Deer and Pond Creeks Surface Water Quality Monitoring and Education Effectiveness Final Report and Data

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Texas Water Resources Institute
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Cover photos: Deer Creek. Photo by Ed Rhodes, TWRI.

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List of Abbreviations

Acronym	Meaning
AU	Assessment Unit
BRA	Brazos River Authority
cfs	Cubic Feet per Second
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency
LDC	Load Duration Curve
MPN	Most Probable Number
NELAC	National Environmental Laboratory Accreditation Conference
NRCS	Natural Resources Conservation Service
QA	Quality Assurance
QAPP	Quality Assurance Protection Plan
QC	Quality Control
QPR	Quarterly Progress Report
RUAA	Recreational Use Attainability Analyses
SWCD	Soil and Water Conservation District
SWQM	Surface Water Quality Monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TSSWCB	Texas State Soil and Water Conservation Board
TWRI	Texas Water Resources Institute
USGS	United States Geological Survey

Executive Summary

Pond Creek at SH53. Photo by Amanda Tague, TWRI.

The Texas Commission on Environmental Quality (TCEQ) conducts a water body assessment on a biennial basis to satisfy requirements of the federal Clean Water Act (CWA) Sections 305(b) and 303(d). The resulting *Texas Integrated Report of Surface Water Quality (Texas Integrated Report)* describes the status of water bodies throughout Texas. The most recent report, the *2022 Texas Integrated Report,* includes an assessment of water quality data collected from December 1, 2013, to November 30, 2020 (TCEQ, 2022).

The *Texas Integrated Report* assesses water bodies at the assessment unit (AU) level. An AU is a sub-area of a segment, defined as the smallest geographic area of use support reported in the assessment (TCEQ, 2022). Each AU has homogeneous chemical, physical, and hydrological characteristics, which allows assignment of site-specific standards (TCEQ, 2022). Each water body is assigned a segment identification number and an AU designation.

Deer Creek and Pond Creek are located within the larger Brazos River Basin. Deer Creek begins west of the unincorporated community Chilton, and flows east to its confluence with the Brazos River within Falls County. Pond Creek begins northwest of the unincorporated community, Belfalls, and flows southeast to the Brazos River in Milam County. AUs within both watersheds are listed as impaired in the *Texas Integrated Report* (TCEQ, 2022). This report will focus on impaired AUs, Deer Creek (1242J_01) and Pond Creek (11242F_01).

Water quality in these creeks currently exceed primary recreational use standards for bacteria concentrations. Deer Creek was first listed in the *2006 Texas Integrated Report* (TCEQ, 2006) and an AU of Pond Creek was designated impaired in 2010 (TCEQ, 2010). In the 2022 report, the *Escherichia coli (E. coli)* geometric means for these creeks ranged from 171 to 288 most probable number (MPN) /100 mL; above the applicable water quality primary contact recreation standards of 126 MPN/100 mL in place for the tributaries (TCEQ, 2022).

Under Texas State Soil and Water Conservation Board (TSSWCB) the Brazos River Authority (BRA) conducted a recreational use attainability analysis (RUAA) in 2013. The results of the RUAA confirmed the primary contact recreational use classification for both Deer and Pond Creeks (TCEQ, 2013). Likely, future action to address these water quality impairments will be necessary. The RUAA conducted by BRA was an initial step to appropriately address these water quality impairments.

It was necessary to supplement water quality and quantity data collection to fill data gaps and to inform future watershed planning and implementation activities. Additionally, expanded data collection allows for a more accurate assessment of each waterbodies' condition, and aids in identifying potential causes and sources of pollution. Each of these actions requires a reasonable amount of water quality data to assess current conditions and estimate pollutant loading reductions necessary to meet applicable water quality standards.

This project increased the spatial and temporal distribution of water quality monitoring activity to better define in-stream water quality conditions. This provides an increase in the quantity of water quality data available for future water body assessments. It is through monitoring and adequate data that watershed managers will be able to get a true assessment of water quality inhibitors.

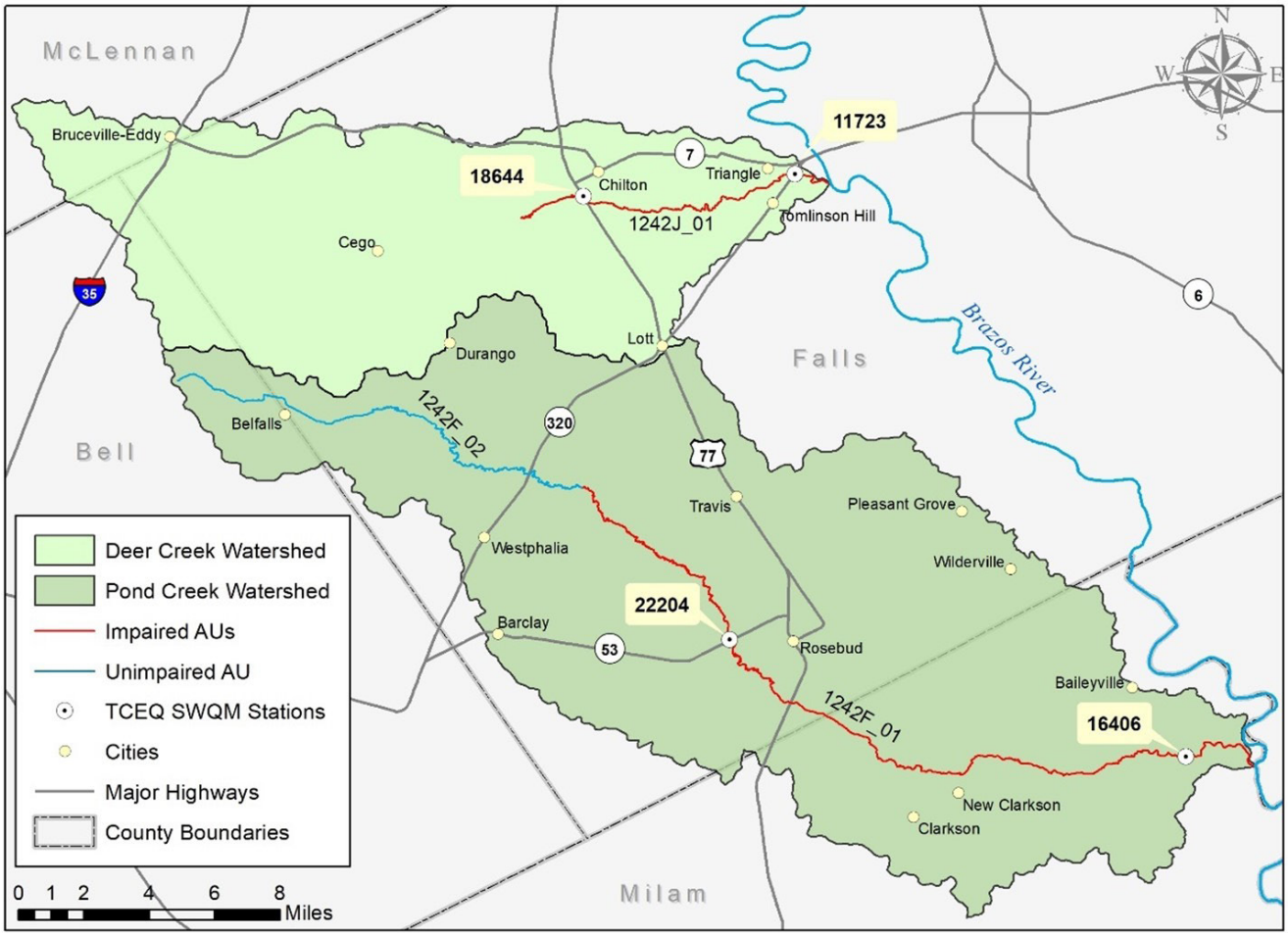

Figure 1. Overview of impaired segments of Deer and Pond creeks within the larger Brazos River Basin. Shows active SWQM stations that used in this project.

Project Description

Throughout this project, routine water quality monitoring was conducted with a focus on *E. coli* concentration data. Data was collected monthly for 20 months at four sites: TCEQ monitoring stations 11723 and 18644 in Deer Creek, and 22204 and 16406 in Pond Creek, resulting in 79 total samples (Figure 1). Station 11723 was dry in September 2023 and therefore no samples could be collected (Table 10). Instantaneous flow data was collected at the Pond Creek stations. The project quality assurance project plan (QAPP) fully outlines all sampling procedures, methods, sampling sites, and planned project activities. Monthly sampling included routine field parameters and *E. coli* grab samples to sufficiently fill data gaps, thus enabling future water quality assessments and watershed analysis. In addition, monthly streamflow measurements were collected at both Pond Creek sites.

Water quality and instantaneous flow data were uploaded to the TCEQ surface water quality monitoring information system (SWQMIS). A summary of collected data, water quality findings, and trends are included in this final project report to provide an informational basis for any future work conducted in these watersheds.

Station 11723, Deer Creek at SH 320

This surface water quality monitoring (SWQM) station is located on AU 1242J_01 immediately downstream of SH 320, west of Marlin. Deer Creek is categorized as impaired due to elevated bacteria.

Station 18644, Deer Creek at US 77

This SWQM station is located on AU 1242J_01, immediately downstream of US 77, south of Chilton and 1.2 km upstream of the WWTP permit WQ0010811-001 outfall. Deer Creek is categorized as impaired due to elevated bacteria.

Station 16406, Pond Creek at FM 2027 4.0 Kilometers South of Baileyville

This SWQM station is located on Segment 1242F_01, 4 km south of Baileyville. Pond Creek is currently categorized as impaired due to elevated bacteria.

Station 22204, Pond Creek Upstream of SH 53 Bridge 2.7 Kilometers West of the City of Rosebud

This SWQM station is located on Segment 1242F_01, 30 m upstream of the SH 53 bridge, 2.7 km west of the city of Rosebud. Pond Creek is categorized as impaired due to elevated bacteria.

Task 1: Project Administration

Texas Water Resources Institute (TWRI) has effectively administered, coordinated, and monitored all work performed under this project including technical and financial supervision and preparation of status reports.

Subtask 1.1: QPRs

To track project progress, TWRI submitted quarterly progress reports (QPRs) to TSSWCB. QPRs contained an overview of project activities completed during each quarter, an overview of activities to be completed in the next quarter, and highlighted related issues or problems associated with the project. The QPRs were submitted by the 1st of December, March, June, and September and distributed to all Project Partners.

Subtask 1.2: Reimbursement Forms

TWRI provided financial supervision to ensure tasks and deliverables were acceptable and completed within budget. Financial supervision consisted of submitting appropriate reimbursement forms at least quarterly to TSSWCB and submitting necessary budget revisions.

Subtask 1.3: Project Coordination

TWRI hosted quarterly coordination meetings or conference calls with Project Partners to discuss project activities, the project schedule, communication needs, deliverables, and other requirements. TWRI developed lists of action items needed following each project coordination meeting and distributed them to project personnel.

Subtask 1.4: Final Report

TWRI developed this Final Report that summarizes activities completed during the duration of the project as well as the conclusions reached. The Final Report also discusses the extent to which the project goals and measures of success were achieved.

Task 2: Quality Assurance

TWRI developed data quality objectives and quality assurance/control (QA/QC) activities to ensure data generated through this project were of known and acceptable quality.

Subtask 2.1: QAPP Development

TWRI developed a QAPP for activities in Tasks 3 and 4 consistent with the most recent versions of the U.S. Environmental Protection Agency (EPA) *Requirements for Quality Assurance Project Plans (QA/R-5)* (EPA, 2001) and the *TSSWCB Environmental Data Quality Management Plan* (TSSWCB). All monitoring procedures and methods prescribed in the QAPP were to be consistent with the guidelines detailed in the *TCEQ Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue (RG-415)* (TCEQ, 2012) and *Volume 2: Methods for Collecting and Analyzing Biological Assemblage and Habitat Data (RG-416)* (TCEQ, 2014). [Consistency with Title 30, Chapter 25 of the Texas Administrative Code, *Environmental Testing Laboratory Accreditation and Certification,* which describes Texas' approach to implementing the National Environmental Laboratory Accreditation Conference (NELAC) standards (TNI, 2016), were required where applicable.] After developing the QAPP, TWRI sent draft and final versions to TSSWCB, and a final document was approved.

Subtask 2.2: QAPP Implementation

TWRI implemented the approved QAPP. TWRI submitted revisions and amendments of the QAPP to TSSWCB when necessary.

Task 3: Continued Surface Water Quality Monitoring for Deer and Pond Creeks

TWRI collected water quality and quantity data of known and acceptable quality for future waterbody assessments.

Subtask 3.1: Water Quality Monitoring

TWRI conducted monthly ambient water quality monitoring at four sites for 20 months. Sampling included basic field parameters (temperature, pH, dissolved oxygen (DO), specific conductance, and flow where conditions allow) and grab sample collection (analyzed for *E. coli)*. Water samples were delivered to a NELAP-accredited laboratory with the appropriate holding time for bacterial analysis. Sampling events were documented in QPRs.

Subtask 3.2: Water Quality Data Submission

The TWRI maintained a database of all collected water quality data from this project. Collected data was submitted to the TSSWCB by TWRI for submission to SWQMIS quarterly.

Task 4: Distribution of Education Materials and Effectiveness Evaluation

TWRI designed and distributed educational direct mail materials to watershed stakeholders and evaluated the impact of the educational campaign.

Subtask 4.1: Landowner Database

TWRI developed a landowner database of contact information (mailing addresses) for 1,050 potential agricultural livestock producers in the watershed using Texas County Appraisal District and National Land Use / Land Cover data (TNRIS, 2022; USGS, 2021). The landowners' contact information was verified for deliverable addresses.

Subtask 4.2: Compile Existing Educational Brochures

TWRI used existing educational materials (6x11" postcard, hereafter "mailer") with information on best management practices for livestock prescribed grazing, including a call to action and contact information for Natural Resources Conservation Service (NRCS) and local Soil and Water Conservation District (SWCD) offices in the watershed. TSSWCB approved use of the mailers prior to distribution.

Subtask 4.3: Distribution of Educational Materials

TWRI distributed the educational mailers once to all 1,050 addresses on the landowner database in March 2023.

Subtask 4.4: Track Plans Implemented

With assistance from NRCS, TWRI is tracking the number of conservation plans implemented in the watershed before and during the project. Due to delays between plan development and implementation, practices applied during the project timeline may not totally reflect the number of existing plans made to date.

Subtask 4.5: Post-Mailer Evaluation

TWRI developed an evaluation questionnaire to be sent by mail following the distribution of the educational mailer. The evaluation was approved by TSSWCB prior to distribution. All 1,050 addresses received the evaluation request.

Appendix A: Data Summary Report

TCEQ conducts a water body assessment on a biennial basis to satisfy requirements of the federal Clean Water Act (CWA) Sections 305(b) and 303(d). The resulting T*exas Integrated Report of Surface Water Quality (Texas Integrated Report)* describes the status of water bodies throughout the state of Texas. The most recent report, the *2022 Texas Integrated Report,* includes an assessment of water quality data collected from December 1, 2013, to November 30, 2020 (TCEQ, 2022).

The *Texas Integrated Report* assesses water bodies at the AU level. An AU is a sub-area of a segment, defined as the smallest geographic area of use reported in the assessment (TCEQ, 2022). Water bodies are divided into segments and each segment can be further split into AUs. Each AU is intended to have homogeneous chemical, physical, and hydrological characteristics, which allows the assignment of site-specific standards to the AU (TCEQ, 2022).

Two tributaries of the Brazos River, Deer Creek, and Pond Creek, are included in the project scope. Independent water quality analysis is performed on each unique AU using data from TCEQ monitoring stations. At least 10 data points within the most recent 7 years of available data are required for all water quality parameters except bacteria, which requires a minimum of 20 samples. Deer Creek (AU 1242J_01) was listed as impaired due to elevated levels of bacteria in the *2006 Texas Integrated Report* (TCEQ, 2006). A portion of Pond Creek, AU 1242F_01 was designated as impaired for elevated levels of bacteria in the *2010 Texas Integrated Report* (TCEQ, 2010).

Monitoring was conducted at four active monitoring stations, two per watershed. Prior to this project, routine water quality monitoring had not been conducted on these creeks since before 2010. SWQM stations 18644 and 11723 are located along Deer Creek (AU 1242J_01). SWQM station 22204 and 16406 are located along Pond Creek (AU 1242F_01) (Figure 1). Field parameters such as temperature, DO, specific conductance, and pH were collected monthly at each station. This is considered routine monitoring because all data and parameters are routinely collected monthly for each site. Each station had water grab samples analyzed for *E. coli* concentrations. Additionally, the instantaneous flow rate was measured at both Pond Creek stations.

Texas Surface Water Quality Standards

The state establishes water quality standards after approval by the EPA to define a water body's ability to support its designated uses. Designated uses may include aquatic life use (fish, shellfish, and wildlife protection and propagation), primary contact recreation (swimming), public water supply, and fish consumption. Water quality indicators for these uses include DO (aquatic life use), *E. coli* (primary contact recreation), pH, temperature, and total dissolved solids (TCEQ, 2022).

Bacteria

The risk of illness during contact recreation is evaluated using fecal indicator bacteria concentrations. In freshwater environments, *E. coli* concentrations indicate that associated pathogens from intestinal tracts of warm-blooded animals could be reaching water bodies and may cause illness in people recreating in them. Indicator bacteria can originate from wildlife, domestic livestock, pets, malfunctioning on-site sewage facilities, urban and agricultural runoff, sewage system overflows, and direct discharges from wastewater treatment facilities. For primary contact recreation, the standard is a geometric mean of ≤126 MPN of *E. coli* per 100 mL of water from at least 20 samples (30 TAC § 307.7 2014).

As previously mentioned, Deer and Pond creeks are impaired for primary contact recreation due to elevated bacteria levels in the 2022 Texas Integrated Report (TCEQ, 2022). Historical data showed a decreasing trend in *E. coli* concentration at Deer Creek and stable *E. coli* concentrations at Pond Creek (Figure 2). Data collected from this TWRI-led monitoring project indicates all AUs have stable bacteria levels above the maximum *E. coli* geomean criterion for recreational use at 126 MPN/100 mL (Figure 3).

Dissolved Oxygen

Dissolved oxygen determines a water body's aquatic life uses. Aquatic life uses indicate whether a water body can support and maintain a healthy aquatic ecosystem. If DO levels drop too low, fish and other aquatic species will not survive. Typically, DO will fluctuate throughout the day, with the highest levels occurring in the mid to late afternoon due to photosynthesis. DO levels are usually at their lowest just before dawn as both plants and animals in the water consume oxygen through respiration. Furthermore, seasonal fluctuations in DO are common because of decreased oxygen solubility in water as temperature increases; therefore, DO levels are typically lower during the summer and higher in the winter

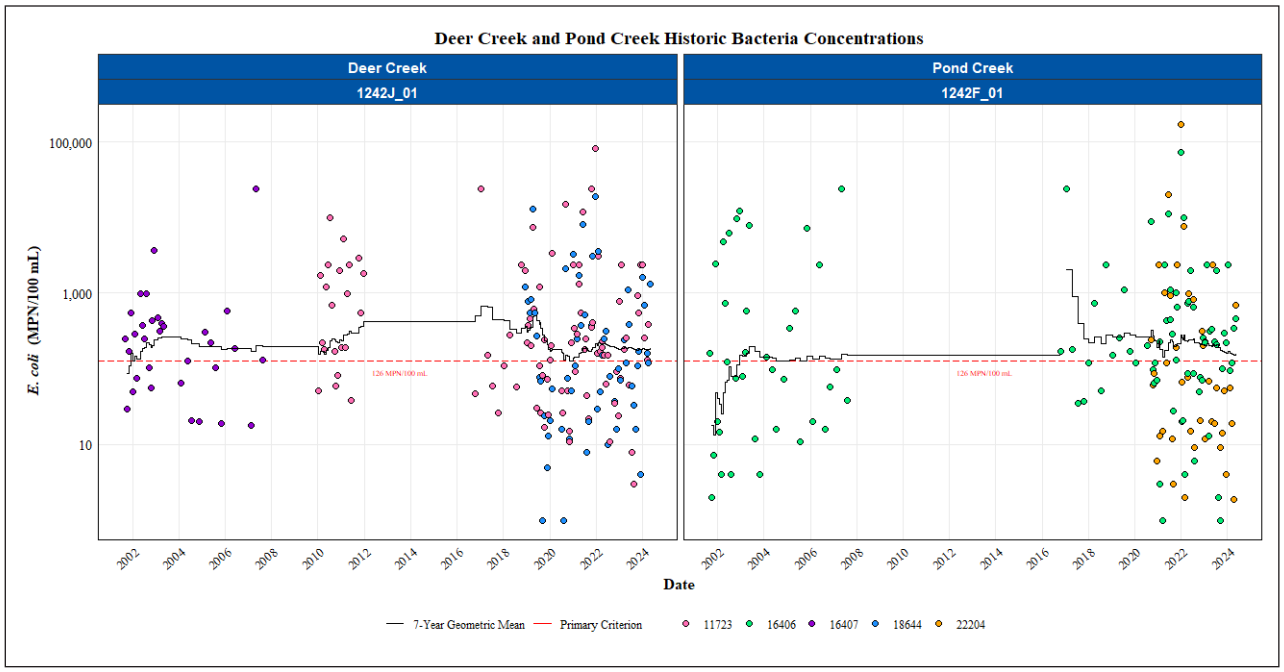

Figure 2. Historic *E. coli* concentration at SWQM stations in Deer Creek and Pond Creek. The standard criterion for primary contact recreation *E. coli* is set at 126 MPN/100mL.

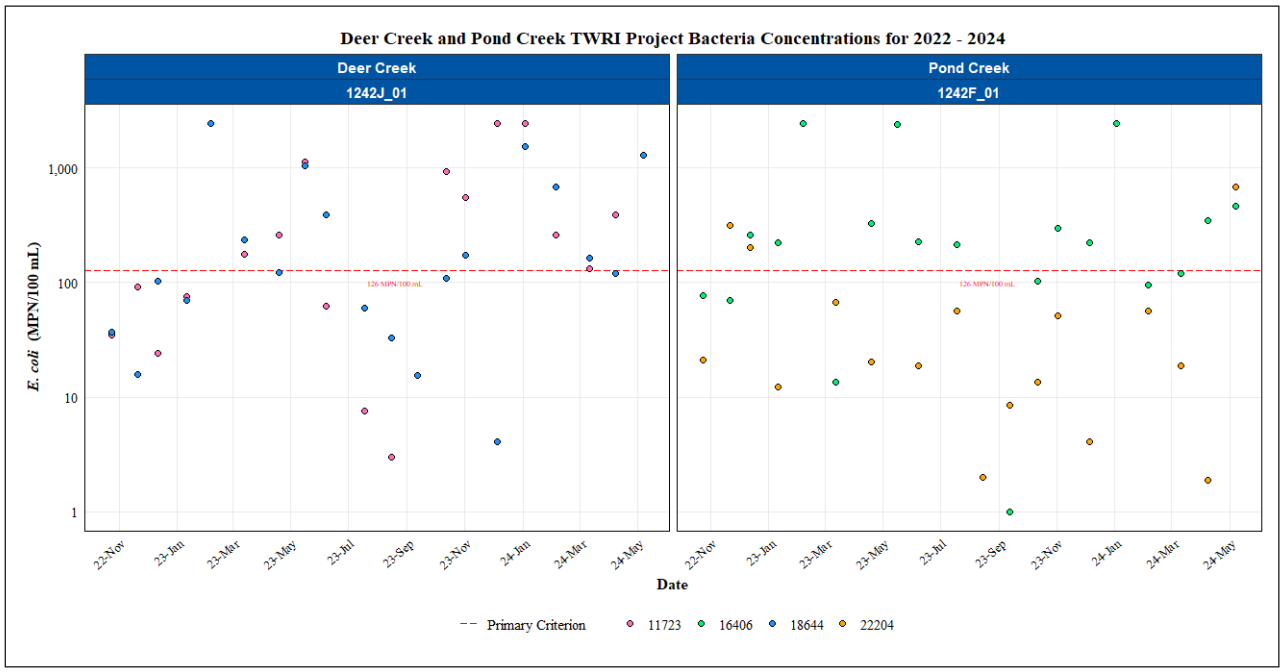

Figure 3. Bacteria concentrations at SWQM stations in Deer Creek and Pond Creek. The standard criterion for primary contact recreation *E. coli* is set at 126 MPN/100mL.

months. While DO can fluctuate naturally, human activities can also cause abnormally low DO levels. Excessive organic matter (vegetative material, untreated wastewater, etc.) can result in depressed DO levels as bacteria break down the materials and consume oxygen. Excessive nutrients from fertilizers and manures can also depress DO as aquatic plants and algae growth increase in response. More respiration from plants and the decay of organic matter as plants die off can also decrease DO concentrations.

In the 2022 Texas Integrated Report (TCEQ, 2022), both Deer Creek (AU 1242J_01) and Pond Creek (AU 1242F_01) fully support the screening level DO criterion of 5 mg/L and 3 mg/L, respectively. Historical DO data for these tributaries indicates otherwise healthy conditions with a geomean significantly above all screening criterion despite exceedances (Figure 4). Figure 5 and Figure 6 show data collected by the TWRI during this project. Project

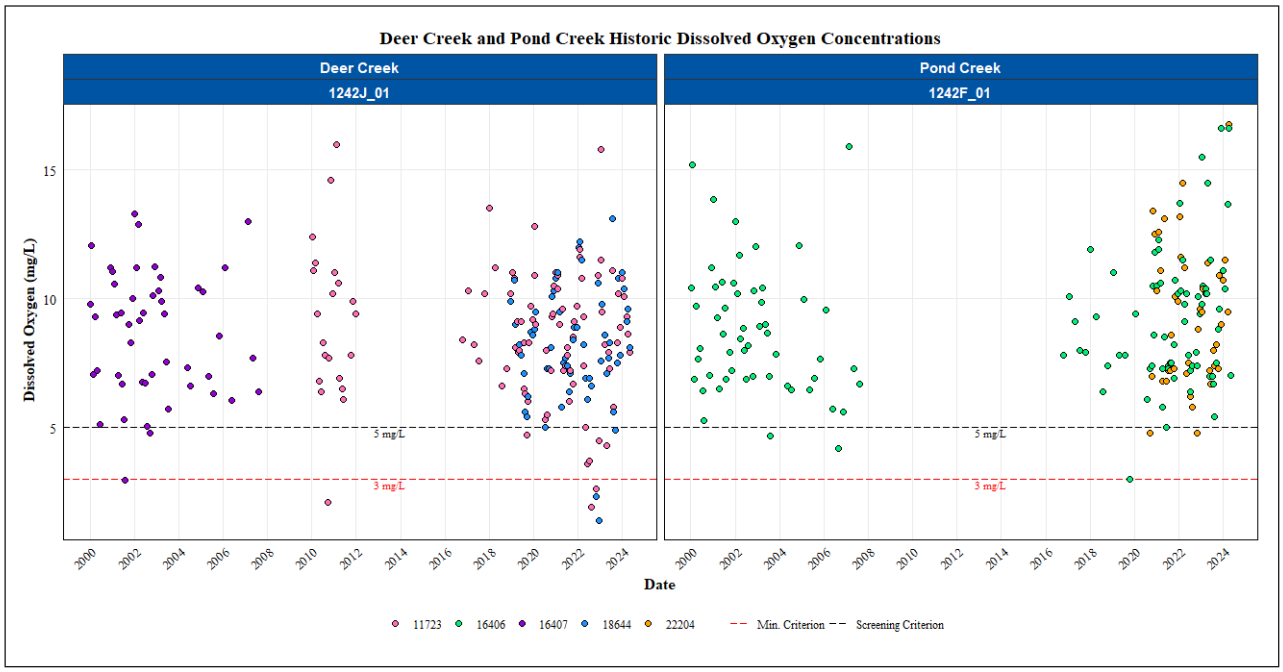

Figure 4. Historic DO concentrations at SWQM stations in Deer Creek and Pond Creek. The creeks fully support the DO screening criterion of 5 mg/L.

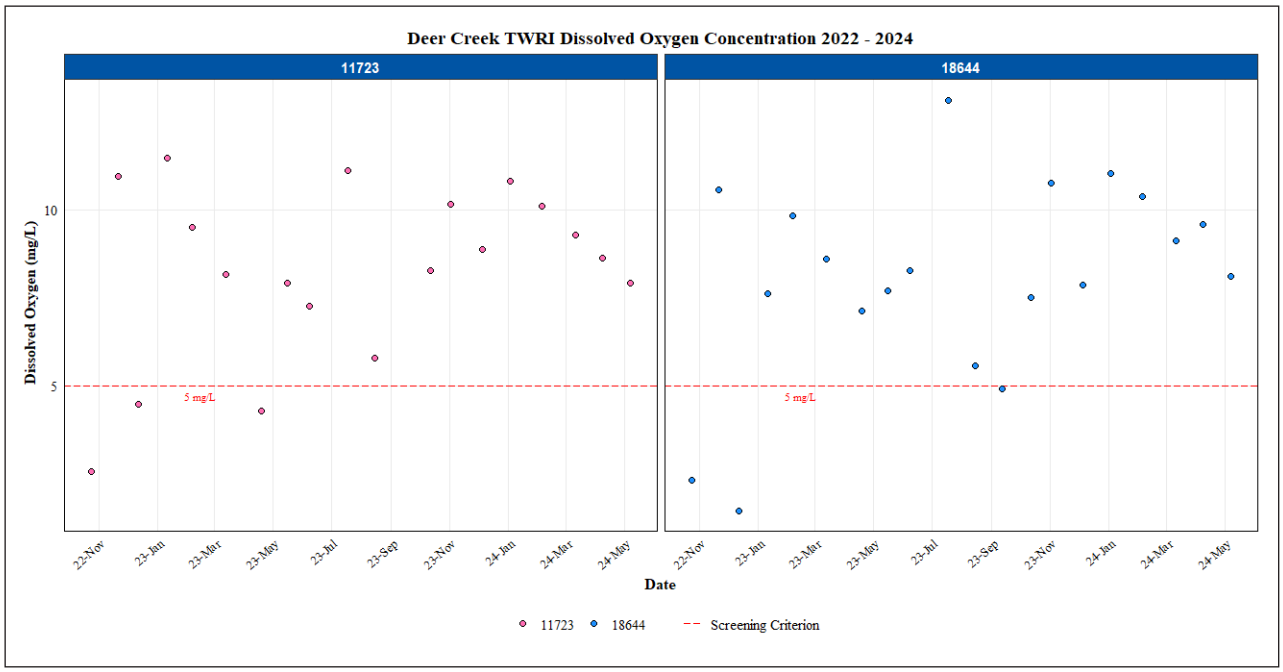

Figure 5. DO Concentrations at SWQM stations in Deer Creek. DO screening criterion for this creek is 5 mg/L, and there are no listed concerns for DO.

data collected agrees with historic data showing the creeks have normal levels of DO with a rolling geomean above the screening criterion for each creek. However, DO levels for Deer Creek (AU 1242J_01) dropped below the criterion in October 2022, December 2022, and April 2023 (Figure 5). For both creeks, the geomean remains much higher than the screening criterion. Overall, the DO concentration indicates a potentially healthy aquatic ecosystem throughout the TWRI-led monitoring project and beyond.

Flow

Generally, streamflow (the amount of water flowing in a river/creek at a given time) is dynamic and always changing in response to both natural (e.g., precipitation events) and anthropogenic (e.g. changes in land cover) factors. From a water quality perspective, streamflow is important because it influences the ability of a water body to assimilate pollutants.

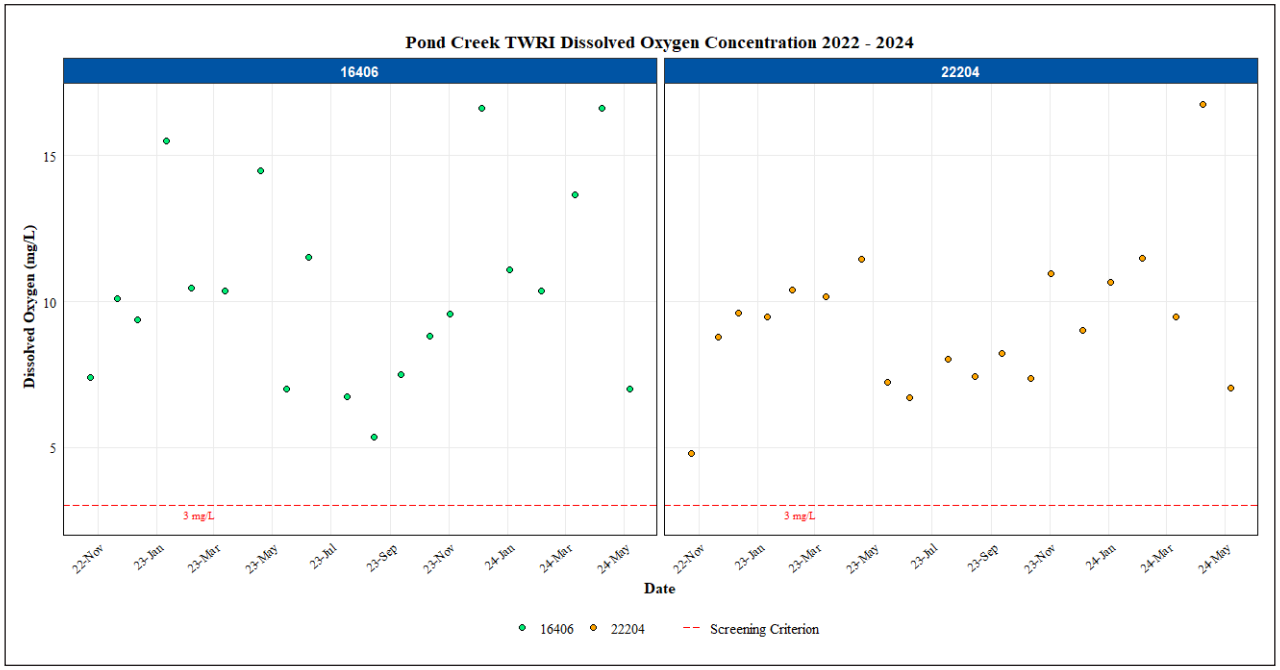

Figure 6. DO concentrations at SWQM stations in Pond Creek. DO screening criterion for this creek is 3 mg/L, and there are no listed concerns for DO.

Flow data is useful in creating flow duration curves (FDC) and load duration curves (LDC). The LDC method is widely used to characterize water quality data across different flow conditions in a watershed. An LDC provides visual display of streamflow, load capacity, and water quality exceedance by first developing a FDC using flow measurements.

Historical flow measurements show exceedingly high flow in 2020 at both Pond Creek stations (Figure 7). This coincides with the low DO measurement on Pond Creek (Figure 4). Extremely elevated flow in Deer and Pond creeks highly influences bacteria levels. For water quality data collected over the course of the TWRI-led project, instantaneous flow was collected at SWQM sites 16406 and 22204 (Figure 8). This recent flow data is consistent with historical data at Pond Creek.

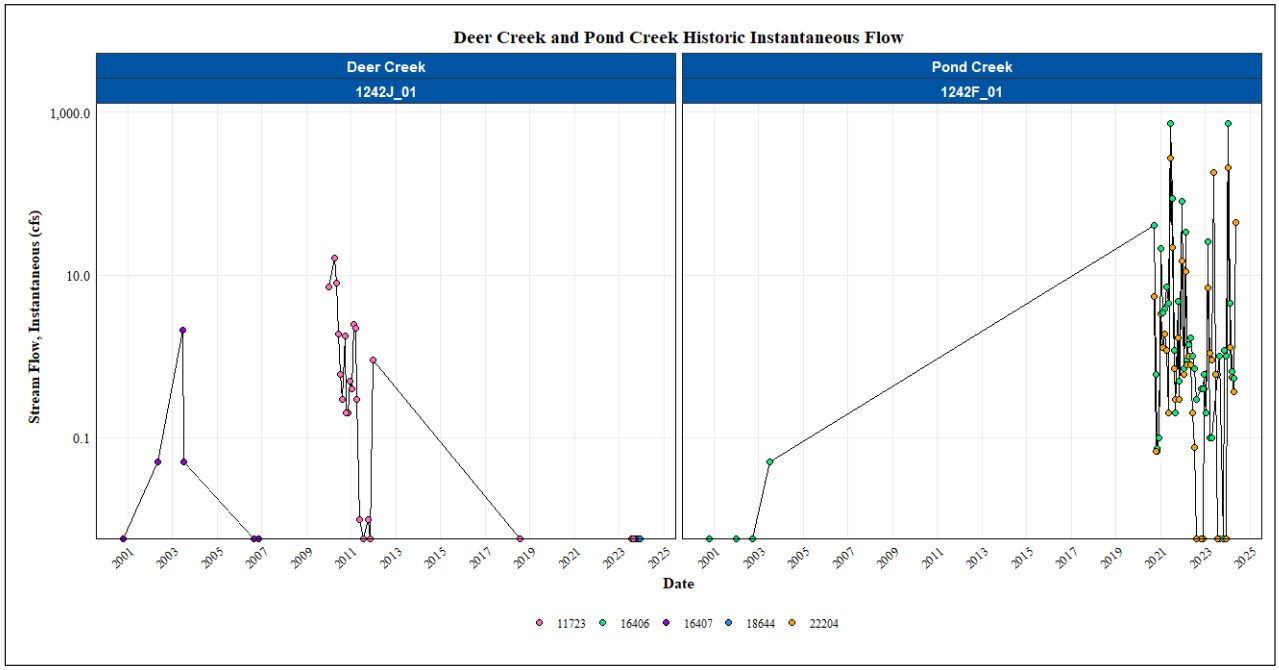

Figure 7. Historic flow at SWQM stations in Deer Creek and Pond Creek.

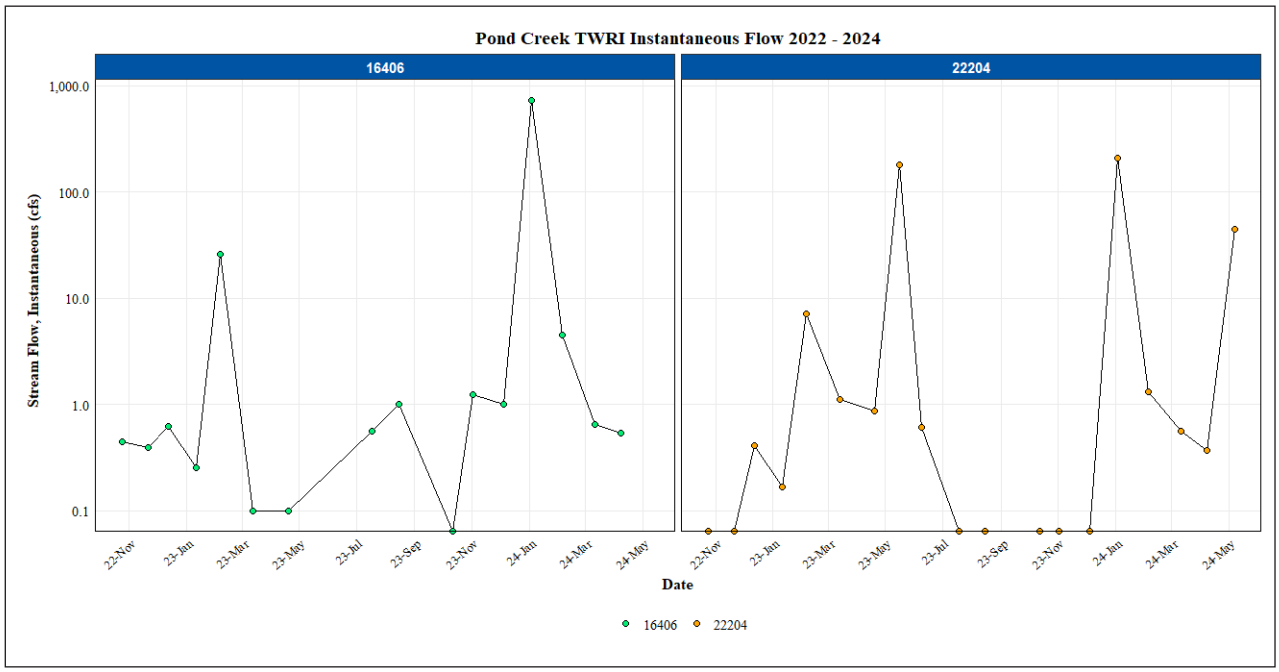

Figure 8. Instantaneous flow values measured in cubic feet per second (cfs) at each project SWMQ station in Pond Creek.

Table 1. NRCS conservation practices applied in Deer Creek and Pond Creek watersheds.

Practice	2019	2020	2021	2022	2023	Average
Brush Management (ac.)	-	-	80.2	26.8	-	53.5
Cover Crop (ac.)	135.5	170	719.8	757.7	723.6	501.3
Critical Area Planting (ac.)	4.3	1.7	-	-	-	3
Fence (ft.)	3,505	1,674	8,364	7,807	10,737.5	6,417.5
GSS (no.)	-	1	-	-	-	1
Grassed Waterway (ac.)	1.2	-	-	-	-	1.2
Herb. Weed Treat. (ac.)	285.2	19.4	-	260.5	250.2	203.8
Pasture & Hay Planting (ac.)	225.9	11.1	95.7	243.1	173.8	149.9
Pest Management (ac.)	-	-	-	72.1	-	72.1
Pond (no.)	2	1	4	2	-	2
Prescribed Grazing (ac.)	-	143.8	-	192.9	180.4	172.4
Range Planting (ac.)	-	-	-	75.9	-	75.9
Terrace (ft.)	-	31,364	-	7,264	-	19,314
Total number of applied practices	27	20	18	40	33	27

GSS = Grade Stabilization Structure

NRCS Data

The NRCS planning numbers varied throughout the project. Table 1 presents data for all (range, pasture, and crop land use) NRCS conservation practices applied before and during the project period. Note that not all practices are applied in all years. Practices applied in 2023 were above the 5-year average.

Table 2 provides specific data about the number of prescribed grazing plans implemented within the watershed during the project period. The number of prescribed grazing plans showed an increasing trend, with 2023 remaining above the average. Due to delays between conservation planning, contract or technical plan obligation, and implementation of practices, data from 2023 likely does not reveal the full impact of watershed activities and promotional materials. Data on practices implemented in subsequent years, at least through 2025, is needed to measure true conservation adoption impact. The number of contracts obligated in 2023 was not available at the time of publication.

Survey Data

Approximately two weeks after the distribution of the mailer, a prenotice postcard was sent to all 1,050 addresses. The postcard was designed to raise awareness of the upcoming evaluation and detailed the purpose and scope of the research project. One week after the distribution of the prenotice postcard, the evaluation packet was sent out. The packet contained a 4-page evaluation, study information sheet, cover letter with instructions, and business reply envelope. The following week, a reminder postcard was sent to all addresses to prompt action and thank individuals who had already responded. All materials and procedures, including the mailer, postcards, evaluation questionnaire, study information sheet, and cover letter were approved by the Texas A&M Institutional Review Board (IRB2022-0482M) prior to distribution.

Of the 1,050 survey packets sent out, 236 responses were returned (22.5% response rate). Of the 236 responses, 104 were not eligible to contribute to the survey. The primary reasons provided for ineligibility were that the respondent did not work the land (e.g., had a wildlife exemption), worked the land but did not own cattle, or no longer owned or leased land within the applicable counties. The final count for completed usable responses was 132 (12.6%).

Most respondents had cattle operations located in Falls County (n = 103, 78%). Additionally, thirteen respondents operated in Bell County (9.8%), nine respondents operated in Milam County (6.8%), and seven respondents operated in McLennan County (5.3%). Fourteen respondents operated in more than one county. Operation types were primarily cow/calf (n = 122, 91.7%), stocker/backgrounder (n = 5, 3.79%), feedlot/finishing (n = 3, 2.27%), one operation was described as genetic/breeder (0.76%), and one listed as a hobby operation (0.76%). Seven cow/calf operations listed secondary operation type as stocker/backgrounder. The median acreage per producer was 100 acres, with a range between 7 and 5,600 acres. Additional landowner and cattle operation characteristics are presented in Table 3.

Table 2. Acres and applied practices for Prescribed Grazing (CP 528).

Measure	2019	2020	2021	2022	2023	Average
Acres applied (ac.)	-	143.8	-	192.9	180.4	172.4
Practices applied (no.)	-	5	-	7	7	6
Percent of total applied practices	-	25	-	17.5	21.2	22.2

Table 3. Self-reported cattle operation and landowner characteristics.

	Bell	Falls	McLennan	Milam	Total
	n	*n*	*n*	*n*	*N* (%)
***Which best describes the type of cattle operation on the land you own or lease?**					
Cow/calf	12	94	7	9	122 (91.7)
Stocker/backgrounder	-	5	-	-	5 (3.79)
Genetic/breeder	1	-	-	-	1 (0.76)
Feedlot/finishing	-	3	-	-.	3 (2.27)
Dairy	-	-	-	-	-
Hobby	-	1	-	-	1 (0.76)
How would you describe the typical stocking rate for this operation?					
Low	3	42	4	3	52 (39.7)
Medium	8	49	2	4	63 (48.1)
High	2	11	1	2	16 (12.2)
What percentage of the cattle's annual forage comes from hay?					
No hay is used	-	-	1	1	2 (1.5)
1 – 20%	4	27	1	3	35 (26.7)
21 – 50%	9	67	4	5	85 (64.9)
51 – 80%	-	8	-	-	8 (6.1)
81 – 100%	-	1	-	-	1 (0.8)
What percentage of your household income comes from cattle production?					
<10%	11	63	7	4	85 (65.4)
10 – 24%		18	-	2	20 (15.4)
25 – 49%	-	9	-	3	12 (9.2)
50 – 74%	1	4	-	-	5 (3.8)
75 – 90%	1	2	-	-	3 (2.3)
91 – 100%	-	5	-	-	5 (3.8)
How long have you been involved in cattle production?					
Less than 10 years	4	15	2	3	24 (18.5)
10 – 19 years	1	18	-	1	20 (15.4)
20 – 29 years	2	14	-	2	18 (13.8)
30 years or more	6	55	4	3	68 (52.3)

*Multiple answers allowed; therefore sum may be greater than total number of survey responses.
Note that counts may be less than total responses received due to skipped questions.

Table 4. Self-assessed changes in knowledge due to mailer.

Category of Knowledge	Before Mailer	After Mailer	Difference
Where to get conservation assistance	2.23	2.60	0.37
Warning signs of overstocking	2.33	2.55	0.22
Issues caused by overstocking	2.38	2.58	0.20
Benefits of balanced stocking rates	2.33	2.45	0.12
How to adjust stocking rates	2.43	2.60	0.17

Knowledge scale: 1 = Poor, 2 = Fair, 3 = Good, 4 = Excellent

Table 5. Landowner perceptions related to education.

	Bell	Falls	McLennan	Milam	Total
	n	*n*	*n*	*n*	*N*
***What information do you use to determine the number of cattle per acre on your land?**					
1-D-1 Exemption guidance	-	2	1	-	3
NRCS or SWCD guidance	-	8	-	2	10
Measured forage available	5	16	1	1	23
Grazable acres available	8	40	1	5	54
Total acres available	4	31	2	2	39
Cattle market prices	1	12	1	2	16
Someone else decides	1	10	3	3	17
Other	2	18	1	1	17
***Which type of educational resource(s) would you be most likely to use?**					
In-person course or seminar	3	46	3	3	55
Online course or seminar	2	15	-	1	18
Online videos or demos	4	28	-	2	34
Online written materials	5	23	1	3	32
Physical print materials	3	46	-	6	55

*Multiple answers allowed; therefore sum may be greater than total number of survey responses.

Table 6. Landowner experiences and intentions related to livestock management activities.

	Never Done	Previously Done	Currently Doing	Plan to Do
	n	*n*	*n*	*n*
On the land that you own or lease for grazing cattle, what is your experience with the following actions:				
Make a grazing plan	40	22	39	12
Install cross fencing	19	67	21	7
Install additional water sources	29	54	22	9
Install additional shade structures	69	24	8	12
Use rotational grazing	22	25	65	4
Measure grass height before grazing	77	16	21	1
Measure grass height after grazing	83	13	17	2
Contact NRCS or SWCD	71	21	11	11
Make plan with NRCS or SWCD	85	12	9	8
Receive financial assistance	81	16	8	9

Of all 132 respondents, 44 (33.3%) recalled that they had received the mailer. For the respondents who stated they had received the mailer, self-assessed knowledge about the categories of information presented on the mailer generally improved. The categories and their respective average scores are presented in Table 4. A few respondents stated they had acted or intended to act on the information from the mailer by making a grazing plan (n = 8), changing their stocking rate (n = 6), installing new practices (n = 4), or contacting NRCS or SWCD offices for assistance (n = 5).

To further understand educational needs, respondents were asked for their current information sources and preferred education formats. The most common informational source used to make decisions about stocking rate was the number of grazable acres available to the producer (n = 54). The most preferred format for educational resources were in-person course/seminar (n = 55) and physical print materials (n = 55; see Table 5). This was followed closely by Online Videos or demos (n = 34), online written (n = 32). The least preferred method was an online course or seminar (n = 18).

When asked about activities related to livestock management and stocking rates, respondents had mixed experiences. Many respondents had never measured grass height before or after grazing, worked with the local NRCS or SWCD offices, or installed shade structures. Most producers had previously installed or planned to install cross fencing and water structures. Most producers were actively using rotational grazing. Table 6 provides individual breakdowns of each activity and experience level.

Finally, producers were asked about their acreage available and stocking rates. The median grazed acreage was 100 acres, with a range of 7 to 5,600 acres. The median herd size was 35 head per respondent, with a range of 1 to 5,000 head. To analyze true stocking intensity, it was assumed that one head was equivalent to one animal unit (AU), which is standard for stocking rate for a cow with calf, given most operations in the survey audience (n = 122, 91.7%) were described as cow/calf operations (Pate et al., 2022). Using this conversion, the median AU per herd for each respondent was 35 AU, with a range of 1 AU to 5,000 AU. Given the available data on grazing area and herd size, the median acres per AU for respondents was calculated at 3.2 ac./AU, with a range of 0.3 ac./AU to 40.0 ac./AU. The appropriateness of intensity of stocking rates for these properties is dependent upon management strategies. Further information is needed to determine whether individual respondents are grazing their land at appropriate intensities.

Conclusions

The educational mailers were responsible for over 1,000 contacts with landowners within a single week. While the scale of this case study limits the conclusions that can be drawn, there is evidence that the mailers improved recipients' knowledge of where to get conservation assistance, warning signs and issues of overstocking, benefits of balanced stocking rates, and how to adjust stocking rates. Additionally, the mailers prompted some recipients to take action by making their own grazing plan, changing their stocking rate, installing practices, or contacting NRCS or SWCD offices for assistance.

The advantage of the educational mailing program is that it provides education and outreach to stakeholders who may not traditionally fit the mold of an Extension program participant. It reaches individuals who may not be interested, willing, or capable of attending in-person programs or other traditional outreach venues. Many of the respondents indicated that they would be receptive of educational resources other than in-person courses. The value of the direct mailing approach continues to grow. This method and other alternative communication channels should be considered in watershed outreach and education programs in order to reach and spark engagement with outlying audiences.

Appendix B: Monitoring Data

Deer Creek

Perennial stream from the confluence of the Brazos River upstream to the confluence of Dog Branch northwest of Lott.

Station 18644

Deer Creek at US 77.

Table 7. Sample event data for routine data collection at Station 18644 along Deer Creek.

Tag ID	Date	Time	End Depth	Collecting Agency	Submitting Agency
TX101531	2022-10-24	9:44:00 AM	0.20	WR (Texas Water Resource Institute)	WR (Texas Water Resource Institute)
TX101535	2022-11-21	9:39:00 AM	0.20	WR	WR
TX101539	2022-12-12	9:48:00 AM	0.20	WR	WR
TX101543	2023-01-11	9:55:00 AM	0.20	WR	WR
TX101547	2023-02-06	9:51:00 AM	0.13	WR	WR
TX101551	2023-03-13	10:08:00 AM	0.15	WR	WR
TX101555	2023-04-19	10:05:00 AM	0.14	WR	WR
TX101559	2023-05-16	10:25:00 AM	0.30	WR	WR
TX101563	2023-06-08	10:19:00 AM	0.23	WR	WR
TX101568	2023-07-18	12:25:00 PM	0.20	WR	WR
TX101572	2023-08-15	11:45:00 AM	0.23	WR	WR
TX101575	2023-09-12	10:30:00 AM	0.20	WR	WR
TX101579	2023-10-12	10:20:00 AM	0.20	WR	WR
TX101583	2023-11-02	10:01:00 AM	0.14	WR	WR
TX101587	2023-12-05	10:18:00 AM	0.27	WR	WR
TX101591	2024-01-03	10:17:00 AM	0.23	WR	WR
TX101595	2024-02-05	10:02:00 AM	0.21	WR	WR
TX101599	2024-03-11	9:38:00 AM	0.21	WR	WR
TX101603	2024-04-08	10:10:00 AM	0.14	WR	WR
TX101607	2024-05-07	10:26:00 AM	0.3	WR	WR

Table 8. Field measurements for Station 18644 at Deer Creek. Red cells indicate measurements over criterion.

Parameter Code	00010	00094	00400	00078	00300	31699	72053
Date	Water Temperature (Celsius)	Specific Conductance (microS/cm)	pH	Secchi Depth (m)	Dissolved Oxygen (mg/L)	*E. coli* (MPN/100mL)	Days Since Last Precipitation Event
2022-10-24	20.7	1168.0	7.3	0.22	2.31	37	0
2022-11-21	7.9	768.0	7.8	0.62	10.56	16	0
2022-12-12	16.7	627.0	7.3	0.51	1.45	102	1
2023-01-11	14.1	688.0	7.8	0.36	7.62	70	4
2023-02-06	11.8	752.3	7.4	0.06	9.83	> 2420	2
2023-03-13	17.2	773.0	7.7	0.16	8.61	236	3
2023-04-19	19.8	525.0	8.0	0.18	7.13	122	12
2023-05-16	22.8	512.0	7.9	0.10	7.70	1050	0
2023-06-08	27.9	658.0	7.8	0.28	8.27	387	0
2023-07-18	34.0	823.0	8.2	0.21	13.12	59	17
2023-08-15	28.6	995.0	7.7	0.20	5.57	33	45
2023-09-12	24.3	1139.0	7.5	0.18	4.90	16	15
2023-10-12	19.4	814.0	7.6	0.16	7.51	108	7
2023-11-02	8.0	778.0	7.8	0.39	10.75	172	3
2023-12-05	8.5	839.5	7.8	0.45	7.85	4	4
2024-01-03	7.9	464.5	7.6	0.08	11.02	1550	1
2024-02-05	12.2	551.0	8.0	0.29	10.38	987	2
2024-03-11	16.1	514.0	8.0	0.26	9.13	162	3
2024-04-08	21.2	563.5	8.0	0.31	9.58	119	< 1
2024-05-07	24.8	520.4	7.9	0.02	8.10	1300	2

Station 11723

Deer Creek at SH 320.

Table 9. Sample event data for routine data collection at Station 11723 along Deer Creek.

Tag ID	Date	Time	End Depth	Collecting Agency	Submitting Agency
TX101530	2022-10-24	9:20:00 AM	0.2	WR	WR
TX101534	2022-11-21	9:20:00 AM	0.0	WR	WR
TX101538	2022-12-12	9:22:00 AM	0.2	WR	WR
TX101542	2023-01-11	9:32:00 AM	0.1	WR	WR
TX101546	2023-02-06	9:28:00 AM	0.1	WR	WR
TX101550	2023-03-13	9:47:00 AM	0.1	WR	WR
TX101554	2023-04-19	9:35:00 AM	0.1	WR	WR
TX101558	2023-05-16	9:54:00 AM	0.3	WR	WR
TX101562	2023-06-08	9:47:00 AM	0.1	WR	WR
TX101569	2023-07-18	12:56:00 PM	0.2	WR	WR
TX101573	2023-08-15	12:12:00 PM	0.2	WR	WR
TX101574	2023-09-12	9:25:00 AM	0.0	WR	WR
TX101578	2023-10-12	9:41:00 AM	0.2	WR	WR
TX101582	2023-11-02	9:35:00 AM	0.1	WR	WR
TX101586	2023-12-05	9:42:00 AM	0.1	WR	WR
TX101590	2024-01-03	9:50:00 AM	0.1	WR	WR
TX101594	2024-02-05	9:32:00 AM	0.1	WR	WR
TX101598	2024-03-11	9:20:00 AM	0.2	WR	WR
TX101602	2024-04-08	09:35:00 AM	0.1	WR	WR
TX101606	2024-05-07	10:04:00 AM	0.3	WR	WR

Table 10. Field measurements for Station 11723 at Deer Creek. Red cells indicate measurements over criterion.

Parameter Code	00010	00094	00400	00078	00300	31699	72053
Date	Water Temperature (Celsius)	Specific Conductance (microS/cm)	pH	Secchi Depth (m)	Dissolved Oxygen (mg/L)	*E. coli* (MPN/100mL)	Days Since Last Precipitation Event
2022-10-24	21.9	1801.0	7.3	0.60	2.56	35	0
2022-11-21	9.0	936.0	7.9	0.68	10.95	91	0
2022-12-12	18.1	901.0	7.0	0.72	4.47	24	1
2023-01-11	15.3	1078.0	7.8	0.85	11.48	75	4
2023-02-06	13.6	753.7	7.0	0.10	9.50	> 2420	2
2023-03-13	15.8	955.0	7.4	0.31	8.17	178	3
2023-04-19	20.7	872.0	7.1	0.45	4.29	260	12
2023-05-16	22.7	428.7	7.6	0.15	7.91	1120	0
2023-06-08	27.6	566.0	7.5	0.26	7.26	62	0
2023-07-18	35.1	743.0	8.5	0.16	11.11	8	17
2023-08-15	29.5	1288.0	8.2	0.05	5.79	3	45
2023-09-12	dry	dry	dry	dry	dry	dry	16
2023-10-12	19.9	*	6.9	0.58	8.26	921	7
2023-11-02	9.5	1237.0	7.6	0.32	10.15	548	3
2023-12-05	10.3	1336.2	7.2	0.16	8.88	> 2420	4
2024-01-03	8.5	471.8	7.1	0.06	10.80	> 2420	1
2024-02-05	12.5	601	8.0	0.20	10.11	260	2
2024-03-11	15.5	571	7.9	0.50	9.29	131	3
2024-04-08	21.3	564.1	7.7	0.50	8.63	387	<1
2024-05-07	23.8	536.1	7.8	0.02	7.91	1300	1

*A corrective action report was filed for the specific conductance observation on 2023-10-12 and the data point was rejected.

Pond Creek

From the Brazos confluence upstream to Live Oak Creek confluence.

Station 22204

Pond Creek upstream of SH 53 Bridge 2.7 Kilometers West of the City of Rosebud.

Table 11. Sample event data for routine data collection at Station 22204 along Pond Creek.

Tag ID	Date	Time	End Depth	Collecting Agency	Submitting Agency
TX101532	2022-10-24	10:16:00 AM	0.2	WR	WR
TX101536	2022-11-21	10:10:00 AM	0.3	WR	WR
TX101540	2022-12-12	11:02:00 AM	0.37	WR	WR
TX101544	2023-01-11	11:14:00 AM	0.3	WR	WR
TX101548	2023-02-06	11:00:00 AM	0.3	WR	WR
TX101553	2023-03-13	1:17:00 PM	0.3	WR	WR
TX101557	2023-04-19	11:40:00 AM	0.3	WR	WR
TX101560	2023-05-16	11:48:00 AM	0.3	WR	WR
TX101564	2023-06-08	12:01:00 PM	0.3	WR	WR
TX101567	2023-07-18	11:50:00 AM	0.2	WR	WR
TX101571	2023-08-15	11:08:00 AM	0.2	WR	WR
TX101576	2023-09-12	11:15:00 AM	0.2	WR	WR
TX101580	2023-10-12	10:50:00 AM	0.2	WR	WR
TX101584	2023-11-02	10:55:00 AM	0.28	WR	WR
TX101588	2023-12-05	10:51:00 AM	0.22	WR	WR
TX101592	2024-01-03	12:28:00 PM	0.3	WR	WR
TX101596	2024-02-05	11:37:00 AM	0.3	WR	WR
TX101600	2024-03-11	11:27:00 AM	0.3	WR	WR
TX101604	2024-04-08	11:45:00 AM	0.3	WR	WR
TX101608	2024-05-07	11:58:00 AM	0.3	WR	WR

Table 12. Field measurement for Station 22204 at Pond Creek. Red cells indicate measurements over criterion.

Parameter Code	00010	00094	00400	00078	00300	31699	72053
Date	Water Temperature (Celsius)	Specific Conductance (microS/cm)	pH	Secchi Depth (m)	Dissolved Oxygen (mg/L)	*E. coli* (MPN/100mL)	Days Since Last Precipitation Event
2022-10-24	21.6	1509.0	8.0	0.09	4.81	21	0
2022-11-21	9.3	310.0	8.0	0.07	8.78	313	0
2022-12-12	18.2	483.5	8.1	0.07	9.61	201	10
2023-01-11	16.6		8.0	0.21	9.49	12	4
2023-02-06	10.9	752.5	7.7	0.16	10.38	> 2420	2
2023-03-13	19.3	856.0	7.8	0.16	10.17	68	10
2023-04-19	21.2	672.0	8.0	0.05	11.45	20	12
2023-05-16	22.1	380.2	7.7	0.30	7.24	> 2400	0
2023-06-08	27.5	623.0	7.8	0.10	6.70	19	0
2023-07-18	30.0	933.0	8.0	0.71	8.02	56	26
2023-08-15	29.1	1186.0	7.9	0.05	7.43	2	45
2023-09-12	27.9	1550.0	8.2	0.05	8.21	9	16
2023-10-12	19.5	1579.0	8.2	0.12	7.35	14	7
2023-11-02	10.3	1725.0	8.2	0.09	10.95	51	3
2023-12-05	11.2	1955.4	8.1	0.14	9.02	4	5
2024-01-03	8.5	351.0	7.7	0.03	10.67	> 2420	1
2024-02-05	13.3	679.0	8.2	0.19	11.49	56	2
2024-03-11	12.3	1034.0	8.0	0.34	9.49	19	3
2024-04-08	21.9	810.0	8.5	0.11	16.77	1.9	< 1
2024-05-07	24.9	545.8	7.7	0.03	7.04	687	2

Station 16406

Pond Creek at FM 2027 4.0 Kilometers South of Bailyville.

Table 13. Sample event data for routine data collection at Station 16406 along Pond Creek.

Tag ID	Date	Time	End Depth	Collecting Agency	Submitting Agency
TX101533	2022-10-24	12:12:00 PM	0.3	WR	WR
TX101537	2022-11-21	11:48:00 AM	0.3	WR	WR
TX101541	2022-12-12	12:24:00 PM	0.6	WR	WR
TX101545	2023-01-11	12:30:00 PM	0.3	WR	WR
TX101549	2023-02-06	12:20:00 PM	0.3	WR	WR
TX101552	2023-03-13	11:25:00 AM	0.3	WR	WR
TX101556	2023-04-19	1:01:00 PM	0.3	WR	WR
TX101561	2023-05-16	12:53:00 PM	0.3	WR	WR
TX101565	2023-06-08	12:46:00 PM	0.3	WR	WR
TX101566	2023-07-18	11:05:00 AM	0.3	WR	WR
TX101570	2023-08-15	10:27:00 AM	0.3	WR	WR
TX101577	2023-09-12	12:05:00 PM	0.3	WR	WR
TX101581	2023-10-12	12:00:00 AM	0.2	WR	WR
TX101585	2023-11-02	12:58:00 PM	0.3	WR	WR
TX101589	2023-12-05	12:25:00 PM	0.3	WR	WR
TX101593	2024-01-03	13:53:00 PM	0.3	WR	WR
TX101597	2024-02-05	12:59:00 PM	0.3	WR	WR
TX101601	2024-03-11	12:50:00 PM	0.3	WR	WR
TX101603	2024-04-08	13:08:00 PM	0.3	WR	WR
TX101609	2024-05-07	12:48:00 PM	0.3	WR	WR

Table 14. Field measurements for Station 16406 at Pond Creek. Red cells indicate measurements over criterion.

Parameter Code	00010	00094	00400	00078	00300	31699	72053
Date	Water Temperature (Celsius)	Specific Conductance (microS/cm)	pH	Secchi Depth (m)	Dissolved Oxygen (mg/L)	*E. coli* (MPN/100mL)	Days Since Last Precipitation Event
2022-10-24	21.7	1753.0	7.9	0.30	7.40	77	0
2022-11-21	9.8	1167.0	7.9	0.35	10.11	70	0
2022-12-12	18.3	501.0	8.0	0.13	9.38	261	1
2023-01-11	15.2	487.8	8.7	0.21	15.50	222	4
2023-02-06	11.7	424.0	7.8	0.05	10.46	> 2420	2
2023-03-13	17.9	766.0	8.0	0.13	10.37	13	4
2023-04-19	22.2	672.0	9.3	0.05	14.48	326	12
2023-05-16	22.4	268.1	7.8	0.04	7.00	> 2400	0
2023-06-08	30.0	485.0	8.9	0.37	11.51	225	0
2023-07-18	31.4	855.0	7.2	0.17	6.73	214	13
2023-08-15	30.0	1087.0	7.5	0.16	5.37	2	45
2023-09-12	27.0	1328.0	8.1	0.21	7.49	1	16
2023-10-12	20.4	1244.0	8.2	0.70	8.82	102	7
2023-11-02	11.6	493.7	8.2	0.06	9.58	299	3
2023-12-05	10.6	572.6	8.9	0.42	16.63	222	5
2024-01-03	9.2	317.7	7.8	0.04	11.09	> 2420	1
2024-02-05	13.9	637.0	8.1	0.22	10.36	96	1
2024-03-11	17.5	900.0	8.7	0.20	13.65	119	3
2024-04-08	22.9	894.9	8.7	0.34	16.63	345	< 1
2024-05-07	25.5	379.7	7.8	0.02	7.01	461	2

Data Conclusions

TWRI worked diligently to complete all project tasks and turn in deliverables on time to the TSSWCB through the project period. As a result, more water quality data was collected for the watersheds and made accessible for future planning within the Deer Creek and Pond Creek watersheds. The additional 20 monthly ambient water quality data samples for each creek fills data gaps enabling future water quality assessments and watershed analysis. This data will be a great tool for stakeholders to determine a path forward for improving the water quality in the watersheds.

This project and similar projects allow progress towards restoring water quality in Texas. The need for such projects statewide in the future is crucial for continued success.

References

EPA. 2001. EPA Requirements for Quality Assurance Project Plans. March 2001. https://www.epa.gov/quality/epa-qar-5-epa-requirements-quality-assurance-project-plans.

Pate, J., Hilken, T., Leech, R. Smith, S., & Carpenter, G. (2022). National range and pasture handbook: Subpart H – Livestock nutrition, Husbandry, and Behavior. U.S. Department of Agriculture Natural Resources Conservation Service. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=48466.wba.

TCEQ. 2006. 2006 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d). https://www.tceq.texas.gov/waterquality/assessment/06twqi/twqi06.html.

TCEQ. 2010. 2010 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d). https://www.tceq.texas.gov/waterquality/assessment/10twqi/10twqi.

TCEQ. 2012. Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods. RG-415. Revised August 2012. https://www.tceq.texas.gov/publications/rg/rg-415.

TCEQ. 2013. Brazos River Recreational Use Attainability Analysis, Part 5. https://www.tceq.texas.gov/waterquality/standards/ruaas/brazospt5.

TCEQ. 2014. Surface Water Quality Monitoring Procedures, Volume 2: Methods for Collecting and Analyzing Biological Assemblage and Habitat Data. RG-416. Revised May 2014. https://www.tceq.texas.gov/publications/rg/rg-416.

TCEQ. 2019. Surface Water Quality Monitoring Data Management Reference Guide. July 2019. www.tceq.texas.gov/waterquality/data-management/dmrg_index.html.

TCEQ. 2020. 2020 Guidance for Assessing and Reporting Surface Water Quality in Texas (May 2020): In Compliance with Sections 305(b) and 303(d) of the Federal Clean Water Act.

TCEQ. 2022. 2022 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d). https://www.tceq.texas.gov/downloads/water-quality/assessment/integrated-report-2022/2022-303d.pdf.

The NELAC Institute (TNI) Standard. 2016. Volume 1, Management and Technical Requirements for Laboratories Performing Environmental Analysis, Module 2, Quality Systems General Requirements. EL-V1M2- Rev. 2.1.

USGS. 2005. Oberg, K.A., Morlock, S.E., and Caldwell, W.S. Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers. Special Investigations Report 2005-5183.

USGS. 2021. National Land Cover Database (NLCD) 2019 Products (ver. 3.0, February 2024). https://doi.org/10.5066/P9KZCM54.

TNRIS. 2022. Land Parcels: 2022 (acquisition date July 1, 2022). https://data.tnris.org/collection/?c=a6a-703ba-df8b-4d1b-8d4c-ece8ae786505.

TSSWCB. Environmental Data Quality Management. Retrieved from TSSWCB Programs: https://www.tsswcb.texas.gov/programs/texas-nonpoint-source-management-program/environmental-data-quality-management.

More information can be found at:

twri.tamu.edu/davidson_deer_creeks

pondcreek.twri.tamu.edu