Brushy Creek Watershed Monitoring and Historical Streamflow Estimation Final Report and Data Summary Report

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Texas Water Resources Institute
make every drop count

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Texas Water Resources Institute

Brushy Creek Watershed Monitoring and Historical Streamflow Estimation Final Report and Data Summary Report

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Cover photo: Brushy Creek. Photo by Cameron Castilaw

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List of Acronyms

AU	Assessment Unit
BRA	Brazos River Authority
CWA	Clean Water Act
DAR	Drainage Area Ratio
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency
MPN	Most Probable Number
NELAC	National Environmental Laboratory Accreditation Conference
QA	Quality Assurance
QAPP	Quality Assurance Protection Plan
QC	Quality Control
QPR	Quarterly Progress Report
RUAA	Recreational Use Attainability Analyses
SWQM	Surface Water Quality Monitoring
SLOC	SWQM Station Location
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

The Texas Commission on Environmental Quality (TCEQ) develops surface water quality standards under the authority of the Clean Water Act (CWA) and the Texas Water Code. Meanwhile, as required under the CWA Sections 305(b) and 303(d), TCEQ conducts biennial water quality assessment on all waters in the state, and the assessment results are synthesized and reported in the *Texas Integrated Report of Surface Water Quality (Texas Integrated Report).* Waterbodies are assessed by assessment unit (AU) using water quality data collected in the most recent seven years. An AU is a subarea of a segment, and a segment is defined by the TCEQ as a portion of a perennial stream, lake, wetland, or estuary that encompasses a large area or of major public interest (TCEQ 2021).

Brushy Creek is in the Brazos River Basin and flows through one of the fastest-growing urban areas in Texas – the I-35 corridor. The headwater of Brushy Creek is in Williamson County and flows east to its confluence with the San Gabriel River in Milam County (TCEQ 2022). Brushy Creek consists of one segment (1244) and four AUs (1244_01 through 1244_04). In the *2006 Texas Integrated Report*, AUs 1244_01 and 1244_03 are first listed as impaired for primary contact recreation use due to elevated *Escherichia coli* (*E. coli*) concentrations (TCEQ 2006). In September 2009, a Recreational Use Attainability Analysis (RUAA) was initiated for Brushy Creek and the results later confirmed that the primary contact recreation use designated to Brushy Creek was appropriate (TCEQ 2010). This RUAA signifies the importance of addressing the bacteria impairment in the creek.

In the *2022 Texas Integrated Report*, based on data collected between December 1, 2013 and November 30, 2020, the geometric mean values of *E. coli* are 181.33 most probable number (MPN) per 100 milliliters in AU 1244_01 and 258.65 MPN per 100 milliliter in AU 1244_03, which are above the applicable criterion of 126 MPN of *E. coli* per 100 milliliters (TCEQ 2022). In addition, AU 1244_02 has concerns for excessive bacteria in water, AUs 1244_01, 1244_02, and 1244_03 have concerns for excessive nitrate in water. AU 1244_03 also had fish kill incident(s) reported during the assessment period.

To enable future watershed-based assessment, planning, and implementation efforts to improve water quality, adequate data are needed. To this end, this project was funded to expand the existing water quality data collection for Brushy Creek. Moreover, a method for estimating streamflow for the relatively rural portion of the watershed was developed and compared with the widely applied drainage area-ratio (DAR) method.

Project Description

Throughout this project, routine water quality monitoring was carried out monthly at two locations, including the TCEQ surface water quality monitoring (SWQM) stations 12059 and 22392, for 18 months (Figure 1). Targeted parameters included instantaneous streamflow, bacteria, dissolved oxygen (DO), pH, Secchi depth, specific conductance, and temperature. All sampling methods, procedures, sites, and planned project activities are fully described in a quality assurance project plan (QAPP).

Data collected through this project were uploaded to the TCEQ surface water quality monitoring information system (SWQMIS). Water quality data summary and streamflow estimation are documented in Appendices A and B, respectively to provide a basis for future watershed-based planning conducted in this area.

Station 12059

This SWQM station is located on AU 1244_02, which has concerns for bacteria and nitrate, in Williamson County on CR 129/Engerman Lane. This location was selected to reflect the water quality and quantity conditions in a highly urbanized area; meanwhile, since the station is located directly downstream of AU 1244_03, it can also be used to indicate the water quality of this AU, which is impaired for bacteria and has concerns for nitrate.

Station 22392

This SWQM station is located on AU 1244_02 and is 1.1 kilometers north and 0.85 kilometers west of the intersection of FM 619 and CR 541 near Beyersville. This station was added through a SWQM station location (SLOC) request during the early stage of the project with the intention to create supplemental data collection for the downstream, relatively rural portion of the Brushy Creek watershed.

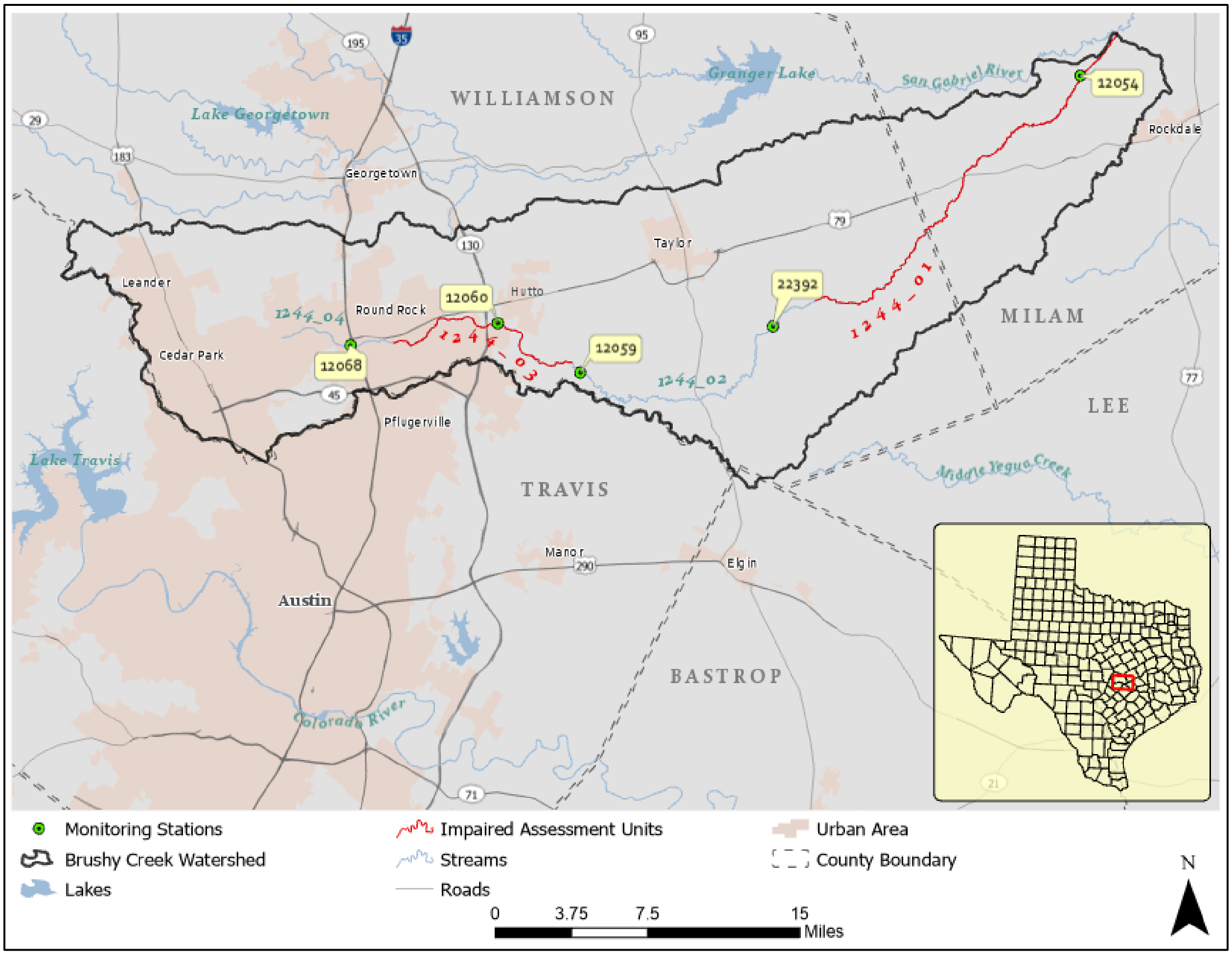

Figure 1. Overview of the Brushy Creek watershed with active monitoring stations.

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: Quality Progress Reports

To track project progress, TWRI submitted quarterly progress reports (QPRs) to the 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*. 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: Supplemental Water Quality and Continuous Streamflow Monitoring

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

Subtask 3.1: Monitoring Site Selection

TWRI conducted sampling site reconnaissance to determine the safest, most accessible sites for water quality monitoring in the project watershed. Two sites were selected, stations 12059 and 22392.

Subtask 3.2: Water Quality Monitoring

TWRI conducted monthly ambient water quality monitoring at two sites for 18 months (36 total samples). Sampling included basic field parameters (temperature, pH, dissolved oxygen (DO), specific conductance, Secchi depth, and flow where conditions allowed) 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 3.3: Water Quality Data Submission

TWRI maintained a master 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: Data Summary Report and Historical Streamflow Estimation

TWRI summarized the water quality and flow data collected in Task 3 and developed a method to estimate streamflow in the ungaged portion of the Brushy Creek watershed.

Subtask 4.1: Summarize Water Quality Data and Estimate Historical Streamflow

TWRI aggregated existing water quality data in addition to the data collected in Task 3. The data was visualized and analyzed using graphs, tables, etc. TWRI also used the continuous flow data collected in Task 3 to develop a validated method for estimating historical streamflow data for ungaged or poorly gaged areas in the watershed.

Conclusions

TWRI worked diligently to complete all project tasks and turn in deliverables on time to the TSSWCB throughout the project period. As a result, an additional 36 water quality samples were collected from Brushy Creek and can be used to assist future watershed-based assessment, planning, and implementation efforts. Projects such as this are why accomplishments are being made toward restoring water quality in Texas. The need for such projects statewide in the future is crucial for continued success.

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Appendix A: Data Summary Report

Since 2001, the TCEQ and the Brazos River Authority (BRA) have conducted quarterly routine monitoring to collect bacteria data in the Brushy Creek watershed. Their monitoring takes place at several locations, with abundant data collected at SWQM stations 12068 (AU 1244_04), 12060 (AU 1244_03), 12059 (AU 1244_02), and 12054 (AU 1244_01) (Figure 1). Routine monitoring involves collecting data and parameters at regular intervals (e.g., monthly, quarterly) at each site, without targeting specific environmental conditions or events.

During the project period (2021 – 2024), monthly routine monitoring was conducted at SWQM stations 12059 and 22392. Data were collected for DO, specific conductance, Secchi depth, pH, water temperature, and instantaneous streamflow. Furthermore, water samples were analyzed for *E. coli* concentrations. Since the scope of this project does not include collecting conventional chemical parameters (e.g., nutrients, chlorophyll a), this report focuses on summarizing and analyzing *E. coli*, DO, and streamflow data collected in the Brushy Creek watershed.

Texas Surface Water Quality Standards

Site-specific water quality standards are established by the TCEQ and approved by the U.S. EPA based on the designated uses of waterbodies, which may include support of aquatic life, human health (e.g., fish consumption, public water supply, etc.), and recreational activities (e.g., swimming, boating, etc.) (TCEQ 2022).

Monitoring Data

Station 12059

This monitoring station is located on AU 1244_02 at CR 129/Engerman Lane in Williamson County, TX. Table A-1 shows the sampling events that took place during the project period at this station. Table A-2 shows the *E. coli* data collected during the sampling events, and concentrations greater than the standard, 126 MPN per 100 milliliters, are highlighted in red.

Table A-1. Sampling events for routine data collection at SWQM station 12059 during the project period.

Tag ID	Date	Time	End Depth (meter)	Collecting Agency	Submitting Agency
TX101486	2022-10-31	10:45:00 AM	0.3	WR	TX
TX101488	2022-11-28	10:22:00 AM	0.3	WR	TX
TX101490	2022-12-21	10:40:00 AM	0.3	WR	TX
TX101492	2023-01-26	10:38:00 AM	0.3	WR	TX
TX101494	2023-02-23	10:17:00 AM	0.3	WR	TX
TX101497	2023-03-28	10:11:00 AM	0.3	WR	TX
TX101499	2023-04-27	10:35:00 AM	0.3	WR	TX
TX101500	2023-05-30	10:36:00 AM	0.3	WR	TX
TX101502	2023-06-27	10:26:00 AM	0.3	WR	TX
TX101504	2023-07-25	10:26:00 AM	0.3	WR	TX
TX101506	2023-08-17	10:43:00 AM	0.3	WR	TX
TX101508	2023-09-19	10:43:00 AM	0.3	WR	TX
TX101510	2023-10-18	10:39:00 AM	0.3	WR	TX
TX101512	2023-11-20	10:41:00 AM	0.3	WR	TX
TX101514	2023-12-19	10:34:00 AM	0.3	WR	TX
TX101516	2024-01-22	09:51:00 AM	0.3	WR	TX
TX101518	2024-02-22	10:30:00 AM	0.3	WR	TX
TX101520	2024-03-20	10:37:00 AM	0.3	WR	TX

Table A-2. Field measurements collected at SWQM station 12059 during the project period. Bacteria concentrations greater than 126 MPN/100 mL are highlighted in red.

Parameter Code	00010	00078	00094	00300	00400	31699	72053
Date	Water Temperature (°C)	Secchi Depth (m)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH	*E. coli* (MPN/100 mL)	Days Since Last Precipitation Event
2022-10-31	19.057	0.94	729	8.56	7.93	1,300	3
2022-11-28	14.769	0.6	633	9.54	7.60	1,990	2
2022-12-21	13.069	0.78	757	9.82	7.91	1,730	2
2023-01-26	11.728	0.56	852	10.36	7.15	1,730	2
2023-02-23	20.497	0.65	861	9.76	7.79	461	7
2023-03-28	20.601	0.25	879	7.67	7.99	98.5	4
2023-04-27	21.292	0.02	552	6.9	7.00	>2,420	0
2023-05-30	24.289	0.45	682	7.98	7.93	345	4
2023-06-27	28.433	0.68	848	7.47	7.92	127	5
2023-07-25	28.987	0.58	1,062	7.05	7.84	126	18
2023-08-17	27.841	0.54	1,128	7.1	7.82	326	41
2023-09-19	26.153	0.59	810	7.24	7.83	145	2
2023-10-18	18.791	0.7	1,005	8.74	7.23	43.2	12
2023-11-20	20.911	1.15	888	8.2	7.70	107	0
2023-12-19	14.19	0.75	962	10.28	7.52	67.6	4
2024-01-22	7.542	0.1	235.2	11.44	7.24	>2,420	1
2024-02-22	19.285	0.8	843	10.27	7.91	345	10
2024-03-20	17.55	1.02	844.1	8.68	7.87	118	2

°C – degree Celsius, MPN – most probable number, µS – micro siemens, cm – centimeter, mg – milligram, mL – milliliter

Station 22392

This monitoring station is located on AU 1244_02, 1.1 km north and 0.85 km west of the intersection of FM 619 and CR 541 near Beyersville, Texas. Table A-3 shows the sampling events took place during the project period at this station. Table A-4 shows the *E. coli* data collected during the sampling events, and concentrations greater than the standard, 126 MPN per 100 milliliters, are highlighted in red.

Table A-3. Sampling events for routine data collection at SWQM station 22392 during the project period.

Tag ID	Date	Time	End Depth (meter)	Collecting Agency	Submitting Agency
TX101487	2022-10-31	12:02:00 PM	0.3	WR	TX
TX101489	2022-11-28	11:54:00 AM	0.3	WR	TX
TX101491	2022-12-21	11:36:00 AM	0.62	WR	TX
TX101493	2023-01-26	11:39:00 AM	0.3	WR	TX
TX101495	2023-02-23	11:29:00 AM	0.3	WR	TX
TX101496	2023-03-28	09:30:00 AM	0.3	WR	TX
TX101498	2023-04-27	09:35:00 AM	0.3	WR	TX
TX101501	2023-05-30	11:58:00 AM	0.3	WR	TX
TX101503	2023-06-27	11:55:00 AM	0.3	WR	TX
TX101505	2023-07-25	11:27:00 AM	0.3	WR	TX
TX101507	2023-08-17	11:38:00 AM	0.3	WR	TX
TX101509	2023-09-19	11:52:00 AM	0.3	WR	TX
TX101511	2023-10-18	12:03:00 PM	0.3	WR	TX
TX101513	2023-11-20	11:48:00 AM	0.3	WR	TX
TX101515	2023-12-19	11:53:00 AM	0.3	WR	TX
TX101517	2024-01-22	12:13:00 PM	0.3	WR	TX
TX101519	2024-02-22	11:54:00 AM	0.3	WR	TX
TX101521	2024-03-20	11:51:00 AM	0.3	WR	TX

Table A-4. Field measurements collected at SWQM station 22392 during the project period. Concentrations greater than 126 MPN/100 mL are highlighted in red.

Parameter Code	00010	00078	00094	00300	00400	31699	72053
Date	Water Temperature (°C)	Secchi Depth (meter)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH	*E. coli* (MPN/100 mL)	Days Since Last Precipitation Event
2022-10-31	18.591	0.17	644	8.61	8.00	272	3
2022-11-28	14.463	0.23	610	9.42	7.92	1,730	2
2022-12-21	11.861	0.15	664	9.97	8.09	1,990	1
2023-01-26	10.42	0.21	728	10.79	7.91	1,200	2
2023-02-23	21.068	0.34	846	8.32	7.90	93.3	7
2023-03-28	19.808	1.2	898	8.77	7.96	88.4	4
2023-04-27	20.688	0.1	430.8	8.04	7.77	> 2,420	0
2023-05-30	25.372	0.22	588	7.39	8.13	258	4
2023-06-27	30.851	0.22	805	6.54	8.00	36.4	5
2023-07-25	31.095	0.21	1114	6.71	7.89	19.7	33
2023-08-17	29.214	0.26	1158	6.26	7.82	37.3	56
2023-09-19	26.467	0.15	737	6.71	7.81	248	3
2023-10-18	17.292	0.37	1,022	8.97	7.99	36.4	6
2023-11-20	19.267	0.38	868	8.32	7.97	47.1	7
2023-12-19	12.494	1.02	915	10.3	8.04	30.5	3
2024-01-22	8.429	0.02	680	10.99	7.91	> 2,420	1
2024-02-22	19.265	0.31	821.2	9.14	8.33	98.8	11
2024-03-20	17.401	0.3	815.7	8.83	8.12	122	3

°C – degree Celsius, MPN – most probable number, µS – micro siemens, cm – centimeter, mg – milligram, mL – milliliter

Bacteria

Concentrations of fecal indicator bacteria are used to assess the risk of illness during contact recreation. In freshwater environments, concentrations of *E. coli* are measured to assess such risks. The presence of *E. coli* in freshwater suggests that associated pathogens from the intestinal tracts of warm-blooded animals could be reaching waterbodies and may cause illness in people that recreate in them. Common sources of indicator bacteria include wildlife, domestic livestock, pets, malfunctioning on-site sewage facilities, urban and agricultural runoff, sanitary sewage overflows, and wastewater treatment facilities. As previously mentioned, the standard for primary contact recreation in freshwater is 126 MPN of *E. coli* per 100 milliliters (TCEQ 2023).

Water quality data collected between 2001 and 2022 by other entities are shown in Figure A-1. The geometric means of data collected from SWQM station 12054, 12059, 12060, and 12068 in this period are all above 126 MPN of *E. coli* per 100 milliliters, and they are 250.5, 265.2, 246.9, and 133.9, respectively. The one-year rolling geometric means suggest that there are decreasing trends in *E. coli* concentrations in AUs 1244_01 and 1244_04 and increasing trends in AUs 1244_02 and 1244_03.

As shown in Figure A-2, *E. coli* concentration data collected during the project period at SWQM stations 12059 and 22392 exhibited seasonality, that is, higher concentrations in winter and spring (December – May) and lower concentrations in summer and fall (June – November). Moreover, during the project period, an overall higher *E. coli* concentration was observed at station 12059 (geometric mean 349.76 MPN per 100 milliliters) than at station 22392 (geometric mean 185.1277 MPN per 100 milliliters). Note that concentrations greater than 2,420 MPN of *E. coli* per 100 milliliters are plotted as 2,420 in Figure A-2.

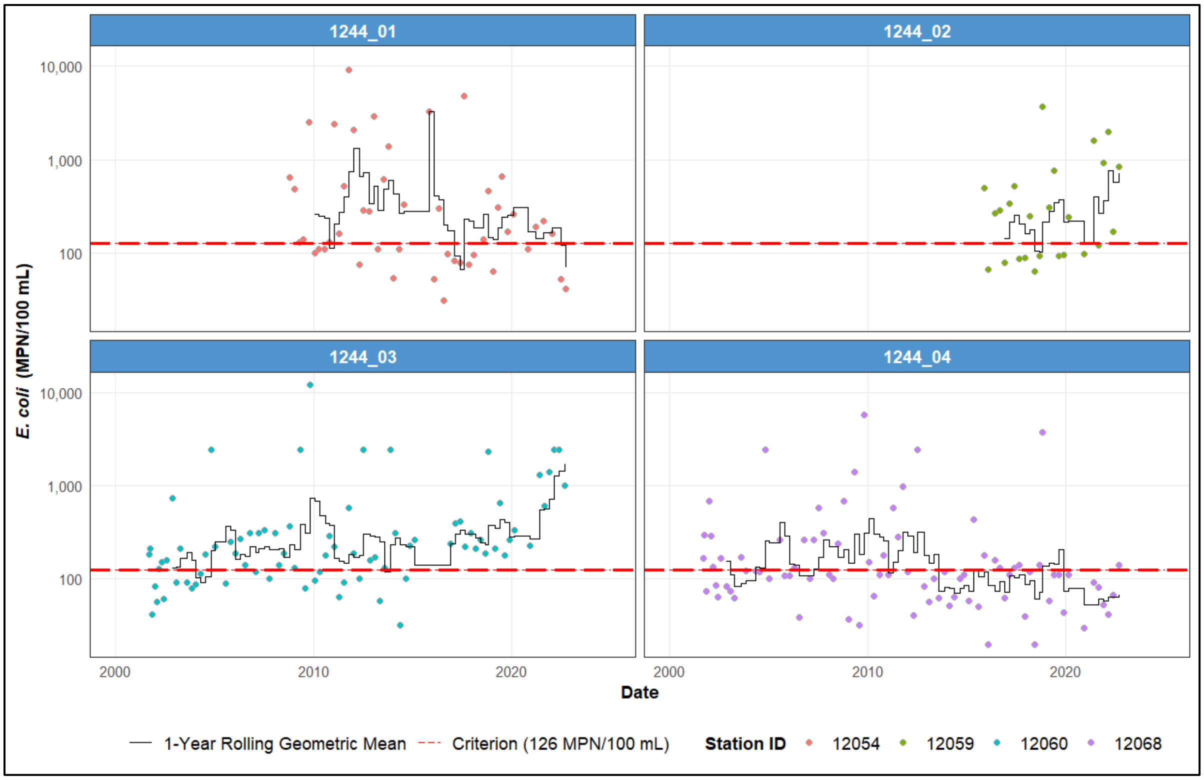

Figure A-1. *E. coli* concentrations measured at SWQM stations along Brushy Creek prior to the project period.

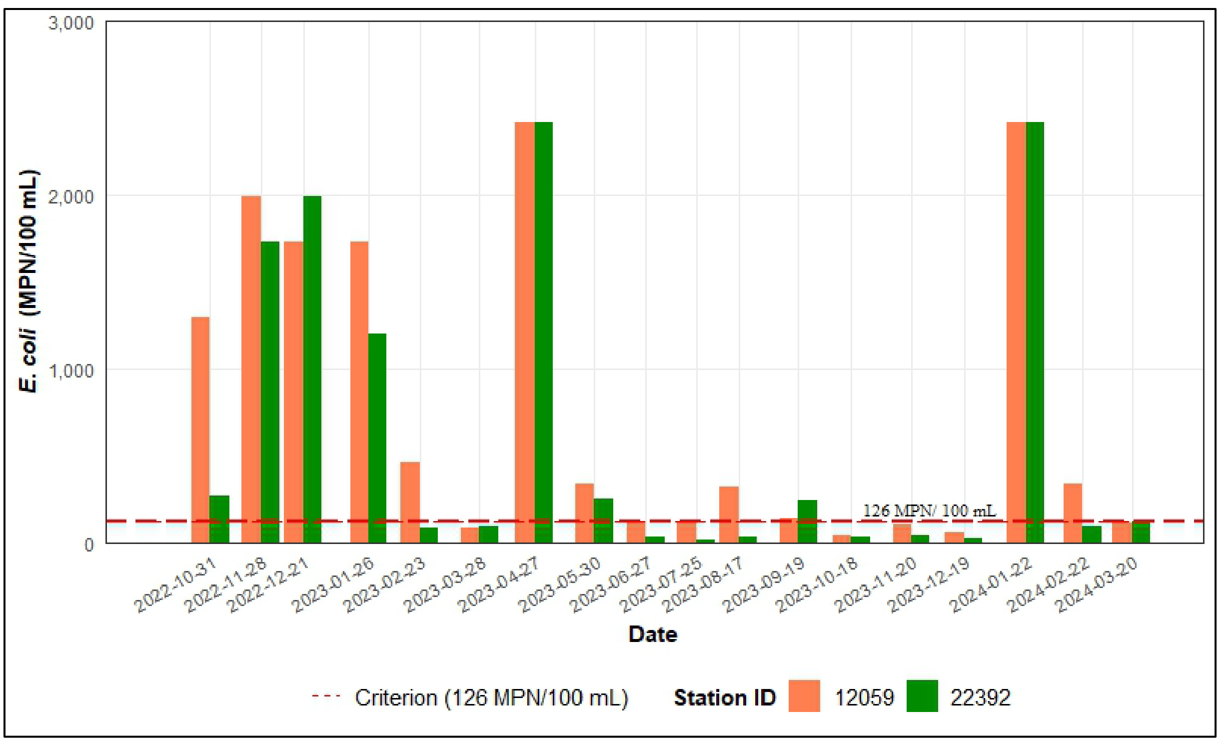

Figure A-2. *E. coli* concentrations measured at SWQM stations 12059 and 22392 on AU 1244_02 during the project period.

Dissolved Oxygen

Changes in DO including low DO and DO swings can indicate eutrophication, which can limit the development of healthy aquatic communities or cause fish kills.

In the *2022 Texas Integrated Report* (TCEQ 2022), grab screening level and grab minimum criterion for Brushy Creek are 5 milligram per liter and 3 milligram per liter, respectively. As shown in Figure A-3, most DO concentration data collected prior to the project exceeded the screening level, and Brushy Creek has no impairments for DO.

DO levels collected during the project period have also consistently exceeded the screening level. Moreover, DO levels at SWQM stations 12059 and 22392 exhibited seasonal patterns, which can be explained by the inverse relationship between DO levels and temperature. Meanwhile, DO levels at the two stations are comparable with no significant differences (Figure A-4).

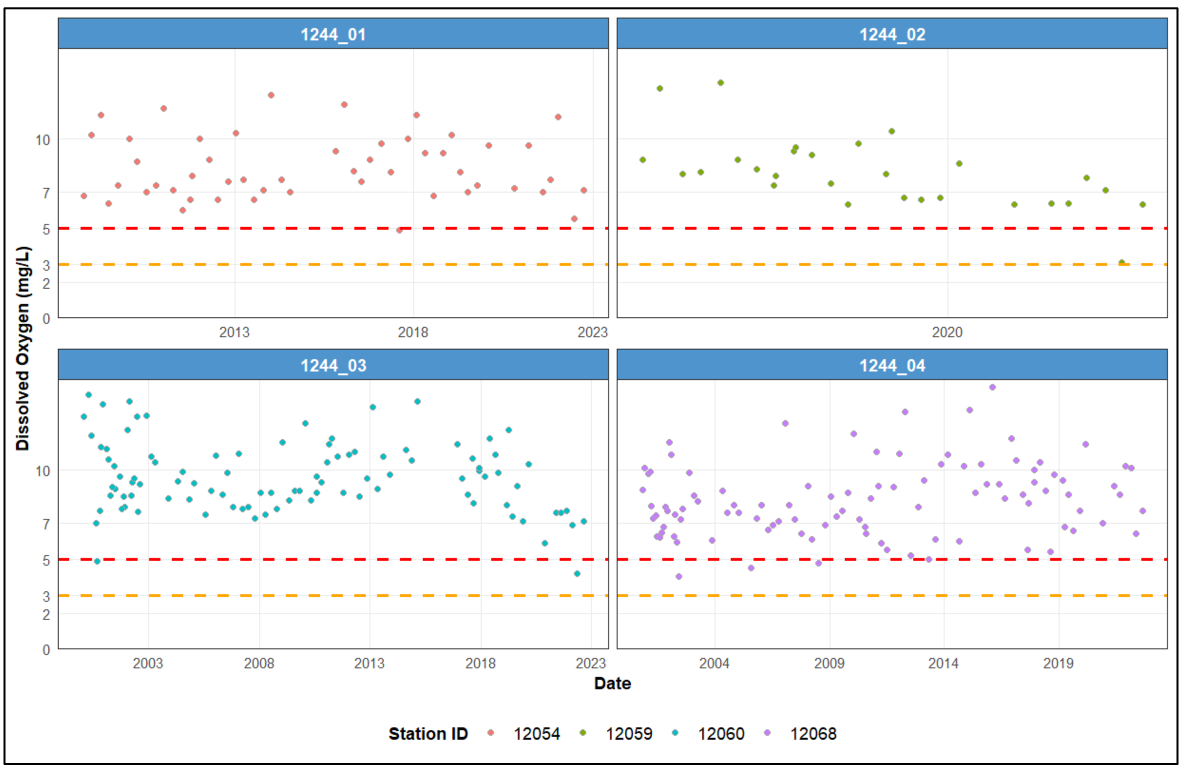

Figure A-3. DO concentrations measured at SWQM stations along Brushy Creek prior to the project period. 5 mg/L screening level is indicated by dashed red line and 3 mg/L screening level is indicated by dashed yellow line.

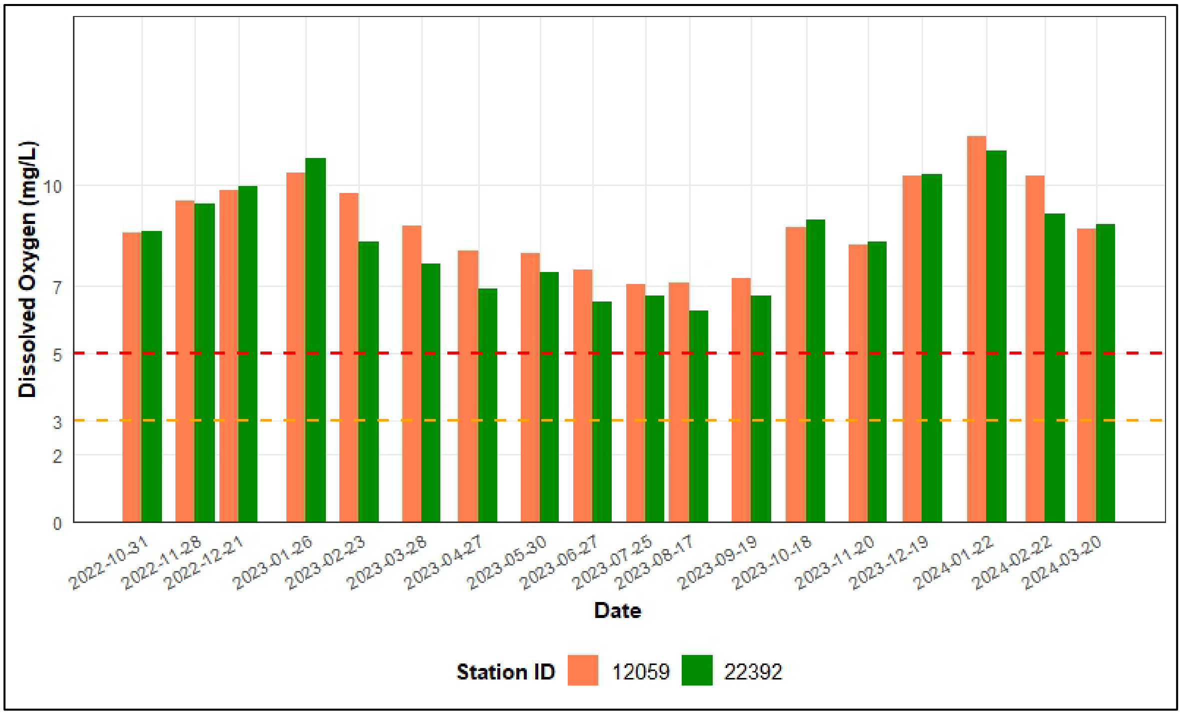

Figure A-4. DO concentrations measured at SWQM stations 12059 and 22392 on AU 1244_02 during the project period. 5 mg/L screening level is indicated by dashed red line and 3 mg/L screening level is indicated by dashed yellow line.

Streamflow

Generally, streamflow (the amount of water passing a cross section at a given time) is dynamic and always changing in response to both natural (e.g., rainfall) and human activities (e.g., land cover change). Water quantity data are important information in water quality assessment because water quantity influences the ability of a water body to assimilate pollutants.

Between 2001 and 2022, instantaneous streamflow data were largely measured at the SWQM station 12060 on AU 1244_03. As shown in Figure A-5, higher flows were observed in colder months and lower flows in warmer months with the exception of July. Moreover, interannual variability in monthly flow can be significant, particularly in February and November.

As shown in Figure A-6, during the project period, higher flows were measured in April and lower flows in July and August. Flows measured at SWQM station 22392 were always higher than those measured at SWQM station 12059 due to a larger drainage area.

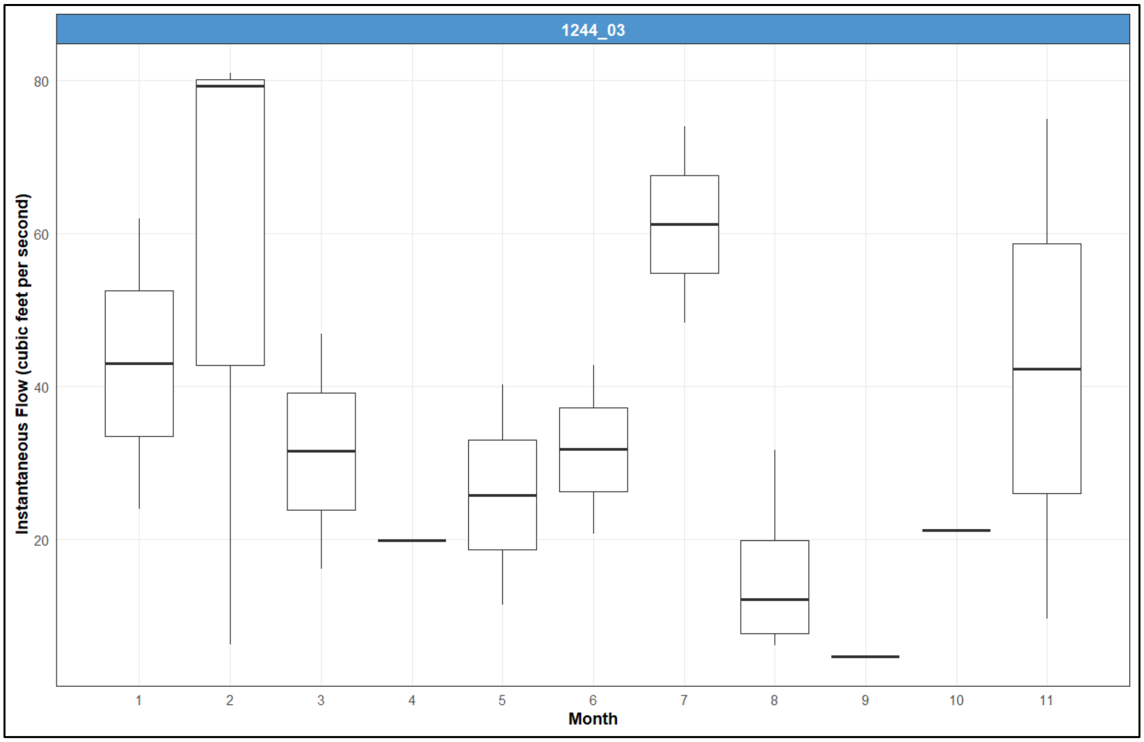

Figure A-5. Average monthly instantaneous flow rates measured at SWQM station 12060 on AU 1244_03 prior to the project period.

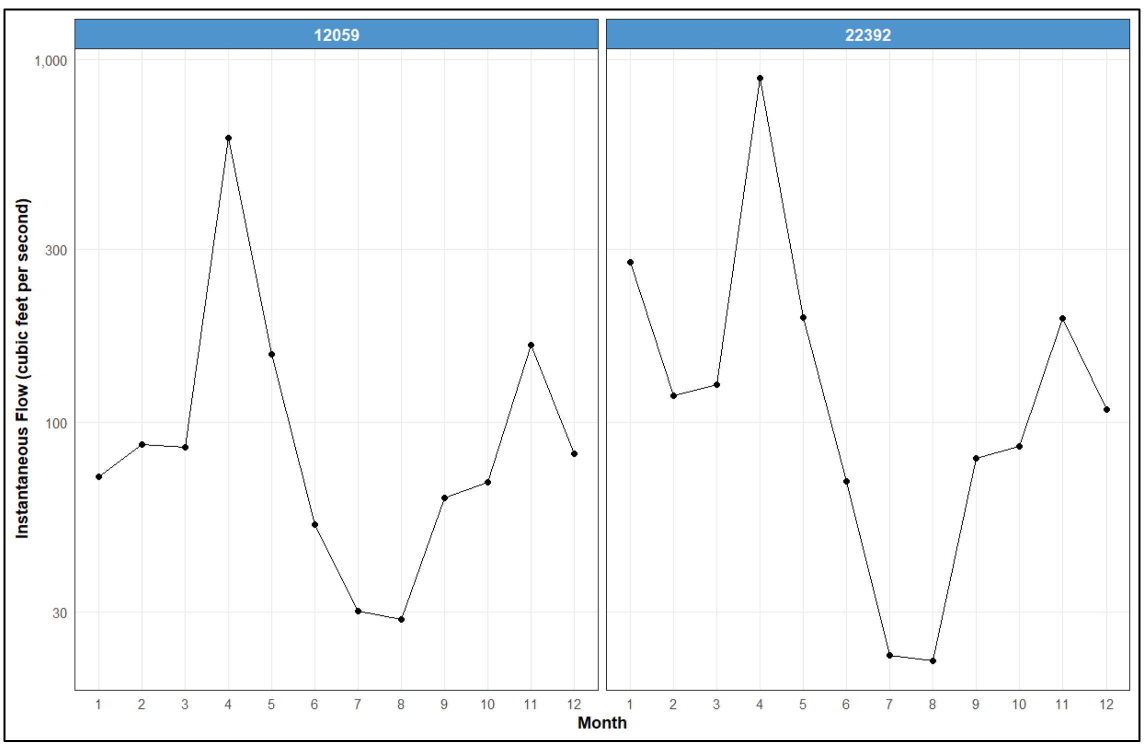

Figure A-6. Instantaneous flow rates measured at SWQM stations 12059 and 22392 on AU 1244_02 during the project period.

Data Conclusion

Water quality data collected between October 2022 and March 2024 suggest that bacteria concentrations in Brushy Creek do not have a distinctive increasing or decreasing trend. Between SWQM stations 12059 and 22392, the former (located upstream) had higher *E. coli* concentrations. DO levels measured through this project showed seasonality and were of satisfactory concentrations indicating a healthy aquatic ecosystem.

Appendix B: Streamflow Estimation at Brushy Creek

Currently, watershed-based planning efforts aiming to identify potential sources of pollutants require analysis of the streamflow-pollutant relationship. To this end, the load duration curve method is commonly used, which requires long-term streamflow records. In the Brushy Creek watershed, there are three active stream gages maintained by the U.S. Geological Survey (USGS). However, the USGS gage (08106050) located at SWQM station 22392 primarily reports gage heights and only reports streamflow data (in cubic feet per second) for high flow/flooding events, where gage heights are above 15.63 ft (USGS 2024a). Consequently, it lacks streamflow data under other flow conditions. Meanwhile, another USGS gage (08105883) located in the City of Round Rock, which reports streamflow data (USGS 2024b), is considered suitable for estimating streamflow at SWQM station 12059 using the drainage area-ratio (DAR) method due to close proximity and similarity in watershed characteristics. This gage, however, may not be appropriate for estimating streamflows at SWQM station 22392 due to significant differences in land cover. Given the above, one of the objectives of this project is to develop a rating curve at SWQM station 22392 that can estimate streamflows for non-high flow conditions.

Rating Curve Method

Between January 24, 2024 and January 29, 2024, continuous water depth data with 15-minute interval were collected at SWQM station 22392/USGS gage 08106050 using a noncontact radar flowmeter. This date range was selected to capture the flow conditions before, during, and post a rain event.

Based on the stream cross-sectional profile surveyed at this location, water depths were converted to streamflow (in cubic foot per second) time series. Paired depth-streamflow data were then used to develop a rating curve. As shown in Figure B-1, the rating curve fitted to water depth (y-axis) and streamflow (x-axis) data achieved high accuracy ($R^2 = 0.9854$). The rating curve can be expressed as a power function:

$$H = 0.4348 \times Q^{0.4687}$$

Consequently, streamflow values can be calculated as:

$$Q = \left(\frac{H}{0.4348}\right)^{1/0.4687}$$

where Q is streamflow in cubic feet per second and H is water depth in feet.

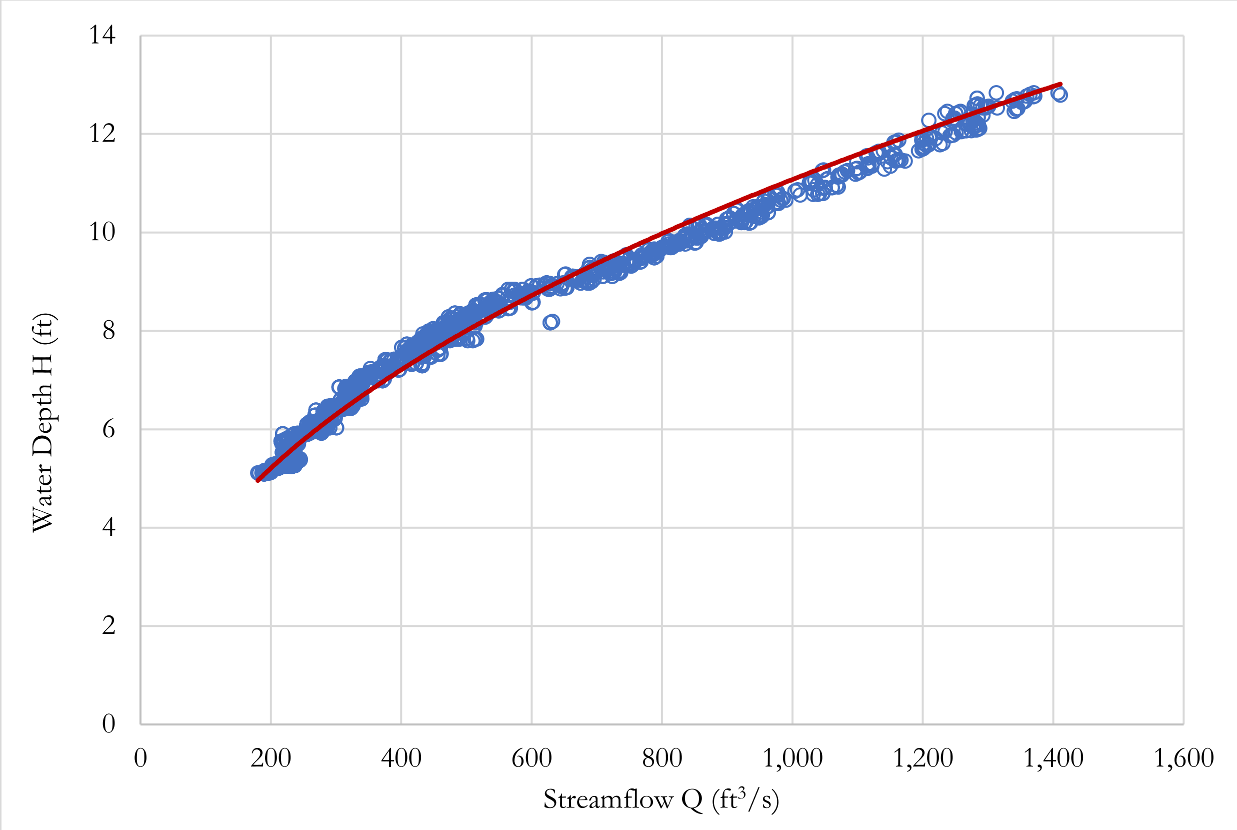

Figure B-1. The rating curve developed at SWQM station 22392/USGS gage 08106050. Blue circles represent measurements, and the red line represents the power function trendline.

Since gage height is the distance between the water surface and a reference point, this height needs to be converted to water depth first and then used in the rating curve. To this end, a linear function as shown below was fitted to the flowmeter-measured water depths (y-axis) and USGS (2024a) reported instantaneous gage heights (x-axis) (Figure B-2), and it achieved high accuracy ($R^2 = 0.9882$).

$$H = -3.7161 + 0.8333 \times Gage\ Height$$

It is worth noting that this relationship does not apply to converting gage heights below 4.46 ft as water depth (H) cannot be negative. The minimum gage height observed in the past seven years at this site is 7.28 ft.

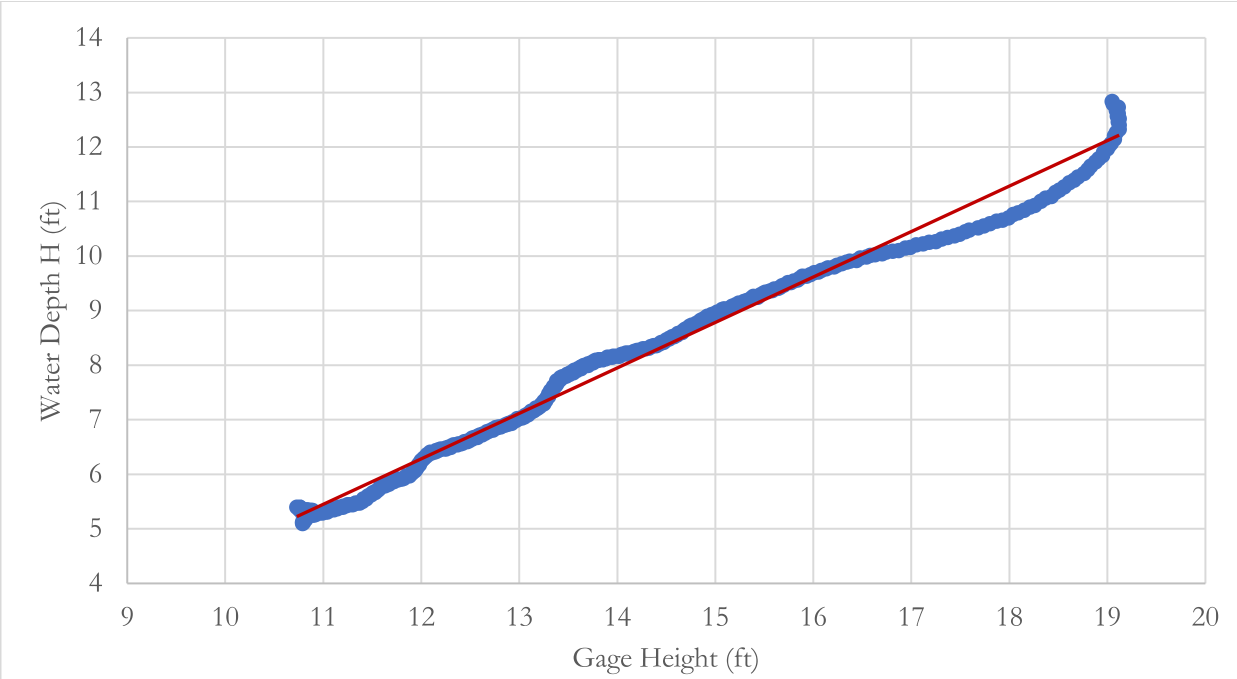

Figure B-2. Relationship between USGS gage heights and radar flowmeter-measured water depths. The red line represents the linear trendline.

After converting gage heights to water depths, streamflow values were estimated for 2,506 out of 2,536 days between April 22, 2017 (gage established) and March 31, 2024. Meanwhile, the other 30 days have streamflow data available because high flow/flooding events occurred. Rating curve estimated streamflow time series at SWQM 22392 is plotted in Figure B-3.

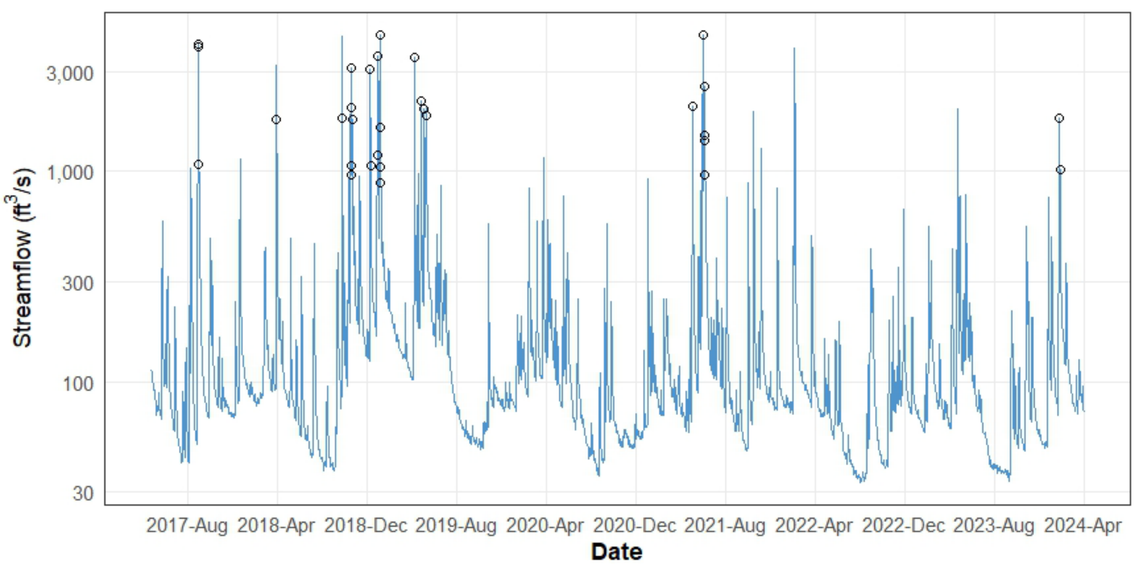

Figure B-3. Estimated streamflow time series at SWQM station 22392 between April 22, 2017 and March 31, 2024. The black circles indicate streamflow values available in USGS (2024a).

Drainage Area-Ratio Method

Traditionally, streamflow at ungaged watersheds in Texas can be estimated using the DAR method developed in Asquith et al. (2006). DAR is considered the most straightforward hydrologic model-independent method for creating and expanding streamflow records and it requires minimum input data (Farmer et al. 2014). In this report, we applied Asquith et al. (2006)'s DAR to estimate historic streamflow time series at SWQM stations 12059 and 22392 and evaluated its capability.

Despite DAR's popularity, its accuracy is highly dependent on the degree of hydrologic similarity between the ungaged "target" watershed and the gaged "donor" watershed, from which streamflow data are extrapolated (Farmer et al. 2014). When the target watershed has no flow records available, quantifying hydrologic similarity can be challenging. A common surrogate for such similarities is spatial proximity, which operates on the assumption that nearby watersheds exhibit similar streamflow behaviors due to similarities in climate and landscape conditions, which are dominant hydrologic controls. Asquith et al. (2006) recommended searching for donor watersheds within a 100-mile radius of the target watershed. Besides, to increase the accuracy of the generalized DAR method, the absolute value of the logarithm of the drainage-area ratio should be no less than 0.25-log cycles.

In this exercise, we used the USGS gage 08105883 (USGS 2024b) as the donor watershed in DAR. The Euclidean distances between the gage and SWQM stations 12059 and 22392 are 4.75 and 9.77 miles, respectively. The drainage-area ratios of the gage and SWQM stations 12059 and 22392 are 0.44- and 0.54-log cycles, respectively. This USGS gage, therefore, satisfies the above-mentioned requirements.

Estimated daily streamflow time series (April 22, 2017 – March 31, 2024) at SWQM station 12059 is plotted in Figure B-4. Estimated daily streamflow time series (April 22, 2017 – March 31, 2024) at SWQM station 22392 is plotted in Figure B-5.

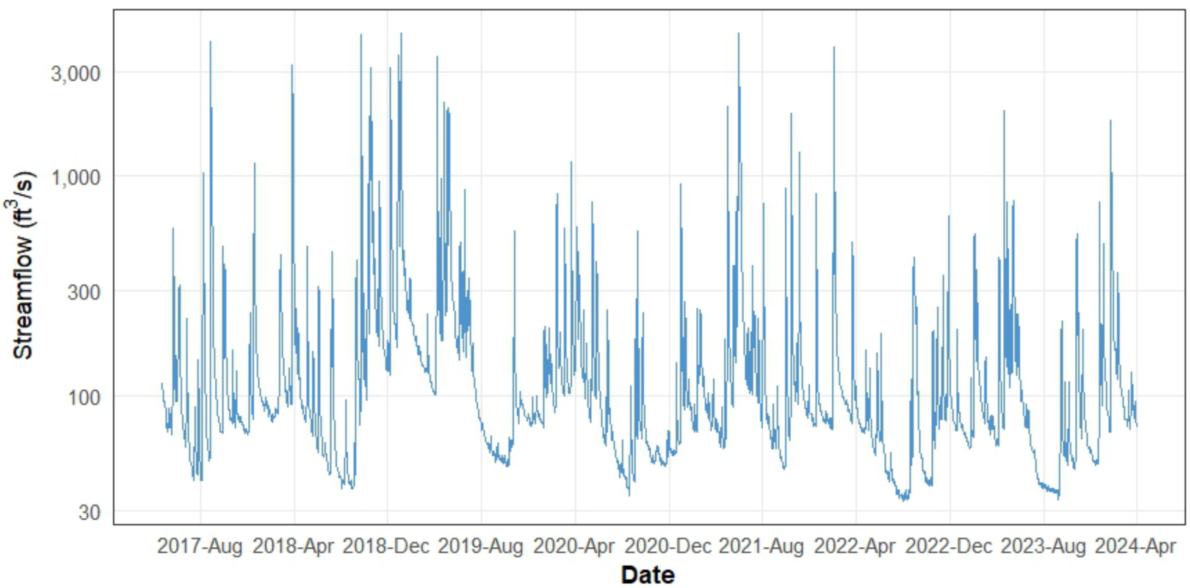

Figure B-4. Estimated streamflow time series at SWQM station 12059 between April 22, 2017 and March 31, 2024.

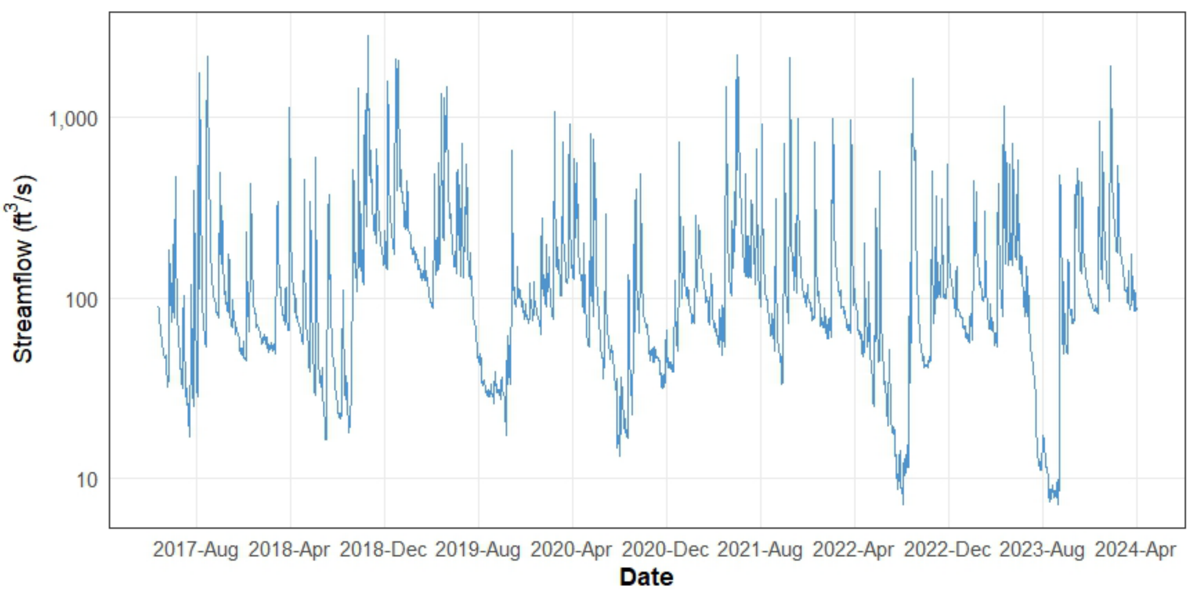

Figure B-5. Estimated streamflow time series at SWQM station 22392 between April 22, 2017 and March 31, 2024.

Method Evaluation

Estimated streamflows using the two methods, rating curve and DAR, were compared using plots and Kling-Gupta Efficiency (KGE). KGE is calculated using the following equations

$$KGE = 1 - (r - 1)^2 + (\alpha - 1)^2 + (\beta - 1)^2$$

where *r* is the Pearson correlation coefficient between the observed and simulated data, representing the linear relationship, α is the ratio of the standard deviation of the simulated data to the standard deviation of the observed data, representing variability, and β is the ratio of the mean of the simulated data to the mean of the observed data, representing bias. A KGE value of 1 indicates perfect agreement between the estimates and observations.

Station 12059

DAR-estimated flow values were assessed by comparing them with 18 instantaneous flow records obtained by TWRI during monthly routine monitoring. The KGE value of 0.8499 indicates that USGS gage 08105883 (USGS 2024b) is a suitable donor for this SWQM station.

Station 22392

As shown in Figure B-6, the DAR method and the rating curve produced notably different streamflow estimates, particular for lower flow events. The temporal variabilities, on the other hand, are comparable between the two methods. Furthermore, estimated streamflows were compared against the 18 instantaneous flows collected at this location during monthly routine monitoring events. The KGE value for DAR-estimated flow values was 0.282 and 0.759 for rating curve-estimated flow values. It is evident that the rating curve outperformed DAR at SWQM station 22392.

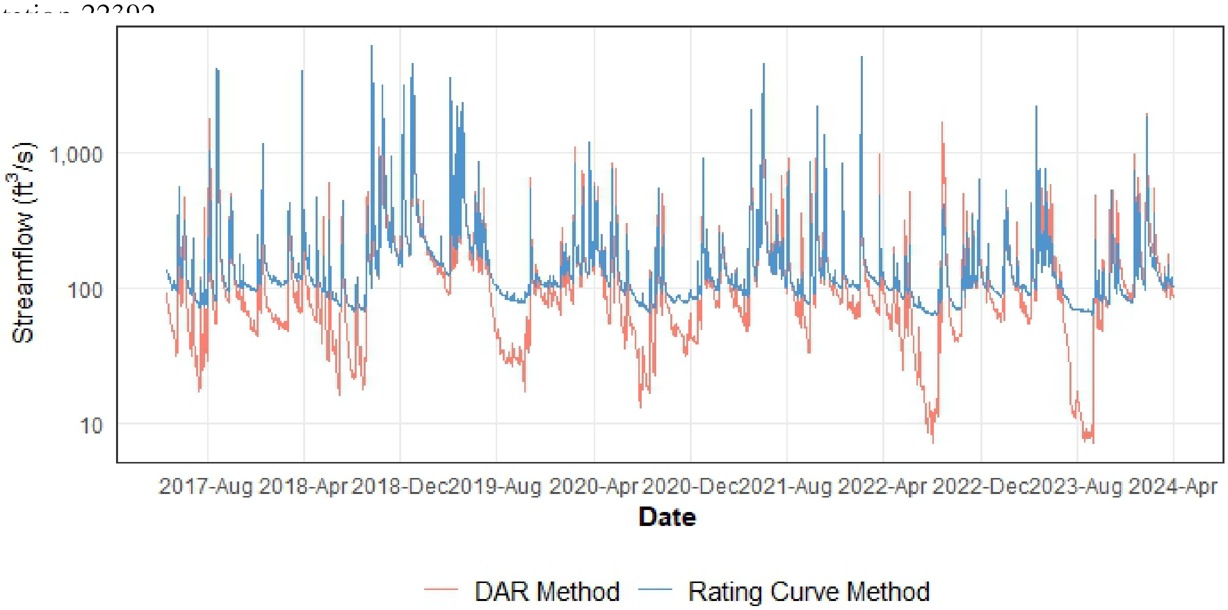

Figure B-6. Comparison between estimated streamflow time series using the DAR and the rating curve methods.

Data Conclusion

The DAR method generated satisfactory long-term continuous streamflow data for SWQM station 12059 using USGS gage 08105883 as the donor. Meanwhile, a rating curve developed at SWQM station 22392 outperformed the DAR method and showed its value in filling the data gap at this site.

It is worth reiterating that the rating curve developed through this project is not a generalized curve for all flow conditions, and it has its limitations, due to data limitations (e.g., incomplete and/or inaccurate data) and uncertainties embedded in model structures. For example, gage heights below 4.46 ft cannot be converted to water depths using the linear model developed; and the rating curve may not be applicable when the gage height is above 19 ft (water depth above 12 ft). These two limitations, however, should not pose a problem because the lowest gage height ever observed since the establishment of gage 08106050 is 7.28 ft. Additionally, for high flow or flooding events (gage heights above 15.63 ft), streamflow data are already available through an existing USGS-developed rating curve for this site.

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USGS. 2024b. Streamflow data for USGS gage 08105883, Brushy Ck at IH 35, Round Rock, TX. https://waterdata.usgs.gov/nwis/uv?site_no=08105883.