Least Disturbed Streams Project: An Extension of the Texas Aquatic Ecoregion Project

Gordon Linam and Stephen Curtis
Texas Parks & Wildlife Department, Inland Fisheries Division

Anne Rogers Harrison, Carly Rotzler and Marty Kelly
Texas Parks & Wildlife Department, Coastal Fisheries Division

AND

Bill Harrison, Laura Ryckman, Lauren Pulliam, Nicole Hughes, Robert Deans and Sarah Whitley
Texas Commission on Environmental Quality, Surface Water Quality Monitoring

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Cover Photo: Rio Grande River downstream of Alamito Creek near Presidio, Presidio County, Texas

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LIST OF ACRONYMNS

ALU	Aquatic Life Use
BIBI	Benthic Index of Biological Integrity
°C	degrees Celsius
Cl	chloride
CFS	cubic feet per second
DEM	Digital Elevation Model
DO	dissolved oxygen
EPT	Ephemeroptera-Plecoptera-Trichoptera
HQI	Habitat Quality Index
IBI	Index of Biotic Integrity
IBWC	International Boundary and Water Commission
ISD	Independent School District
LDS	Least Disturbed Streams
LULC	Land Use & Land Cover
m	meter
mg/L	milligrams per liter
mL	milliliter
MRLC	Multi-resolution land characteristics
NELAC	National Environmental Laboratory Accreditation Certified
NLCD	National Land Cover Database
NH3	ammonia
NO3 + NO2	nitrate + nitrite
RBP	Rapid Bioassessment Protocols
SO_4	sulfate
SWQM	Surface Water Quality Monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TAC	Texas Administrative Code
30 TAC …	Title 30, Texas Administrative Code, Chapter or Section…
TCEQ	Texas Commission on Environmental Quality
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TP	total phosphorus
TPWD	Texas Parks and Wildlife Department
USGS	United States Geological Survey
YSI	Yellow Springs Instruments Company
σV	standard error of velocity

ACKNOWLEDGMENTS

Thank you to numerous staff from various programs at the Texas Parks and Wildlife Department and the Texas Commission on Environmental Quality, as well as several river authorities, who contributed countless hours of field work, sample analyses and data management for this project. We thank numerous landowners, as well as the National Park Service, for providing access to least disturbed stream sample sites.

The authors thank Steve Twidwell and Jack Davis, formerly with the Texas Commission on Environmental Quality, who conceptualized and coordinated field and lab work for the earliest stages of this project.

RECOMMENDATIONS FOR NAVIGATING AND UTILIZING THIS DOCUMENT

This report is an extensive document which contains a large amount of data that can be challenging to navigate. Given the size of this document and scope of work, the authors agreed that it would be beneficial to provide an overview of the structure of this report along with recommendations for navigating and utilizing this document.

Biological data used in this report span a 32-year period (1986-2018) and include data from Bayer et al. 1992 (1986-1990), opportunistic and routine collections between 1991 and 2015, and targeted collections by the authors from 2016-2018. Watershed characterization and land use have been assessed for each site and the following data were collected in the field: in-channel and riparian physical habitat, water quality, fish community, and benthic macroinvertebrate community. Specific details regarding desktop and field data collection for these five primary parameters can be found in the methods.

The results and discussion are organized by aggregated ecoregions based on ecoregion groupings associated with regionalized fish and benthic indices of biotic integrity (Linam et al. 2002; TCEQ 2019). Each section includes a general characterization of the ecoregions within the aggregated ecoregion, results for each individual site, and summary of data/trends for the aggregated ecoregion. A general description of the geographic extent, climatic and landscape characteristics, and major water features are provided for each ecoregion. Least disturbed streams are grouped alphabetically within each ecoregion and include results and discussion for each of the five primary parameters. Summary sections provide an overview of watershed characterization and land use trends and summarize water quality, physical habitat, and biological community data across all sites within the aggregated ecoregion.

For most sites, data were collected at a single station; however, there are instances where data were combined for multiple stations within a reach to characterize a reach of a least disturbed stream (e.g., Slaughter Creek: stations 12185 and 12186). Given the variation in the number of sampling events across least disturbed streams, basic summaries and descriptive statistics are presented in this report. More detailed data can be requested from the Texas Commission on Environmental Quality (TCEQ).

All water quality, physical habitat, and biological data were collected by TCEQ and Texas Parks and Wildlife Department (TPWD) who drafted this document and similar collection methodologies were used for each sampling event across the full time period. Additional water quality data were included from routine monitoring conducted by TCEQ's Surface Water Quality Monitoring (SWQM) Regional staff and Clean Rivers Program partners.

The authors recommend that users treat this document as a reference tool rather than a traditional project report. Please consult the Table of Contents to find specific sites and/or ecoregions of interest and review supplemental habitat and biological data for that site and/or ecoregion in the appendices.

A complete list of least disturbed streams can be found in Appendix A.

EXECUTIVE SUMMARY

The Texas Aquatic Ecoregion Project was originally undertaken from 1986-1990 in an effort to describe the biological diversity of wadeable streams across the state of Texas (Bayer et al. 1992). This project was necessary to address the diversity in the state recognized by the Texas Water Quality Standards which divides major water bodies into classified segments which have been assigned specific uses and water quality criteria. Prior to this project, however, most wadeable streams in Texas were placed in the limited aquatic life use category based on little data and the presumption that higher aquatic life uses were generally precluded because of wadeable streams' smaller size. Bayer et al. (1992) clearly demonstrated that wadeable streams in Texas exhibit a great diversity of aquatic life and deserve higher levels of protection.

Since the conclusion of the Texas Aquatic Ecoregion Project Report (Bayer et al. 1992), sampling in least disturbed streams has been sporadic and relatively uncoordinated. Thus, the Least Disturbed Streams Project was launched in 2016 as a cooperative project between TCEQ and TPWD to develop a coordinated plan for the continued assessment of least disturbed streams. Least disturbed streams represent the best available habitat in each ecoregion and serve as indicators of baseline conditions to be considered in the development of water quality standards. These data also contribute to the development and application of methods to effectively monitor, evaluate, and manage water quality in the state as directed in Title 30 of the Texas Administrative Code (30 TAC). Specifically, data collected from least disturbed streams have supported the development and refinement of the index of biotic integrity (IBI) for fishes and benthic macroinvertebrates. These IBIs are used to set aquatic life use categories for water bodies and assess attainment of established aquatic life use categories as directed in 30 TAC Chapter 220 which specifies that TCEQ conduct monitoring and assess the health of aquatic life in Texas.

This report provides summaries of data collected from 114 least disturbed streams across Texas since 1986 and includes an inventory of all fishes and benthic macroinvertebrates collected, results for water quality sampling, watershed land use information, and local physical habitat data for each stream. The report also includes results of the fish and benthic macroinvertebrate IBIs for each sample site. Of the 445 fish samples collected across all ecoregions, 78% (n = 346) indicated high or exceptional aquatic life use, while 63% (n = 262) of the 415 benthic macroinvertebrate samples also indicated high or exceptional aquatic life use.

INTRODUCTION

BACKGROUND

Water quality and biotic assemblages exhibit spatial heterogeneity at regional scales, at least in part, in response to variability in climatic and physiographic characteristics. In Texas, these characteristics exhibit considerable variability across the state exemplified by variation in water quality. As a result, spatial frameworks are necessary to structure monitoring, assessment, and management of environmental resources. Such a framework is provided by ecological regions, or ecoregions, which are areas of relatively homogeneous soil, vegetation, climatic, geologic, and physiographic profiles. Ecoregions also incorporate patterns in anthropogenic pressure on ecosystems and in the existing and attainable quality of environmental resources.

Griffith et al. (2007) identified twelve level III ecoregions in Texas (Figure 1) based on an analysis of spatial variability of climatic and physiographic characteristics. Previous studies by Twidwell and Davis (1989) and Bayer et al. (1992) have demonstrated that water quality and biotic assemblages vary geographically in Texas in a generally systematic way, and that ecoregions can provide an effective framework for analysis and management.

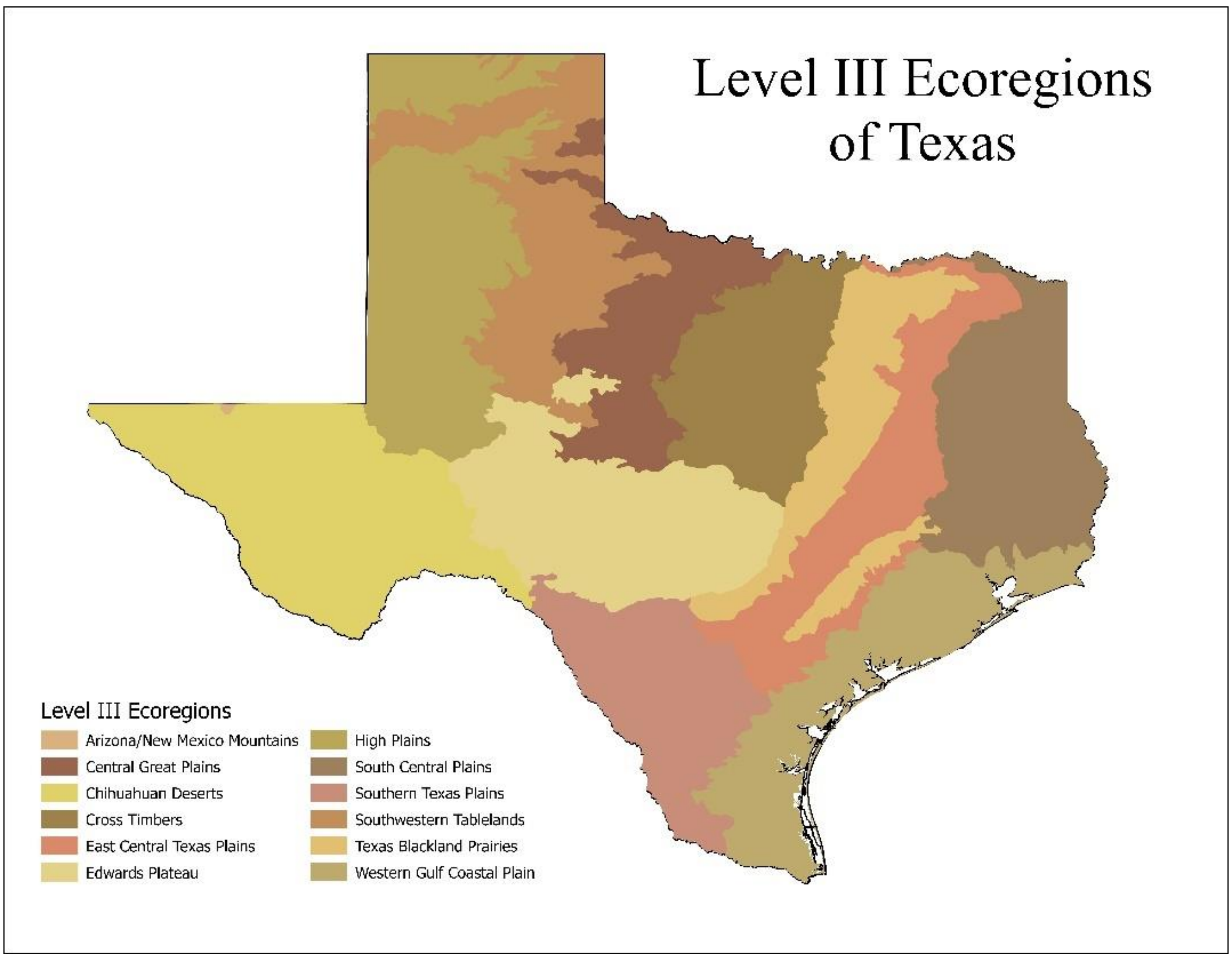

Figure 1. Level III Ecoregions of Texas.

The Texas Aquatic Ecoregion Project was the first comprehensive, coordinated effort to sample least disturbed streams to describe the biological and physical characteristics of lotic systems in Texas and to establish baselines for the development of indices designed to evaluate aquatic life use. Two primary publications resulted from the 1986-1990 effort: *An Assessment of Six Least Disturbed Unclassified Texas Streams* (Twidwell and Davis 1989) and *Texas Aquatic Ecoregion Project: An Assessment of Least Disturbed Streams* (Bayer et al. 1992). This project was designed as a continuation of the Texas Aquatic Ecoregion Project, and both utilized the following set of characteristics to select least disturbed streams to sample in each of the ecoregions in Texas specifying that each stream sampled should:

1. have little urban and industrial development in the watershed;
2. have little high intensity agriculture (i.e., cultivated crops);
3. have no major point sources of pollution;
4. have no atypical sources of non-point source pollution;
5. are not channelized or have not had major physical habitat modifications.

The least disturbed streams designation applies to the sample site and upstream watershed and does not include downstream portions that may not meet the criteria listed above. Streams with these characteristics provide information on background regional (ecoregion) water quality. These data can be utilized for water quality management objectives as described in Title 30 Texas Administration Code (30 TAC) §307.3(a) of the Texas Surface Water Quality Standards related to background (henceforth baseline) water quality. This section characterizes conditions that would occur in a waterbody in the absence of anthropogenic activities. Development of site-specific criteria using known baseline conditions of specific toxins of concern in receiving waters, sediment and/or indigenous biota (e.g., 30 TAC §307.6(c)(11)(A)) is an example of an application for this type of data.

Data collected on fish and benthic macroinvertebrate assemblages in these least disturbed streams describe biotic integrity on an ecoregion specific basis. This includes metrics such as species composition, diversity, and functional organization of a community of organisms in an environment relatively unaffected by pollution. Fish, benthic macroinvertebrate, and physical habitat data collected from least disturbed streams are used to quantitatively define aquatic life use (ALU) categories defined in 30 TAC §307.7(b)(3) and provide a mechanism for assessing support of these ALU categories in other streams not considered least disturbed.

PROJECT OBJECTIVE

The overall objective of the Least Disturbed Streams Project was to expand, refine, and consolidate the information on streams that can potentially serve as reference streams to support TCEQ and TPWD efforts to manage lotic systems most effectively in Texas.

The Least Disturbed Streams Project had five primary goals which will continue to be updated through future continuances:

1. Provide a list of least disturbed reference streams for each of the Texas ecoregions that have been evaluated as being appropriate reference streams (Appendix A).

2. Provide an organized, readily accessible database describing all fishes and benthic macroinvertebrates collected (Appendices D and E).
3. Provide an organized, readily accessible database of the physio-chemical characteristics of the streams sampled (Appendices B and C).
4. Provide detailed narrative interpretations of GIS data for all watersheds sampled in this report as well as making the GIS database available as needed.
5. Provide more quantitatively defined characteristics for least disturbed streams as given in the narratives associated with each watershed sampled for this report.

Actions to accomplish the Least Disturbed Streams Project objective and goals fell in five major categories:

- **Historical Data Compilation:** All available data on streams currently identified as least disturbed streams were organized and compiled, including historic data in paper files as well as in TCEQ's Surface Water Quality Monitoring Information System (SWQMIS) in the project module for the Texas Aquatic Ecoregion Project.

- **Designation Review of Existing Reference Streams:** Streams identified as least disturbed streams in the Texas Aquatic Ecoregion Project were evaluated to determine if the designation was still suitable (Appendix A).

- **Evaluation of Candidate Streams:** Candidate streams were evaluated to determine the necessity for adding to the list of least disturbed streams (Appendix A).

- **Ecoregion Surveys:** Field sampling was conducted in several—usually five to ten—streams in each ecoregion. Streams currently identified as least disturbed streams as well as candidate streams were sampled.

- **Temporal Variability Surveys:** A subset of the streams were sampled on several occasions to provide data on temporal variability at least disturbed sites (Appendix A and Figure 3).

The Least Disturbed Streams Project was planned and carried out in cooperation with the TPWD/TCEQ Interagency Biological Workgroup. Field sampling and data compilation was conducted cooperatively by TCEQ Central Office SWQM Team, TPWD River Studies Team, TCEQ regional biologists, and TPWD Water Resources Program. Data collected include field measurements, routine water chemistry, 24-hour dissolved oxygen, fish, benthic macroinvertebrates, periphyton cover, and physical habitat. Similar collection methods were used for each sampling event across the full time period from 1986-2018 unless specified. Data analysis was also conducted cooperatively between TPWD and TCEQ SWQM.

All data collected for the Least Disturbed Streams Project resides in SWQMIS and is associated with Project ID 312.

MATERIALS AND METHODS

WATERSHED CHARACTERIZATION

Figure 2 shows the workflow for characterizing the watersheds described in this report. ArcGIS was used to delineate watersheds for each site sampled. Digital Elevation Models (DEMs) for Colorado, New Mexico, and Texas were used for terrain pre-processing (USGS 2001). Each DEM was 7.5-minute data elevation with 30-meter resolution. The Arc Hydro Tools Tutorial (ESRI 2011) was followed to perform terrain pre-processing and subsequent terrain processing and watershed delineation.

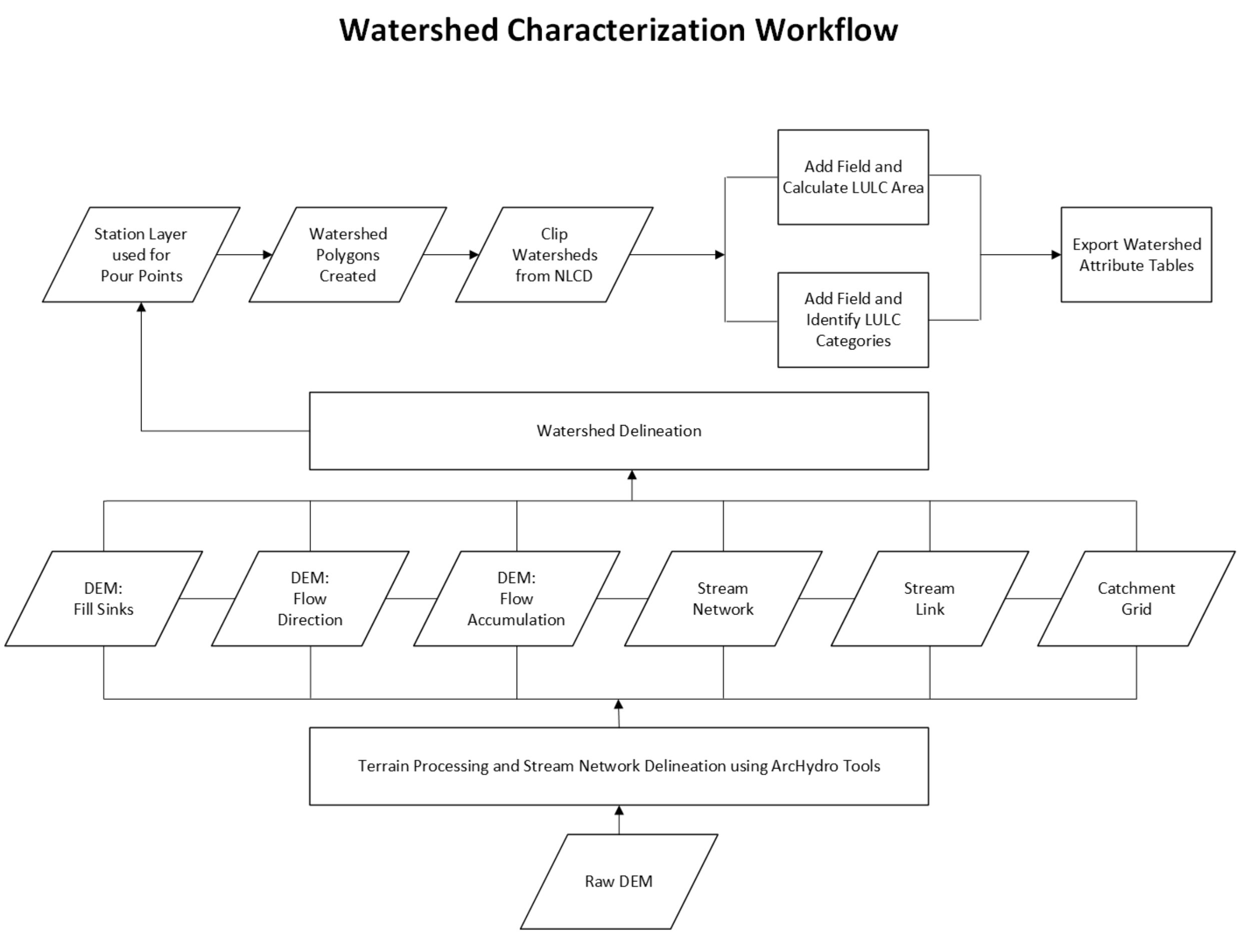

Figure 2. Watershed characterization workflow.

National Land Cover Data (NLCD) from the Multi-Resolution Land Characteristics (MRLC) Consortium was used to determine land uses within each watershed. Once watersheds were delineated using GIS, the resulting watershed layers were used to clip the NLCD land cover data. Land cover data for 1992, 2001, 2006, and 2011 were used for analyses. Fields for land use/land cover area (sq km) and land use classifications were added to each watershed attribute table (Table 1). Watershed land use data were exported into Excel and analyzed.

Due to the rapid advancement of mapping methods and surveying technologies, the 1992 land cover data is not entirely comparable to subsequent land use data sets and some land use changes over time may be attributed to these differences. The NLCD refined the land use classification approaches post-1992 resulting in slightly different land cover classifications for the 2001-2011 data sets (Wickham et al. 2014). Therefore, in order to make all land use data sets more comparable in our study, some of the 1992 land use classes were revised to align with the 2001-2011 land use classifications (Table 2). Land use classifications were further simplified in our study by grouping forest categories and wetland categories for analyses.

Outfall information was found in the TCEQ permits database. Unless otherwise specified, outfall information was accessed between 2018-2020.

Table 1. The land use/land cover for the watershed areas was obtained from the National Land Cover Database (NLCD) maintained by the U.S. Geological Survey. This table is adapted from the NLCD legend and describes the classifications for each class value used in this report.

Class/Value	Classification Description
Water	
11	**Open Water**- areas of open water, generally with less than 25% cover of vegetation or soil.
12	**Perennial Ice/Snow**- areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.
Developed	
21	**Developed, Open Space**- areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
22	**Developed, Low Intensity**- areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
23	**Developed, Medium Intensity**- areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
24	**Developed high Intensity**- highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
Barren	
31	**Barren Land (Rock/Sand/Clay)**- areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
Forest	
41	**Deciduous Forest**- areas dominated by trees generally greater than 5 m tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
42	**Evergreen Forest**- areas dominated by trees generally greater than 5 m tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
43	**Mixed Forest**- areas dominated by trees generally greater than 5 m tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
Shrubland	
52	**Shrub/Scrub**- areas dominated by shrubs; less than 5 m tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
Herbaceous	
71	**Grassland/Herbaceous**- areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling but can be utilized for grazing.

Class/Value	Classification Description
Planted/ Cultivated	
81	**Pasture/Hay**- areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
82	**Cultivated Crops**- areas used to produce annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
Wetlands	
90	**Woody Wetlands**- areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
95	**Emergent Herbaceous Wetlands**- areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Table 2. Combined 1992 land use classifications to align with 2001-2011 land use classifications.

LULC 1992	LULC 2001-2011
11 Open Water	11 Open Water
12 Perennial Ice/Snow	12 Perennial Ice/Snow
33 Transitional Barren; 85 Urban/Recreational Grasses	21 Developed, Open Space
21 Low Intensity Residential	22 Developed, Low Intensity
32 Quarries/Strip Mines/Gravel Pits	23 Developed, Medium Intensity
22 High Intensity Residential; 23 Commercial/Industrial/Transportation	24 Developed, High Intensity
31 Barren Land (Rock/Sand/Clay)	31 Barren Land (Rock/Sand/Clay)
41 Deciduous Forest	41 Deciduous Forest
42 Evergreen Forest	42 Evergreen Forest
43 Mixed Forest	43 Mixed Forest
51 Shrub/Scrub	52 Shrub/Scrub
71 Grassland/Herbaceous	71 Grassland/Herbaceous
81 Pasture/Hay; 84 Fallow	81 Pasture/Hay
82 Row Crops; 83 Small Grains; 61 Orchards/Vineyards/Other	82 Cultivated Crops
91 Woody Wetlands	90 Woody Wetlands
92 Emergent Herbaceous Wetlands	95 Emergent Herbaceous Wetlands

In-Channel and Riparian Physical Habitat

Physical habitat data was collected following the methods outlined in Chapter 9 of the SWQM Procedures Manual Volume 2 (TCEQ 2014). The length of each study reach is 40 times the average wetted width with a minimum reach length of 150 m and a maximum of 500 m. For streams with a reach length of 150 to 300 m five equidistant transects are placed including the upper and lower ends of the reach. Reaches with a length of 301 m to 500 m were divided into six equidistant transects including the upper and lower ends. Transects were marked with survey flagging or some other identifiable markings and labeled “A” through “E” or “F” depending on the number of transects. Biological sampling was not conducted outside of the study reach unless it was deemed necessary by field crews.

Physical stream characteristics were measured at each transect. Stream characteristics were counted or observed in each study reach and included the number of riffles, the number of stream bends (poorly, moderately, or well-defined), the number of channel obstructions, the maximum pool width and depth, and water level. Instream physical characteristics were measured or observed 3 m upstream and downstream of each transect and included the stream width at the transect; the bank slope, erosion potential, and dominant riparian vegetation types on the left and right bank; the mesohabitat at the transect (riffle, run, glide, pool); the dominant substrate type; percent gravel or larger; percent instream cover; the instream cover types; the amount of macrophytes and algae; and the percentage of tree canopy cover. Additionally, stream depth is measured at 11 equidistance points along each transect and the thalweg depth (deepest portion of the channel) is recorded. The width of the natural vegetative buffer is recorded at each transect and the aesthetic (wilderness, natural, common, offensive) is recorded for the reach.

Physical habitat data is summarized and compiled averaging stream width and depth, percent of substrate gravel sized or larger, percent instream cover, percent stream-bank erosion potential, stream-bank slope, width of natural buffer vegetation, percent composition of riparian vegetation, and percent of tree-canopy coverage. The summarized physical habitat data is used to calculate the Habitat Quality Index (HQI), however data collected in the earlier studies do not include physical habitat measurements. Instream cover, bottom substrate stability, dimension of largest pool, water level, bank stability, channel sinuosity, riparian buffer, and overall aesthetic of the reach are used as metrics to calculate the HQI score. Each metric is scored based on the data collected at each site where higher scores correspond with reference conditions and lower scores correspond with more degraded conditions. Scores for each metric are totaled and the total HQI score relates to one of four categories (Exceptional, High, Intermediate, Limited).

Water Quality

Multi-parameter water quality data sondes (YSI, Hydrolab) were used to measure temperature, pH, specific conductance, and dissolved oxygen. All water quality data sondes were calibrated and post-calibrated according to procedures from the TCEQ SWQM Procedures Manual Volume 1 (TCEQ 2012).

Water quality samples were collected by TCEQ field personnel or Clean Rivers Partners and submitted to a National Environmental Laboratory Accreditation Certified (NELAC) laboratory for analysis (TCEQ Laboratory in Sugar Land or LCRA-ELS in Austin). Parameters that were analyzed include: alkalinity, total organic carbon, chloride, sulfate, phosphorus, ammonia, total Kjeldahl nitrogen, total nitrogen, and chlorophyll-*a*; however, not all parameters were collected and analyzed at all stations. Water quality samples are generally collected from the centroid of the flow and at a depth of 0.3 meters as outlined in the TCEQ SWQM Procedures Manual Volume 1 (TCEQ 2012). Water quality data collected by TCEQ and the Clean Rivers Program partners are housed in TCEQ's SWQMIS database. Water quality data used for this report were accessed from SWQMIS on February 11, 2022.

Stream discharge data were pulled from stations where U.S. Geological Survey (USGS) stream flow gages were located. At stations where data were available, the median daily flow for the site was plotted.

FISH

Nekton samples were collected using both backpack electrofishers and seining methods as described in Chapter 3 of the SWQM Procedures Manual Volume 2 (TCEQ 2014). Backpack electrofishing samples were collected in an upstream manner starting at the bottom of the reach and working toward the top, while seines were fished in a downstream direction. Level of effort for backpack electrofisher was a minimum of 900 seconds and a minimum of six successful seine hauls were completed. Nekton sampling was conducted until no new species were collected for both methods. All available habitats were sampled along the reach. Nekton samples were vouchered by either photographing and/or preserved in 10% formalin and brought back to the lab to be stored in 95% ethanol for long term storage. Species that could not be identified in the field were preserved and identified later in the laboratory.

An index of biological integrity (IBI) was calculated for each fish assemblage sampling event using the regionalized IBI (Linam et al 2002). In general, the metrics to calculate the IBI are based on species richness, the proportions of tolerant and intolerant species, the percentages of different feeding guilds, the number of individuals collected, the number of non-native species, and fish health. The different ecoregions of Texas have between 8 and 12 metrics that were derived from historic data. Fish assemblage data for each sample event was scored according to the metrics of the ecoregion where the site is located, and the metric scores were summed to calculate aquatic life use (exceptional, high, intermediate, limited). These aquatic life use scores were summarized for each aggregated ecoregion by displaying the ranked mean for each stream sampled. Additionally, IBI scores and raw metric values were plotted through time to assess temporal trends ($\alpha = 0.05$).

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate samples were collected following either the rapid bioassessment protocols (RBP) or quantitative Surber sampling methods outlined in Chapter 5 of the SWQM Procedures Manual Volume 2 (TCEQ 2014). The RBP's used to collect benthic macroinvertebrate samples in this study are for wadable streams using a D-frame kicknet with mesh size ≤ 590 μm. Samples were collected from riffle habitat where available, otherwise samples were collected from runs, glides, and pools if no other preferred habitat were available along the reach. D-frame kicknet is placed with the mouth of the net facing into the flow of the stream while the sampler disturbs approximately 0.3 m^2 of the bottom substrate immediately upstream of the net. Any benthic organisms that are present are swept by the current and captured into the net. This process is repeated for a total of 5 minutes of sampling time. After the 5-minute sampling period is complete, the sample is washed in either the net or the sample is transferred into a No. 30 sieve or sieve bucket (mesh size ≤ 595 μm) to remove any sediments. The sample was then transferred into a specimen tray and a minimum of 140 organisms were collected with a goal of collecting 175 (+/- 20 percent). If 140 benthic macroinvertebrates were not present after 5 minutes of sampling, field crews would conduct another 5-minute round of sampling and continue processing the sample in the field until the appropriate number of benthic macroinvertebrates were collected.

Surber samples were collected by placing the Surber sampler on the substrate of a riffle with the mouth of the net facing into the current. Large rocks and debris in the Surber sample area were picked up and washed thoroughly allowing the macroinvertebrates and debris to flow into the net. A total of three replicates were collected from the stream in a manner that would represent the cross-sectional heterogeneity of the riffle.

Specimens were preserved in either 40% isopropyl alcohol or 70% ethanol and brought back to the laboratory for identification and enumeration. Benthic macroinvertebrates are identified to the appropriate taxonomic level based on recommendations from the SWQM Procedures Manual Volume 2 and are listed in Table 3 (TCEQ 2014). For reference, taxa that were identified to finer levels of taxonomic resolution were included in the species lists for each ecoregion. Voucher specimens from each sample event are retained for a period of no less than five (5) years.

A benthic index of biological integrity (BIBI) was calculated for each benthic macroinvertebrate assemblage sampling event using the Texas BIBI for surber samples (TCEQ 2014) and regionalized BIBI for RBP samples (TCEQ 2019). In general, the metrics to calculate the BIBI are based on taxa richness, an analysis of the presence of and relative abundance of tolerant and intolerant taxa, the percentages of different feeding guilds, and the taxa richness of sensitive taxa such as the Ephemeroptera, Plecoptera, and Trichopera (EPT). The different ecoregions of Texas each have 10 metrics that were derived from historic data. Benthic macroinvertebrate assemblage data for each sample event was scored according to the metrics of the ecoregion where the site is located, and the metric scores were summed to calculate aquatic life use (exceptional, high, intermediate, limited). These aquatic life use scores were summarized for each aggregated ecoregion by displaying the ranked mean for each stream sampled. Additionally, the aquatic life use categories associated with each BIBI score were plotted through time for each aggregated ecoregion to illustrate changes in the stream's benthic community over time.

Table 3. Taxonomic levels of identification for benthic macroinvertebrates from the SWQM Procedures Manual Volume 2.

Taxon	Identify to this level
Insecta	genus, except leave Chironomidae at family
Oligochaeta	leave at Oligochaeta
Hirudinea	leave at Hirudinea
Hydracarina	leave at Hydracarina
Isopoda	genus
Amphipoda	genus
Nematoda	leave at Nematoda
Ostracoda	leave at Ostracoda
Palaemonidae	genus
Cambaridae	leave at Cambaridae
Gastropoda	genus
Turbellaria	family
Pelecypoda	genus

RESULTS AND DISCUSSION

This report provides a summary of data collected from 142 sites on 114 least disturbed streams from 1986 to 2018 and includes data presented in Bayer et al. 1992 (Figure 3). Since the release of the Texas Aquatic Ecoregion Project report in 1992 (Bayer et al. 1992), a total of 101 sampling events were conducted on 85 streams across all aggregated ecoregions, and seventy of those were conducted on newly established sites (Figure 3). Blue dots represent historic sites that were sampled and included in Bayer et al. 1992 but were not revisited. Yellow dots represent revisited sites that were sampled and included in Bayer et al. 1992 and were re-sampled and included in this report. Green dots represent new sites that have been sampled since the release of Bayer et al. 1992 and were included in this report. Red dots represent sites that are not recommended as least disturbed streams because they are not representative of the respective ecoregion even though they meet the standards used to identify least disturbed streams.

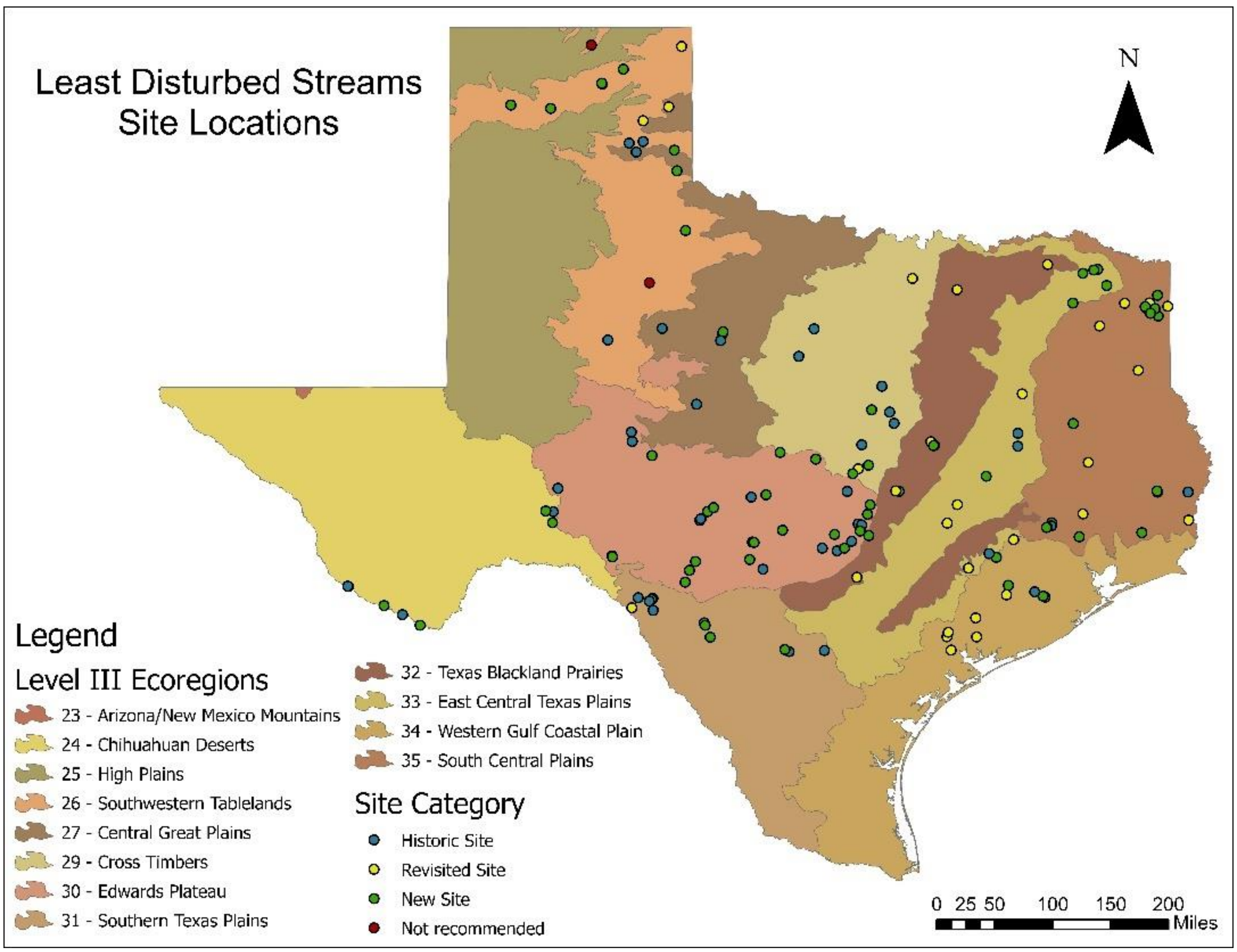

Figure 3. Map of least disturbed stream sampling locations in Texas.