever 'One Water' school in the State of Texas when it opens its doors in August 2020.

It should be noted that Task 5 included two shortcomings in terms of project deliverables.

First, it was anticipated that MCWE and Doucet and Associates, Inc. would have the opportunity to evaluate nine proposals via the fast-track process in cooperation with partners, Hays County, Wimberley and Woodcreek. MCWE and Doucet and Associates, Inc. did provide development guidance to the City of Wimberley for two potential projects that were in the very early stages of planning; however, no official plan reviews were performed or requested. This was in large part due to delays in watershed ordinance adoption.

Second, as CCWPP implementation began to move forward, it became apparent to local government staff and officials that they did not have the resources (software, hardware, staff availability) to implement and operate a DSS for the Cypress Creek watershed. While it may be of interest to track in a geographic information system the location of a new development, a project would be subject to the local water quality and drainage regulations, thus, mitigating potential adverse water quality impacts. The local governments already note development patterns in their land planning process, thus, a DSS, that would require a considerable expense and staff resources would have limited benefits in the role of water quality protection. Therefore, the local governments indicated that a DSS would not be useful to them at this time and a DSS was not established for the Cypress Creek watershed.

Funds originally allocated in the contractual category to manage the 9 fast-track reviews and DSS deliverables were shifted to ensuring perhaps the most important deliverable of this project, ordinance adoption. While success was ultimately achieved, ordinance adoption required considerable effort, more than anticipated, as MCWE and Doucet worked through the city's zoning and council processes. The City of Woodcreek was poised to adopt the revised ordinance in October 2019 but the Council election generated significant turnover. As such, the process with the City of Woodcreek required a re-start, including board and council workshops. Considerable effort in the response to commission and council input was also required as MCWE and Doucet worked closely with the city engineers, planning staff, and mangers to obtain council approval.

Total Education, Outreach and Community Support Costs[12] = $510,771

Task 6: Final Report

Total Final Report Costs[13] = $6,319

[12] Includes $303,314 in federal costs related to salary, fringe, travel, supplies, contractual and other. Includes $207,457 in non-federal costs reported as in-kind support from project partners.
[13] Includes $6,319 in federal costs related to salary and fringe.

Summary

Adverse effects on water quality resulting from on-going development within the Cypress Creek watershed have already been observed. This project selected a suite of structural and non-structural BMPs to mitigate current and future potential water quality impairments in the watershed.

Routine surface water and groundwater quality monitoring and data collection undertaken during the course of this project has been used track water quality and better understand current and trending nonpoint source contributions to Cypress Creek. Thanks to committed CCWPP partners, the cities of Wimberley and Woodcreek, WVWA, and HTGCD, local, non-federal funds have supported Cypress Creek monitoring efforts since 2018.

Site specific BMPs including rainwater harvesting, rain gardens, vegetated swales, and permeable pavers installed during this project are highlighting to developers and citizens the effectiveness of GSI. Educational signage, materials, and reports/documents have been coupled with the BMPs to enhance understanding and impact. The high visibility of the BMPs and signage, which have been installed on both public and privately held properties available to the public, will further serve to instill confidence in the community for the overall direction of the CCWPP.

Because Cypress Creek is an increasingly urban watershed, a review of existing ordinances served to assist the cities and county encompassed within the watershed to quantify the effectiveness of ordinances pertaining to water quality. Project partners and CCWPP stakeholders have worked extensively with city and county staff to interpret the findings of this comprehensive assessment and to incorporate additional recommendations resulting in revised water quality ordinances for the cities of Wimberley and Woodcreek. The updated ordinances have been designed to significantly protect water quality during and after the development process, essentially achieving a non-degradation standard. From that perspective, the lower one-third of the watershed in a full-build out 2040 condition will essentially experience the same pollutant loads as the existing condition.

A multifaceted approach to education and outreach has served to engage the community and key stakeholders in both the implementation of WPP activities and the expansion of pollution reduction strategies across the basin. Specific activities have included public service announcements, community workshops, a speaker series, newsletters, watershed tours, and other outreach efforts. Effective outreach and education have no doubt played a crucial role in both the adoption of revised water quality ordinances in the watershed as well as the WISD decision to build the first 'One Water' school in Texas, Blue Hole Primary School.

The continued implementation of the CCWPP will encourage stakeholders to holistically address all of the sources and causes of impairments and threats to both surface and groundwater resources within the watershed. A federal CWA 319(h) grant has been awarded to MCWE to continue watershed coordination efforts throughout years 4-6 of CCWPP implementation. The role of the coordinator will be to support and facilitate stakeholders and partners in implementing management measures, developing additional proposals to acquire funding, tracking projects, and encouraging adoption of BMPs.

Appendices

Appendix I: Cypress Creek WPP - Surface and Groundwater Monitoring Results

Cypress Creek Watershed Protection Plan (WPP) Implementation (Years 1-3)

Annual Water Quality Data Summary Report

February 14, 2020

Background

The Cypress Creek watershed is comprised of a unique set of rural and urban communities, ecosystems, and a long-standing reliance on groundwater as both a drinking supply and for recreational uses (Fig. 1). Cypress Creek flows through unincorporated portions of Hays County and the cities of Wimberley and Woodcreek and merges with the Blanco River near the Wimberley town center. Nearly five and a half miles upstream of the confluence, near the City of Woodcreek, is Jacob's Well, the headwaters of the perennial Cypress Creek. Jacob's Well is an artesian spring originating in the Trinity Aquifer that perennially feeds water to the lower third of the creek. Above Jacob's Well, flows in the Cypress Creek (Dry Cypress) are driven by rain events. Once the water is in the creek bed, part of it flows back underground into the aquifer. Flow between land surface and the subsurface creates a complex interaction between groundwater and surface water in Cypress Creek.

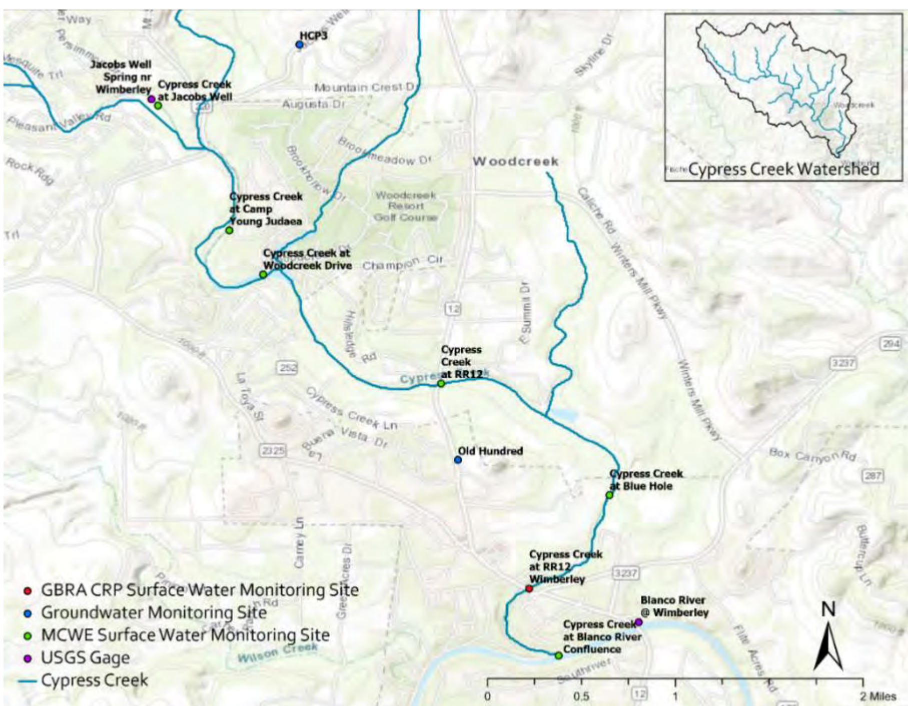


Figure 13. Cypress Creek watershed and monitoring sites.

Until recently, Cypress Creek exhibited relatively "good" water quality. Cypress Creek was assessed in the 2018 Texas Integrated Report (IR) and was listed as having a concern for depressed dissolved oxygen (DO). A total of 158 dissolved oxygen measurements were assessed with 32 exceedances of the 6.0 mg/L 24-hour minimum DO criterion. Cypress Creek was also assessed in the Draft 2020 Texas Integrated Report and is listed on the 303(d) List (Category 5) of impaired waters. The impairments in the Draft 2020 IR are for depressed DO and fish and macrobenthic communities in water in the lower seven miles of the segment. The listing category (5c) is described as "additional data or information will be collected and/or evaluated for one or more parameters before a management strategy is selected."

Cypress Creek is a TCEQ classified segment (Segment 1815) that extends from the confluence with the Blanco River in Hays County to a point 6.4 km (4.0 mi) upstream of the most upstream unnamed county road crossing in Hays County. The designated uses for Cypress Creek as described in the TCEQ's Texas Surface Water Quality Standards (March 6, 2014) include primary contact recreation, exceptional aquatic life use, public water supply and aquifer protection which applies to the contributing, recharge, and transition zones of the Edwards Aquifer. Numeric criteria to determine standards attainment of the designated uses are provided in Table 1.

This data summary report is being prepared to meet contract (#582-16-60282) deliverables under Task 3. This report will fulfill the annual acquired and collected water quality data summary report under Subtask 3.2 Data Submittals.

Table 4. Water quality criteria for Cypress Creek (Segment 1815).

Parameter	Criterion	Description
Chloride (Cl^{-1})	50 mg/L	Maximum annual average
Sulfate (SO_4^{-2})	50 mg/L	Maximum annual average
Total Dissolved Solids (TDS)	400 mg/L*	Maximum annual average
Dissolved Oxygen (DO)	6.0 mg/L	Minimum 24-hour means and grab screening levels
	4.0 mg/L	Minimum 24-hour values and grab minimums
pH Range	6.5-9.0 SU	Absolute minima and maxima
Indicator Bacteria (*E. coli*)	126 CFU/100mL	Geometric mean
	399 CFU/100mL	Single sample maximum
Temperature	30 °C	Maximum value

*TDS is calculated from specific conductance (TDS=SC*0.65); the SC criterion is 615 mg/L.

Collected Data

Surface Water Quality Monitoring

Routine surface water quality monitoring was conducted approximately quarterly at six Clean Rivers Program (CRP) sites by The Meadows Center for Water and the Environment (MCWE) (Fig. 1, Table 2). All water samples were collected under the TCEQ-approved Quality Assurance Project Plan (QAPP) titled *Cypress Creek Watershed Protection Plan Implementation Water Quality Monitoring and Data Acquisition QAPP* and adhered to the TCEQ Surface Water Quality Monitoring Program Procedures. Eight monitoring events were conducted between September 2016 and August 2018 for previous contracts, Phases 1 and 2, and five monitoring events were conducted between December 2018 and December 2019 to meet the contractual obligations of the current contract (Phase 3). A total of thirteen events were conducted in the Cypress Creek Watershed Protection Plan Implementation project for Phases 1-3 between September 2016 and December 2019. Field measurements collected *in situ* included water temperature, specific conductance, pH, dissolved oxygen, and stream flow. Water samples were collected and analyzed by the Guadalupe-Blanco River Authority Laboratory. Samples were analyzed for total suspended solids (TSS), total nitrate-nitrogen, ammonia-nitrogen, total phosphorous, and *E. coli* bacteria.

Twenty-four hour dissolved oxygen monitoring occurred at two sites (Table 1) within the Cypress Creek watershed. Four 24-hour monitoring events were conducted in April and September 2019 for Phase 3.

Table 5. Clean Rivers Program Monitoring Sites.

Site ID	Site Description	Number of Events (n) Sept. 2016 – Dec. 2019
12677	Cypress Creek @Jacob's Well	13
22109	Cypress Creek @ Camp Young Judea	5
22110	Cypress Creek @ Woodcreek Drive	5
12676	Cypress Creek @ RR12	13
12675*	Cypress Creek @ Blue Hole	13
12673*	Cypress Creek @ Blanco River confluence	13

**24-hour dissolved oxygen monitoring occurred at these sites*

Groundwater Quality Monitoring

Two groundwater wells were sampled between November 2019 and January 2020 for Phase 3 within the Cypress Creek watershed. The two groundwater wells included the HCP3 (#5764718), sampled three times, and Old Hundred (#5764721), sampled twice (Fig. 1). Field measurements were conducted in a bucket with sample water from the well and water samples were collected from the well for laboratory analyses. The same parameters were measured for field and laboratory samples as described above for routine surface water quality monitoring.

Acquired Data

Clean Rivers Program Water Quality Monitoring Data

The Guadalupe Blanco River Authority (GBRA) conducted CRP monitoring at one site (12674 – Cypress Creek at FM12 at Wimberley) in the Cypress Creek watershed (Fig. 1). Routine quarterly water quality monitoring data was downloaded from the TCEQ Surface Water Quality Web Reporting Tool website (https://www80.tceq.texas.gov/SwqmisPublic/index.htm). Data were downloaded for thirteen monitoring events from August 2016 to August 2019.

No macroinvertebrate monitoring data was available for site 12674 for the project period. The last time macroinvertebrate data was collected by GBRA for Cypress Creek was in 2013 (Lee Gudgell, personal communication).

Texas Stream Team Water Quality Monitoring Data

The Texas Stream Team Dataviewer was queried for all citizen scientist data collected in the Cypress Creek watershed. Texas Stream Team data was retrieved for six active sites within Cypress Creek (Table 3). A total of 152 events were conducted between February 2006 and December 2019 by trained citizen scientists. Most water quality parameters measured were standard core parameters and included air and water temperature, specific conductance, pH, dissolved oxygen and transparency. A limited number of advanced water quality parameters were measured including *E. coli* bacteria and nitrate-nitrogen. No riparian habitat or macroinvertebrate assessments have been conducted in the Cypress Creek watershed by Texas Stream Team citizen scientists.

Table 6. Texas Stream Team citizen scientist monitoring sites and events between February 2006 and September 2019.

Site ID	Site Description	Number of Events (n)	Period of Record
12677	Cypress Creek @ Jacob's Well	55	Feb 2006 to Sep 2019
13513	Cypress Creek @ CR220 downstream of Jacob's Well	3	Feb 2007 to May 2007
80502	Cypress Creek @ Woodcreek Drive	8	Mar 2010 to Oct 2019
80933	Cypress Creek @ First Dam	7	May 2013 to Jul 2014
80415	Cypress Creek @ Blue Hole	15	Feb 2007 to Nov 2019
80443	Cypress Creek @ Old Kyle Road	64	Sep 2007 to Dec 2019

United States Geological Survey (USGS) Stream Discharge Data

One USGS gauge is located within the Cypress Creek watershed at Jacob's Well (#08170990 – Jacob's Well Spring near Wimberley, Texas). Stream discharge data from Jacob's Well was acquired and submitted to the TCEQ's Surface Water Quality Monitoring Information System (SWQMIS) state-wide database along with the routine surface water quality data collected at Jacob's Well (12677). Continuous discharge data was also acquired from the USGS National Water Information System Web Interface (https://waterdata.usgs.gov/usa/nwis/uv?08170990) for September 2016 through February 2020.

Hays Trinity Groundwater Conservation District (HTGCD) Well Data

The HTGCD conducts bi-annual monitoring of water quality and water levels within the Trinity Aquifer to detect changes in aquifer conditions over time. Water quality samples are collected from the Old Hundred Dedicated Monitoring Well (#5764721) and submitted to the Lower Colorado River Authority Laboratory for analysis. The groundwater samples are analyzed for trace metals, anions, total dissolved solids, alkalinity, and dissolved nitrate/nitrite. Water levels are also measured at the Old Hundred well to determine the water level of the aquifer.

Results - Collected Data

Surface Water Quality Monitoring

The combined collected (Table 1 MCWE sites) and acquired (GBRA site 12674) surface water quality monitoring results are presented in the subsequent box plots. The box plots are organized from left to right in an upstream to downstream orientation and they represent a graphical summary of the distribution of the data at each site. The horizontal line within each box represents the median sample value, while the ends of the box represent the 75th and 25th quantiles, or the 3rd and 1st quartile, respectively. The whiskers that extend from each end of the box represent the outermost data point values not including outliers. Outliers are depicted as points outside the box. The red line represents the TCEQ water quality criterion or Cypress Creek WPP established target.

Water temperature values for all sites ranged from 12.0 to 28.8°C with all values falling below the TCEQ water quality criterion (30°C) (Fig. 2). The site with the least variability was Jacob's Well (12677) which is influenced predominantly by artesian spring water from the Trinity Aquifer.

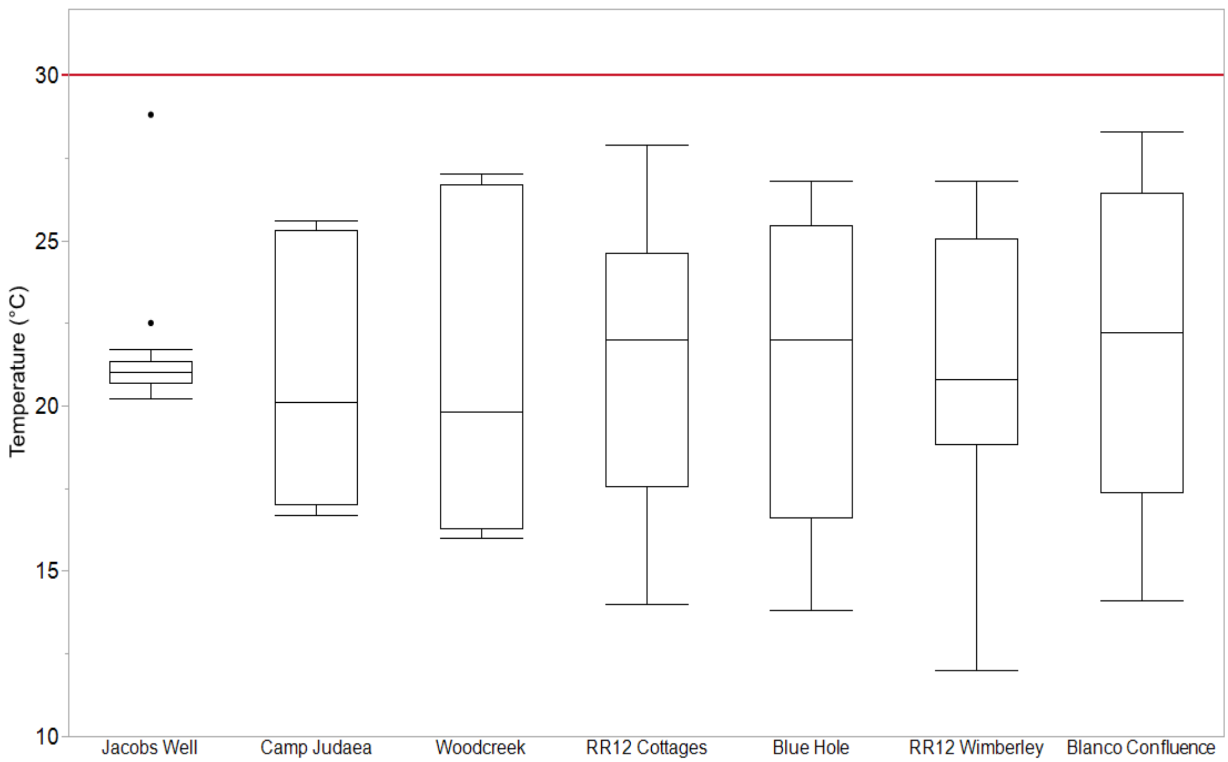


Figure 14. Water temperature for all CRP water quality monitoring sites in the Cypress Creek watershed from August 2016 to December 2019 (TCEQ criterion 30℃; n=64).

- Conductivity values for all sites ranged from 512 to 652 µS/cm (Fig. 3). Most sites had conductivity values in exceedance of the water quality criterion (615 µS/cm), except the RR12 Wimberley site.
- DO values for all sites ranged from 1.0 to 10.9 mg/L (Fig. 4). Most values for all sites were above the grab minimum water quality criterion (4.0 mg/L). Two outliers, one each at RR12 Cottages (12676) and Blue Hole (12675), fell below the 4.0 mg/L criterion.
- The pH values for all sites ranged from 6.5 to 8.1 s.u. and were at or within the high and low water quality criteria (Fig. 5).
- *E. coli* values ranged from 1 to 2400 MPN/100 mL (Fig. 6). The RR12 Wimberley and Blanco Confluence sites exceeded the water quality geometric mean criterion (126 CFU/100mL) for most events.
- TSS for all sites ranged from 0.5 to 144 mg/L (Fig. 7). All sites had values below the Cypress Creek WPP water quality target (5.0 mg/L) except for RR12 Wimberley. This site had two outliers above the water quality target established in the Cypress Creek WPP.
- The range of nitrate-nitrogen values for all sites was from 0.05 to 0.67 (Fig. 8), well below the Cypress Creek WPP water quality target (1.65 mg/L).

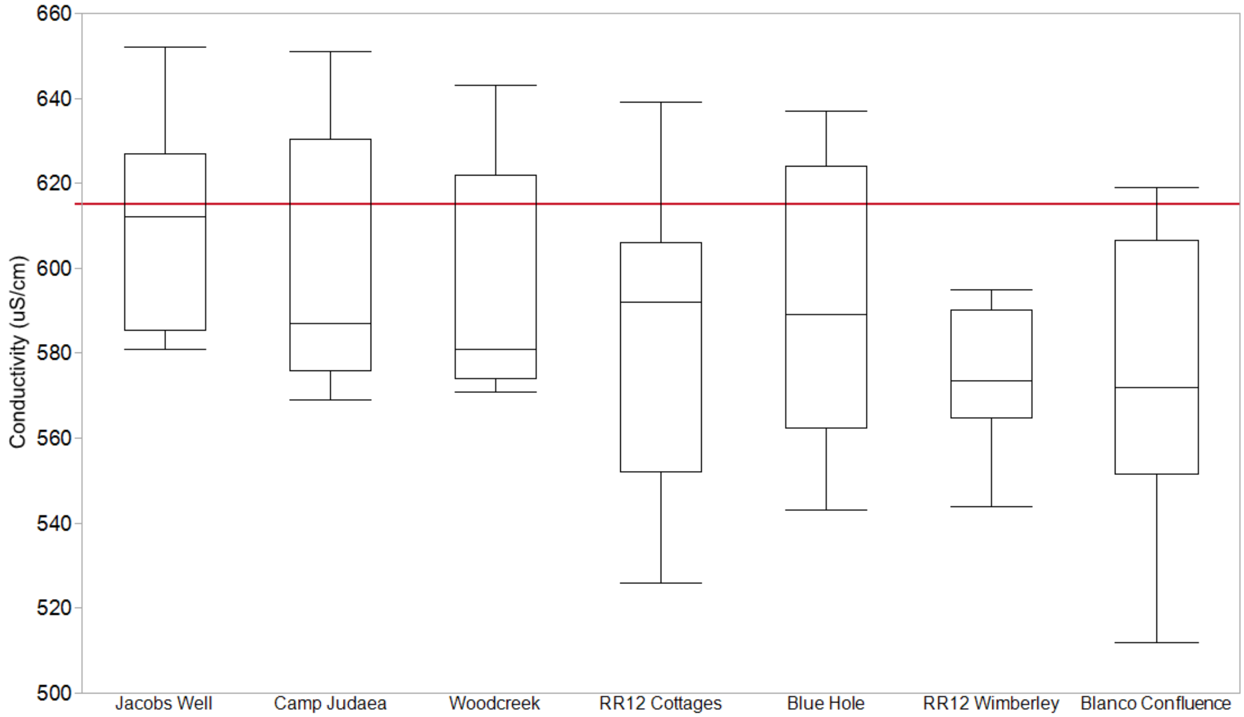


Figure 15. Conductivity for all CRP water quality monitoring sites in the Cypress Creek watershed from August 2016 to December 2019 (TCEQ criterion 615 µS/cm; n=64).

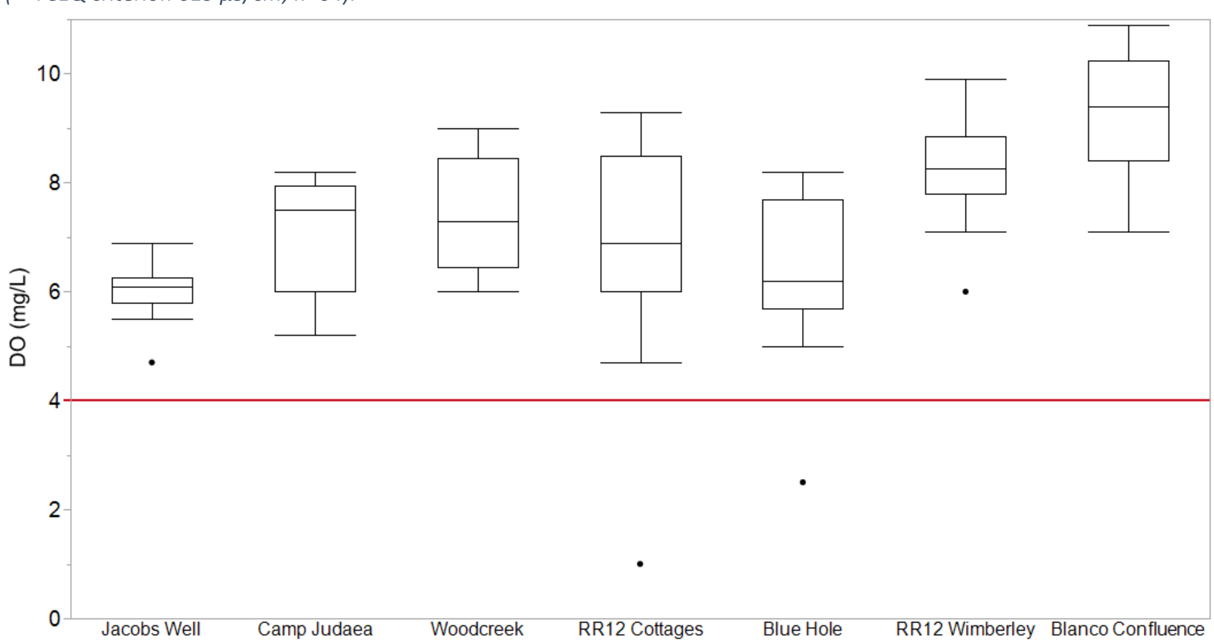


Figure 16. DO for all CRP water quality monitoring sites in the Cypress Creek watershed from August 2016 to December 2019 (TCEQ criterion 4.0 mg/L; n=64).

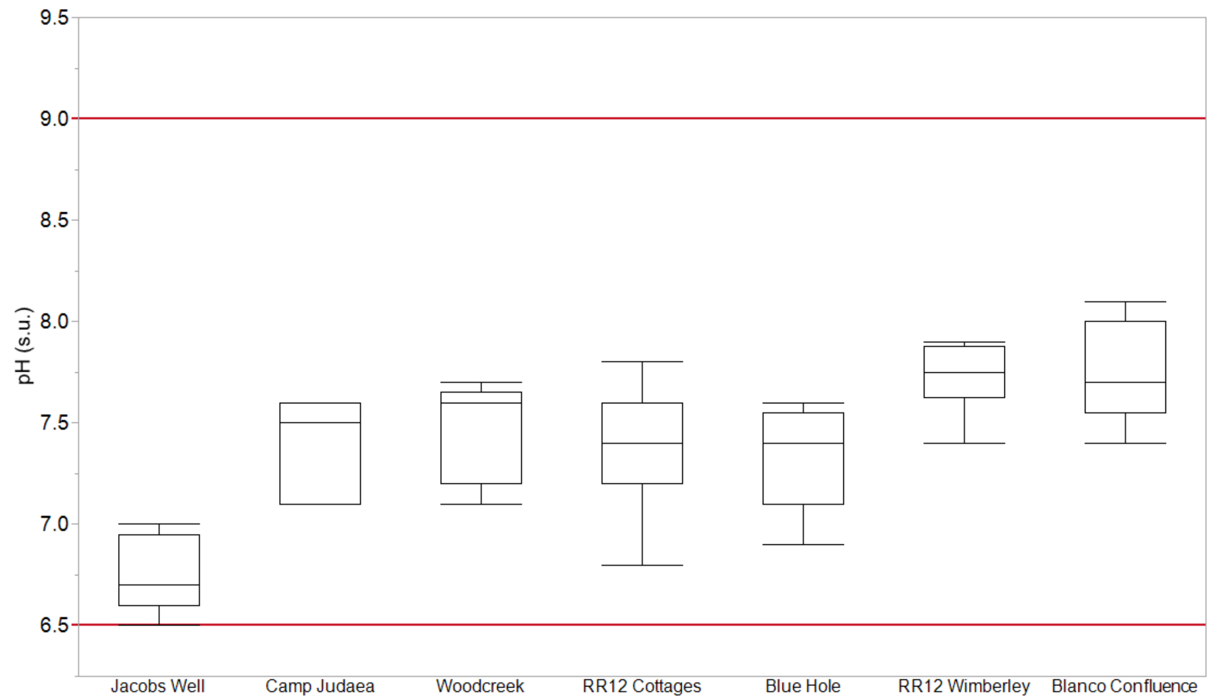


Figure 17. pH for all CRP water quality monitoring sites in the Cypress Creek watershed from August 2016 to December 2019 (TCEQ criteria 6.5 and 9.0 s.u.; n=64).

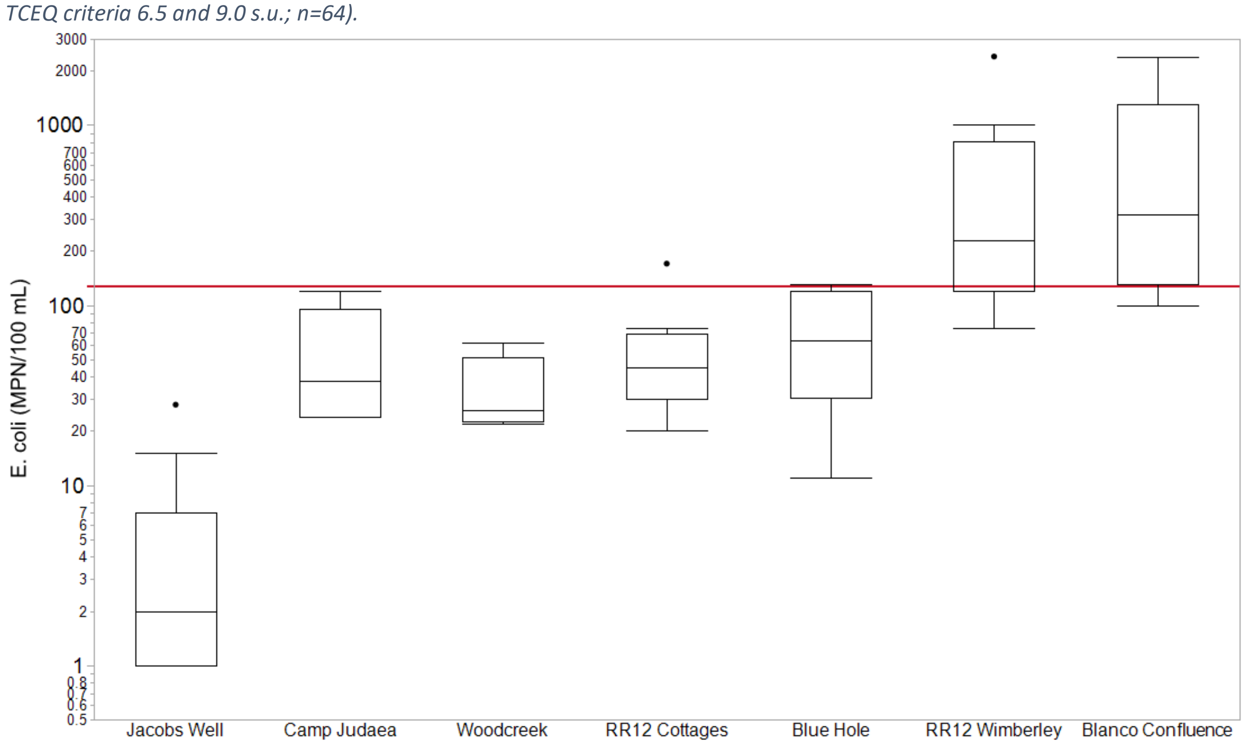


Figure 18. E. coli for all CRP water quality monitoring sites in the Cypress Creek watershed from August 2016 to December 2019 (TCEQ criterion 126 CFU/100mL; n=64).

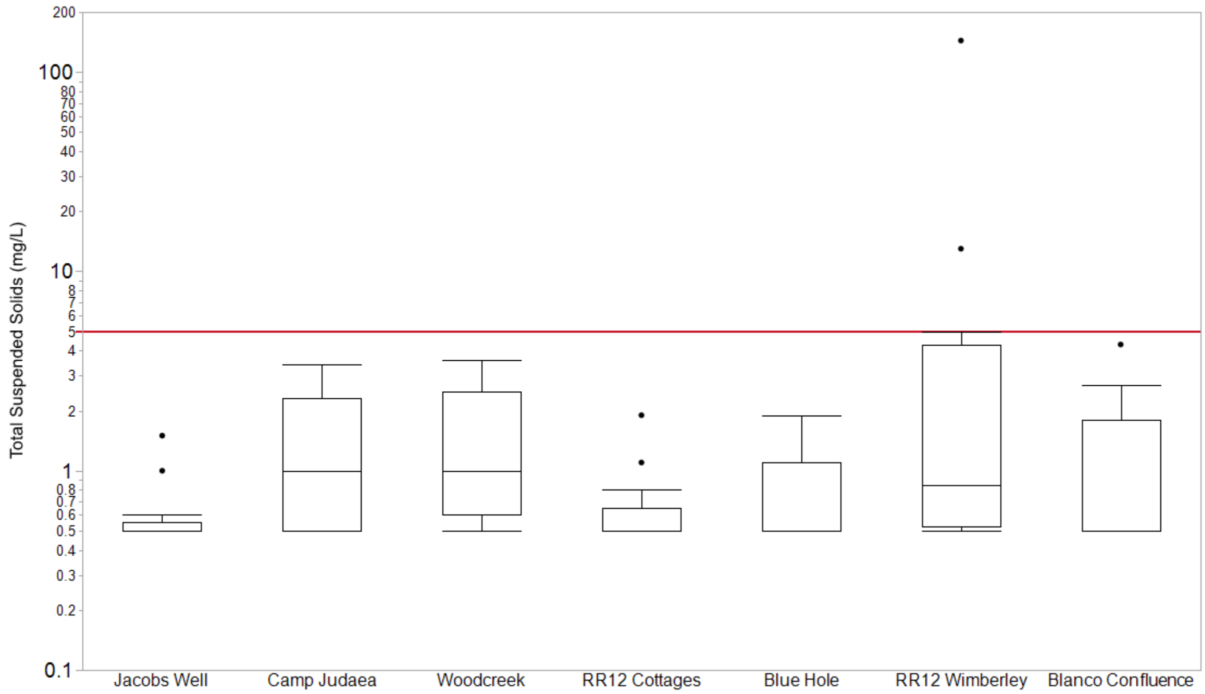


Figure 19. TSS (mg/L) for CRP sites in the Cypress Creek watershed from August 2016 to December 2019 (Cypress Creek WPP target 5.0 mg/L; n=64).

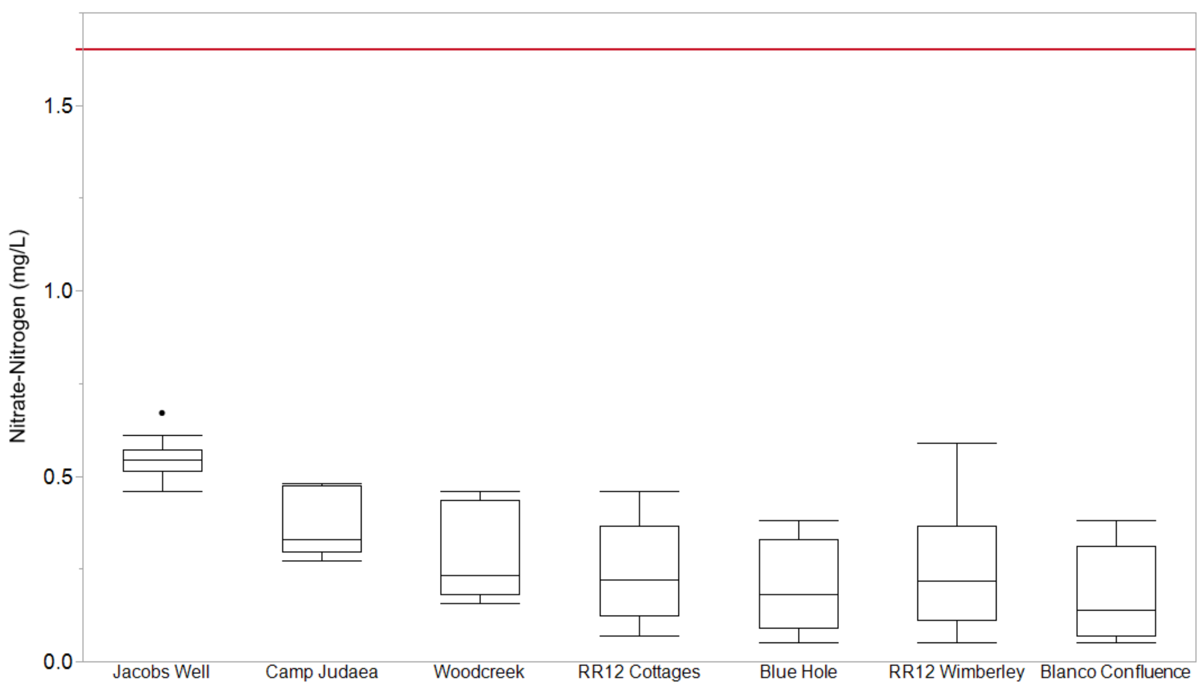


Figure 20. Nitrate-Nitrogen (mg/L) for CRP monitoring sites in the Cypress Creek watershed from August 2016 to December 2019 (Cypress Creek WPP target 1.65 mg/L; n=64).

The 24-hour DO monitoring results exceeded both the average and minimum criteria at Blue Hole in September 2019 (Table 4). The remaining events at both sites met all criteria.

Table 7. 24-Hour dissolved oxygen monitoring in the Cypress Creek watershed.

Site	Blue Hole		Blanco Confluence	
Date	4/2-3/2019	9/4-5/2019	4/3-4/2019	9/5-6/2019
24-hour average (mg/L)	8.20	3.79	8.91	7.75
24-hour minimum (mg/L)	7.18	3.18	8.46	7.47

Flow measurements were collected along-side field measurements and water monitoring activities for all sites in the Cypress Creek watershed. Relationships between flow and water quality monitoring parameters were explored using regression analysis. Results for the regression analyses produced R-squared coefficients that explained 66.5 and 57.6 % of the variability for conductivity at the Camp Judea and Woodcreek sites (Fig. 9). The regression analyses for nitrate-nitrogen resulted in R-squared coefficients that explained between 66.3 and 93.0 % of the variability at all sites except Jacob's Well (Fig. 10).

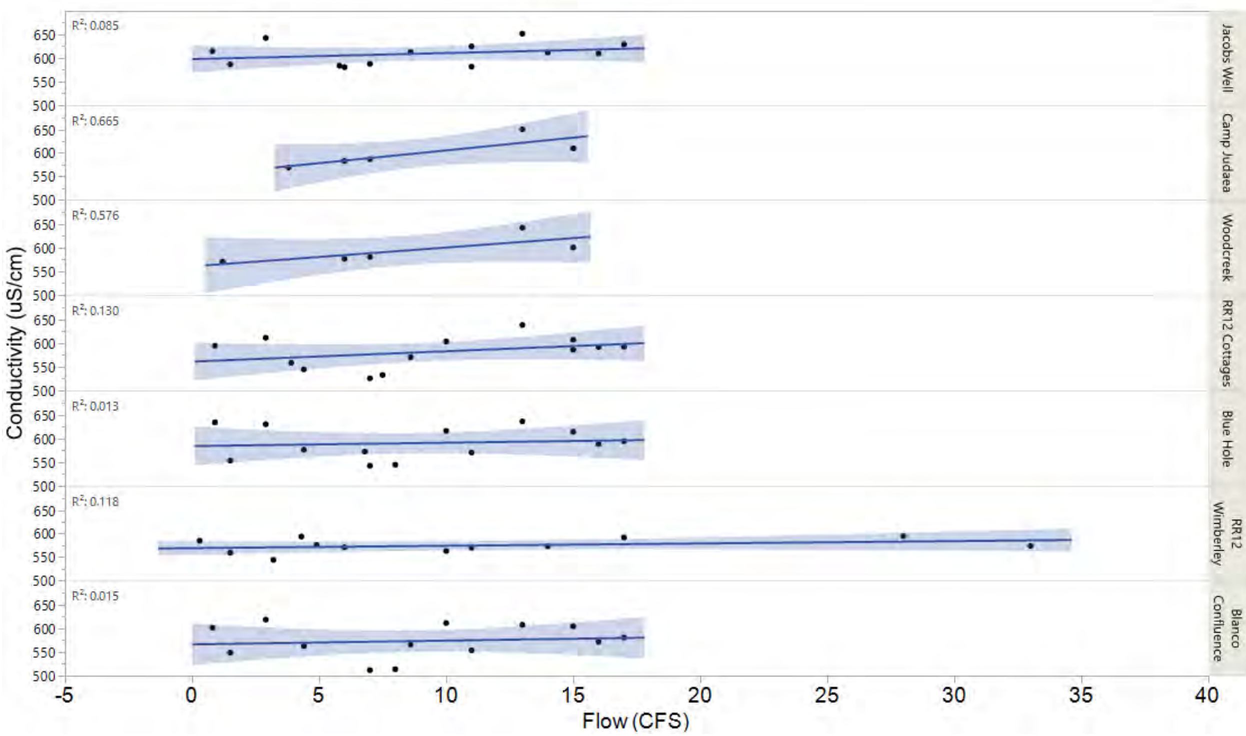


Figure 21. Regression analysis for flow and conductivity for CRP sites in the Cypress Creek watershed from August 2016 to December 2019 (n=64).

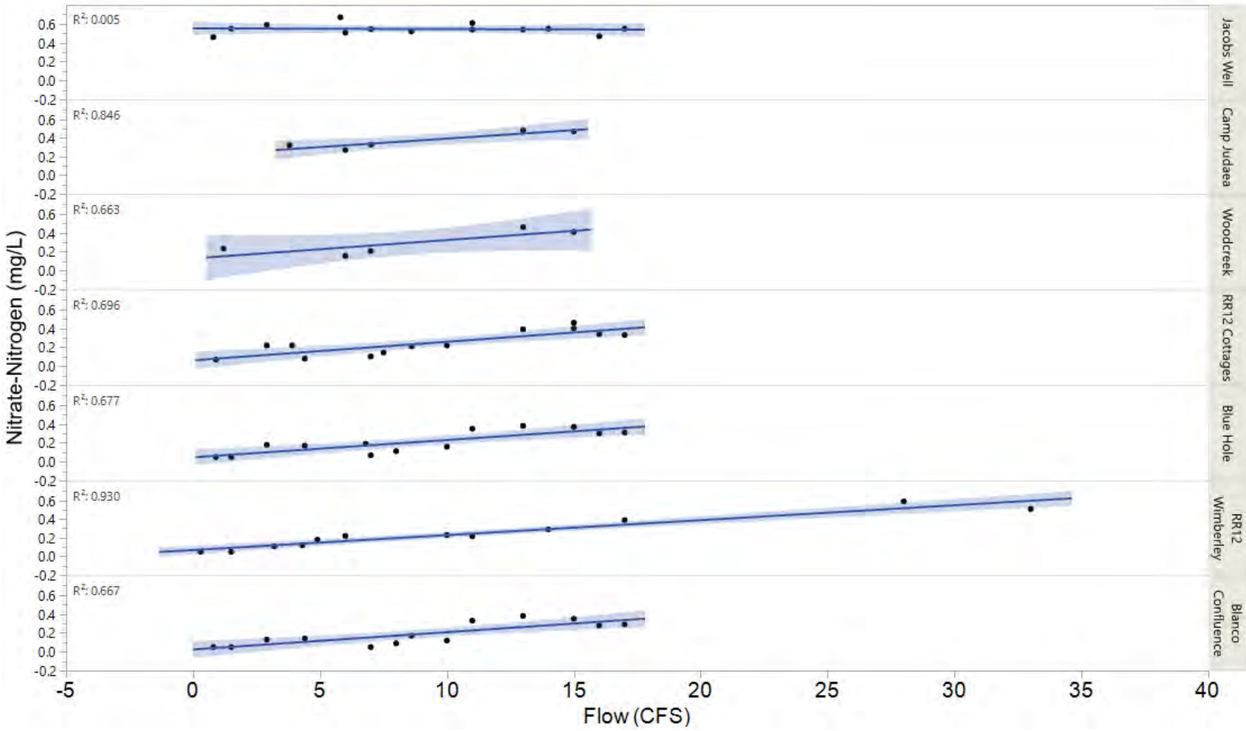


Figure 22. Regression analysis for flow and nitrate-nitrogen for CRP sites in the Cypress Creek watershed from August 2016 to December 2019 (n=64).

Groundwater Quality Monitoring

Results of the MCWE groundwater quality monitoring are displayed in (Table 5). Non-detects resulted for all samples at both sites for ammonia-nitrogen, total phosphorus, *E. coli*, and TSS. Nitrate-nitrogen results varied, with about half non-detects and half reportable values. All non-detects for nitrate-nitrogen were from Old Hundred and all reportable values from HCP3.

Table 8. MCWE groundwater sampling results in Cypress Creek watershed (NA=no data).

Date	8/22/2019		11/5/2019			1/23/2020	
Well	HCP3	HCP3 (Dup)	HCP3	Old Hundred	Old Hundred (Dup)	HCP3	Old Hundred
Laboratory							
Nitrate-Nitrogen (mg/L)	1.08	1.10	1.09	<0.05	<0.05	0.98	<0.05
Ammonia-Nitrogen (mg/L)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Phosphorus (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
E. coli (MPN/100mL)	<1	<1	<2	<1	<1	<1	<2
Total Suspended Solids (mg/L)	4.10	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Field							
Temperature (°C)	NA	NA	22.4	24.4	24.4	22.4	24.0
pH (s.u.)	NA	NA	7.0	7.2	7.2	8.0	7.4
DO (mg/L)	NA	NA	3.9	2.6	2.6	9.5	3.4
Conductivity (µS/cm)	NA	NA	666	677	677	588	673

Results - Acquired Data

Texas Stream Team Water Quality Monitoring Data

The Jacob's Well (n=55) and Old Kyle Rd (n=64) sites had the greatest number and most-recent sampling events on record. Both nitrate-nitrogen and *E. coli* measurements were sparse throughout the dataset. Most of the measurements recorded were standard core Texas Steam Team field parameters.

Air and water temperature averages ranged between 18.3 to 26.5 °C and 18.6 to 23.6 °C, respectively. The lowest average air and water temperatures were observed at the Old Kyle Rd. site and the highest were observed at Woodcreek Dr. The average pH values for all sites ranged from 7.0 at Jacob's Well to 7.7 s.u. Old Kyle Rd. Average conductivity measurements ranged from 510 to 723 µS/cm, with the highest values at Blue Hole and lowest at CR220. DO ranged from 5.8 to 13.6 mg/L and *E. coli* ranged from 48.4 to 110 cfu/100mL.

Most reported values met the TCEQ water quality criteria and/or Cypress Creek WPP targets. The conductivity at Blue Hole was one exception (724 µS/cm).

Table 9. Texas Stream Team Water Quality Monitoring Data (Averages ±Standard Deviation) in the Cypress Creek watershed. NA=no data available

Site Number-Name (sample count)	Air Temp (°C)	Water Temp (°C)	pH (s.u.)	Conductivity (µS/cm)	DO (mg/L)	Nitrate-Nitrogen (mg/L)	*E. coli* Avg. (cfu/100 mL)*	Secchi Disk (m)
12677 Jacob's Well (n=55)	22.6 (±7.2)	20.3 (±2.8)	7.0 (±0.12)	577 (±73)	5.8 (±0.97)	NA	64 (±71.2)	3.0 (±3.5)
13513 CR220 (n=3)	24.7 (±4.9)	20.1 (±2.5)	7.4 (±0.4)	510 (±66.8)	6.8 (±0.5)	NA	NA	1.5 (±0.2)
80502 Woodcreek Dr (n=8)	26.5 (±8.2)	23.6 (±4.8)	7.5 (±0.4)	594 (±11.1)	6.8 (±0.7)	NA	NA	1.7 (±1)
80933 First Dam (n=7)	22.1 (±5.7)	21.7 (±7.0)	7.2 (±0.2)	543 (±35.7)	7.5 (±1.3)	0.5 (±0)	110 (±0)	1.4 (±0.8
80415 Blue Hole (n=15)	20.8 (±6.3)	20.8 (±4.9)	7.1 (±0.2)	723 (±135.3)	6.6 (±2.2)	NA	48.4 (±39.5)	1.6 (±0.2)
80443 Old Kyle Rd (n=64)	18.3 (±6.7)	18.6 (±5.6)	7.7 (±0.3)	584 (±32.0)	13.6 (±53.3)	NA	90.6 (±45.6)	1.1 (±1.2)

*Sample counts (n) varied for *E. coli*

United States Geological Survey Stream (USGS) Discharge and Hays Trinity Groundwater Conservation District (HTGCD) Well Data

Time series data for the USGS gauge at Jacob's Well (Fig. 11) and HTGCD groundwater level at Old Hundred (Fig. 12) were acquired for the project period of record (2016 – 2020). Inverse relationships appear between the two time series datasets. When higher discharges are measured at Jacob's Well, groundwater well measurements from the ground surface to the water surface in the well are lower, resulting in higher groundwater levels in the aquifer.

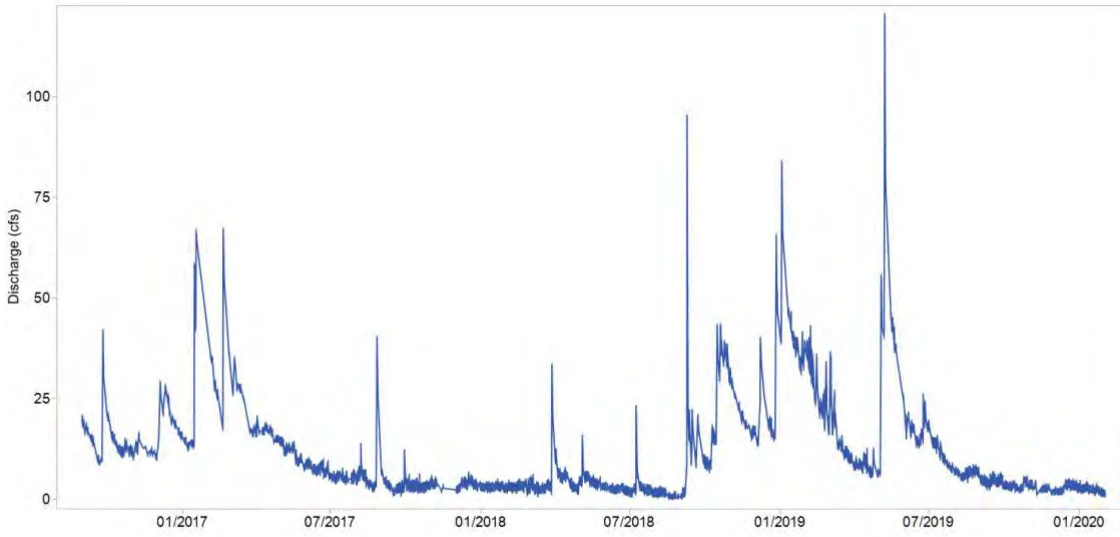


Figure 23. USGS stream discharge data from Jacob's Well Spring near Wimberley (#08170990) in the Cypress Creek watershed from September 2016 to February 2020 (n=119,235).

Figure 24. HTGCD HCP3 well monthly average depth measurements to surface of groundwater in the Cypress Creek watershed from January 2016 to December 2019 (n=48).

The HTGCD conducts chemical analyses on groundwater from Old Hundred. Table 7 represents the chemical results for the biannual groundwater sampling conducted at Old Hundred well in 2019.

Table 10. Hays Trinity Groundwater Conservation District Old Hundred well biannual chemical sampling results for 2019.

Parameter	1/29/2019	6/27/2019
Nitrate/Nitrite Dissolved (mg/L)	0.0216	<0.02
Total Dissolved Solids Dissolved (mg/L)	329	416
Chloride Dissolved (mg/L)	10.3	9.78
Bromide Dissolved (mg/L)	0.0464	0.04
Fluoride Dissolved (mg/L)	0.429	0.40
Sulfate Dissolved (mg/L)	102	101
Aluminum Dissolved (mg/L)	<0.0500	<0.05
Boron Dissolved (mg/L)	0.0518	0.06
Calcium Dissolved (mg/L)	70.3	80.3
Iron Dissolved (mg/L)	<0.0500	<0.05
Magnesium Dissolved (mg/L)	38.0	43.9
Manganese Dissolved (mg/L)	<0.0100	<0.01
Potassium Dissolved (mg/L)	2.66	2.89
Sodium Dissolved (mg/L)	7.78	8.74
Strontium Dissolved (mg/L)	1.10	1.20
Phenolphthalein Alkalinity (mg/L)	0.00	0.00
Hydroxide Alkalinity (mg/L)	0.00	0.00
Bicarbonate Alkalinity (mg/L)	247	248
Carbonate Alkalinity (mg/L)	0.00	0.00
Total Alkalinity ($CaCO_3$) (mg/L)	247	248

Discussion

Surface water quality in Cypress Creek has historically been "good." Early proponents of the Cypress Creek WPP foresaw the increasing urbanization in the watershed and chose to be proactive in the development of the WPP. Recent results of the TCEQ's Texas Integrated Reports, both the 2018 and Draft 2020, are beginning to identify concerns and impairments in Cypress Creek using data that covers a longer period of record than is reported here. Results of both the collected and acquired surface and groundwater data from this project reveal similar concerns.

The conductivity criterion (615 µS/cm) is designed for surface water streams, not groundwater from springs. Cypress Creek is predominantly a spring-fed creek. Although the conductivity surface water quality criterion was exceeded by most sites sampled for this project, the RR12 Wimberley site (12674) did not exceed the criterion. In addition, the regression analysis using flow as an independent variable only explained a minimal source of the variability at RR12 Wimberley. These preliminary results may suggest a local water source influencing this site relative to the remaining sites sampled for this project.

Almost half of all impaired waters on the Texas Integrated Report (IR) 303(d) List are from exceedances of the *E. coli* bacteria geometric mean criterion (126 CFU/100 mL). Exceedance of the bacteria criterion results in numerous impairments of the contact recreation use state-wide. Two sites, RR12 Wimberley (12674) and Blanco Confluence (12675), within the Cypress Creek watershed exhibited exceedances of the contact recreation bacteria criterion for this project. Cypress Creek is not currently listed for an impairment of the contact recreation use, however given the proximity of the urbanization to the sites exceeding the bacteria criterion, coupled with the use of on-site septic facilities (OSSFs) and the inference of local source water to this area of the stream stated previously, it is prudent to continue water quality monitoring and analysis, and implementation of management measures to address bacteria water quality.

Cypress Creek is on the Draft 2020 IR 303(d) List for depressed dissolved oxygen. Findings presented in this report for DO grab sampling resulted in only two outliers exceeding the DO criterion. However, the 24-hour DO monitoring conducted at Blue Hole (12675) on September 4-5, 2019, resulted in exceedances of both the average and absolute minimum DO criteria. Many variables affect dissolved oxygen measurements. Rainfall, flow, temperature, time of year/day and decomposition of organic matter are some of the variables that impact DO measurements. Additional data is needed to determine the best management strategies to address the DO impairment.

Appendix II: Cypress Creek WPP - BMP Final Design Report

Cypress Creek Watershed Protection Plan

Implementation (Years 1-3)

BMP Final Design Report

Prepared for:

The Meadows Center for Water and the Environment Texas State University

Prepared by:

Doucet and Associates, Inc.
January 9,2020

Funding for this project was provided in part by the EPA through the Texas Commission on Environmental Quality.

DOUCET & ASSOCIATES

Section 1.0 Introduction

Ten Best Management Practices (BMPs) were implemented as demonstration projects to improve water quality, enhance water supplies, and illustrate the methods and techniques that can be used by residents, developers, and commercial operators in the Wimberley Valley. This report summarizes the practices and BMP load reductions at the following sites:

Rainwater Harvesting

- Hays County Precinct 3 Office
- Blue Hole Regional Park
- Wimberley Valley Watershed Association (WVWA) offices
- Woodcreek Golf Course

Pervious Paver

- Blue Hole Park Trail
- Blue Hole Park Main Entrance
- Blue Hole Park ADA Parking Area
- Wimberley Central Business District

Rain Garden

- Woodcreek Golf Course

Vegetated Filter Infiltration Strip

- Wimberley Valley Watershed Association offices

As noted in Task 4 of the 319 Scope of Work, the purpose of these BMPs is to install functioning nonpoint source pollution (NPS) pollutant control technologies which will educate stakeholders on the pollution reduction and water conservation benefits of simple, relatively inexpensive management measures.

Section 2.0 BMP Projects

The Cypress Creek watershed is located in the Edwards Aquifer Contributing Zone. Therefore, all development projects that disturb more than five acres of land must comply with the Texas Commission on Environmental Quality (TCEQ) Edwards Aquifer Protection Program and design, permit, and install water quality measures to improve stormwater runoff quality. Thus, pollutant load management was defined by the use of the TCEQ Edwards Aquifer Protection Program Design Spreadsheet which assesses pounds of total suspended sediment (TSS) managed per year. Average annual rainfall for Hays County per the TCEQ design requirements is 33 inches per year. To determine the management of phosphorus, nitrogen, and E. coli in the various BMPs, guidance was provided by the City of Austin Environmental Criteria Manual (tables 1-9, 1-10, 1-11), the Water Environment Research Foundation (WERF) *User's Guide to the BMP SELECT Model,* and the Lower Colorado River Authority (LCRA) Highland Lakes Watershed Ordinance *Water Quality Management Technical Manual.* The following provides design, cost, pollutant management, and other information at each site. Photographs of each measure follow the summary.

Section 2.1 Rainwater Harvesting

Per the TCEQ Edwards Aquifer Protection Program, rainwater harvesting systems can be used in the Edwards Aquifer Recharge and Contributing Zones. Roof areas connected to a rainfall harvesting system do not need to be included in the post development impervious cover calculation, but the volume of the rainfall collection system must be sufficient to retain the runoff from a 1.5-inch rainfall and the system should be emptied at least weekly to provide storage for subsequent storms. The design assumption is that managing this runoff volume will achieve the 80% TSS reduction requirement.

Hays County Precinct 3 Office

- Storage type – Metal Tank
- Storage size – 1,000 gallons
- Project Cost = $9,157.50 (includes gutter improvements, tank, and site work)
- Roof material and area – Metal, area = 4,200 square feet
- Use – Rainwater harvested will be used to irrigate the native landscape.
- Delivery method – Gravity fed
- Potential annual harvesting capacity – 18,000 gallons
- Tank is filled by 0.4 inches of rainfall runoff from the roof surface
- TSS pounds managed per year = 58
- Phosphorus pounds managed per year = 0.10
- Nitrogen pounds managed per year = 0.45
- E. coli cfu managed per year = 3.45E+10
    - Due to the size of the roof area in relation to the rainwater tank size, this system does not achieve the TCEQ Edwards Aquifer Protection Program target of 86 pounds per year. However, since this project is a demonstration project to highlight the tools and techniques that can be used to manage stormwater, it is not subject to the TSS removal requirement. The tank would need to be about 3,900 gallons in size to meet the TCEQ criteria.

Blue Hole Regional Park

- Storage type – Metal Tank
- Storage size – 3,453 gallons
- Project Cost = $14,992.00 (includes concrete foundation, tank, connection to the existing in-building water system, trenching, and gutter improvements)
- Roof material and area – Metal, area = 2,200 square feet
- Use – Rainwater harvested will be used for the toilets at the parks pavilion
- Delivery method – Pump
- Potential annual harvesting capacity – 35,000 gallons
- Tank is filled by about 2.5 inches of rainfall runoff from the roof surface
- TSS pounds managed per year = 51
- Phosphorus pounds managed per year = 0.05
- Nitrogen pounds managed per year = 0.24
- E. coli cfu managed per year = 1.88E+10
    - This rainwater tank has volume in excess of the 1.5-inch storm, thus, it satisfies the 80% TSS removal requirement. If the tank was sized for the 1.50-inch storm, it would need to contain about 2,100 gallons of storage.

Wimberley Valley Watershed Association

- Storage type – Metal Tank
- Storage size – 29,173 gallons
- Cost = $14,800.00 (tank and placement on the site)
- Roof material and area – Metal, 3,400 square feet
- Use – Rainwater harvested will be used to run the Wimberley Valley Watershed Association headquarters on a completely potable system. WVWA will fund the treatment systems to complete the potable water system.
- Delivery method – Pump
- Potential annual harvesting capacity – 55,000 gallons
- Tank is filled by about 14 inches of rainfall runoff from the roof surface
- TSS pounds managed per year = 78
- Phosphorus pounds managed per year = 0.08
- Nitrogen pounds managed per year = 0.36
- E. coli cfu managed per year = 2.88E+10
    - This rainwater tank has volume in excess of the 1.5-inch storm, thus, it satisfies the 80% TSS removal requirement. If the tank was sized for the 1.50-inch storm, it would need to contain about 3,200 gallons of storage. The tank is sufficiently larger than required for stormwater management per TCEQ, however, as a water supply system for the WVWA facility, it will have considerable storage to retain roof runoff for periods of drought will enable the facility to minimize groundwater usage.

Woodcreek Golf Course

- Storage type – Polyethylene Tank
- Storage size – 5,000 gallons
- Cost = $14,990.00 (tank, downspouts, rock trenching, underground pipe installation, pump and components)
- Roof material and area – Metal, area = 2,700 square feet
- Use – Rainwater harvested will be used to clean golf carts
- Delivery method – Pumped to the golf cart cleaning area
- Potential annual harvesting capacity – 45,000 gallons
- Tank is filled by about 3 inches of rainfall runoff from the roof surface
- TSS pounds managed per year = 62
- Phosphorus pounds managed per year = 0.06
- Nitrogen pounds managed per year = 0.29
- E. coli cfu managed per year = 2.28E+10
    - This rainwater tank has volume in excess of the 1.5-inch storm, thus, it satisfies the 80% TSS removal requirement. If the tank was sized for the 1.50-inch storm, it would need to contain about 2,800 gallons of storage. The tank is sufficiently larger than required for stormwater management per TCEQ, however, as a water supply system for the golf course management facility, it will have considerable storage to retain roof runoff for periods of drought that will enable the facility minimize groundwater usage.

Section 2.2 Permeable Pavers

Per the TCEQ Edwards Aquifer Protection Program, permeable pavers may only be used on the Edwards Aquifer Contributing Zone. To achieve the 80% TSS management requirement, the subsurface storage system must be able to store the rainfall treatment depth of 1.64 inches.

The paver projects used the Eco-City lock pavers supplied by Pavestone, Inc., herringbone pattern based on the input from the Wimberley Blue Hole Park staff. The rock water storage area below the pavers is 6 inches thick and composed of clean, open graded ASTM #57 stone. Based on a void ratio of 0.3, the rock water storage area can retain a rainfall depth of 1.8 inches which exceeds the TCEQ requirements of 1.64 inches. The soils were evaluated in the field and compared to the permeability values fond in the Comal and Hays County Soil Conservation Service Soil Survey. These soils can infiltrate runoff at the rate of 0.2 to 0.6 inches per hour. Using 0.2 inches per hour to be conservative, the water storage area will drain in 30 hours.

Blue Hole Regional Park Trail Project

- Drainage Area = Paver footprint = 1,500 square feet
- Cost = $19,875.00 (pavers, mortar edge with reinforcing bar, gravel, bedding materials, installation)
- Average annual infiltration is approximately 30,000 gallons per year
- TSS pounds managed per year = 37
- Phosphorus pounds managed per year = 0.06
- Nitrogen pounds managed per year = 0.19
- E. coli cfu managed per year = 1.12+10

Blue Hole Regional Park – Main Entrance Pavers

- Drainage Area = Paver footprint = 250 square feet
- Concrete aggregate sidewalk – 1015 square foot to replace a continuously eroding granite gravel sidewalk that was discharging to the Blue Hole swim area
- Cost = $3,312.00 (pavers, installation, spikes, bedding material, concrete sidewalk, excavation)
- Average annual infiltration is approximately 5,000 gallons per year
- TSS pounds managed per year = 6
- Phosphorus pounds managed per year = 0.01
- Nitrogen pounds managed per year = 0.03
- E. coli cfu managed per year = 1.98E+9

Blue Hole Regional Park – ADA Parking Spaces Permeable Pavers

- Drainage Area = Paver footprint = 840 square feet
- Concrete sidewalk = 250 square feet to replace a continuously eroding granite gravel sidewalk that was discharging to Cypress Creek
- Cost = $13,020.00 (pavers, bedding, concrete ribbon curb, installation, concrete sidewalk)
- Average annual infiltration is approximately 17,000 gallons per year
- TSS pounds managed per year = 20
- Phosphorus pounds managed per year = 0.03
- Nitrogen pounds managed per year = 0.11
- E. coli cfu managed per year = 6.28E+

Section 2.3 Rain Gardens

Installation of rain gardens is outlined in the Cypress Creek Implementation Plan. Rain gardens of at least 400 square feet were installed at the Woodcreek Golf Course. Four hundred square feet was chosen as a minimum as it is an average size for commercial or public scale rain gardens. Rain gardens are an aesthetically pleasing opportunity for pollutant uptake. They are recommended for shaded or sunny areas, close to a water source, or within a wet portion of the basin. These can be used in commercial and residential development.

The management of TSS in rain gardens is computed through the use of the TCEQ "Complying with the Edwards Aquifer Rules Technical Guidance on Best Management Practices" design spreadsheet. The TCEQ Technical Guidance indicates that rain gardens generate an 89 percent reduction in TSS. When the runoff is entirely infiltrated, TSS and other pollutant management approaches 100 percent. The TCEQ Edwards Aquifer Technical Guidance also provided design details in the preparation of the rain garden plans. Preliminary soils analysis was provided by the Soil Survey of Comal and Hays County Texas that was prepared by the U.S. Department of Agriculture.

Woodcreek Golf Course Rain Garden

The rain garden was installed in the summer of 2019.

- Drainage Area = 0.4 acres
- Rain garden volume = 540 cubic feet with a depth of one foot.
- Soils were determined to provide sufficient infiltration capacity so that an underdrain was not required. This information was provided by the golf course manager based on the knowledge of imported soil and nearby golf course runoff characteristics.
- Side slopes are at 5 feet horizontal for one- foot of elevation change to facilitate mowing.
- Cost = $14,100
- Average annual infiltration is approximately 160,000 gallons per year
- TSS pounds managed per year = 118
- Phosphorus pounds managed per year = 0.25
- Nitrogen pounds managed per year = 0.96
- E. coli cfu managed per year = 7.63E+10

In early 2020, the golf course manager will place Bermuda sod with a sand base to create a fully vegetated rain garden. Rain gardens can be planted in various manners, from extensive plants and shrubs to grass covered bottom. Pollutant management is essentially the same as infiltration through soil is the pollutant management process. To minimize maintenance and cost, grass bottom rain gardens can be an attractive alternative to a shrub and landscape planted basin.

Wimberley Valley Watershed Association Vegetated Filter Infiltration Strip

The vegetated filter infiltration strip was constructed in October 2019 and based on the design guidance in the Lower Colorado River Highland Lakes Watershed Ordinance Technical Manual. A vegetated berm was constructed on the contour to intercept runoff from upstream sources. The retained runoff infiltrates and evaporates to reduce runoff volume and provide pollutant treatment. This measure is also effective in reducing peak runoff rates as the travel flow path is increased in length and runoff volume detention is also provided.

The photos below illustrate the placement of brush on top of the berms to deter deer grazing and allow the vegetation to sprout. By spring, the berms are anticipated to be fully vegetated.

- Drainage Area = 1.8 acres
- Berm length = 500 feet with a berm height of 15 inches, a top width of one foot, and 4:1 side slopes. Three berm rows were constructed to retain runoff.
- Cost = $20,000
- Average annual infiltration is approximately 280,000 gallons per year
- TSS pounds managed per year = 450
- Phosphorus pounds managed per year = 0.98
- Nitrogen pounds managed per year = 5.51
- E. coli cfu managed per year = 3.03E+11

This measure is very effective in treating runoff as a stand-alone BMP or can function as a secondary treatment device downgradient of structural measures to polish runoff and enhance infiltration.

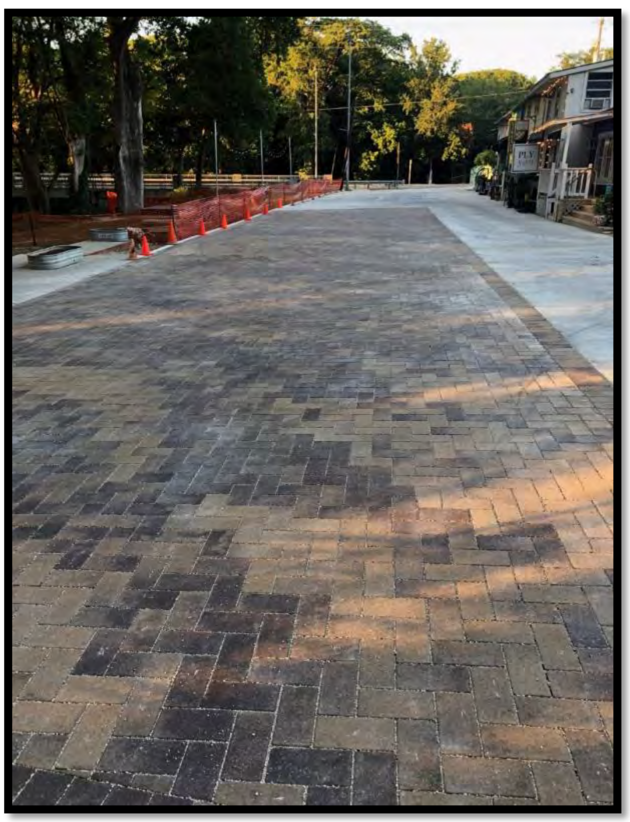
Section 3.0 Wimberley Central Business District Pervious Pavers Project

Pervious pavers were installed in the Wimberley Central Business District in the spring/summer of 2019. The project is about 2,400 square feet in area and in a highly visible location alongside Cypress Creek. The grant required a BMP size of 700 square feet, however, the partnership with the landowner and the City allowed this project to be larger in size to provide additional water quality and infiltration benefits. Runoff from the permeable pavement area in excess of the sub-surface water storage capacity will flow across an existing vegetated surface that functions as a vegetated filter strip. The pervious pavement section is about 20 feet wide.

- Drainage Area = Paver footprint = 2,400 square feet
- Cost = $24,500 (pavers, mortar edge with reinforcing bar, gravel, bedding materials, installation)
- Average annual infiltration is approximately 70,000 gallons per year
- TSS pounds managed per year = 117
- Phosphorus pounds managed per year = 0.23
- Nitrogen pounds managed per year = 0.72
- E. coli cfu managed per year = 4.30E+10

Parking Lot Prior to Pavers Being Installed

Completed Paver Project



Pavers and Concrete Edge Interface

Table 1: BMP Summary

Location and BMP Type	Approx. Treatment Area	Cos t ($)	Runoff Storage Volum e	Avg. Annua l TSS Removal	Cost per Lb. TSS Managed ($)	Avg. Annual Water Supply (gallons)
Rainwater Harvesting						*Water usage*
Hays County Precinct 3 Office	4,200 SF roof	9,157	1,000 gal	58	158	18,000
City of Wimberley Blue Hole Regional Park	2,200 SF roof	14,992	3,453 gal	51	294	35,000
Wimberley Valley Watershed Association Offices	3,400 SF roof	14,800	29,173 gal	78	190	55,000
City of Woodcreek Golf Course Maintenance Shed	2,700 SF roof	14,990	5,000	62	242	45,000
Pervious Pavers						*Infiltration*
City of Wimberley Blue Hole Park Bathhouse	250 SF surface	3,312	38 cu ft	6	552	5,000
City of Wimberley Blue Hole Park Trail	1,500 SF surface	19,875	225 cu ft	37	537	30,000
City of Wimberley Blue Hole Park ADA Parking	840 SF surface	13,020	126 cu ft	20	651	17,000
Rain Gardens and Vegetated Filter Strip-						
City of Woodcreek Golf Course Clubhouse Rain Garden	0.40 acres	14,100	540 cu ft	108	130	160,000
Wimberley Valley Watershed Association Offices Vegetated Filter Infiltration Strip	1.8 acres	20,000	12,500	450	45	280,000
Wimberley Central Business District Pervious Pavers						
Square Permeable Pavement	2,400	24,500	560	117	210	70,000

See the individual BMP summaries for nitrogen, phosphorus, and E. coli management. TSS removal computed per the TCEQ "Complying with the Edwards Aquifer Rules Technical Guidance on Best Management Practices".

Average annual water supply based on the average rainfall of 33 inches per year. For permeable pavement, rain gardens, and vegetated filter strip, water supply is based on potential infiltration amount.

Woodcreek Golf Course Rain Garden

Woodcreek Golf Course Rainwater Harvesting

Appendix III: Cypress Creek WPP - Technical Resource Guide for Developers and Engineers, Green Infrastructure Plan Review Guide and Fast Track Review Process

Cypress Creek Watershed Protection Plan

Technical Resource Guide for Engineers and Developers

Prepared for:

The Meadows Center for Water and the Environment

Texas State University

Prepared by:

Doucet and Associates, Inc.

February 2020

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1.0 Introduction

This guidance is designed to assist developers and engineers in complying with the City of Wimberley and City of Woodcreek water quality ordinances. The ordinances were amended in late 2019 by the City of Wimberley and early 2020 by the City of Woodcreek and are consistent in their requirements to manage construction and post-construction stormwater management. The ordinances can be found at:

City of Wimberley website

City of Woodcreek website

This guidance also illustrates an approach to "fast-track" development proposals for projects that are less than five acres in area and/or projects that are not required to obtain approval from the Texas Commission on Environmental Quality (TCEQ) for the Edwards Aquifer Protection Program (EAPP). An Alternate Standards (Green Infrastructure) design approach is encouraged to manage stormwater through natural and vegetative processes while managing stormwater construction and long-term maintenance costs.

The Wimberley and Woodcreek water quality ordinances are directly connected to the TCEQ EAPP in that satisfying the TCEQ EAPP requirements for water quality management complies with the Wimberley and Woodcreek water quality treatment requirements. Projects subject to the TCEQ EAPP requirements will use the Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices (RG-348) and other supporting documents to demonstrate compliance with the EAPP rules.

However, the local ordinances have additional requirements including water quality buffer zones, maintenance requirements, and other measures that are found in the respective water quality ordinances. Developers and engineers should understand the water quality ordinance requirements and coordinate with the respective City/County staff and City/County Engineer to define the most appropriate design approaches, gain compliance, and facilitate an efficient permitting process. This should take place in a pre-development planning meeting early in the design process.

In the event of conflicts with water quality ordinance requirements for the cities' of Woodcreek and Wimberley or the TCEQ Edwards Aquifer Protection Program or Hays County drainage criteria, then, previously listed regulations supersede this Guidance.

This guidance neither replaces the need for engineering judgment nor precludes the use of any information relevant to the accomplishment of the purposes of this guide. If approved by the city engineer, other generally accepted, or innovative and effective, engineering designs, practices and procedures may be used in conjunction with, or instead of, those prescribed by this Guidance.

2.0 Permit Determination and Water Quality Treatment Design

This section outlines potential exemptions and the types of permits required for development activities under the Wimberley and Woodcreek water quality ordinances. A water quality ordinance permit is required for land development activities unless the proposed activities fall in the exemption categories. Small projects with minimal and disconnected impervious cover have limited to negligible effect on water quality.

Exemptions. The following are exempt from the provisions of the Wimberley and Woodcreek Ordinances:

(1) Development or redevelopment that adds less than 5,000 square feet of new impervious cover

(2) Development of a single-family residence on an existing platted lot

(3) Development of a single-family residence that creates more than 5,000 square feet of new impervious cover and provides erosion and sediment control during construction and is in compliance with the water quality buffer zone requirements found in the pertinent water quality ordinance.

(4) Agricultural activities

Impervious cover limits

If a proposed development tract is located in a City's Extraterritorial Jurisdiction (ETJ), then the maximum impervious cover is 30%.

If a Tract proposed for development is located in the City Limits, then the impervious cover limits are established in compliance with the City's Zoning Ordinance according to the particular Zoning District the tract is designated as.

Impervious cover - All roads, driveways, buildings, parking areas, and other impermeable construction covering the natural land surface that prevents runoff infiltration. Swimming pool surface water areas for pools which discharge to the storm drain system shall also be included. Water quality, detention basins, and other conveyances for drainage purposes only shall not be calculated as impervious cover. For purposes of compliance with the ordinances, the term expressly excludes storage tanks for rain-water collection systems.

Obtaining Water Quality Treatment Compliance

Alternate Standards – Green Infrastructure Compliance

Alternate BMP requirements employing low impervious cover levels with vegetative conveyance (green infrastructure) are described below. Compliance with the following specifications is assumed to meet the water quality performance standards found in the ordinances as stormwater runoff is slowed, soaked, spread, and saved by distributing runoff over vegetated and natural areas.

(1) Not part of a common plan of development and the project impervious cover is less than 15% and the cluster development sections (individual drainage areas) have impervious cover less than 20 percent,

(2) The street and drainage network is designed to include the use of open roadway sections (no curb and gutter), ribbon curb, drainage channels and the maintenance of sheet flow, and

(3) Impervious cover credits described below may be used to gain compliance with this section by achieving the 15% effective impervious cover criteria.

Developments applying the green infrastructure compliance approach can move more efficiently through the permitting process as plan review is not required for constructed water quality controls. In addition, TCEQ EAPP permanent water quality treatment measures are not required.

A common plan of development is a construction activity that is completed in one or more of the following ways:

- In separate stages
- In separate phases
- In combination with other construction activities

Conventional Approach

For projects that cannot comply with the Green Infrastructure Approach, conventional methods of stormwater management can be used to meet the ordinance water quality treatment requirements.

- *Five (5) acres or less and not part of a common plan of development (exempt from TCEQ rules).* The applicant must provide technical demonstration that water quality must be managed through the use of conventional and low impact development measures. These measures include all BMPs in the TCEQ Edwards Aquifer Protection Manual and the those described in Chapter 4 in the Highland Lakes Watershed Ordinance Water Quality Management Technical Manual. The applicant may also submit an alternative design that is subject to the review and approval of the City Engineer.

- Greater than five (5) acres. Technical demonstration that the development obtained a Contributing Zone Plan (CZP) approval including permanent water quality BMPs from the Texas Commission on Environmental Quality (TCEQ) per the Edwards Aquifer Protection Program. If the project is exempt from a CZP permanent water quality measures, the project shall comply with the requirements found in this document.

Impervious Cover Credits (Projects Not Required to Comply with the TCEQ EAAP)

The techniques presented below are considered options by designers to gain compliance with Alternate Standards (Green Infrastructure). Due to soil conditions and topography, some of these site design features may be restricted.

Stormwater Credits	Alternate Standard Application	Water Quality Volume Application	Comments
Porous pavement (concrete) or paver blocks	Reduce paved area IC by 90% for porous pavement, reduction for pavers based on void space and reduction factor	Reduce paved area IC by 90% for porous pavement, reduction for pavers based on void space and reduction factor	Paving blocks receive reduced credit per design guidance
Rainwater harvesting (cisterns)	Reduce roof top IC up to 75%	Reduce roof top IC based on tank volume ratio to catchment area	Tank volume requirements related to catchment area
Soil amendment	Reduce IC by 2%	Reduce drainage area IC by 2% to water quality basin	6-8" blended soil depth and appropriate turf
Conservation landscaping	Reduce IC by 5%	Reduce drainage area IC by 5% to water quality basin	Limitations on turf area, use native plants/shrubs
Disconnection of roof-top runoff	Deduction of rooftop IC based on flow length and rainwater storage	Deduction of rooftop IC based on flow length and rainwater storage	75' flow length for full deduction with 90% grass
Natural area Preservation	Include natural area in development cluster impervious cover calculation	Natural area is subtracted from drainage basin area	Supports conservation development initiatives, yet connects to hydrology

IC = Impervious cover

VFS = Vegetated filter strip

See the design spreadsheet to compute the impervious cover credits. It can be found at the LCRA Highland Lakes Watershed Ordinance Water Quality Management Technical Manual link above.

Each jurisdiction may develop their own set of standards/requirements that may deviate from this guidance. If so, the design calculations will also be modified to reflect these modifications.

Water Quality Ordinance Permit Checklist

If your project is:	Erosion & Sediment Controls	WQ Mgmt. Per City Ordinance	Creek Buffer Zones Per City Ordinance	WQ Mgmt. Per TCEQ Edwards CZ Plan
Development < 5,000 SF of impervious cover and disturbs less than 5 acres	**No**	**No**	**No**	**No**
Development of a single-family residence on an existing platted lot	**No**	**No**	**No**	**No**
Development of a single-family residence on a newly platted lot that adds more than 5,000 square feet of new impervious cover	**Yes**	**No**	**Yes**	**No**
Development that adds more than 5,000 square feet of new impervious cover and disturbs less than 5 acres of land	**Yes**	**Yes**[1]	**Yes**	**No**
Development that adds more than 5,000 square feet of impervious cover and disturbs more than 5 acres and the project impervious cover exceeds 15 percent	**Yes**[2]	**No**	**Yes**	**Yes**
Development that adds more than 5,000 square feet of impervious cover and disturbs more than 5 acres of land but the project impervious cover is less than 15%	**Yes**[2]	**Yes**[1]	**Yes**	**No**

CZ = Contributing Zone

Disturb = land that is modified by construction and/or land grading activities

[1] Alternate Standards Compliance can be used which includes ribbon curb, open drainage systems, rainwater harvesting, pervious pavement, rain gardens, and other low impact development measures to avoid the construction of structural water quality controls (ponds, etc.). Or, conventional stormwater systems can be used.

[2] Erosion control plan per the TCEQ Edwards Contributing Zone Plan

Notes

- Creek buffer zones are not part of the TCEQ Edwards Aquifer Protection Plan requirements but are included in the City water quality regulations.

- Hays County does not require creek buffer zones at this time, but they are included in the draft Hays County Drainage Criteria Manual that will be considered for adoption by the Commissioners Court in 2020.

- Sites that disturb less than 5 acres are not required to obtain TCEQ Contributing Zone Plan (CZP) approval.

- Sites that disturb more than 5 acres and add less than 20% impervious cover must submit a CZP to the TCEQ for their review and approval. However, permanent water quality measures are not required in the CZP application but will be addressed by the appropriate City water quality ordinance.

3.0 Design and Plan Review Guide

Erosion and Sediment Control

Erosion and sedimentation shall be controlled throughout the entire development process in accordance with the TCEQ Edwards Aquifer Manual.

Preparation of and adherence to a TCEQ Stormwater Pollution Prevention Plan (SWPPP) shall be considered to meet the requirement for erosion and sedimentation control. The permittee shall make the SWPPP inspection reports and records available to City staff upon request.

Site disturbance must be phased to limit soil erosion and final stabilization shall be accomplished with each phase.

Sediment basins are required for drainage areas serving at least 10 acres and are sized to capture the runoff from the 2-year 24-hour storm (8,000 cubic feet per acre). The runoff shall be detained for a minimum of 48 hours. Sediment basins cannot be installed in drainage areas greater than 40 acres and are not allowed in the Water Quality Buffer Zone.

Water Quality Buffer Zones

Natural buffer areas adjacent to creeks and drainage ways play an important role in maintaining pre-development water quality. The riparian vegetation stabilizes stream channels and floodplain areas, reducing the potential for creek erosion. In addition, they provide an area to filter overland flow from adjacent development projects. This filtering is beneficial during construction to retain sediment from up-gradient disturbed areas and also after construction as a BMP to polish stormwater discharged from water quality basin.

There are many benefits provided by riparian buffer systems. Some of those benefits include:

- Increases pollutant removal,
- Increases the distance of impervious areas from the drainage/creek,
- Moderates overland flow,
- Discourages excessive storm drain systems,
- Increases property values,
- May prevent severe rates of soil erosion,
- Minimizes disturbance to steep slopes,
- Mitigates creek warming,
- Provides effective flood control,
- Helps protect nearby properties from the shifting and widening of the stream channel that occurs over time,

- Reduces small drainage problems and complaints by residents that are likely to experience backyard flooding, and
- Serves as the foundation for present or future greenways,

The purpose of the riparian buffer is to adequately protect waterways and aquatic resources from the short and long-term impacts of development activities by providing a contiguous protection zone along the riparian corridor that is associated with natural drainage features. In many creeks, streams, and rivers, the floodplain is an integral part of the stream-riparian ecosystem. Due to natural topography and geomorphology, some streams are constrained to narrow valleys or ravines.

A riparian buffer approach is an effective tool to reduce overland flow to streams; however, riparian buffer effectiveness is dependent on the condition of the watershed and should be used in concert with upslope watershed management efforts.

Water quality buffer zones shall remain free of construction, development, or other alterations except for utility and roadway crossings and wastewater lines that are a minimum of 100 feet from the creek centerline. The number of crossings should be minimized and be perpendicular to the buffer zone. No stormwater treatment facilities, golf courses, septic systems, or wastewater irrigation shall be located in the buffer zone. Allowances in the buffer zone include low impact development parks, hike and bike trails, restoration of natural vegetation, water quality monitoring devices, fences that do not obstruct flow, private drives, and regional detention for the purpose of flood management.

There are two options to define the water quality buffer zone (WQBZ) limits.

Option 1 – Setbacks

A water quality buffer zone is established along each waterway with the specified contributing (watershed drainage) area as follows.

(a) *Greater than 5 acres and up to 40 acres and excluding roadside swales.* The WQBZ shall extend a minimum of 25 feet from either side of the centerline of the waterway (total of 50 feet of buffer zone) This buffer zone category will not apply within the City Limits.

(b) *Greater than 40 acres and up to 128 acres.* The WQBZ shall extend a minimum of 50 feet from either side of the centerline of the waterway (total of 100 feet of buffer zone).

(c) *Greater than 128 acres and up to 320 acres.* The WQBZ shall extend a minimum of 100 feet from either side of the centerline of the waterway (total of 200 feet of buffer zone).

(d) *Greater than 320 acres and up to 640 acres.* The WQBZ shall extend a minimum of 200 feet from either side of the centerline of the waterway (total of 400 feet of buffer zone).

(e) *Greater than 640 acres.* The WQBZ shall extend a minimum of 300 feet from either side of the centerline of the waterway (total of 600 feet of buffer zone)

Option 2 – Floodplain Buffer Zone

For creeks or rivers draining less than 40 square miles but more than five acres, excluding roadside swales, the WQBZ shall extend a minimum of 25 feet from the 100-year floodplain boundary paralleling each side of the creek or river. The 100-year floodplain shall be based on modeling approaches as approved by the City Engineer. For creeks or rivers draining more than 40 square miles, the WQBZ shall be considered equal to the 100-year floodplain as designated by the Federal Emergency Management Agency or by an engineered floodplain study approved by the City Engineer.

<u>Pre-Development Planning</u>

Site Planning Process

Preventing problems is much more efficient and cost-effective than attempting to correct problems after the fact. Sound land use planning decisions based on the site planning principles discussed in this section are essential as the first, and perhaps the most important, step in managing construction and post-development runoff problems. All new development plans (e.g., subdivisions, shopping centers, industrial parks, office centers) and redevelopment plans should be based upon accurate topographic data, up-to-date aerial photographs, field reconnaissance of the site, and knowledge of unique resources that serve as an amenity and add value to the project. Site planning can then proceed to minimize drainage impacts, avoid the concentration of flow to the maximum extent practical, and use the natural topography and vegetation to manage stormwater quality and quantity. Comprehensive site planning can reduce impervious cover and stormwater runoff volume, potentially gaining compliance with Alternate Standards and avoiding the need for costly structural water quality basins. In the end, good site planning can protect the natural resources, increase the project financial return, yet minimize long-term maintenance and liability issues.

Developing a site plan requires a careful step-by-step analytical approach, which often includes the following steps:

- Conduct a site evaluation. Assess existing natural features and determine suitability for the proposed development activity.
- Develop site maps. These allow visual inspection and analysis of site features and their relationship to alternative site development plans. The maps should include topographic maps, aerial photographs, slope maps, soil maps, and utility information.
- Review site plan goals. Goals should properly address requirements of local, state and federal laws, ordinances, permitting regulations, comprehensive plans, and land development codes.
- Develop and integrate the individual components of the site plan. Each component should include goals, desired performance, design considerations for chosen BMPs, operation and maintenance needs, costs, and scheduling.

Stormwater Runoff Planning

The following guidance details considerations in stormwater runoff planning which should be based on and support a plan for the entire drainage basin.

a. The runoff management system should mimic and use the features and functions of the natural runoff system, which is largely capital, energy, and maintenance cost free.

b. Each development plan should carefully map and identify the existing natural system.

c. In parking areas, pervious cover designs such as porous pavement, geogrid blocks, and grass cover should be incorporated into the site plan.

d. Runoff should not be discharged directly to receiving waters. Runoff should be routed over a longer distance, through grassed conveyances (swales), vegetated buffers, creek buffers, and other practices that increase overland sheet flow.

e. Plan, construct, and stabilize runoff management systems, especially those emphasizing vegetative practices, before development.

f. Design the runoff management system beginning with the project's outlet or point of outflow.

g. Whenever possible, follow the topography to construct the components of the runoff management system. This step will minimize erosion and stabilization problems caused by excessive velocities.

h. Whenever practical, integrate multiple-use storage into the management system. Recreational areas (e.g., ballfields, tennis courts, volleyball courts), greenbelts, neighborhood parks, and even parking facilities provide excellent settings for runoff storage.

i. Retain vegetated buffer strips in their natural state and protect the buffer zones along the banks of all water bodies.

j. Maintain the runoff management system. Failure to provide proper maintenance reduces the system's pollutant removal efficiency and hydraulic capacity.

k. Provide financing mechanisms for maintenance activities. All BMPs require maintenance to assure proper functioning.

l. Preserve and mimic the natural runoff system by routing roof runoff to pervious areas, using grassy swales instead of storm drains, and use landscaping techniques to retain runoff.

m. Consider using the characteristic "stair step" topography of the Hill Country to mitigate the increase in runoff from developed areas. Guidance is found in this manual.

The following table can be used to aid in site planning and preparing the pre- development planning meeting.

Pre-Development Planning Checklist

Complete	Development Layout	Comments	Complete	Impervious Cover Management	Comments
	Property map			Reduce street width	
	Aerial Photograph Overlay			Reduce street length	
	Topographic Map Overlay			Sidewalks on one side of the street	
	Soils map overlay			Shorter driveways	
	Delineate floodplains			Shared driveways and parking areas	
	Delineate creek buffers			Reduced cul-de-sac radii	
	Identify natural areas, wetlands, terraces			Vegetated remote or overflow parking	
	Identify steep slopes (> 10%)				
	Recharge and discharge				
	Identify natural areas (terraces, meadows, deep soil areas) for stormwater management			Cluster development	
	Thorough field reconnaissance of site			Reduce setbacks and frontage	
	Locate natural resources, specimen trees, seeps, bluffs, and other features			Flexible minimum lot sizes	
	Layout roads along the ridge line			Disconnected roof down spouts	
	Minimize road crossings of creeks			Roadside swales instead of curb and Gutter	
	Avoid using roads as first order tributaries			Pervious pavement	

Complete	Development Layout	Comments	Complete	Impervious Cover Management	Comments
	Use roadside swales, not curb and gutter			Rainwater collection	
	Define existing drainage			Native landscaping	
	Hydrologic design to mimic natural drainage				
	Avoid concentrated flow, maintain sheet flow			Natural area preservation	
	Achieve compliance with Alternate Standards			Use stormwater credits to achieve alternative standards compliance	
	Locate water quality basins at discharge points			Use stormwater credits to reduce water quality basin	
	Select low maintenance BMPs with a good				
	Prepare landscape plan for water quality basins using native plants				
	Complete the erosion control site rating form				

4.0 Construction-Phase Erosion and Sediment Control

Introduction

This section provides guidance on planning the construction erosion control and site stabilization plan. Techniques are included to assist in rating development sites for erosion potential and suggesting the appropriate erosion and sediment control BMPs to manage construction sites and promote rapid vegetation growth.

Erosion and Sediment Control Planning

The following planning and construction practices were described by the U.S. Environmental Protection Agency (EPA, 1993) and North Carolina (North Carolina, 1993) to illustrate the types of measures that can be applied successfully to achieve a reduction in the amount of erosion occurring on active construction sites. These practices are used to reduce the amount of sediment that is detached during construction and to prevent sediment from entering runoff. **Erosion control is based on two main concepts:**

(1) disturb the smallest area of land possible for the shortest period of time, and

(2) stabilize disturbed soils to prevent erosion from occurring.

Development Siting

Review and consider all existing conditions in the initial site selection for the project. Select a site that is suitable rather than force the terrain to conform to development needs. Figure 1 illustrates a sound grading approach on the left and a destructive approach on the right. Ensure that development features follow natural contours. Steep slopes, areas subject to flooding, and highly erodible soils severely limit a site's use, while level, well- drained areas offer few restrictions. Any modification of a site's drainage features or topography requires protection from erosion and sedimentation. Instead, performance of careful planning to integrate natural landforms into the development plan will reduce erosion and sediment control costs and requirements.

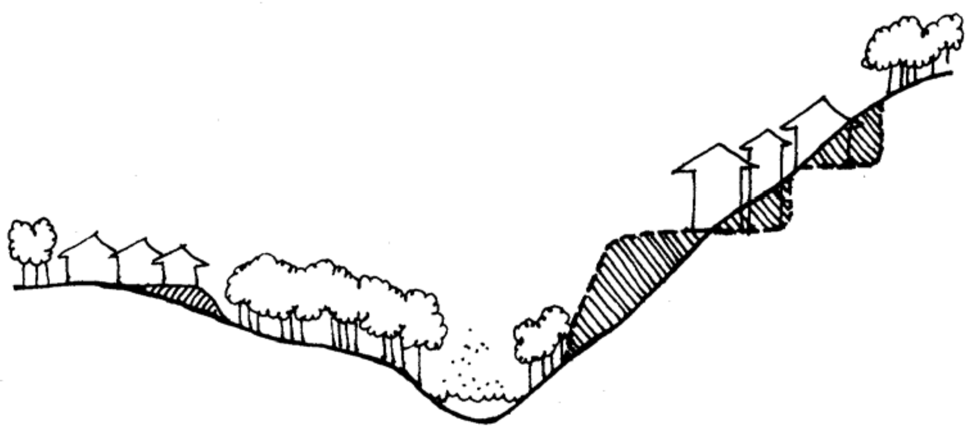


Figure 25 Examples of Proper and Improper Siting (Proper approach on the left bank, improper approach on the right bank)

Project Scheduling

Often a project can be scheduled during the time of year that the erosion potential of the site is relatively low. In central Texas, rainfall amounts are generally lower during July and August and the hot temperatures quickly dry out exposed soils. During the wetter months (spring and fall), construction vehicles can easily turn the soft, wet ground into mud, which is more easily washed offsite.

Scheduling can be a very effective means of reducing the hazards of erosion. Schedule construction activities to minimize the exposed area and the duration of exposure. In scheduling, take into account the season and the weather forecast. Stabilize disturbed areas as quickly as possible.

Avoid area wide clearance of construction sites. Plan and stage land disturbance activities so that only the area currently under construction is exposed. As soon as the grading and construction in an area are complete, the area should be stabilized and/or vegetated.

Material Management

Locate potential pollutant sources away from steep slopes, streams, and critical areas. Material stockpiles, borrow areas, access roads, and other land-disturbing activities can often be located away from critical areas such as steep slopes, highly erodible soils, and areas that drain directly into geologically sensitive features. The exposure of litter, construction debris, and chemicals to stormwater should be minimized to prevent them from becoming a pollutant source. Daily litter removal and screening outfalls and storm drain inlets may help retain these materials onsite.

Stockpile topsoil and reapply to revegetate site. Because of the high organic content of topsoil, it cannot be used as fill material or under pavement. Topsoil is typically removed when a site is cleared. Since topsoil is essential to establish new vegetation and typically contains native viable seed material, it should be stockpiled and then reapplied to the site for revegetation, if appropriate. Although topsoil salvaged from the existing site can often be used, it must meet certain standards and topsoil may need to be imported onto the site if the existing topsoil is not adequate for establishing new vegetation.

Apply temporary erosion controls such as silt fence and berms around stockpiles to prevent sediment wash-off. In addition, spoils should not be stored within the 100-year floodplain where they can be disturbed during high flow conditions.

Vegetation Protection

By clearing only those areas immediately essential for completing site construction, buffer zones are preserved and soil remains undisturbed until construction begins (Figure-2). Physical markers, such as tape, signs, or barriers, indicating the limits of land disturbance, can ensure that equipment operators know the proposed limits of clearing. The area of the watershed that is exposed to construction is important in determining the net amount of erosion. Reducing the extent of the disturbed area will ultimately reduce sediment loads to surface waters. Existing or newly planted vegetation that has been planted to stabilize disturbed areas should be protected by routing construction traffic around the areas and protecting natural vegetation with fencing, tree armoring, retaining walls, or tree wells. Avoid disturbing vegetation on steep slopes or other critical areas.

Where possible, construction traffic should travel over areas that must be disturbed for other construction activity. This practice will reduce the area that is cleared and susceptible to erosion.

Tree armoring protects tree trunks from being damaged by construction equipment. Fencing can also protect tree trunks, but should be placed at the tree's drip line so that construction equipment is kept away from the tree. The tree drip line is the minimum area around a tree in which the tree's root system should not be disturbed by cut, fill, or soil compaction caused by heavy equipment. When cutting or filling must be done near a tree, a retaining wall or tree well should be used to minimize the cutting of the tree's roots or the quantity of fill placed over the roots.

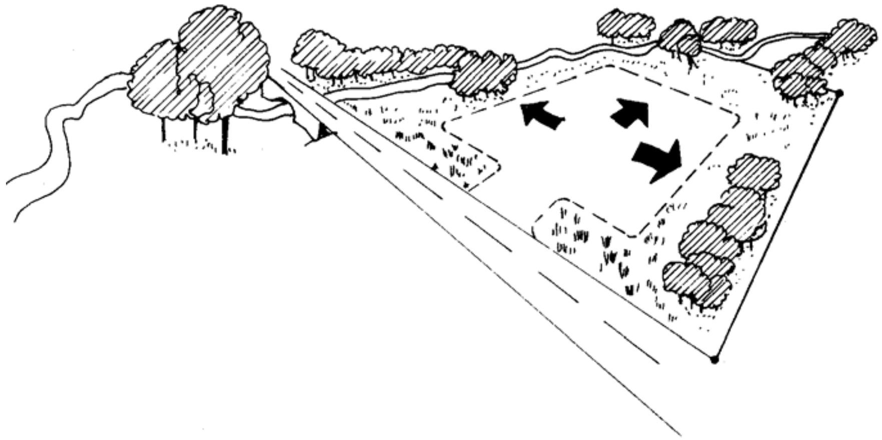


Figure 26: Example of Conservative Site Clearing

Protect Area from Upgradient runoff

Protect areas to be disturbed from stormwater runoff. Use dikes, diversions, and waterways to interrupt runoff and divert it away from cut-and-fill slopes or other disturbed areas. To reduce on-site erosion, install these measures before clearing and grading.

Earth dikes, perimeter dikes or swales, or diversions can be used to intercept and convey runoff above disturbed areas (Figure 3). An earth dike is a temporary berm or ridge of compacted soil that channels water around or away from disturbed areas. A perimeter dike/swale or diversion is a swale with a supporting ridge on the lower side that is constructed from the soil excavated from the adjoining swale. These practices should be used to intercept flow from denuded areas or newly seeded areas to keep the disturbed areas from being eroded from the uphill runoff. The structures should be stabilized within 14 days of installation or as soon as practicable with vegetation, slope coverings or other appropriate erosion prevention measures. A pipe slope drain is a temporary pipe placed from the top of a slope to the bottom of the slope to convey concentrated runoff down the slope without causing erosion.

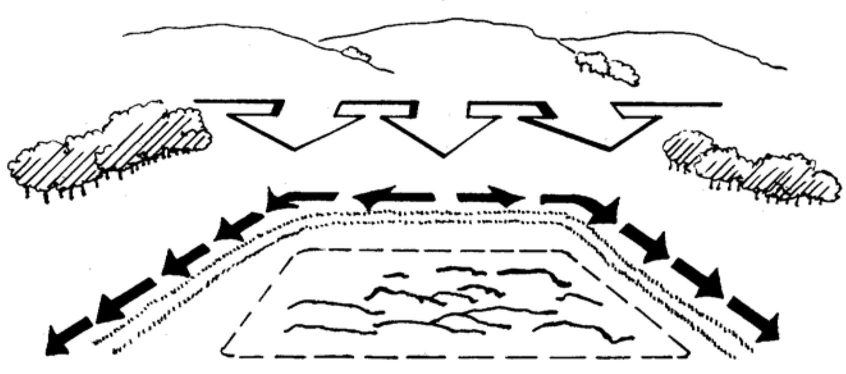


Figure 27: Diversion of Runoff away from Construction Area

Reduce Runoff Velocities

Keep runoff velocities low. Clearing existing vegetation reduces the surface roughness and infiltration rate and thereby increases runoff velocities and volumes. Use measures that break the slopes (Figure 4) to reduce the problems associated with concentrated flow volumes and runoff velocities. Practical ways to reduce velocities include conveying stormwater runoff away from steep slopes to stabilized outlets, preserving natural vegetation where possible, and mulching and vegetating exposed areas immediately after construction.

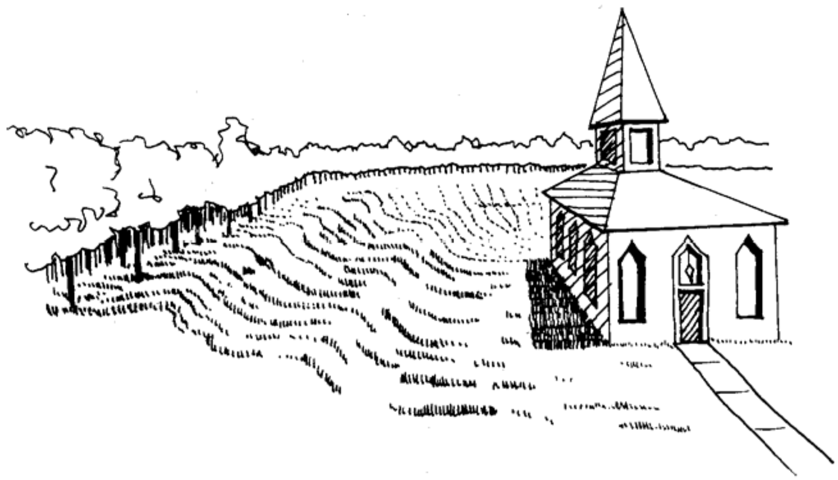


Figure 28: Slow Runoff by Breaking Slopes

Benches, terraces, or ditches break up a slope by providing areas of low slope in the reverse direction. This keeps water from proceeding down the slope at increasing volume and velocity. Instead, the flow is directed to a suitable outlet, such as a sediment basin or trap. The frequency of benches, terraces, or ditches will depend on the erodibility of the soils, steepness and length of the slope, and rock outcrops. This practice should be used if there is a potential for erosion along the slope.

Use retaining walls. Often retaining walls can be used to decrease the steepness of a slope. If the steepness of a slope is reduced, the runoff velocity is decreased and therefore, the erosion potential is decreased. Retaining walls also may actually encourage water to infiltrate rather than runoff, thereby helping maintain the natural hydrologic characteristics of a site.

Provide linings for urban runoff conveyance channels if necessary. Construction often increases the velocity and volume of runoff, which causes erosion in newly constructed channels. If the runoff during or after construction has excessive velocities, the designer can use the guidance in Chapter 3 to select the appropriate flow control BMP. The first choice of lining should be grass or sod since this reduces runoff velocities and provides water quality benefits through filtration and infiltration. If the velocity in the channel would erode the grass or sod, then soil protection blankets, riprap, or gabions can be used.

Use check dams. Check dams are small, temporary dams constructed across a swale or channel. They can be constructed of gravel and rock berms. They are used to reduce the velocity of concentrated flow and, therefore, to reduce the erosion in a swale or channel.

Site Stabilization

Removing the vegetative cover and altering the soil structure by clearing, grading, and compacting the surface increases an area's susceptibility to erosion. Apply stabilizing measures as soon as possible after the land is disturbed (Figure 5). Plan and implement temporary or permanent vegetation, mulches, or other protective practices to correspond with construction activities. Protect channels from erosive forces by using protective linings and the appropriate channel design. Consider possible future repairs and maintenance of these practices in the design.

Seeding establishes a vegetative cover on disturbed areas. Seeding is very effective in controlling soil erosion once a vegetative cover of about 80% has been established. However, often seeding and fertilizing do not produce as thick a vegetative cover as do seed and mulch or netting. Newly established vegetation does not have as extensive a root system as existing vegetation and therefore is more prone to erosion, especially on steep slopes. Care should be taken when fertilizing to avoid untimely or excessive application. Since the practice of seeding and fertilizing does not provide any protection during the time of vegetative establishment, it should be used only on favorable soils in very flat areas and not in sensitive areas.

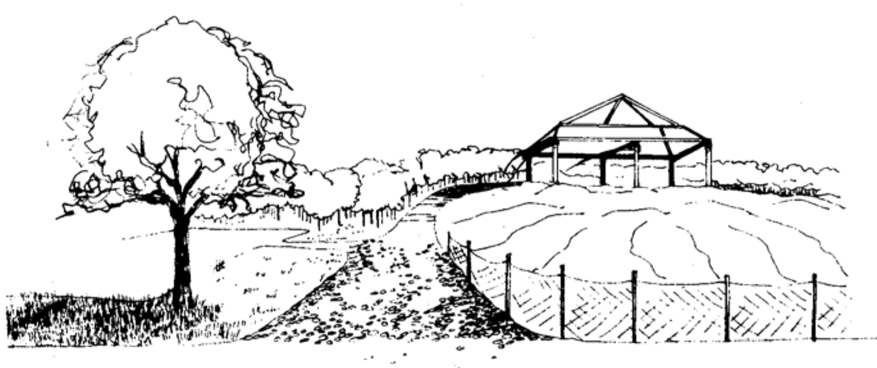


Figure 29: Stabilization of Disturbed Areas

The management of land by using ground cover reduces erosion by reducing the flow rate of runoff and the raindrop impact. Bare soils should be seeded or otherwise stabilized within 14 calendar days after final grading or where construction activity has temporarily ceased for more than 21 days. In very flat, non-sensitive areas with favorable soils, stabilization may involve simply seeding and fertilizing. Mulch and/or sod may be necessary on steeper slopes, for erodible soils, and near sensitive areas. Sediment that has escaped the site due to the failure of sediment and erosion controls should be removed as soon as possible to minimize offsite impacts. Permission should be obtained from adjacent landowners prior to offsite sediment removal.

Mulching/mats can be used to protect the disturbed area while vegetation becomes established. Mulching involves applying plant residues or other suitable materials on disturbed soil surfaces. Mulches/mats used include tacked straw, wood chips, and jute netting and are often covered by blankets or netting. Mulching alone should be used only for temporary protection of the soil surface or when permanent seeding is not feasible. The useful life of mulch varies with the material used and the amount of precipitation, but, is approximately 2 to 6 months.

During times of year when vegetation cannot be established, soil mulching should be applied to moderate slopes and soils that are not highly erodible. On steep slopes or highly erodible soils, multiple mulching treatments should be used. Erosion control blankets, filter fabric, and netting are available for this purpose. Before stabilizing an area, it is important to have installed all sediment controls and diverted runoff away from the area to be planted. Runoff may be diverted away from denuded areas or newly planted areas using dikes, swales, or pipe slope drains to intercept runoff and convey it to a permanent channel or storm drain. Reserved topsoil may be used to revegetate a site.

Consideration should be given to maintenance when designing mulching and matting schemes. Plastic nets are often used to cover the mulch or mats; however, they can foul lawn mower blades if the area requires mowing.

Sod can be used to permanently stabilize an area. Sodding provides immediate stabilization of an area and should be used in critical areas or where establishment of permanent vegetation by seeding and mulching would be difficult. Sodding is also a preferred option when there is high erosion potential during the period of vegetative establishment from seeding.

Because of the hardy drought-resistant nature of wildflowers, they may be more beneficial as an erosion control practice than turf grass. While not as dense as turfgrass, wildflower thatches and associated grasses are expected to be as effective in erosion control and contaminant absorption. Because thatches of wildflowers do not need fertilizers, pesticides, or herbicides, and the need for watering is minimal, implementation of this practice may result in cost savings. In 1987, Howard County, Maryland, spent $690.00 per acre to maintain turfgrass areas, compared to only $31.00 per acre for wildflower meadows. A wildflower stand requires several years to become established; however, maintenance requirements are minimal once the area is established.

Plan for Temporary Structural Controls

Retain Sediment on the Site. Even with careful planning, some erosion is unavoidable. The resulting sediment must be trapped on the site. Plan the location where sediment deposition will occur and maintain access for cleanout. Protect low points below disturbed areas by building barriers to reduce sediment loss. Whenever possible, plan and construct sediment traps and basins before other land-disturbing activities (Figure 6).

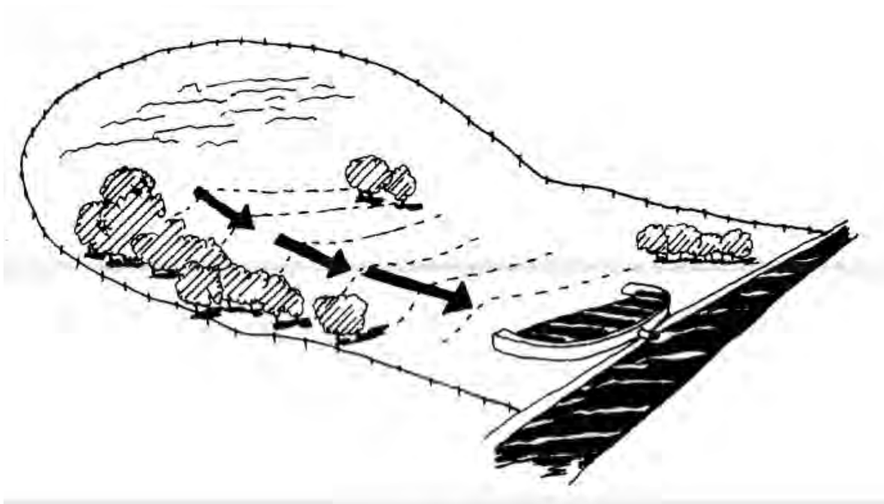


Figure 30: Retention of Eroded Sediment on Site

5.0 Development Permit/Subdivision Construction Plan Approval Submittal Information

Provide two (2) copies of documents listed below (except the application form). Electronic copies of reports and documents may be required upon request.

1. Completed application form and fee.
2. Detailed location map, description and address of the property.
3. Engineering Report – the report shall discuss site characteristics, water quality management strategies and include the following information:
   - description of site and of proposed development.
   - location and type of soils. This information can be obtained from the County Soil Survey.
   - vegetative cover map including tree and ground cover.
   - engineer's seal, signature and statement certifying that the plan is complete and in compliance with this ordinance.
   - data and calculations for water quality BMPs and associated drainage facilities, including

drainage area, impervious cover area, time of concentration, runoff coefficients and discharges for the design storms.

- description of the permanent BMPs to be implemented to achieve the performance standards for Water Quality Management.

4. Water Quality Management Plan – the plan shall include sheet(s) at an appropriate scale and in sufficient detail to ensure that permanent BMPs and associated drainage facilities are constructed in accordance with the design intent. Required information on the plan includes the following, however additional information may be required:

- existing topography.
- proposed grading and drainage patterns including drainage area maps for any offsite contributing areas (may be larger scale as needed).
- delineation of buffer zones and notes restricting activities within same.
- site layout showing all existing and proposed improvements and structures including buildings, parking areas, utilities, driveways, sidewalks, trails, etc.
- location and schematic of the Best Management Practices (BMPs).
- details for drainage system and permanent BMPs.
- permanent BMPs shall be drawn at a scale to allow readability by reviewers and contractors, and include all notes and details.

5. Erosion and Sedimentation Control (ESC) Plan – plan sheets(s) at appropriate scale showing the following information:

- existing topography.
- proposed grading and drainage patterns.
- all existing and proposed improvements and structures, including buildings, parking areas, utilities, driveways, sidewalks, trails, etc.
- limits of construction line.
- location of all access roads, haul roads, equipment storage areas, spoil and topsoil stockpile areas.
- location and schematic of temporary and permanent ESC.
- detailed sequence of construction indicating items to be constructed in each construction stage and ESC modifications to be implemented as construction progresses.
- details and specifications for ESC, and locations of controls.

- location and specifications for all structural stabilization, including stabilization of cut and fill areas.
- restoration plans for all disturbed areas on the site that include seed, sod and mulch type and rate of application; application technique; watering and fertilization schedule; criteria for acceptance of site stabilization.

  Suggested minimum scale of 1”=50’ for tracts under 100 acres, 1" = 100' for tracts 100 to 250 acres 1" = 200' for tracts 250 to 400 acres, and 1" = 400' for larger tracts. Suggested contour line interval of 2' intervals for projects up to 400 acres or 5' intervals for projects greater than 400 acres. Offsite areas can utilize USGS topographic maps at a scale of 1”= 2000’ to delineate drainage area boundaries.

6. A maintenance plan as described in the Water Quality Ordinance if permanent BMPs are included in the application.

6.0 References

Lower Colorado River Authority, Highland Lakes Watershed Ordinance, Water Quality Management Technical Manual, 2007.

Texas Commission on Environmental Quality, Edwards Aquifer Protection Program, Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices, 2005 and Errata Sheet (2009) and Addendum Sheet (2017).

Appendix IV: Cypress Creek WPP - Technical Resource Guide for the Public

Technical Resource Guide for the Public

The Cypress Creek Project

Prepared by Doucet & Associates, Inc. and The Meadows Center for Water and the Environment

Funding for this project was provided in part by the EPA through the Texas Commission on Environmental Quality

Contents

CYPRESS CREEK

Let's keep it clean, clear & flowing

DOUCET & ASSOCIATES

THE MEADOWS CENTER FOR WATER AND THE ENVIRONMENT

TEXAS STATE UNIVERSITY

Demonstration Best Management Practices (BMP) Sites in the Cypress Creek Watershed

BMPs are constructed and used to treat, prevent or reduce water pollution. They are meant to slow down stormwater runoff and remove pollution before they enter our waterways. Slowing down stormwater is important, especially in areas like the Hill Country as it experiences extreme rain events, which can cause heavily polluted runoff to enter rivers, streams, and eventually the aquifer.

BMPs can come in several different shapes, sizes, and functions. Below are the several BMPs that were installed in the Cypress Creek Watershed:

Rainwater Harvesting

- Hays County Precinct 3 Office
- Blue Hole Regional Park
- Wimberley Valley Watershed Association (WVWA) offices
- Woodcreek Golf Course

Pervious Paver

- Blue Hole Park Trail
- Blue Hole Park Main Entrance
- Blue Hole Park ADA Parking Area
- Wimberley Central Business District

Rain Garden

- Woodcreek Golf Course

Vegetated Filter Infiltration Strip

- Wimberley Valley Watershed Association offices

You can learn more information about these specific BMPs and take a virtual "tour" by viewing an online StoryMap, which can be found on our website:

www.CypressCreekProject.net

How Can Residents Help Protect Water Quality?

Adapted from "How Residents Can Help Protect Water Quality", created for the Texas General Land Office

Pet Waste Disposal

Picking up after your pet and ensuring proper disposal is a great and easy way to help protect waterways.

What are safe pet waste disposal methods?

- Pet waste can be flushed down the toilet as long as it is not mixed with other materials
- Pet waste can be disposed of in the garbage
- Pet waste can be buried in a hole 1' deep, but keep it away from gardens and compost piles

Have livestock or other large animals?

- Keep filtering vegetation between livestock and water sources. High-use areas should be away from water bodies.
- Manure and soiled bedding should be collected and sheltered from rain.

Household Hazardous Waste

Many towns and cities in Texas have designated facilities where residents can drop off hazardous waste items.

These materials should never be poured down the drain or disposed of on the ground:

- Corrosive cleaners
- Drain cleaner
- Fluorescent light bulbs
- Fuels (gasoline, propane, diesel)
- Paints
- Pesticides
- Pool chlorine and acid
- Wood stains or varnishes

Hays County citizens can drop off their hazardous waste in San Marcos on designated days:
Tuesday and Friday, 12-3:30 pm (WEEKLY)
630 East Hopkins St
San Marcos, TX 78666

Home Septic System Care

Maintaining septic systems is vital to protecting public health and the environment. Proper operation and maintenance, and occasional inspections by professionals, will keep septic systems working properly for a very long time. Even if your septic system has been maintained, you should still be aware of possible system malfunctions.

Contact a professional if any of the following occur:

- Wastewater backing up into drains
- Bright green, spongy grass on the drain field
- Pooling water or muddy soil around the septic system or in basement
- A strong, foul odor around the septic tank and drain field.

Though this list shows the possible symptoms of a system malfunction, it is possible for systems to not show any signs of malfunction above the ground surface. Having your septic system inspected by a professional periodically will ensure that the system is working properly.

Water-smart Gardening

Landscapes can be designed to take in runoff from impervious surfaces and treat the water before it runs into waterbodies. They can also be designed to reduce soil erosion.

Tips for water-smart gardening and landscapes:

- **Nurture the soil:** Healthy soil is an important part of reducing or eliminating the need for quick release fertilizers and pesticides.
- **Select the right plants:** Proper plant selection can reduce the need for synthetic pesticides and fertilizers.
- **Reduce irrigation use:** Use efficient irrigation to reduce over spray, evaporation, and runoff.
- **Use integrated pest management:** Reduce or eliminate fertilizers, pesticides and fungicides.

Rainwater Harvesting

Rain barrels and cisterns can be installed to capture and store stormwater runoff from rooftops for later use in landscape irrigation.

Rain barrels and cisterns are ideal for areas with the following characteristics:

- Roof areas that drain to downspouts
- A level, firm surface to support a rain barrel(s) or cistern and prevent shifting or falling over.
- A landscaped area where the captured can be used within a reasonable distance
- A landscaped area or safe path to the storm drain system that can handle overflow.

Proper maintenance is crucial for a functioning capture system:

- Check gutters and gutter guards regularly to make sure debris is not entering the rainwater harvesting system
- Inspect screens on the rain barrel or system for holes that would allow debris, or mosquitoes to enter the barrel
- Clean the barrel once a year, vinegar or another nontoxic cleaner can be used to clear heavier debris.

Financial Assistance and Grants for Implementation Activities

Financial Assistance, Grants for 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, http://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	http://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			
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)	http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/eqip/?cid=stelprdb1242633
Watershed Action Plan Implementation	Watershed protection	EPA	

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 WAP activities	Multiple	--
Specific Implementation, Management Measure Funding	Water quality, watershed protection, restoration, water conservation, land management and conservation, and implementation of WAP activities	Corporate, NGOs	--
Environmental Impact Bonds:			https://www.quantifiedventures.com/ https://www.cbf.org/how-we-save-the-bay/programs-initiatives/environmental-impact-bonds.html
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.		
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

Technical Assistance for Implementation Activities

Technical Assistance for Implementation Activities	
Organization	**Focus/Management Area**
National Center for Appropriate Technology, EPA, , Texas State University (facilities, Environmental Health, Safety and Risk Management), and EAHCP 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. Can share lessons learned on Waller Creek in the Shoal Creek watershed
Texas State University, TCEQ, and Texas Water Resources Institute	Technical, water quality modeling
The Meadows Center	Technical, water quality modeling
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

Como los residents pueden proteger la calidad del agua

ELIMINACIÓN DE LOS DESECHOS DE ANIMALES DOMÉSTICOS
Métodos seguros para eliminar los desechos de animales domésticos

- Retrete: Mientras las heces no se mezclen con otras materias, el desecho animal puede eliminarse por el inodoro.
- Basura: El desecho animal debe ser recogido con una bolsa de plástico y depositado en la basura si las leyes municipales lo permiten.
- Enterramiento: El desecho animal debe ser enterrado en un agujero con una profundidad de un pie. Debe mantenerse fuera de los huertos y no mezclarse con el abono.

Animales Grandes
- Mantenga la mayor cantidad de vegetación posible entre establos, corrales, etc., y cualquier cuerpo acuífero. Las áreas muy transitadas deben estar alejadas de los cuerpos acuíferos.
- El estiércol y el heno contaminado deben ser recogidos y almacenados cuando llueva.

DESECHOS TÓXICOS DOMÉSTICOS
Muchos pueblos y ciudades de Texas tienen instalaciones específicas donde los residents pueden depositar desechos tóxicos.

Dichos materiales no se deben verter por el desagüe o ser depositados en el suelo o el Sistema de drenaje pluvial:
- Limpiadores corrosivos
- desastacadores
- bombillas de luz fluorescente
- carburantes (gasolina, propano, diesel)
- pintura
- pesticidas
- cloro de piscina y ácido
- barnizantes y tintes para madera

EL CUIDADO DEL SISTEMA SÉPTICO DOMÉSTICO
Los olores fétidos no son el único indicio de un mal funcionamiento del sistema séptico**.**

Debe ponerse en contacto con un técnico en cualquiera de los siguientes casos:
- Las aguas residuales regresan a la boca del desagüe.
- Aparición del césped o hierba mullida y de color verde vivo en el campo de drenaje, incluso en épocas de sequía.
- Agua encharcada o suelos fangosos alrededor del tanque séptico y del campo de drenaje.
- Olor penetrante alrededor de la fosa séptica y del campo de drenaje.

JARDINERÍA EFICIENTE PARA LA CONSERVACIÓN DEL AGUA

La planificación de zonas verdes que reciben vertidos de agua de lluvia procedente de calles y otras superficies duras puede ayudar a reducir la erosión del suelo y proteger los procesos naturales del suelo que descomponen las substancias contaminantes.

- **Nutrición del suelo:** Desarrollar y mantener un suelo saludable es una parte importante a la hora de reducir o eliminar la necesidad del uso de fertilizantes de liberación rápida y de pesticidas.
- **Seleccione las plantas apropiadas:** La selección de las plantas apropiadas puede reducir la necesidad de recurrir a pesticidas sintéticos y fertilizantes.
- **Reduzca el uso de irrigación:** Use un sistema de irrigación eficiente para reducir el rociado excesivo de agua, la evaporación y el vertido.
- **Manejo integrado de pesticidas:** Reduzca o elimine fertilizantes, pesticidas y fungicidas

RECOLECCIÓN DE AGUA DE LLUVIA

Los barriles de agua y las cisternas pueden instalarse para recolectar agua de lluvia de los tejados y guardarse para ser empleados posteriormente en regadío.

Los barriles de lluvia y las cisternas son idóneas para áreas de las siguientes características:

- Áreas del tejado cuyo drenaje se hace a través de los canalones.
- Una superficie plana y firme para soportar el barril de lluvia o una cisterna para evitar el desplazamiento.
- El área ajardinada donde se va a usar el agua recolectada (y donde se puede realizar el drenaje mediante el flujo gravitatorio) debe estar localizada a una distancia razonable del barril de lluvia.
- Un área ajardinada o una ruta segura al sistema de drenaje pluvial que pueda soportar un desbordamient.

Operación y mantenimiento:

- Los canalones y las rejillas protectoras deben inspeccionarse regularmente para asegurar que la broza y la suciedad no se infiltran en el sistema de recolección del agua de lluvia.
- Las rejillas en el barril de lluvia o la cisterna se deben inspeccionar para asegurar que la broza y la suciedad no se acumula en la superficie y que no hay agujeros por los cuales los mosquitos puedan meterse en el barril. Inspeccione las rejillas con mayor frecuencia si hay árboles que depositan broza en el tejado.
- El interior del barril de lluvia debe limpiarse una vez al año para evitar la acumulación de broza y de suciedad. Si la suciedad no puede eliminarse con un aclarado, debe usarse vinagre o un limpiador no tóxico

Appendix V: Cypress Creek WPP – Executive Summary

CYPRESS CREEK PROJECT

Task #5877 Subtask 5.2 – WPP Report

EXECUTIVE SUMMARY

Throughout the implementation of the current contract period, the Cypress Creek Project team has worked on a variety of projects that support the vision of ensuring a clean, clear, and flowing Cypress Creek for the Wimberley Valley region. This was done through many different avenues, including hosting informative public workshops to educate local stakeholders on ways to prevent non-point source pollution, quarterly water quality monitoring, and installing Best Management Practices (BMPs) throughout the watershed.

From August 2017 to October 2017, The Meadows Center for Water and the Environment at Texas State University, in conjunction with the City of Wimberley and Texas A&M University, conducted a 3-month Bacterial Source Tracking (BST) study to determine the source(s) of elevated E. coli bacteria discovered in Cypress Creek near downtown Wimberley. Results from the BST found the source of elevated E. coli levels to be a result of livestock and wildlife. Based on the findings, two sites were determined as ideal locations for implementation of best management practices. Earlier in the summer, The Meadows Center and Aqua Texas visited the location of a collapsed feature on a dam on Cypress Creek in the Woodcreek area. A dye-test was conducted to find the exact locations of the collapse, and results of samples collected upstream and downstream of the dam showed that bacteria levels were not exceeding state standards..

We also hosted several workshops and meetings in 2017 for local stakeholders, including the Blanco River/Onion Creek Water Forum where over 100 attendees who live in the area gathered to find common ground and discuss resolutions for current and future water issues in the watershed. The Texas Well Owner Network, a program run by Texas A&M AgriLife Extension, also hosted a "Well Educated" workshop to educate Wimberley residents about managing household wells, improving and protecting water resources, septic system maintenance, well maintenance and construction, and water quality treatment.

Team members continued monitoring efforts throughout 2018, collecting water quality data on a quarterly basis at several different locations along Cypress Creek and the Blanco River. Five workshops were hosted for stakeholders, including the Soil for Water workshop where attendees learned about soil and range management techniques, riparian restoration techniques and riparian ecosystem monitoring. Participants learned how to improve the condition of their land, store more water on-site, increase biodiversity and productivity, and how to reduce the effects of drought and flooding. The newly created Central Texas Feral Hog Task Force also lead a workshop, where attendees learned about how feral hogs can degrade waterways and different management techniques. 2018 also saw the first of many BMPs to be completed, a rainwater harvesting system at the Patsy Glenn Wildlife Refuge.

Map of 2017 Bacterial Source Tracking Study

Dye Tracing Event at the Woodcreek Dam

Blanco River/Onion Creek Forum

The Meadows Center for Water and the Environment
Texas State University

MeadowsCenter@txstate.edu
www.MeadowsWater.org

Rainwater Harvesting Systems installed at the Patsy Glenn Wildlife Refuge

In 2019, much of our efforts focused on completing the remaining BMPs in the Wimberley Valley region. Rainwater harvesting systems, permeable pavers, and rain gardens were installed at the Wimberley Valley Watershed Association (WVWA) headquarters, Blue Hole Regional Park, the Woodcreek Community Golf Course, and downtown Wimberley. The Meadows Center along with WVWA spearheaded a design for a new primary school that would use 90 percent less water than a traditional school would use. The design also includes several green stormwater infrastructure features that support our mission of keeping Cypress Creek clean, clear, and flowing. The design was selected by the district's board of trustees, and construction for the new campus began in July. We continued quarterly water quality monitoring, and held three more educational workshops for local stakeholders to learn about their watershed and how to protect it.

As the contract is coming to an end, the Cypress Creek team is wrapping up several projects. The last BMP to be completed - a hybrid vegetated filter strip/raingarden at the WVWA headquarters – as well as educational signage for all the other projects are set to be constructed and installed by the end of October 2019. We are also producing a self-guided, informative tour of all BMPs in the watershed to be viewed on a mobile device or desktop, which is set to be published by the end of November.

The next phase of the Cypress Creek Project will focus on a transition to more local ownership and sustainability. An interlocal agreement among key stakeholders will be sought to ensure technical and financial resources are in place to continue water quality monitoring and BMP implementation. A One Water approach to watershed management will remain the critical, long-term strategy for a clean, clear and flowing Cypress Creek.

Rain garden at Woodcreek Community Golf Course just after completion, pre-plant establishment

Permeable Paver parking lot in Downtown Wimberley

Rainwater Harvesting System installed at WVWA Headquarters

Permeable paver sidewalk at Blue Hole Regional Park

The Meadows Center for Water and the Environment
Texas State University

MeadowsCenter@txstate.edu
www.MeadowsWater.org

Appendix VI: Cypress Creek WPP – NPS Prevention Guide

Figure 1: Cypress Creek Watershed NPP Prevention Guide (Front)

The Cypress Creek Watershed

Know Your Watershed

Cypress Creek is a tributary of the Blanco River in Hays County. The upper portion of the creek is ephemeral and dominated by undeveloped terrain. The lower portion contains a concentration of urban land as it passes through the towns of Woodcreek and Wimberley before meeting the Blanco River. Jacob's Well, an iconic artesian spring, provides Cypress Creek with the crystal-clear flows that many consider the lifeblood of the Wimberley Valley. The source of water for Jacob's Well is the Trinity aquifer, an underground reservoir that has been impacted by excessive pumping to support growth throughout the county. Flows from Jacob's Well will continue to diminish unless proactive steps are taken to preserve this invaluable resource.

WHY DOES CYPRESS CREEK NEED A WATERSHED PROTECTION PLAN?

- Population growth is increasing water consumption, which negatively affects aquifer recharge.
- Reduced groundwater affects water quality, limiting swimming and fishing.
- Wimberley Valley tourism depends on the health of Jacob's Well, Cypress Creek, and Blue Hole. If they cease to flow with clean & clear water, the local economy will dry up with the creek.
- Protecting the creek and watershed lessens impacts of droughts and floods.

WATERSHED FACTS:

DRAINAGE AREA:
38.3 sq miles / 24,486 acres

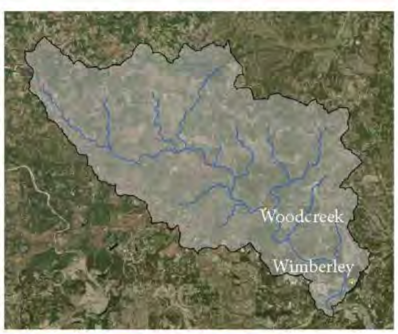
100-YR FLOODPLAIN AREA:
2.30 sq miles / 1472 acres

STREAM LENGTH: 15.7 miles

SOIL TYPES:
Bolar, Brackett, Comfort, and Doss

LAND COVER:

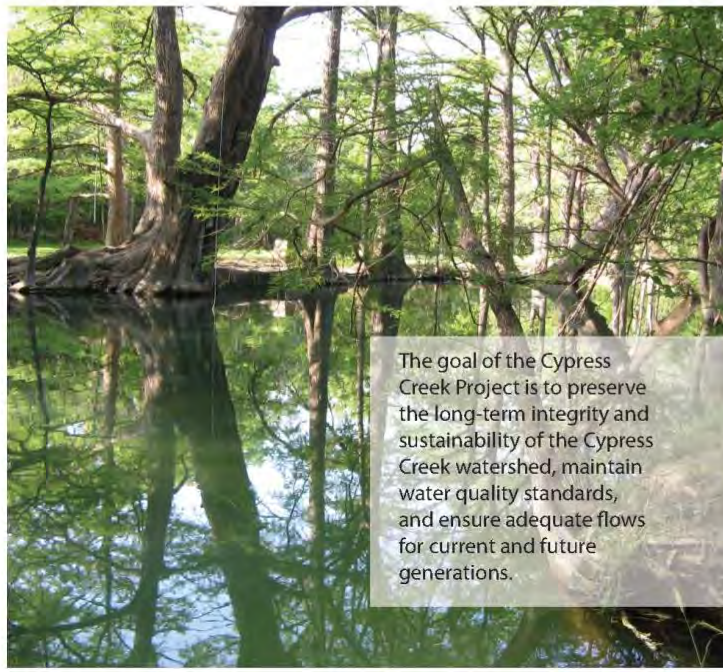
- 45% Mixed Forest
- 31% Shrub / Scrub
- 10% Evergreen Forest
- 10% Developed
- 6% Herbaceous



WWW.CYPRESSCREEKPROJECT.NET

Nonpoint Source Pollution Prevention

RESOURCE GUIDE

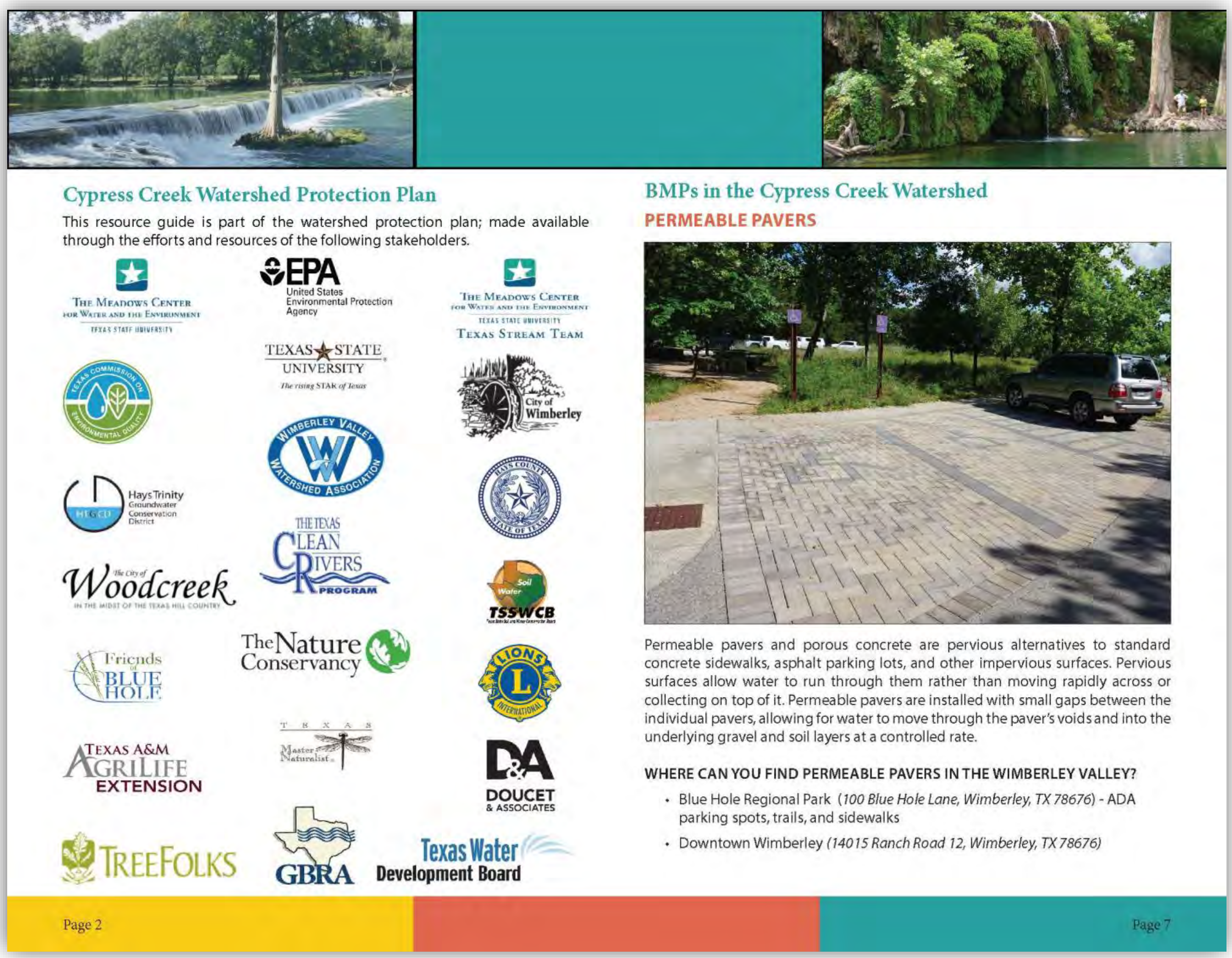


CYPRESS CREEK

Let's keep it clean, clear & flowing

Funded in part through a grant from the U.S. Environmental Protection Agency through the Texas Commission on Environmental Quality.

Figure 2: Cypress Creek Watershed NPP Prevention Guide (pages 2 and 7)



Cypress Creek Watershed Protection Plan

This resource guide is part of the watershed protection plan; made available through the efforts and resources of the following stakeholders.

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BMPs in the Cypress Creek Watershed

PERMEABLE PAVERS

Permeable pavers and porous concrete are pervious alternatives to standard concrete sidewalks, asphalt parking lots, and other impervious surfaces. Pervious surfaces allow water to run through them rather than moving rapidly across or collecting on top of it. Permeable pavers are installed with small gaps between the individual pavers, allowing for water to move through the paver's voids and into the underlying gravel and soil layers at a controlled rate.

WHERE CAN YOU FIND PERMEABLE PAVERS IN THE WIMBERLEY VALLEY?

- Blue Hole Regional Park (*100 Blue Hole Lane, Wimberley, TX 78676*) - ADA parking spots, trails, and sidewalks
- Downtown Wimberley (*14015 Ranch Road 12, Wimberley, TX 78676*)

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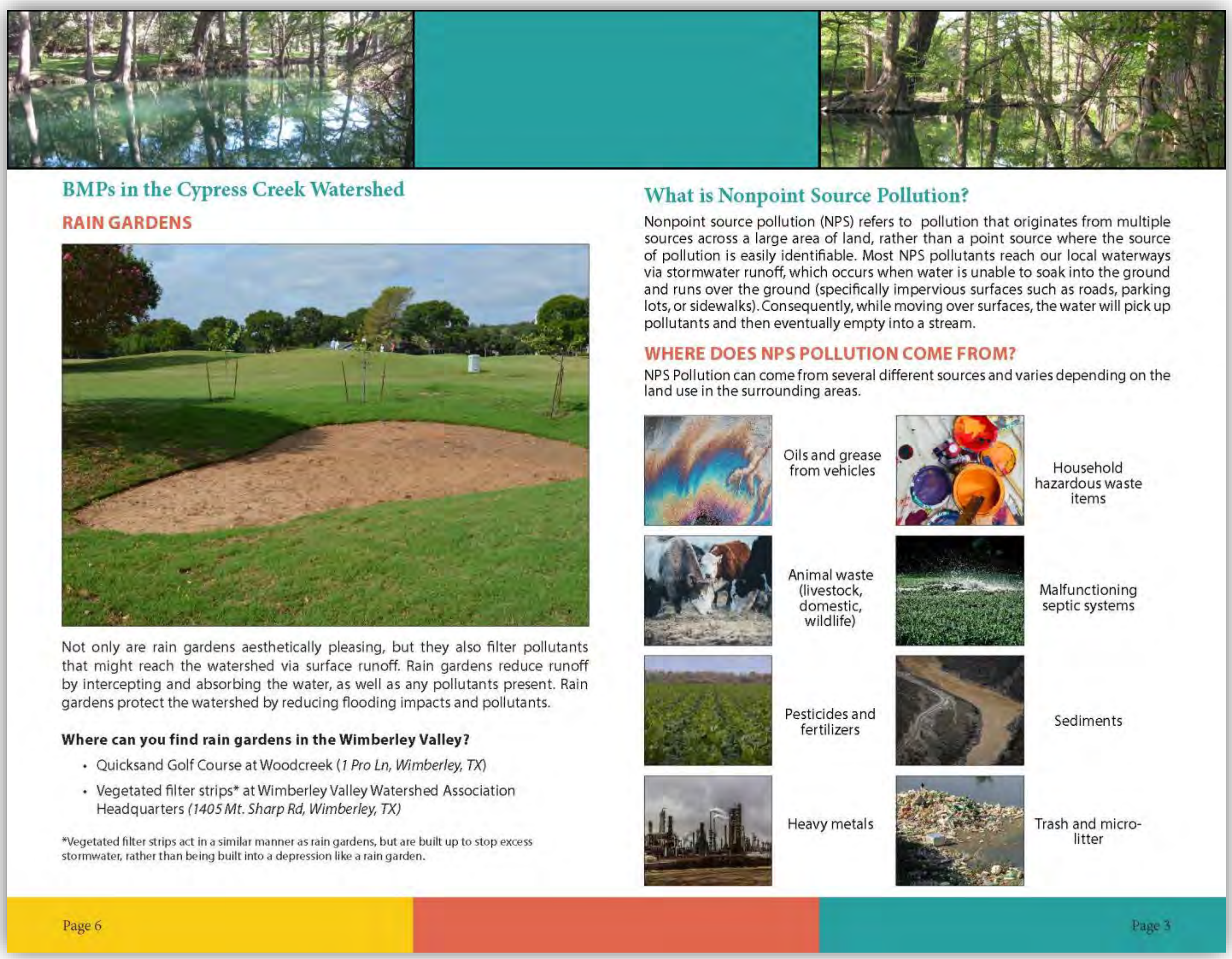
Figure 3: Cypress Creek Watershed NPP Prevention Guide (pages 6 & 3)



BMPs in the Cypress Creek Watershed

RAIN GARDENS

Not only are rain gardens aesthetically pleasing, but they also filter pollutants that might reach the watershed via surface runoff. Rain gardens reduce runoff by intercepting and absorbing the water, as well as any pollutants present. Rain gardens protect the watershed by reducing flooding impacts and pollutants.

Where can you find rain gardens in the Wimberley Valley?

- Quicksand Golf Course at Woodcreek (*1 Pro Ln, Wimberley, TX*)
- Vegetated filter strips* at Wimberley Valley Watershed Association Headquarters *(1405 Mt. Sharp Rd, Wimberley, TX)*

*Vegetated filter strips act in a similar manner as rain gardens, but are built up to stop excess stormwater, rather than being built into a depression like a rain garden.

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What is Nonpoint Source Pollution?

Nonpoint source pollution (NPS) refers to pollution that originates from multiple sources across a large area of land, rather than a point source where the source of pollution is easily identifiable. Most NPS pollutants reach our local waterways via stormwater runoff, which occurs when water is unable to soak into the ground and runs over the ground (specifically impervious surfaces such as roads, parking lots, or sidewalks). Consequently, while moving over surfaces, the water will pick up pollutants and then eventually empty into a stream.

WHERE DOES NPS POLLUTION COME FROM?

NPS Pollution can come from several different sources and varies depending on the land use in the surrounding areas.

- Oils and grease from vehicles
- Household hazardous waste items
- Animal waste (livestock, domestic, wildlife)
- Malfunctioning septic systems
- Pesticides and fertilizers
- Sediments
- Heavy metals
- Trash and micro-litter

Page 3

Figure 4: Cypress Creek Watershed NPP Prevention Guide (pages 4 & 5)

Cypress Creek Today

The Cypress Creek watershed is located within the heart of the Texas Hill Country. Cypress Creek is an important source of water for both residents and wildlife that reside in the area, and it provides flow to local recreational attractions such as Jacob's Well and Blue Hole Regional Park.

Growth in Hays County is expected to increase pressure on our water resources. The Cypress Creek Watershed Protection Plan addresses issues such as surface runoff and overusing our water sources through the implementation of best management practices (BMPs).

SOLUTIONS: BEST MANAGEMENT PRACTICES

Best management practices (BMPs) are structural, vegetative, or managerial practices used to treat, prevent or reduce water pollution. They are meant to slow down stormwater runoff and remove pollution before they enter our creeks, rivers, and lakes. There are various types of BMPs that target different types of stormwater runoff; agricultural, commercial and institutional, municipal, industrial, and wholesale. Because each type of runoff contains different pollutants, menus of BMPs are tailored for these different sectors' impacts.

BMPs in the Cypress Creek Watershed:

- Rainwater Harvesting Systems
- Rain gardens
- Permeable Pavement
- Vegetated filter strips

BMPs in the Cypress Creek Watershed prevent the following pollutants from entering the creek:

- **Total Suspended Solids (TSS)**: the amount of solids that are not dissolved in the water; they can reduce overall clarity of water.
- **Nitrogen (N)**: nitrogen in rivers and streams can typically be attributed to pesticides and fertilizers; an excess of nitrogen can cause algal blooms.
- **Phosphorus (P)**: phosphorus is essential for healthy vegetation; an excess of phosphorus can also cause algal blooms.

BMPs in the Cypress Creek Watershed

There are eleven completed BMPs in the Cypress Creek Watershed, below are examples of the different types that have been completed:

RAINWATER HARVESTING SYSTEMS

Rainwater harvesting (RWH) is the collection of rainwater from a roof surface into a storage vessel for outdoor watering, or indoor uses. RWH systems protect the watershed by reducing demand on groundwater, reducing stormwater runoff, and reducing pollutants.

Where can you find rainwater harvesting systems in the Wimberley Valley?

- The Patsy Glenn Refuge (*417 Mill Race Ln, Wimberley, TX*)
- Blue Hole Regional Park (*100 Blue Hole Lane, Wimberley, TX 78676*)
- Wimberley Valley Watershed Association Headquarters *(1405 Mt. Sharp Rd, Wimberley, TX, 78676)*
- Hays County Precinct 3 (*200 Stillwater Rd, Wimberley, TX 78676*)
- Quicksand Golf Course at Woodcreek (*1 Pro Ln, Woodcreek, TX 78676*)

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Appendix VII: 2020 Addendum to the Cypress Creek Watershed Protection Plan – 'One Water'

2020 Addendum to the Cypress Creek Watershed Protection Plan- 'One Water'

To support development and implementation of the Cypress Creek Watershed Protection Plan (CCWPP), the Stakeholder Committee approved a suite of BMPs necessary to address water quality threats as urbanization increases in the watershed. This was done to enable the Stakeholder Committee to act on monitoring data that indicates a new threat without having to go through the process of researching new management practices. This suite of BMPs was recognized as the "Adaptive Management Toolbox". While the term was not widely recognized at the time of WPP development, this toolbox taken together with the stakeholder-driven plan for pollution prevention and source water protection represents what should be aptly described as a 'One Water' roadmap for Cypress Creek WPP implementation.

One Water is a water planning and management approach that rethinks how water moves through and is used in a community; it brings stakeholders like developers, community leaders, urban planners, water managers and engineers together with the goal of utilizing water as thoughtfully and efficiently as possible.

A collaborative effort with the Wimberley Independent School District (WISD) spearheaded by The Meadows Center for Water and the Environment at Texas State University (MCWE) and the Wimberley Valley Water Association (WVWA) will culminate in August 2020 with a project in the heart of the Cypress Creek watershed that demonstrates the value and critical importance of One Water when Blue Hole Primary, the "first One Water school in Texas", opens its doors for classes. The school's One Water design acknowledges The importance of protecting Wimberley's sensitive water resources by managing all the water as a single resource that is sustainable and reusable.

Figure 1. Wimberley Independent School District groundbreaking ceremony for Blue Hole Primary, the first 'One Water' school in Texas, July 29, 2019.

Blue Hole Primary School, will utilize a variety of One Water strategies to reduce groundwater usage from the Trinity Aquifer by 90 percent when compared to traditional construction standards, thereby protecting groundwater that supplies crystal clear spring flows to Jacob's Well, Blue Hole and Cypress Creek. It will incorporate best practices such as collecting rainwater and AC condensate to flush toilets and irrigate landscaping and an onsite treatment and reuse system to beneficially reuse gray/black water produced by the school. Additional green stormwater infrastructure will comprise of permeable pavers, vegetated swales and rain gardens to highlight a 21st century approach to managing nonpoint source pollution from new developments. To complete the One Water immersive, educational experiences for students, staff and visitors, such as clear pipes and signage, will be built into the very architecture of Blue Hole Primary.

Table 1. The CCWPP Adaptive Management Toolbox with highlighted cells recognizing key 'One Water' components of Blue Hole Primary School.

Highest Prioritization	Second Highest Prioritization	Medium Prioritization	Low Prioritization
Water Conservation Pricing Strategies	Urban Wildlife Management – Deer	Rainwater Harvesting Strategies	Rock Weirs/Cross-vanes
Water Conservation Program for Water Providers or Municipalities	Riparian Buffers	Cypress Creek Land Trust	Vegetative Filter Strips
Groundwater Management strategies assessment and research	Water-intensive Turf Grass Ordinances and/or Ban	Nutrient & Fertilizer Management	Livestock Water Quality Management Plan
Groundwater Protection Strategy	Groundcover Establishment – Agricultural	Habitat Conservation Areas – Urban	Rain/soil moisture sensors
	Parking Lot Pervious Design Strategies	Rock Berms/Gabions	Wastewater solutions
	Xeriscaping/Nativescaping	Biofiltration/Rain Garden	Septic replacement program
	Engineered Swales	Tree Protection	
	Conservation Easements	Groundcover Establishment – Urban	
	Karst Feature Protection Measures	Porous/Pervious Pedestrian Walkways	
	Comprehensive Stormwater Assessment	Alternative Brush Control -- Prescribed burns	
	Purchase of Development Rights	Grazing Management Strategies	
	Landscape Mulching	Landowner Incentive Program	
		Pet Waste Ordinance & Stations	

The new school will not only benefit the environment but will also save money for WISD in the long-term. The district projects that it will save nearly $800,000 over the next 30 years in utilities as less water is being used to operate the school. The money saved can help the district employ additional staff and teachers, while keeping the district less dependent from outside water and energy resources.

Texas' first One Water school will serve as a model for communities throughout the Texas Hill Country as well as a teaching tool to WISD students about the value of water conservation. The region will face enormous water challenges over the next 100 years and beyond, however Blue Hole Primary School will provide an important reminder that it is possible to balance the challenges of growth with the continued stewardship of our precious water resources.

WVWA funded the engineering and design of the One Water infrastructure through a generous grant from the Harry L. Willett Foundation. Thanks also to the WISD Board of Trustees and Superintendent, Dwain York for their vision, as well as Joe Day, David Venhuizen, PE, O'Connell Robertson & Associates, Inc., Doucet & Associates, Inc., AGCM, Inc., WISD, WVWA and Meadows Center staff for their expertise and valuable contributions to this project.

Appendix VIII: Cypress Creek WPP - Water Quality Ordinance Report and NPS Assessment Report

Cypress Creek Watershed Protection Plan

Implementation (Years 1-3)

NPS Assessment and Water Quality Ordinance Report

Prepared for:
The Meadows Center for Water and the Environment
Texas State University

Prepared by:
Doucet and Associates, Inc.
March 4, 2020

DOUCET & ASSOCIATES

Funded in part through a Clean Water Act 319(h) grant from the Environmental Protection Agency and the Texas Commission on Environmental Quality

Table of Contents

1.0 Introduction

A number of studies were conducted in the past decade to assess the water quality, hydrology, and hydraulics in the Cypress Creek watershed. Some studies focused on water quality addressing spatial and temporal trends of pollutants and identifying likely nonpoint sources, while others developed the hydrology and hydraulics modelling data of the streams in the watershed, providing the base for floodplain mapping.

Previous and Ongoing Water Quality Assessment/Management Activities

Activities	Content	Conclusion
Cypress Creek Project Watershed Characterization Report	Water quality data collection, initial analyses of land use, pollution loadings in the watershed, vulnerability of the watershed to future pollution, overall water quality	Cypress Creek, as a whole, is in adequate condition based on State water quality standards; three groups of tributaries are recommended for priority attention
Cypress Creek Project Phase Two Watershed Protection Plan	Comparison between future and existing water quality parameters, list of best management practices (BMPs) for immediate implementation, project locations	Continue water quality monitoring, watershed wide implementation of BMPs, especially in priority sub-watersheds
Roadway Improvement Drainage Assessment for Woodcreek	HEC-RAS modeling for culvert crossings; Rational Method calculation for flows to roadway sections	Improved culvert crossings can help with flooding and optimum roadway cross-section is determined to reduce sheet flow across residential property
Lower Guadalupe River Basin Guadalupe-Blanco River Authority (GBRA) Interim Feasibility Study	Developed hydrology and hydraulics model for watersheds and for streams	Provide base for further studies, e.g. water quality, flood reduction alternatives
Implementation of BMPs at Highly Visible Sites	Summarized rainwater harvesting and rain garden demonstration sites	Opportunity for simple, relatively low-cost, demonstration BMPs
Cypress Creek Water Quality Report	Summarized watershed wide water quality data from several studies	Spatial and temporal trends for water quality
Hays County Drainage Criteria Manual (Draft – 2020)	Design criteria for engineers to use in land development designs to mitigate drainage and floodplain issues	Enhanced drainage criteria with stream buffers to protect water quality, riparian areas, and aquatic habitat
Hays County Conservation Development Criteria (Proposed)	The County issued an RFQ in January 2020 to contract with an engineering consultant to research and develop design	Will protect larger areas of land from development while incentivizing low impact development measures. Results could be presented in late 2020.

	incentivized regulatory guidance	

City of Wimberley Water Quality Ordinance Amendments	The City staff, elected officials, and community engaged in a process to update the existing water quality ordinance. Revised ordinance will be compatible with the City of Woodcreek.	City Council adopted the revised water quality ordinance in December 2019 that improves buffer zones, links water quality requirements to existing criteria, and encourages low impact development practices
City of Woodcreek Water Quality Ordinance Amendments	The City staff, elected officials, and community engaged in a process to update the existing water quality ordinance. Revised ordinance will be compatible with the City of Wimberley	City Council will consider adoption in February 2020 to improve buffer zones, link water quality requirements to existing criteria, and encourage low impact development practices

2.0 Study/Report Summary

Cypress Creek Project Watershed Characterization Report

The Cypress Creek Project was initiated in 2008 with the goal to ensure that the long-term integrity and sustainability of the Cypress Creek watershed is preserved and that the water quality standards are maintained for present and future generations.

The watershed was defined and characterized with efforts including spatial delineation of the watershed and sub-watersheds, installation, data collection, and analysis of water monitoring stations, and watershed simulation modeling.

Specifically, rainfall data was collected at 5 monitoring stations in and adjacent to the watershed. Instantaneous flow data and water quality parameters, including temperature (°C), dissolved oxygen (DO) (milligram per liter; mg/L), specific conductance (umhos.cm), pH (SU), nitrate-nitrogen (mg/L), total phosphorus (mg/L), total suspended solids (TSS) (mg/L), ammonia (mg/L), and *E. coli* (colonies/100mL), were collected at TCEQ and Clean River Program (CRP) sites. Additional monitoring was done by two automatic stormflow monitoring devices were installed to record stage, sediment, nutrient, and bacteria concentrations during runoff events to provide a fuller range of water quality and quantity variability. In total, there were 16 monitoring sites that recorded water quality and/or water quantity data for various time spans.

Land use and land cover in the watershed were also developed using existing available spatial parcel data. These data, together with soils, topography, rainfall, and temperature data for the watershed and sub-watersheds, were used to model flow, sediment, and nutrients across the watershed and stream channels with the Soil and Water Assessment Tool (SWAT). The SWAT results were compared to land-use pollution loading results that used modeled water yield with event mean concentrations data in a previous land study. Though these two methods generated different results quantity wise, they both indicated that different areas of the watershed should be targeted for various pollution mitigation strategies. Areas with a high density of roads tend to have higher estimated loadings of suspended soils, oil and grease, etc., while areas with more residential land uses tend to have higher estimated nutrient loadings. Land uses with the highest relative contribution should be targeted in watershed protection planning for BMPs that address those parameters of concern.

Regarding water quality in the creek, target levels for nitrogen, phosphorus, ammonia, suspended sediment, and *E. coli* were determined. Monitoring data, after computation and normalization, showed that RR12 in the downtown Wimberley area experiences elevated levels of nutrients, and the primary area where sediment is problematic is the stretch of creek from RR12 south to the confluence with the Blanco River. The results also show elevated *E. coli* values during high, median, and low flows in this region.

The study found that the Cypress Creek, as a whole, is in adequate condition when assessments are based on State water quality standards. However, there are indications that healthy Cypress Creek watershed functions are negatively impacted by land use change, especially as land use in this area continues to shift from open space and ranching to residential and commercial.

<u>Cypress Creek Project Watershed Protection Plan</u>

In Phase two of the Cypress Creek Project, the watershed Protection Plan (WPP) was developed. Future water quality parameters were modeled with predicted land use data to compare with existing water quality parameter results from Phase one. Stakeholders identified priority reaches of the creek, sub-watersheds that have high baseline nitrogen concentrations, TSS concentrations, bacteria loads, and are subject to low DO during times of low flows.

Stakeholders developed a list of BMPs that are sub-watershed specific for initial implementation (first 3 years) and identified possible locations in Hays County, City of Wimberley, and City of Woodcreek for these projects. Many of these projects were implemented in the Cypress Creek WPP Implementation Years 1-3 Project (See the BMP Design Report).

A suite of BMPs was also approved to be included in a “toolbox” for long term and adaptive management to address water quality treats that arise as urbanization increases in the watershed. Also, the Stakeholder Committee determined it is best to coordinate all the concurrent monitoring activities (Figure 32 shows existing USGS, CRP, Cypress Creek Project/TST monitoring sites and LCRA rain gages) occurring in the watershed throughout implementation so the monitoring efforts will continue.

<u>Roadway Improvement Drainage Assessment for Woodcreek</u>

Hog Branch, a tributary of Cypress Creek, runs through the middle of Woodcreek, flowing from the north to Cypress Creek in the south. This study aimed to determine if increasing the sizes of the culvert crossings along Hog Branch at Brookmeadow Street, Brookhollow Drive, and Brookside Drive, can reduce the frequency of overtopping. The optimum cross-section for conveying the more frequent storms along the residential roadways was also determined to convey water within the road right-of-way.

A HEC-RAS model was used to determine the proposed crossing culvert size upgrades and the rational method was used to calculate flows for individual sections of roadway. The study indicates that improving the culverts can help contain 2-year storm at some crossings and improve water surface elevations for less frequent larger storm events for all crossings. At the same time, improving roadway cross-sections could capture the most frequent storm events and reduce the sheet flow amount across residential property.

Though this project does not directly study the water quality in the watershed, the proposed improvements along the creek and for the roadways could affect water quality during project construction.

Lower Guadalupe River Basin GBRA Interim Feasibility Study

GBRA conducted a watershed wide hydrology and hydraulics study to develop baseline existing condition hydrologic and hydraulic modeling for the streams in the watershed and define floodplain boundaries and risk areas. More specifically, a new hydrology model and frequency flows for Hog Creek, Cypress Creek Tributary 1, and Cypress Creek Tributary 2 were developed in Phase 1 of the project, and new hydrology and hydraulic models, environmental constraints, and economics for Cypress Creek were developed in Phase 2 of the project. The results can be used to analyze various flood reduction alternatives for the watersheds. Combined with water quality sampling data, these models and results can be used to assess watershed wide water quality conditions.

Implementation of BMPs at Highly Visible Sites

Based on the Cypress Creek WPP, Cypress Creek WPP Implementation Years 1-3 Project implemented rainwater harvesting, pervious paver, and rain garden opportunities at highly visible demonstration sites to educate stakeholders concerning the pollution education and water conservation benefits of simple and relatively low-cost management measures. See the BMP Design Report for the projects and their design features implemented in this phase of the Cypress Creek Project. BMPs constructed with this project were:

Rainwater Harvesting

- Hays County Precinct 3 Office
- Blue Hole Regional Park
- Wimberley Valley Watershed Association (WVWA) offices
- Woodcreek Golf Course

Pervious Paver

- Blue Hole Park Trail
- Blue Hole Park Main Entrance
- Blue Hole Park ADA Parking Area
- Wimberley Central Business District

Rain Garden

- Woodcreek Golf Course

Vegetated Filter Infiltration Strip

- Wimberley Valley Watershed Association offices

3.0 Surface Water Assessment Tool (SWAT) Summary

Cypress Creek Water Quality Report

This report combined data from the Cypress Creek Project Watershed Characterization Report, Cypress Creek WPP, water quality data from CRP (which provides continued monitoring data), and several other studies. This study provided graphics and charts to help illustrate the trend in watershed water quality including DO, *E. coli*, nutrients (nitrogen-N and phosphorus-P), and TSS. The results indicate that there is a general decline in DO level in the creek due to depletion by pollution from point and non-point sources; *E. coli* concentrations tends to be cyclical with higher concentrations in wet years and lower concentrations in dry years; nutrient levels are generally low and high occurrence likely resulted from human factors (fertilizer, poorly maintained septic systems) and pet/animal waste as nonpoint sources; and TSS levels are generally low and any elevated concentrations are most likely related to construction activities.

The study also identified the influential factors for different stream sections and showed that the area between downtown Wimberley and the Blanco River confluence is more at-risk for water quality degradation. Current wastewater treatment status in the watershed is also discussed, noting that aging and poorly maintained septic systems create an increasing threat to the watershed water quality. Through SWAT modeling, the impacts of urbanization indicated that there would be a decreased base flow in the ambient condition, an increased surface runoff, and a decreased percolation and aquifer recharge rate due to impervious cover. A summary of the SWAT modeling follows.

Cypress Creek Water Quality Modeling Summary

Background

Watershed models were used to develop the Cypress Creek WPP. The models were key to evaluating the hydrologic and water quality impacts of various urbanization scenarios envisioned by stakeholders for the year 2040 (i.e. thirty years in advance).

The main modeling software was SWAT which as jointly developed by USDA Agricultural Research Service and Texas A&M AgriLife Research. SWAT is widely used across the nation to assess issues like soil erosion prevention and control, non-point source pollution control, and regional management in watersheds.

To develop the scenarios, the stakeholders evaluated Wimberley and Woodcreek planning documents that project future land use change and population increase. Potential growth areas were delineated based on road networks, Hays County’s 2025 Transportation Plan, city limits and extra-territorial jurisdiction areas, water and wastewater service areas, and existing parcel boundaries (Vogl, 2011).

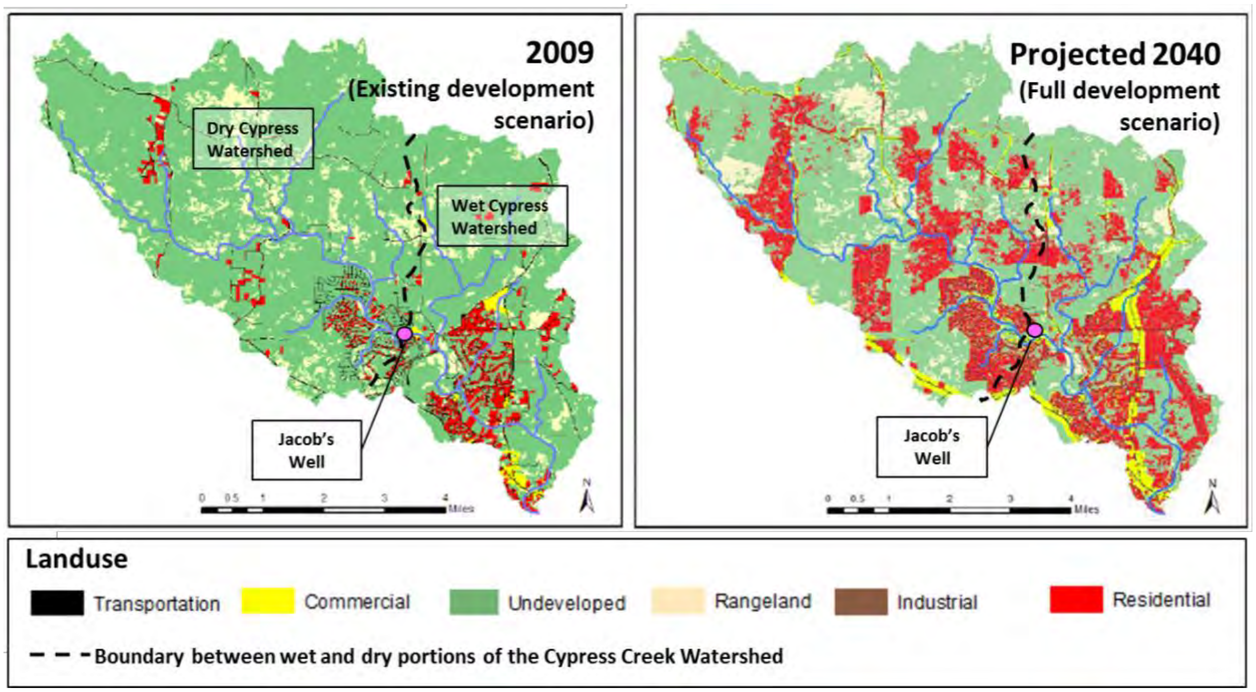

Figure 31. Existing 2009 and Projected 2040 (Full Development – Worst Case Scenario) Landuse Scenario in the Cypress Creek Watershed (Vogl, 2011).

Watershed Development Scenarios

Several urbanization scenarios were identified ranging from limited to full development. Among them, the full development scenario assumes that all major development areas in the Cypress Creek watershed were built out for residential and commercial land use. At the same time, the full development scenario assumes no implementation of BMPs nor stormwater management measures. **Error! Reference source not found.** shows the existing 2009 and projected 2040 full development land use in the Cypress Creek watershed.

Residential land use type experiences the greatest change between the full development and the existing scenario. Under the full development scenario, residential area is expected to increase from 5% of the total watershed area to 26% (CCWPP,2014). This results in significant increase in impervious cover which can lead to increased runoff and stormwater pollution. Compared to the full development scenario, the other scenarios (limited, moderate development, etc.) contain lesser degrees of residential increase.

Water Quality Impacts

The SWAT model was used to simulate the water quantity and quality for the various identified scenarios. The hydrological conditions such as rainfall, evaporation, etc., from 2000 to 2009 were incorporated. The model parameters were calibrated to data from 2000 to 2009. The predicted water quality conditions from each scenario were compared with the existing land use conditions. Figure 2 shows the percent change in runoff, sediment, and nitrogen loads between 2040 full development and 2009 existing scenario (Vogl, 2011).

Several key observations can be made from comparing the full development scenario and the existing condition:

- Responses to land use changes vary spatially from sub-basin to sub-basin. Some sub-basins experience more increase in storm runoff and pollutant loads, while others less so.
- Surface runoff in sub-basins can increase up to 50%, and the highest increases are seen in central and southern areas (Woodcreek and Wimberley) where high-intensity development is concentrated.
- Sediment yields can increase to over 60% for sub-basins and up to 25% for stream channels.
- Nitrogen loads can increase up to 60%, and the highest increases are seen in central and southern areas where high-intensity development is concentrated.

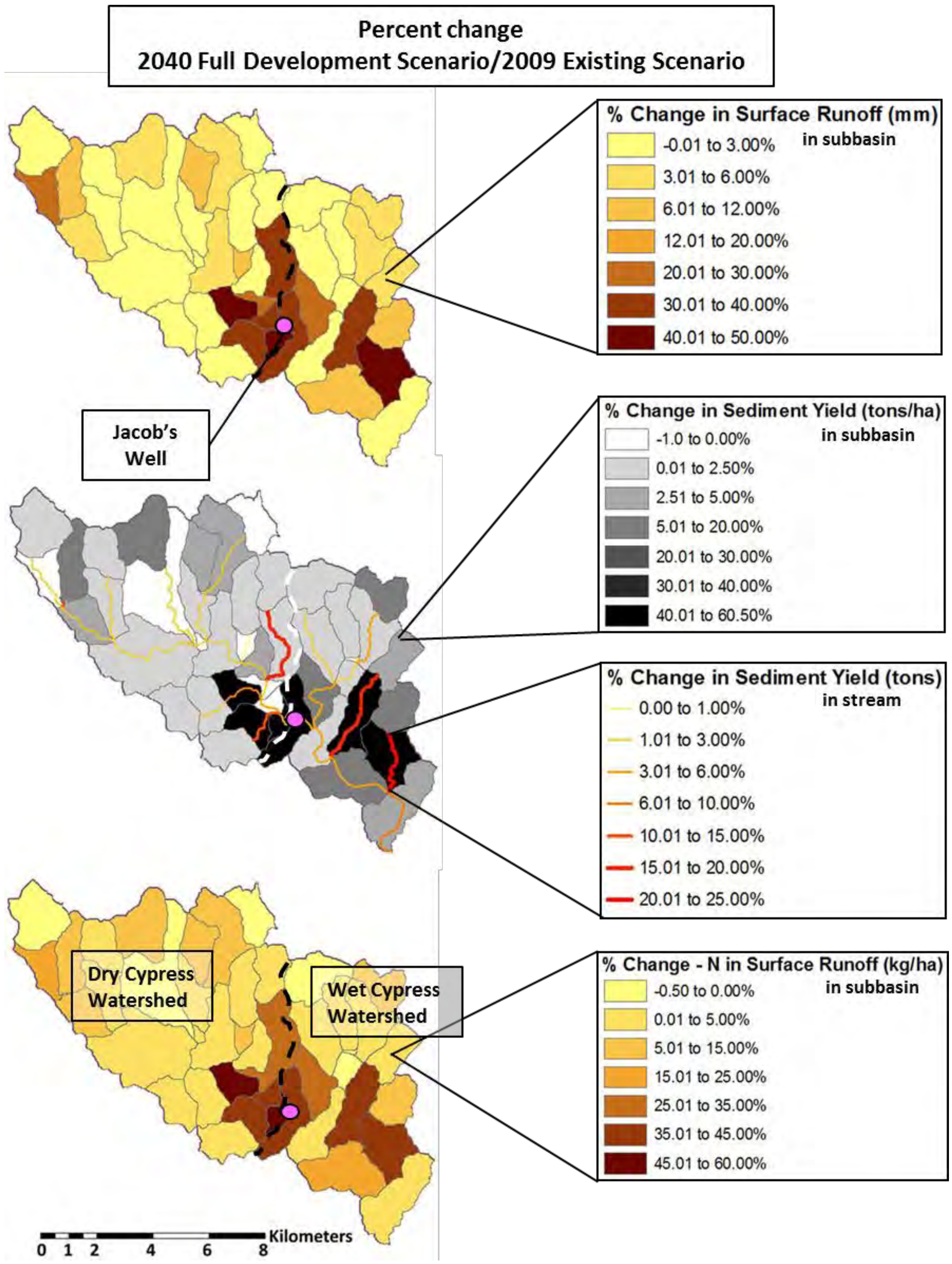

Figure 32. Percent change in runoff, sediment, and nitrogen loads between 2040 Full Development Scenario and 2009 Existing Scenario (Vogl, 2011).

In addition to land use changes, the model also simulated baseflow levels under different urbanization scenarios. Groundwater pumpage increases with urbanization which results in lower baseflow. Under existing conditions, simulated stream flow exceeds the target flow levels approximately 67% of the time, under full development the flow target is met only 60% of the time. Compared to land use changes, baseflow reduction causes greater impact on the maintenance of target flow (Vogl, 2011).

Conclusions

Based on the SWAT modeling results, the most significant impacts of urbanization relative to changing watershed hydrologic response are identified as 1) a decrease in baseflow between storm events, 2) an increase in surface runoff and maximum flows, and 3) decreasing percolation and aquifer recharge. These impacts can all be related to the increase in impervious cover and groundwater pumpage.

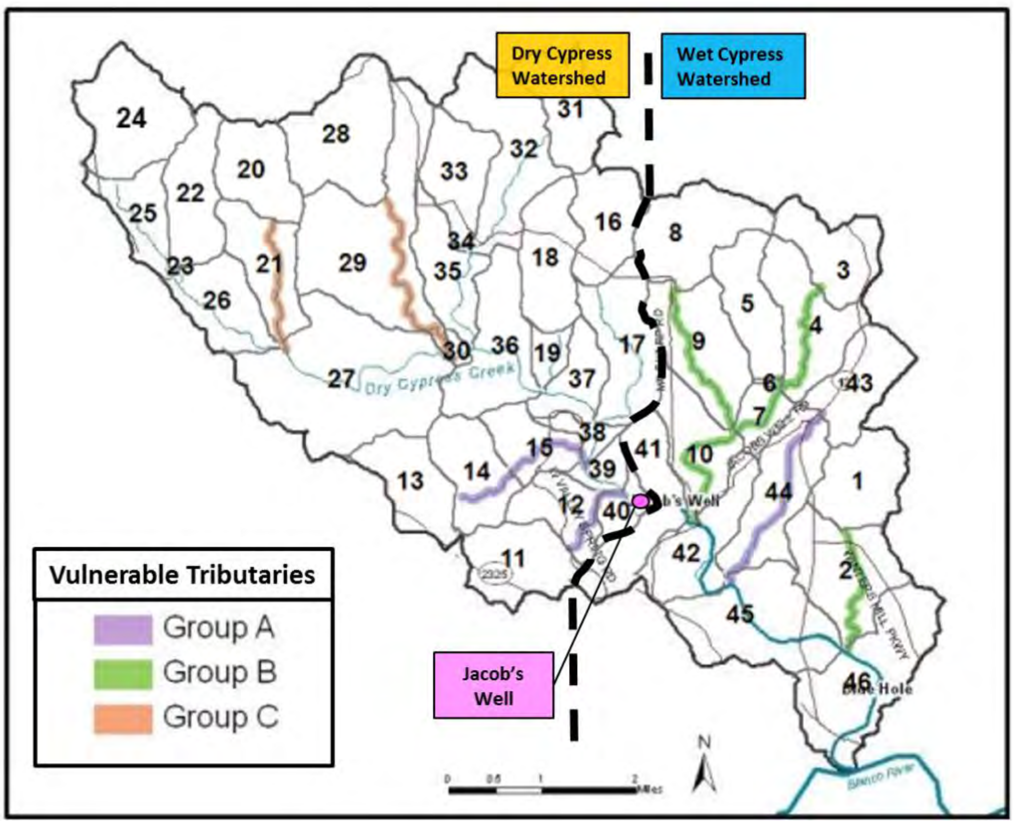

Figure 33. Vulnerable Tributaries and Priority Sub-basins (Priority sub-basins are sub-basins that intersect with Vulnerable Tributaries).

Stakeholders used the SWAT model results to identify 1) priority sub watersheds that are most likely to have substantial increase in pollutant loads or have high concentrations of septic tanks; and 2) the most vulnerable tributaries where water quality will be most likely violate screening levels. Figure 3 is a map of the identified vulnerable tributaries and priority sub basins. The tributaries are broken up into groups with similar characteristics including Group A (sub watersheds 12, 14, 15 and 44), Group B (sub watersheds 2, 4, 6, 7, 9 and 10), and Group C (sub watersheds 21 and 29).

Stakeholders selected a suite of BMP to mitigate identified and potential water quality impairments in the watershed. When possible, BMPs are targeted for priority sub watersheds. The BMPs were prioritized for immediate implementation and as future options in an adaptive management suite.

Tables comparing load contributions from Existing and Future Scenarios for the Cypress Creek Watershed (extracted from Tables 15, 16 and 17 of the Cypress Creek WPP, 2014).

Table 15. Existing Scenario: Contribution from Source Land Uses

Existing Land Use Coverage in Cypress Creek Watershed	Area (acres)	Nitrogen EMC	Total Nitrogen Load	Percent of Nitrogen Load	TSS EMC	Total TSS Load	Percent of TSS Load
Residential	1231.57 acres	1.82 mg/l	2479.02 lb/yr	7%	41 mg/l	55846 lb/yr	4%
Commercial	200.01 acres	1.34 mg/l	282.55 lb/yr	1%	55.5 mg/l	11702.54 lb/yr	1%
Industrial	15 acres	1.26 mg/l	21.52 lb/yr	<1%	60.5 mg/l	1033.35 lb/yr	<1%
Transportation	798.12 acres	1.86 mg/l	1502.21 lb/yr	4%	73.5 mg/l	59361.54 lb/yr	4%
Rangeland	2656.78 acres	.70 mg/l	1809.45 lb/yr	5%	1 mg/l	2584.93 lb/yr	<1%
Undeveloped	19426.08 acres	1.50 mg/l	28241 lb/yr	82%	70 mg/l	1317912.15 lb/yr	91%
TOTAL	24327.56		34335.72			1448440.51 lb/yr	

* Estimated pollution load reductions needed to meet water quality goals in the watershed. This analysis is submitted to satisfy Element A of the EPA 9-element criteria for watershed-based plans.

Table 16. Future Scenario: Contribution from Source Land Uses

Future Land Use Coverage in Cypress Creek Watershed	Area (acres)	Nitrogen EMC	Total Nitrogen Load	Percent of Nitrogen Load	TSS EMC	Total TSS Load	Percent of TSS Load
Residential	6434.11 acres	1.82 mg/l	13053.63 lb/yr	33%	41 mg/l	294065.4 lb/yr	20%
Commercial	1235.57 acres	1.34 mg/l	1967.92 lb/yr	5%	55.5 mg/l	81507.24 lb/yr	6%
Industrial	11.56 acres	1.26 mg/l	19.42 lb/yr	<1%	60.5 mg/l	932.67 lb/yr	<1%
Transportation	798.55 acres	1.86 mg/l	1738.59 lb/yr	4%	73.5 mg/l	68702.46 lb/yr	5%
Rangeland	1932.66 acres	.70 mg/l	1335.62 lb/yr	3%	1 mg/l	1908.03 lb/yr	<1%
Undeveloped	13904.58 acres	1.50 mg/l	21383.92 lb/yr	54%	70 mg/l	997916.17 lb/yr	69%
TOTAL			39499.11 lb/yr			1445031.97 lb/yr	

* Estimated pollution load reductions needed to meet water quality goals in the watershed. This analysis is submitted to satisfy Element B of the EPA 9-element criteria for watershed-based plans.

Table 17. Land Use Contributions to Nitrogen and TSS Loads

Change of Land Use Coverage and Loads in Cypress Creek Watershed	Change in Land Use Cover	Existing Percent of Nitrogen Load	Future Percent of Nitrogen Load	Change in Nitrogen Load	Existing Percent of TSS Load	Future Percent of TSS Load	Change in TSS Load
Residential	440%	7%	33%	371%	4%	20%	400%
Commercial	400%	1%	5%	400%	1%	6%	500%
Industrial	0%	<1%	<1%	0%	<1%	<1%	0%
Transportation	0%	4%	4%	0%	4%	5%	25%
Rangeland	[-27%]	5%	3%	[-40%]	<1%	<1%	0%
Undeveloped	[-29%]	82%	54%	[-34%]	91%	69%	[-24%]

* Estimated pollution load reductions needed to meet water quality goals in the watershed. This analysis is submitted to satisfy Element B of the EPA 9-element criteria for watershed-based plans.

4.0 Recommendations for BMP Placement and Ordinance Adoption

BMP Placement

Based on the SWAT modeling, water quality monitoring data, and findings from BMP installations with this project, a priority area for BMP installations is the lower third of the watershed that includes the cities of Wimberley and Woodcreek. This area is projected to be the most rapidly growing area as noted in Figure 1. The BMPs installed with this project were located in the high priority area noted above. Future BMP retrofits should focus on areas of high impervious cover such as retail centers and multi-family housing that are directly connected to Cypress Creek via storm drain and other conveyance systems. In addition, roads such as RR 12 should be investigated as a retrofit opportunity as the drainage system flows directly into Cypress Creek.

Potential retrofit partners include:

- Texas Department of Transportation
- City of Wimberley
- City of Woodcreek
- Private development sites undergoing redevelopment
- Hays County
- Blue Hole Park
- Jacobs Well Park
- Wimberley Valley Watershed Association

If flood mitigation projects are considered, a water quality component should be evaluated in all cases to minimize aquatic habitat impacts and enhance water quality. Often, the most cost-effective means to reduce flood risk and protect public safety is through the acquisition of frequently flooded properties/structures. This approach should be the first option evaluated in the flood mitigation design process.

Water Quality Ordinance Adoption

During this project, the cities of Wimberley and Woodcreek revised their water quality ordinances to enhance water quality protection and promote aquatic health. The ordinance updates created a set of rules and criteria that are consistent with the TCEQ Optional Enhanced Measures that were determined by the United States Fish and Wildlife Service to be protective of threatened and endangered species. These updated ordinances can be considered to significantly protect water quality during and after the development process, essentially achieving a non-degradation standard through the cumulative treatment effect of multiple measure. From that perspective, the lower one-third of the watershed in a full-build out 2040 condition will essentially experience the same pollutant loads as the existing condition. This is accomplished through the following measures:

- Water quality best management practices that must remove at least 80% of the increase in TSS load through the TCEQ Edwards Aquifer Protection program or city requirements;
- Water quality measure inspection and maintenance requirements that are enforced by the local government to ensure pollutant treatment performance;
- Creek buffer zones, that function similarly to filter strips as they are designed so that upstream runoff is converted to sheet flow. Filter strips are noted as providing 85% TSS management;

- Water quality education materials and workshops that can reduce the use of landscape chemicals, and
- Construction sediment controls that significantly reduce sediment loads during the construction period.

The above approach mimics the TCEQ "Optional Enhanced Measures for the Protection of Water Quality in the Edwards Aquifer", RG-348A that were noted by the United States Fish and Wildlife Service (USFWS) as protecting threatened and endangered species from impacts due to water quality degradation.

Thus, the water quality ordinance revisions are the single most important measure enacted by this project to provide long-term protection of water quality and aquatic habitat. The ordinance revisions, applied to a large land area, manage pollutant loads for generations and place the maintenance burden on the development community and not local and state government operations.

Other Regulatory Activities

Hays County is considering the adoption of a Drainage Criteria Manual in 2020. If adopted as currently drafted, version 7, stream buffers will be implemented in creeks with drainage areas greater than 64 acres to provide floodplain risk reduction and water quality benefits. This will extend water quality protection beyond the cities of Wimberley and Woodcreek.

The Texas Commission on Environmental Quality Edwards Aquifer Protection Program applies throughout the Cypress Creek watershed as it is noted as being in the contributing zone. All development projects that are more than five acres in area must obtain a permit from the TCEQ. Permit compliance is obtained through the preparation of a temporary erosion control and permanent water quality protection plan that includes such measures as sedimentation-filtration, extended detention, bioretention, pervious pavers, rainwater harvesting, and other techniques.

GBRA does not have regulatory authority in the Cypress Creek watershed or exercise this authority in other parts of the Guadalupe -Blanco River basin.

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Appendix IX: Cypress Creek WPP - DSS Evaluation Report

Cypress Creek Watershed Protection Plan

Decision Support System (DSS) Summary

February 24, 2020

A digital support system (DSS) was contemplated early in the Cypress Creek Project process to help evaluate new land development projects and their potential impact on water quality. A DSS is an information system that supports business, organizational, and local government decision making activities. A DSS can be used to help manage operations, planning, and organizations and help people make decisions about problems that may be rapidly changing and not easily defined in advance. Decision support systems can be either fully computerized or driven by local government decision makers or a combination of both.

As the Cypress Creek project began to develop, it became apparent to local government staff and officials that they did not have the resources, (software, hardware, staff availability) to implement and operate a DSS for the Cypress Creek watershed. While it may be of interest to track in a geographic information system (GIS) the location of a new development, a project would be subject to the local water quality and drainage regulations, thus, mitigating potential adverse water quality impacts. The local governments already note development patterns in their land planning process, thus, a DSS, that would require a considerable expense and staff resources would have limited benefits in the role of water quality protection. Therefore, the local governments indicated that a DSS would not be useful to them at this time and a DSS was not established for the Cypress Creek watershed.

Details are provided below on the required software, data analyses, data visualization, and watershed analysis to illustrate the challenges for small local governments.

<u>Required Software:</u>
ArcGIS 9.3 with Spatial Analyst Extension (possibly 3D Analyst)
AGWA 2.0 software includes SWAT program and KINEROS program

ArcView is a geographic information system (GIS) developed by ESRI. A GIS is a computer-based tool for mapping and analyzing data in a spatial context. For example, through mapping of data ArcView can identify hot spots, perform statistical analysis on the data, and follow trends in data over time. ArcView can be used to visualize the data in 2 or with extensions (additional software available from ESRI) 3 dimensions.

GIS technology integrates common database operations such as query and statistical analysis with the visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies.

Advantages

ArcView is one of the most widely used GIS systems in the United States and is the most widely used for environmental contamination problems. ArcView and its extensions, Spatial Analyst and 3DAnalyst, have been extensively applied to environmental contamination problems as a tool for assessing site and contaminant characterization. ArcView has also been used to support risk assessment and remedial action work. ArcView and its extensions include the ability to integrate data from a series of databases, provide geographic display and mapping capability, and they have a script language that permits model interfaces to be developed.

Limitations

ArcView is a general software tool that by itself is not focused solely on decision support for environmental contamination problems. The generality of the software requires that it support a wide range of functions to address different situations. Although ArcView is relatively easy to use, efficient and proper use requires some training and continual usage.

For the full range of problem areas where GIS techniques can provide decision support, specific problem related models are needed. For this wide range of second order uses, spatial data and additional processing or integration with non-spatial models is required to fully support the decision maker.

Two important extensions to ArcView, Spatial Analyst and 3D Analyst, are sold separately. These extensions permit the user to perform more sophisticated statistical analysis of the data and to visualize the data in 3 dimensions.

ArcView, Spatial Analyst, 3D Analyst	
Software Cost For Desktop Standard Version	**Upfront license purchase (Perpetual License)** $7000 (2 or more: $6300 each) Maintenance: $1500 Most extensions would be $2500 each Maintenance is $500 per extension each year Bundled extensions at a cost of $7,500 per year for the bundle. Bundled extension Annual Maintenance is $1,500 per year for the bundle. Extension bundle includes 3D, Data Interoperability, Data Reviewer, Geostatistical Analyst, Network Analyst, Publisher, Schematics, Spatial Analyst, Tracking Analyst, and Workflow Manager. **Subscription Service (Term License)** Desktop Standard Term: $3000 Most extensions at a cost of $600 per extension each year. Bundled extensions at a cost of $1800 per year for the bundle.

	Extension bundle includes 3D, Data Interoperability, Data Reviewer, Geostatistical Analyst, Network Analyst, Publisher, Schematics, Spatial Analyst, Tracking Analyst, and Workflow Manager.

In general, decision support tools are developed as modular platforms that integrate a wide variety of software applications into a single program. In principle, it would be possible to incorporate any model into the framework, increasing the functionality of the software program which often requires a larger knowledge base for the user and makes the program more difficult to use.

For site characterization problems, the user may select from several different decision support tools to analyze the problem. There exists a trade-off between the use of simple models that are easy to use and more complex models which can more accurately reflect field conditions. Conceptually, the use of more accurate models (which generally involves more detailed and complex models) can lead to a better resolution of the contamination problem with less uncertainty than the simple model. This can lead to lower remediation costs. On the other hand, simpler models are easier to use, defend, and gain acceptance from the regulators and stakeholders. The appropriate selection of a model is site and problem specific.

Application

Environmental problems may include:

- water quality protection
- meteorological data (e.g., temperature, pressure, wind speed, precipitation, etc.),
- geologic data (soil structure, physical and chemical properties of the soil, etc.),
- hydrologic data (depth to the water table, groundwater elevation, groundwater flow rate and direction, hydraulic properties of the soil, etc),
- contamination data (source, distribution in the soil and groundwater over time, physical and chemical form of the contamination, etc.) and
- exposure pathway data (location of receptors, contamination uptake factors in plants, resuspension factors, etc.).

It is essential for a decision support system to take the appropriate data from all of the available data and synthesize this information to provide knowledge useful to the decision process (e.g. define likelihood of exceeding a risk threshold, identify uncertainties in the analysis and model parameters that could impact decisions).

Data Analysis

Data analysis for a site characterization involves the determination of the nature and extent of potential contamination. Important considerations in the analysis include:

- The type of analysis - static (snapshot) or transient (predictive)
- The spatial dimensions in the analysis (1, 2, or 3)
- The ability to define areas/volumes where contamination exists above a predefined threshold
- The ability to define uncertainties in the decision variable. For example, if the decision variable is the volume of contaminated soil above a threshold, software with geostatistical simulation capabilities

can estimate the volume of soil exceeding the threshold with 50, 75, and 95% confidence that the site will be clean if the soil is removed. As one goes to higher confidence, more soil needs to be removed.

- The ability to assist in sample optimization. Software often contains algorithms to select sample locations that optimize a constraint. For example, sample optimization can be based on minimizing the largest distance between two sample points, defining the boundaries of a contaminated zone, or reducing overall uncertainty in prediction of contamination zones. This type of software can also address data questions such as will collection of additional data reduce uncertainty in the decision.

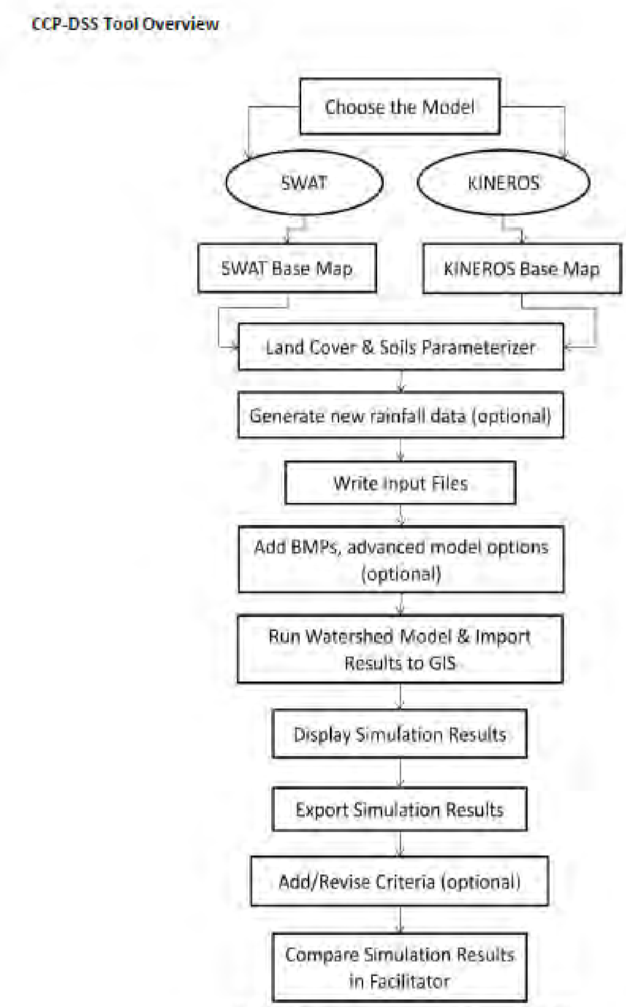


Figure 4. Basic processing steps for the CCP-DSS.

Data Visualization

The ability to visualize the data in a spatial frame of reference is often crucial to understanding and being able to communicate the extent of a potential problem. Important visualization capabilities include:

- The ability to include surface structures such as roads, buildings, well locations, and water bodies as part of the visualization
- The ability to define hydrologic structures including aquifers and confining layers.
- The ability to represent subsurface structures such as buildings or piping that may be relevant to contaminant location (e.g. leaking pipes).
- The ability to post, map, and contour the data to define the extent of contamination.

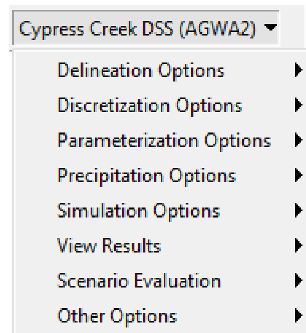
Watershed Modeling

There are five basic components: watershed (hydrologic) processes and characteristics; input data; governing equations; initial and boundary conditions; and output (Singh, 1995). Despite their uniform general structure, however, various treatments of the five model components have resulted in a significant range of available model types. Distinguishing between these different model types is an important first step in selecting the appropriate model for a project.

Watershed models are generally classified according to the method they use to describe the hydrologic processes, the spatial and temporal scales for which they are designed, and any specific conditions or intended use for which they are designed. Some knowledge of these components is highly recommended when selecting the combination that is best suited to a specific watershed and task.

Kinematic Runoff and Erosion Model – KINEROS2
KINEROS2 utilizes a network of channels and planes to represent a watershed and the kinematic wave method to route water off the watershed (Figure 3). It is a physically-based model designed to simulate runoff and erosion for single storm events in small watersheds less than approximately 100 km^2.

Soil & Water Assessment Tool - SWAT
The Soil and Water Assessment Tool (SWAT) (Arnold et al., 1994) was developed to predict the effect of alternative management decisions on water, sediment, and chemical yields with reasonable accuracy for ungaged rural basins. It is a distributed lumped-parameter model developed at the USDA Agricultural Research Service (ARS) to predict the impact of land management practices on water, sediment and agricultural chemical yields in large (basin scale) complex watersheds with varying soils, land use and management conditions over long periods of time (> 1 year). SWAT is a continuous-time model, i.e. a long-term yield model, using daily average input values, and is not designed to simulate detailed, single-event flood routing. Major components of the model include: hydrology, weather generator, sedimentation, soil temperature, crop growth, nutrients, pesticides, groundwater and lateral flow, and agricultural management. The Curve Number method is used to compute rainfall excess, and flow is routed through the channels using a variable storage coefficient method developed by Williams (1969).



CCP-DSS Toolbar and Tools menu.

The Cypress Creek Project (CCP) DSS would be designed to be run in a stepwise manner (Figure 4). The AGWA2 tool, on which the DSS is based, is packaged as an extension for the ESRI ArcGIS 9.3 GIS software and uses geospatial data to parameterize two watershed runoff and erosion models: KINEROS2, and SWAT (Version 2000; Neitsch et al. 2002). A schematic of the procedure for utilizing these models with the CCP-DSS is presented above.

The AGWA2 installation for ArcGIS adds the **Cypress Creek DSS (AGWA2) Toolbar** to the map project in ArcGIS. The **AGWA2 Tools** menu on the toolbar is designed to reflect the order of tasks necessary to conduct a watershed assessment, which is broken out into seven major steps:

1. Watershed delineation
2. Watershed discretization
3. Watershed parameterization
4. Writing a precipitation file for model input
5. Writing parameter files and running the chosen model
6. Viewing results
7. Exporting and evaluating scenario results

Step 1. Watershed Delineation (optional):
Required if using a watershed not already delineated or expanding the model boundary to a larger area.

The user first creates a watershed outline, which is derived from a grid based on the accumulated flow to the designated outlet (pour point) of the study area. A polygon feature class is built from the watershed outline grid and stored in a geodatabase. Either a single watershed or a group watershed may be created.

Step 2. Watershed Discretization (optional):
This step is required only if the user has created a new delineation or wishes to change the way that the watershed is modeled (such as changing the number of sub watersheds). This step may also be necessary if ponds or other in-channel structures are added that change the routing of water through the channel network**:**

The user specifies the threshold of contributing area for the establishment of stream channels, and the watershed is divided into model elements as required by the chosen model. The created watershed elements are referred to as the discretization itself. If internal runoff gages for model validation or ponds/reservoirs are present, they can be used to further subdivide the watershed at this time. From this point forward, the tasks are specific to the model that will be used, but both follow the same general process.

Step 3. Watershed parameterization:
Each time the user creates a new discretization or introduces a new land cover scenario, new land cover parameters must be calculated before running simulations for the watershed.

The Land Cover and Soils Parameterizer sets new parameters for each model element from the topography, land cover and soils data. Each model requires a different set of parameters, but generally includes things like canopy cover, roughness, etc. Land cover datasets must be in GRID format; soil datasets must be in vector format. The soils dataset must extend beyond the edges of the watershed and must not contain any internal voids or gaps, otherwise the user must correct the soils theme.

The discretization is parameterized by both its topographic properties and land cover and soils information. AGWA2 is predicated on hydraulic geometry relationships to establish channel geometries and the presence of both land cover and soil GIS coverages. First, the discretization is parameterized according to its topography and then is intersected with these data where parameters necessary for the hydrologic model runs are determined through a series of look-up tables. The hydrologic parameters are added to the polygon and stream attribute tables.

Step 4. Writing a precipitation file for model output (optional):
Required if data does not include pre-defined precipitation data for the watershed. This step is for advanced users.

Rainfall input files are built. For SWAT, the user must provide daily rainfall values for rainfall gages within and near the watershed. If multiple gages are present, AGWA2 will build a Thiessen polygon map and create an area-weighted rainfall file. For KINEROS2, the user can select from a series of pre-defined rainfall events or choose to build his/her own rainfall file through an AGWA2 module. Precipitation files for model input are written from uniform (single gage) rainfall or distributed (multiple gage) rainfall data.

Step 5. Writing parameter files and running the chosen model:
At this point, all necessary input data have been prepared: the watershed has been subdivided into model elements; hydrologic parameters have been determined for each element; and rainfall files have been prepared. The user can proceed to run the model of choice.

Step 6. Viewing results:
AGWA2 imports the model results and joins them to the discretization and stream attribute tables for display. A separate module controls the visualization of model results. The user can toggle between viewing the total depth or accumulated volume of runoff, erosion, and infiltration output for both upland and channel elements. This enables problem areas to be identified visually so that limited resources can be focused for maximum effectiveness. Model results can also be overlaid with other digital data layers to further prioritize management activities.

Step 7. Export and compare results:
The user can export simulation results to the Facilitator, a scenario evaluation package. Once there, additional criteria or outputs may be entered, a ranking is created, and results between multiple simulations/scenarios may be compared.

Required data

Table 1. Data included in CCP-DSS database.

	Data type	Description (source)
Data required to run hydrologic simulation models (SWAT2000 and KINEROS2)	Topography	10m resolution DEM from USGS. Sinks were filled using the DSS tools (USGS, 2009)
	Flow direction and flow accumulation grids	Created from 10m DEM using DSS tools
	Soils	SSURGO soils data for Hays County (NRCS, 2008)
	Climate	NCDC and LCRA rain gauge locations and daily data CCP rain gauge locations and storm event data Weather generator file with statistics for Cypress Creek area
	Land cover	2001 land cover (MRLC, 2001) 2009 land cover (RSI, 2010)
	Spring flow inputs	Daily mean spring flow at Jacob's Well
	Stream flow	Estimated daily mean stream flow at watershed outlet Observed stream flow for storm events
	Water quality	Observed water quality data (sediment and nutrient concentrations) for storm events (CCP) Observed ambient water quality monitoring data (nitrate-nitrogen, total phosphorous, TSS, *E. coli*, temperature; TCEQ, 2010)

Data for visualizing, creating scenarios and interpreting results

Data to assist users in visualizing, creating scenarios and interpreting results	Aerial photos 2004, 2008
	City boundaries and extra-territorial jurisdictions
	Road networks (Hays County)
	Subdivision boundaries
	Parcels geodatabase (information on parcel boundaries, land use designations and tax appraisal values)
	Water quality monitoring site locations
	Land cover layers for example scenarios: stream buffers, mixed intermediate development, full development of selected subdivisions, etc.
	Spring flow inputs at average, reduced, and increased levels
	Example pond and reservoir files

As with any software, the more accurate the data is, the more accurate the results are. Based on the overall area, a model for a small development would not show a significant impact county-wide but may show a significant impact locally.

The role each local community plays is vital to the success of any decision support system. It is these communities that ultimately contribute to the larger picture (the trickle-down effect). Development projects are approved locally, and then approved by county (based on inter-agency regulations). As these projects are approved/built, their corresponding data needs to be entered into the database so the database itself is current.

Obtaining the data in the proper format can be an important problem. Often the software requires that specific fields are used for data (e.g., the first three fields are often Easting, Northing, and Elevation). There is substantial data management (reformatting the data into appropriate columns, removing extraneous information, combining data from different spreadsheets, etc.) that is required. This is the single most important process in developing a DSS. This and on-the-ground surveys require the most manpower.

Changes that affect DSS?

- Floodplain (i.e. CLOMR, LOMR)
- Large developments
- New/improvements to roadways/drainage structures
- Land use designations

Future implementations for DSS:

1) Ability to compare, using aerial photos, any historical changes (side by side comparison)
2) Include flood studies showing possible property damage and affected population (cost, etc).