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Guadalupe River Habitat Conservation Plan

TECHNICAL MEMORANDUM: HYDROLOGIC MODELING NEEDS

Prepared for

GBRA

by

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1.0 INTRODUCTION

The purpose of this technical memorandum is to summarize the Guadalupe River Habitat Conservation Plan (GRHCP) Project Team's assessment of existing information and studies on water quantity and water quality in the Guadalupe River Basin, as well as to present the Team's proposed approach for conducting hydrological modeling and analyses to support species impact assessments for the GRHCP. The GRHCP Project Team's proposed data analysis and modeling will be performed for the sole purpose of completing the species impact assessments needed to determine the potential for take, as defined by the federal Endangered Species Act (ESA), of covered species from GRHCP covered activities that affect water flow and/or water quality. Therefore, the approach and recommendations contained in this technical memorandum are focused on achieving this specific purpose.

Sections of this technical memorandum are summarized as follows:

Section 2 – Identifies those covered species that may be affected by factors such as water flow, temperature, and quality, and describes potential impact mechanisms for those covered species. This section sets the context for the types of information on water flows and water quality that may be needed for the GRHCP.

Section 3 – Describes Guadalupe-Blanco River Authority's (GBRA's) covered activity types that may affect water flows and/or water quality. This section links the specific GRHCP covered activities to the potential aquatic impact mechanisms of the covered species.

Section 4 – Provides summaries of historical water quantity and water quality data, including applicable environmental flow and water quality standards, at key locations or control points throughout the Guadalupe River Basin. Environmental flow and water quality standards provide baselines and/or reference points with which to compare water quantity and quality modeling results and to consider in the assessment of potential impacts from covered activities. This section also includes identification of key relevant findings of important reference studies focused on the Guadalupe River Basin and estuarine system.

Section 5 – Discusses the water quantity and water quality modeling/analysis efforts that the GRHCP Project Team proposes to conduct to assess potential effects and potential for take of covered species from the GRHCP covered activities that affect water flow and water quality.

Section 6 – Provides a summary and conclusion of the information in this technical memorandum.

Section 7 – Lists references considered in the preparation of this technical memorandum.

2.0 FOCAL SPECIES AND POTENTIAL IMPACT MECHANISMS

As stated above, the sole purpose of the data analyses and hydrologic modeling efforts proposed in this technical memorandum is to complete the species impact assessments needed to determine the potential for take of covered species from GRHCP covered activities that affect water flow and/or water quality. The potential covered species that may be affected by water flow and/or water quality include the following:

- Freshwater mussels. Three freshwater mussel species that are proposed for ESA listing are known to occur in portions of the Guadalupe River and major tributaries: false spike (*Fusconaia mitchelli*), Guadalupe fatmucket (*Lampsilis bergmanni*), and Guadalupe orb (*Cyclonaias necki*). They require aquatic habitats that could be impacted by activities affecting water flows and/or water quality.

- Salamanders. Three salamander species that have the potential to become ESA-listed during the GRHCP permit term (i.e., in the next 30 to 50 years) are known to occur in springs and/or spring runs within portions of the Upper Guadalupe River and its major tributaries: Cascade Caverns salamander (*Eurycea latitans*), Fern Bank salamander (*E. tridentifera*), and an undescribed salamander (*Eurycea* sp. 2). They are primarily subterranean/aquifer-dwelling species but also occur in restricted surface water habitats near spring outlets that could be impacted by activities affecting water flows and/or water quality.

- Whooping crane (*Grus americana*). This species overwinters in coastal marshes and other habitats in the coastal portion of the GRHCP plan area. Changes in freshwater flows into the estuaries is one factor in a suite of regional environmental influences that have the potential to affect the suitability of habitats and the abundances of preferred food sources. (Slack et al., 2009)

Although other covered species may be included in the GRHCP, they are not addressed in this technical memorandum because they or their habitats are not expected to be affected by changes in water flow or water quality. These species include the Eastern black rail (*Laterallus jamaicensis* ssp. *jamaicensis*), golden-cheeked warbler (*Setophaga chrysoparia*), piping plover (*Charadrius melodus*), red knot (*Calidris canutus rufa*), and monarch butterfly (*Danaus plexippus*). Although the Eastern black rail relies on coastal marsh habitats in Texas, potential covered activities are not expected to affect water flows and/or water quality to an extent that would affect overall marsh habitat in a way that would adversely affect this species. However, as modeling, data analysis, and impact assessments progress, the potential effects on the black rail and its habitat from covered activities that affect water quantity and/or quality will be assessed.

The following sub-sections provide preliminary information on potential ways that each species/group may be impacted by covered activities that affect water flow and/or water quality. This information is intended to provide an overview of potential impact mechanisms related to water quantity and quality and will be further developed as the GRHCP and modeling/data analysis efforts progress. The assessment of potential impacts to covered species will also be conducted as the GRHCP progresses and will use the results of the water quantity and quality modeling and data analysis efforts.

2.1 Mussels

Most riverine freshwater mussels generally require persistent aquatic habitats that maintain adequate water quality conditions during periods of drought and that are hydraulically stable during high flow events (Strayer 2008). Due to the dynamic nature of fluvial systems, mussel populations and the habitats they occupy are often heterogenous and fragmented. At local scales, mussels frequently occur in dense aggregations where suitable habitat persists across a range of environmental variation (Allen and Vaughn 2010, Maloney et al. 2012, Randklev et al. 2019). Therefore, a variety of natural and anthropogenic mechanisms can lead to the degradation or loss of instream mussel habitat and further fragment suitable habitat areas (Newton et al. 2008, Strayer 2008).

Habitat fragmentation and isolation have been shown to reduce population connectivity and other dynamic processes, preventing maintenance of genetic diversity and population demographic structure, limiting potential rescue efforts for at-risk populations, and impacting dispersal into previously uncolonized areas, among others. Impacts associated with habitat modification and fragmentation are considered focal threats to the persistence of mussel populations (Newton et al. 2008, Strayer 2008). The following sub-sections describe threats specific to mussel habitats that could degrade or eliminate suitable habitat and thus result in increased fragmentation and/or isolation of populations in the Guadalupe River Basin.

2.1.1 Altered Flow Regime

The increase in human demand for water resources has modified riverine systems via reservoir installation, surface water diversions, surface water discharges, and groundwater extraction. These anthropogenic activities have altered the natural flow regime of rivers throughout North America, resulting in changes to the magnitude, frequency, duration, and timing of river or streamflow (Poff et al. 1997). In turn, altered flows have changed the temporal and spatial distribution of water quantity.

Large reservoirs typically result in changes to the natural hydrology, such as decreases in peak discharges, increases in minimum flows, increases in base flow levels, and alterations to the timing of low and high flow events (Zhang and Wurbs 2018, Graf 2006, Kondolf and Batalla 2005, Magilligan and Nislow 2005, Wellmeyer et al. 2005). These conditions may positively influence mussel communities by preventing desiccation during drought conditions and preventing displacement during extreme high flow events. However, altered flows have also been shown to negatively impact mussel populations. Potential benefits from increased minimum flows by reservoirs vary on a case-by-case basis. For example, high water velocities associated with increased base flows can displace juveniles from suitable habitat (Layzer and Madison 1995).

Increased numbers of high flow pulses can increase the frequency of bedload movement and sediment scour, which also may displace juvenile mussels (Layzer et al. 1993). Such hydrologic changes may result in changes to mussel community composition by favoring mussels with certain life history strategies (Khan et al. 2020b). Reductions in water temperature resulting from hypolimnetic reservoir releases may also limit mussel reproduction (Layzer et al. 1993), whereas increases in water temperature due to altered hydrology may negatively impact mussel populations (Khan et al. 2020a). Additionally, deviations to the timing of high and low flows may prevent the presence of the required host fish species during mussel reproductive seasons (Freeman and Marcinek 2006, Gido et al. 2010).

2.1.2 Reduced Water Quality

Anthropogenic activities that alter flow regimes and landscapes may exacerbate natural fluctuations in water quality, resulting in physiological stress and potentially leading to declines in survival, growth, and reproduction within mussel populations (Strayer 2008). Reductions in surface flows have been shown to elevate surface water temperatures and reduce dissolved oxygen (DO) concentrations, which may result in high mussel mortality (Gagnon et al. 2004, Golladay et al. 2004, Haag and Warren 2008). Moreover, water quality changes associated with drought conditions have been shown to cause gravid females to abort immature glochidia, limiting reproductive output, and potentially causing recruitment failure (Aldridge and McIvor 2003).

The input of excess ammonia (NH_3) and nutrients (i.e., nitrate, total phosphorus) also pose a threat to freshwater mussel persistence. Sources of excess NH_3 and nutrients include urban and agricultural runoff, as well as return flows from water treatment facilities and various industries. Exposure to increased NH_3 concentrations can have lethal and sublethal effects on juvenile mussels and has been implicated as one of multiple focal contributors to declines in North American mussel populations (Strayer et al. 2004, Newton and Barsch 2007, Environmental Protection Agency [EPA] 2013). For example, elevated levels of NH_3 and nitrate directly downstream of a wastewater treatment plant in the Grand River, Ontario, Canada have been associated with the extirpation of mussel populations in large sections downstream of the treatment plant (Gillis et al. 2017). Further, the EPA used data on physiological tolerances of mussels to develop and recommend aquatic life criteria for acute and chronic exposure to NH_3 (EPA 2013).

2.1.3 Runoff, Erosion, and Channel Modification

Landscape-level factors within a watershed have strong influences on the geomorphology and hydrodynamics of lotic systems (Brim-Box and Mossa 1999, Newton et al. 2008). Alterations to the landscape (i.e., urbanization, agriculture) can increase the magnitude of runoff and bank erosion, contributing to excess fine sediment inputs in river systems (Brim-Box and Mossa 1999). Negative impacts to unionids by increased sedimentation are well supported in the literature, which can result in changes in stream geomorphology, water quality, and reductions in substrate complexity (Poff et al. 1997, Brim-Box and Mossa 1999).

Additionally, in-channel modifications that alter hydrology also affect sediment regimes (Petts 1980, Ligon et al. 1995, Baxter 1997). Elevated base flows from dam releases can cause bed scour, which channelizes the river and decreases habitat diversity (Poff et al. 1997). Channelization can also lower the base level of a river and initiate upstream erosion (Shields et al. 2000). Lastly, barriers to dispersal from channel modification pose a threat to freshwater mussels and may prevent intrapopulation connectivity and range expansion. Dams can act as permanent barriers to host fish movement, and hydroelectric dams may impinge or entrain hosts and result in mortality (Watters 1996, Newton et al. 2008, Rytwinski et al. 2017).

2.2 <u>Whooping Crane</u>

2.2.1 Altered Flow Regime – Freshwater Inflows

The whooping crane was listed as endangered for various reasons (USFWS 2007). The Aransas-Wood Buffalo Population (AWBP) faces threats to its wintering grounds, which are within the GRHCP plan area and could suffer impacts to their hydrologic regime from human activities, though natural factors, like warmer or drier conditions, may influence this as well (Smith 2019; CWS and USFWS 2007, Johnson and Miyanishi 2008, Timoney 2012). Decreases in freshwater inflows may result in an increase in salinity in the coastal system and whooping crane marsh habitats, and higher salinities could lead to a decrease in drinking water availability and changes in availability of food items such as blue crabs. This, in turn, may cause the birds to have lower health conditions before beginning their spring migration and impacts breeding ability (Chavez-Ramirez 1996, Westwood and Chavez-Ramirez 2005). It is noted, however, that winter numbers in the wild Aransas-Wood Buffalo whooping crane population have increased exponentially since the minimum count of 15 in 1941 despite increasing consumptive uses of water in the Guadalupe and San Antonio River Basins. Estimated crane population in this flock during the winter of 2021-2022 is reported at 543 (Butler, Sanspree, Moon, and Harrell 2022).

2.2.2 Reduced Water Quality

As discussed above, increased salinities during low-flow periods could adversely impact whooping crane habitats. At this time, potential GRHCP covered activities are not expected to affect water quality in other ways that would have a substantial impact on whooping crane habitats; however, potential water quality impacts will be addressed as modeling, data analysis, and impact assessments progress. For example, one of the principal threats of environmental pollutants to whooping cranes is the possibility of contaminant spills, particularly along the Gulf Intracoastal Waterway in Texas (Lewis et al. 1992).

2.3 Salamanders

The known distributions of the undescribed *Eurycea* sp. 2 salamander, Cascade Caverns salamander, and Fern Bank salamander are limited to the headwaters and spring/cave systems of the Blanco, Guadalupe, Medina, and Pedernales rivers. Springflow in these systems is provided by several sources including the Edwards, Edwards-Trinity, and Trinity aquifers. Primary threats to these salamander species include groundwater depletion, which results in diminished springflow and water table declines; degradation of water quality due to urban runoff and reduced groundwater flows; and physical modification of habitat.

2.3.1 Reduced Springflow

The aquifers that provide water for the spring systems are also the source of water for a rapidly growing population that stretches from the San Antonio–Austin corridor west into the Hill Country. The increasing surge in population, along with a changing climate, has the potential to alter the hydrology of the spring systems on which the species rely (Heitmuller and Reece 2006). For groundwater-obligate species such as *Eurycea* salamanders, declining water tables and reduced springflow cause habitat loss at the surface and subsurface, resulting in declines in individual abundance and eventually population extinction. They are particularly vulnerable because most *Eurycea* salamanders have small distributions and are adapted to a narrow range of environmental conditions (Devitt et al. 2019). Currently, GBRA's groundwater pumping in the Hill County region is limited to the Cordillera Ranch and Comal Trace water supply systems, which are in the general vicinity of known Cascade Caverns salamander locations.

2.3.2 Reduced Water Quality

Changes in springflow associated with groundwater withdrawals can impact water quality in the cave/spring systems inhabited by the salamanders. A direct correlation between flow and DO has been observed, with DO concentrations decreasing with reduced flows (Turner 2004, Bendik et al. 2019). In addition, reduced springflow can increase the water temperature of spring systems beyond the narrow range of temperatures required by the *Eurycea* salamanders (Crow et al. 2016, Bendik et al. 2019). These changes can ultimately affect reproduction and recruitment success.

Though no recovery plan exists for the undescribed *Eurycea* sp. 2, Cascade Caverns, and Fern Bank salamanders, a recovery plan is in place for the Barton Springs salamander (*E. sosorum*), a similar neotenic species endemic to the Barton Springs system in Austin, Texas. Along with increased water withdrawals from the Edwards Aquifer, threats to the Barton Springs salamander's long-term survival include the degradation of the quality and quantity of water that feeds Barton Springs as a result of urban expansion over the watershed, the vulnerability of the species to acute and chronic groundwater contamination and/or catastrophic hazardous materials spills due to its limited range, and impacts to the surface habitat (USFWS 2005). One can assume similar threats apply to the neotenic salamanders that may be covered by the GRHCP.

3.0 GBRA'S COVERED ACTIVITIES AFFECTING WATER FLOWS AND WATER QUALITY

GBRA's covered activities that affect water flows and water quality and have the potential to impact covered species are briefly described in the following subsections. **Figure 1** illustrates the geographic locations of the key activities affecting water flows relative to the major environmental flow control points discussed in **Section 4**. Control points are key reference points within a river basin typically associated with U.S. Geological Survey (USGS) streamflow gaging stations. The GRHCP is expected to address activities of potential second party take participants, but for the purposes of this technical memorandum, it is assumed that potential second party take participant activities that affect water quantity and/or quality will be similar to GBRA's covered activities.

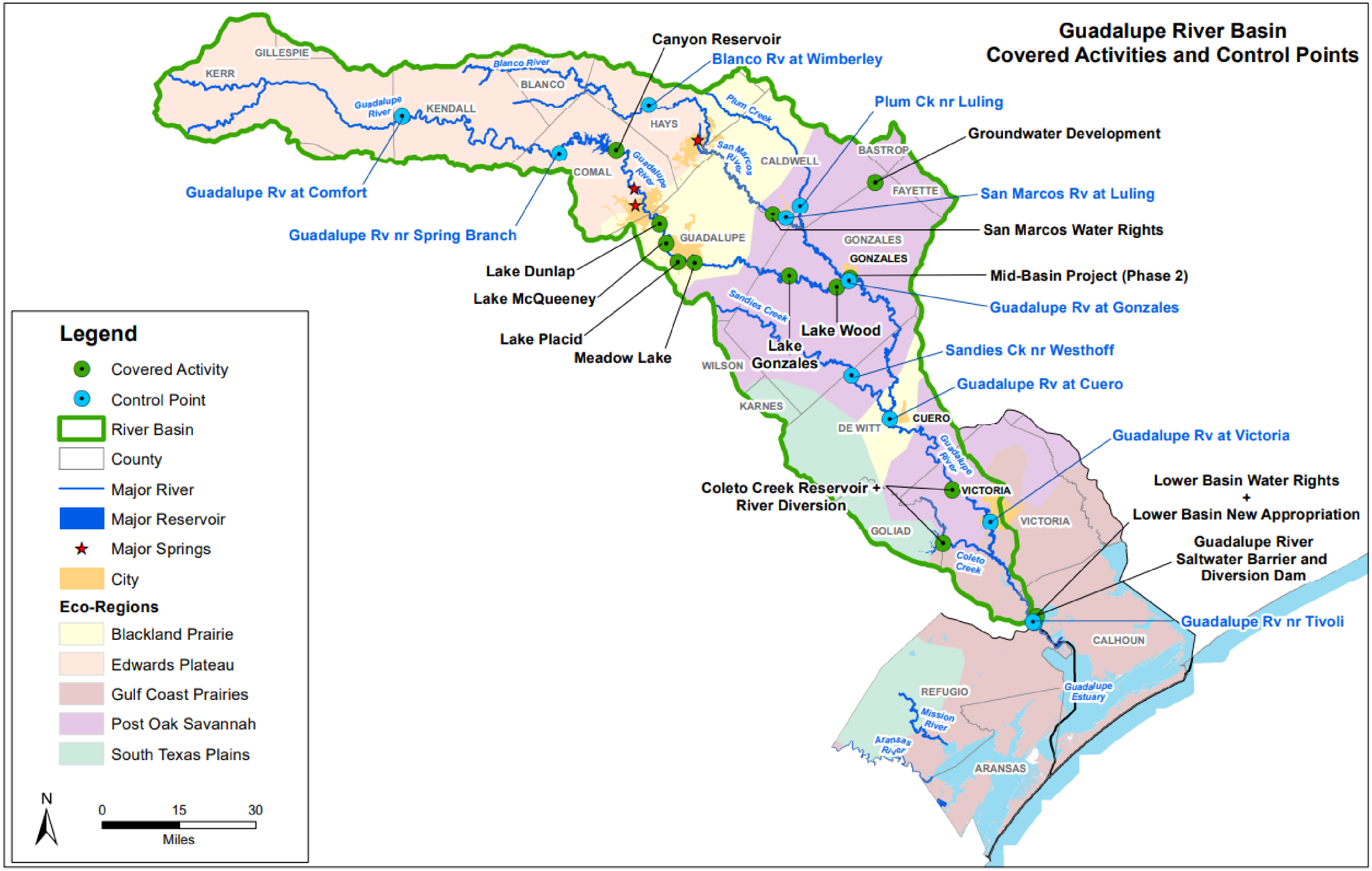

Figure 1. Potential Covered Activities and Flow Control Points

3.1 Operation and Maintenance of On-Channel Dams and Reservoirs

GBRA owns or operates eight (8) on-channel dams and reservoirs in the Guadalupe River Basin: seven (7) on the Guadalupe River and one (1) on Coleto Creek, a major tributary entering the Guadalupe River downstream of Victoria. Operations of each of these dams and reservoirs as they affect flows are discussed in the following subsections. At this time, GBRA is not planning the construction of additional on-channel dams and reservoirs.

3.1.1 Canyon Dam and Reservoir

Canyon Dam is located on the Guadalupe River near the city of Sattler in Comal County and impounds the largest reservoir in the Guadalupe River Basin, Canyon Reservoir. It has an authorized conservation storage capacity of 386,200 acre-feet (ac-ft) and authorized consumptive use of an average of 90,000 ac-ft in any five-year period, with a maximum consumptive use of 120,000 ac-ft in a single year. Construction of the dam was completed in 1964 by the U.S. Army Corps of Engineers (USACE), and current uses include water supply, flood control, recreation, and hydropower generation. Above the conservation pool, Canyon Dam is authorized to impound up to an additional 354,700 ac-ft in the flood pool. Evacuation of the flood pool is managed by the USACE and is generally accomplished by controlled releases at up to 5,000 cubic feet per second (cfs). Daily operations of Canyon Reservoir in the conservation storage pool are managed by GBRA, subject to water supply customer needs, under Certificate of Adjudication No. 18-2074 (CA18-2074, as amended) issued by the Texas Commission on Environmental Quality (TCEQ), as well as under a hydropower license issued by the Federal Energy Regulatory Commission (FERC). Inflows are lawfully impounded in Canyon Reservoir in accordance with priority dates established in CA18-2074 or passed in accordance with instream flow provisions in CA18-2074, GBRA's FERC license, or an agreement with Guadalupe River Trout Unlimited, whichever requires the greater inflow passage or release. Some water supply diversions are made directly from the reservoir, while others are made at downstream locations based on delivery of releases from reservoir storage via the bed and banks of the Guadalupe River. Comprehensive records of daily operations are maintained by GBRA in its Canyon Reservoir Log, thereby demonstrating compliance with all regulatory requirements.

Relative to the natural flow regime, operations of Canyon Reservoir tend to:

- reduce downstream peak flood flows through impoundment,
- extend durations of high flows during controlled evacuation of the flood pool (i.e., releasing flood waters over a longer period than would occur naturally),
- incrementally reduce typical normal flows in excess of pass-through requirements, and
- incrementally increase low flows between Canyon Dam and points of delivery when downstream contractual deliveries from storage exceed Canyon Reservoir inflow (i.e., releases through the dam for contractual purposes provide downstream flows that exceed natural flows during low-flow periods).

From a water quality perspective, flows passed through or released from Canyon Reservoir tend to have less suspended solids than natural river flows due to deposition of sediment within the reservoir. Furthermore, releases from storage come from the lower, cooler portion of the reservoir, typically resulting in lower-than-natural water temperatures in the river below the dam during the summer and fall. These lower water temperatures support a seasonal stocked trout fishery.

3.1.2 Hydropower Dams and Reservoirs

GBRA has owned and operated a series of six hydropower dams and reservoirs inundating portions of the Guadalupe River from the city of New Braunfels in Comal/Guadalupe County almost to the city of Gonzales in Gonzales County since the late 1920s and early 1930s. From upstream to downstream, these dams and reservoirs include the following:

- TP-1 Dam impounding Lake Dunlap,
- TP-3 Dam impounding Lake McQueeney,
- TP-4 Dam impounding Lake Placid,
- Nolte (TP-5) Dam impounding Meadow Lake,
- H-4 Dam impounding Lake Gonzales, and
- H-5 Dam impounding Lake Wood.

Each of these dams includes a concrete spillway controlled by two or three spillgates that normally raise the upstream reservoir pool by approximately 12 feet above the concrete principal spillway crest; the spillgates lay down to pass flood flows. Hydropower generation units are typically located immediately adjacent to the dams; however, two of the hydropower reservoirs (Dunlap and Meadow) include diversion canals to hydropower generation units located a short distance away. In recent years, spillgate failures have occurred at TP-1 (Lake Dunlap), TP-4 (Lake Placid), H-4 (Lake Gonzales), and H-5 (Lake Wood) Dams. GBRA has begun a process of safety improvements and spillgate replacements at the three upstream dams (i.e., TP-1, TP-3, and TP-4) and reservoirs (Lakes Dunlap, McQueeney, and Placid, respectively). Decisions regarding safety improvements and/or spillgate replacements at the downstream dams are pending, and current reservoir levels at Lake Gonzales and Lake Wood remain just above the principal concrete spillway crest levels.

From a regulatory perspective, operations of these hydropower dams and reservoirs are governed by CA18-5488 (TP-1, TP-3, TP-4, and TP-5) and CA18-5172 (H-4 and H-5) issued by the TCEQ. These Certificates of Adjudication authorize impoundment to a specified elevation at each dam and diversion of 1,250 cfs to 1,300 cfs through turbines for hydropower generation. No consumptive use of water is authorized, so all inflows are ultimately passed through, with the minor exception of net evaporation loss from the surfaces of the reservoirs. Construction of these facilities predates the 1977 establishment of FERC.

Relative to the natural flow regime, effects of operations of the six hydropower dams are minimal when flows exceed about 800 cfs. When streamflow falls below this level, GBRA will typically impound for part of the day and generate for the rest of the day so that the turbines operate within their design efficiency ranges. As flows are further reduced during severe drought, impoundment periods become longer and generation periods shorter to maintain efficiency. This results in a flow cycling pattern apparent in downstream gage records during low flow periods. Hydropower dam operations have no apparent effect on water quality.

3.1.3 Coleto Creek Dam and Reservoir

[**Note to Reader:** *The operation of Coleto Creek Dam and Reservoir will likely not be a covered activity in the GRHCP based on an April 2022 site visit. However, this summary is provided for context and completeness for GBRA's system.*]

Coleto Creek Dam and Reservoir are located on Coleto Creek near the community of Raisin, southwest of the city of Victoria, in Goliad and Victoria Counties. Coleto Creek Reservoir is the second largest reservoir in the Guadalupe River Basin, with an authorized conservation storage capacity of 35,084 ac-ft and authorized consumptive use of 24,160 ac-ft/year for industrial purposes, pursuant to CA18-5486, as amended. CA18-5486 is owned by Coleto Creek Power, LP and also authorizes the diversion of up to 20,000 ac-ft/year from the Guadalupe River about 3.25 miles southwest of the community of Nursery in Victoria County, at a maximum rate of 35.65 cfs. Coleto Creek Reservoir serves as a cooling reservoir for a power plant owned and operated by Coleto Creek Power, LP. As only one of the originally planned power generation units has been installed at the power plant, neither consumptive water use at the reservoir by forced evaporation associated with cooling, nor diversions from the Guadalupe River, have ever approached the maximum authorized amounts. Inflows are lawfully impounded in Coleto Creek Reservoir in accordance with the priority date established in CA18-5486 or passed in accordance with instream flow provisions in CA18-5486 requiring the passage of inflow up to 5 cfs.

Although the dam, appurtenant works, reservoir, and river diversion intake and pump station are owned by Coleto Creek Power, LP, GBRA is responsible for daily operations of these facilities. Comprehensive records of daily operations are maintained by GBRA in the Coleto Creek Reservoir Accounting Plan required by CA18-5486.

Relative to the natural flow regime, operations of Coleto Creek Reservoir do not greatly affect downstream flood flows because the reservoir has no flood control capacity and is typically within four feet of the top of the conservation storage pool. The large principal spillway controlled by radial gates was designed to pass peak flood inflow. Normal flows in excess of the 5 cfs pass-through requirement are impounded, thereby decreasing downstream flows in Coleto Creek from those that would occur naturally. Historical gaged streamflows at Victoria have exceeded the authorized maximum diversion rate of the Guadalupe River pump station by a factor of more than 10 almost 90 percent of the time. Hence, infrequent diversions from the Guadalupe River to Coleto Creek Reservoir would be expected to have potentially significant effects on instream flows only during severe drought when river flows are depleted.

From a water quality perspective, flows passed through or released from Coleto Creek Reservoir may tend to be of slightly higher temperature than naturally occurring streamflows during some seasons due to heat loading associated with power plant cooling operations. During the summer, however, the reservoir typically experiences thermal stratification and flows passed through from the lower stratum of the reservoir may be cooler than naturally occurring streamflows.

3.1.4 Guadalupe River Saltwater Barrier and Diversion Dam

GBRA's Saltwater Barrier and Diversion Dam is located on the Guadalupe River in the Guadalupe River delta about 0.5 mile downstream of the San Antonio River confluence and about 560 feet downstream of GBRA's diversion gates for the Calhoun Canal System. It was constructed in the 1960s and is comprised of two 50-foot concrete spillway bays with attached 10-foot diameter inflatable fabridam bags. The elevation of the crest of the spillway bays is approximately -6 feet mean sea level (ft-msl), allowing free passage of river flows during high flow periods when the bags are deflated and river flows prevent saltwater from reaching the diversion gates. During lower flow periods, the fabridam bags are inflated with water, creating a small freshwater impoundment at about 4 ft-msl, which facilitates freshwater diversions by gravity into the Calhoun Canal System. GBRA is currently planning replacement of the fabridam bags with an Obermeyer spillgate system by early 2024. CA18-5484 authorizes maintenance of the Saltwater Barrier and Diversion Dam, as well as the impoundment of up to 600 ac-ft in the small associated on-channel reservoir. Pursuant to CA18-5484, a 12-inch diameter conduit through the Diversion Dam is maintained to allow free passage of flow at all times.

Similar in function to the Guadalupe River Saltwater Barrier, GBRA also owns and operates gates on Hog and Goff Bayous in the Guadalupe Delta to control the intrusion of saltwater and sustain the delivery of fresh water to municipal, industrial, and irrigation customers served by the Calhoun Canal System. The Hog Bayou saltwater barrier is formed by a small, partially wood bulk-headed, earthen embankment penetrated by two 48-inch diameter steel conduits with manually-operated sluice gates installed at the upstream ends. GBRA is considering the possibilities of reconfiguring the saltwater barrier and relocating it to a point on Hog Bayou much closer to State Highway 35 for increased safety and reduced cost of operations and maintenance. The Goff Bayou saltwater barrier is formed by an earthen embankment and concrete spillway structure with a crest elevation of approximately –6.0 ft-msl and including two 16-foot by 8-foot corrugated steel radial gates. New gates of a different type are currently being installed. Gates at both of these saltwater barriers are typically closed and only opened during high flow period.

3.2 Construction and Operation and Maintenance of Off-Channel Reservoirs

GBRA presently owns and operates only one small off-channel reservoir but has plans to develop two or more additional off-channel reservoirs to enhance the reliability of its run-of-river water rights. As they are, by definition, not located on a watercourse, operation of these off-channel reservoirs does not affect streamflow or water quality. Diversions from the Guadalupe River that feed these off-channel reservoirs, and associated effects of these diversions on water quantity and quality, are discussed in **Section 3.3** below. GBRA's existing or planned off-channel reservoirs are briefly described in the following subsections.

3.2.1 Port Lavaca Water Treatment Plant

GBRA owns, operates, and maintains an off-channel reservoir inundating approximately 23 acres near the Port Lavaca Water Treatment Plant in Calhoun County. This small, terminal storage reservoir provides pretreatment sedimentation as well as capacity to sustain municipal supply during any periods when there is insufficient water available from the Guadalupe River or canal system, or when pump station repairs might limit or delay water deliveries from the Guadalupe River.

3.2.2 Lower Basin Storage Project

GBRA is currently planning the development of an off-channel reservoir potentially located adjacent to the Main Canal near the Dow Chemical Company/Union Carbide Corporation (Dow/UCC) facility northwest of the city of Seadrift in Calhoun County. Such a reservoir would substantially enhance the firm yield (i.e., reliable supply without shortage during a repeat of the drought of record) of GBRA's current run-of-river surface water rights (see **Section 3.3.2**) to meet customer needs. Pursuant to these surface water rights, GBRA is authorized to construct and maintain one or more off-channel reservoirs in Calhoun, Victoria, and Refugio Counties with a maximum combined storage capacity of 150,000 ac-ft of water. GBRA has performed a draft feasibility study evaluating four alternative off-channel reservoir sites and a range of storage capacities within each site. Preliminary geotechnical investigations focused on parts of two of these sites have shown favorable results. The GBRA Lower Basin Storage Project is a recommended water management strategy in the 2022 State Water Plan.

3.2.3 Lower Basin New Appropriation

See **Section 3.3.3** for discussion of GBRA's pending application for Water Use Permit No. 12482 (P12482), which includes requested authorization of off-channel storage of 200,000 ac-ft at one or more locations in Calhoun and Victoria Counties.

3.2.4 Mid-Basin Project (Phase 2)

See **Section 3.3.4** for discussion of GBRA's P12378, which includes authorization of off-channel storage of 125,000 ac-ft at one or more locations in Gonzales County. After performance of extensive feasibility studies of many alternative project formulations, GBRA's current planning includes use of P12378 to make run-of-river diversions from a small existing reservoir on the Guadalupe River near the city of Gonzales and treat this water for direct delivery to customers and for an aquifer storage and recovery (ASR) project. The ASR component would provide reliable supplies to customers when run-of-river diversions are not possible under P12378. Surface off-channel storage for this project would likely be limited to that required for pre-sedimentation of river water in advance of treatment and may include artificial wetlands pursuant to an agreement with the Texas Parks & Wildlife Department (TPWD). The GBRA Mid-Basin Project (Phase 2) is a recommended water management strategy in the 2022 State Water Plan.

3.2.5 Other Settling Ponds and Terminal/Balancing Reservoirs

GBRA and some of GBRA's raw water customers have settling ponds and/or terminal/balancing reservoirs at their points of raw water delivery. These facilities generally serve two important functions: 1) detention time sufficient to facilitate settling of suspended sediments in advance of treatment and use; and 2) storage sufficient to support uninterrupted customer operations for a period of time sufficient to address operations and maintenance issues with the raw water delivery system (e.g., pipeline break repair, pump replacement, severe levee breach repair, etc.). An example of such a GBRA facility is the terminal settling and storage pond at the Port Lavaca Water Treatment Plant, which receives raw water diverted from the Guadalupe River and delivered via canal, bayou, and pump station. Similarly, GBRA lower basin customers such as Union Carbide Corporation, INEOS Nitriles, and Seadrift Coke have terminal water storage on their properties. It is expected that future GBRA customers receiving water via lengthy or multi-component delivery systems will likely include terminal storage at the point of delivery. Whether GBRA or the customer will be responsible for this terminal storage is to be determined.

3.3 Water Diversions

3.3.1 San Marcos River Water Rights

GBRA's San Marcos River Water Rights include CA18-3896, P3600, and P5234, as amended, with total authorized diversions of 4,572 ac-ft/year and a combined maximum instantaneous diversion rate of 22.96 cfs. Diversions under CA18-3896 may only occur when flow is passing Zedler Dam (CA18-3897) located in the city of Luling in Caldwell/Guadalupe County. Diversions during the months of May through August under P3600 and P5234 may only occur when flows passing the San Marcos River at Luling streamflow gaging station exceed 130 cfs and 135 cfs, respectively. The existing intake facilities are located a short distance upstream from the gaging station adjacent to GBRA's Luling Water Treatment Plant, from which it supplies water to the cities of Luling and Lockhart under contractual agreements.

3.3.2 Lower Basin Water Rights

GBRA's Lower Basin Water Rights include CA18-5173, CA18-5174, CA18-5175, CA18-5176, CA18-5177, and CA18-5178, as amended, with total authorized diversions of 172,501 ac-ft/year and a combined maximum instantaneous diversion rate of 622 cfs. Because GBRA's Lower Basin Water Rights are very senior, pre-dating more than half the volume of consumptive surface water use in the Guadalupe and San Antonio River Basins, they do not include instream flow pass-through requirements. Nevertheless, pursuant to CA18-5484 and as discussed in **Section 3.1.4** above, water is always passed through the Saltwater Barrier and Diversion Dam. Diversions from the Guadalupe River under these rights are accomplished through a gated structure about 550 feet upstream of the Saltwater Barrier and Diversion Dam, and proceed by gravity through a maintained diversion canal, a segment of Hog Bayou, another maintained diversion canal parallel to State Highway 35, a segment of Goff Bayou, and inverted siphons under the Victoria Barge Canal into a box structure. This gravity diversion system is protected from saltwater intrusion by gated structures on Hog and Goff Bayous near their respective outfalls to Mission Lake within the Guadalupe Delta Wildlife Management Area in Calhoun County. The Dow Main Pump Station draws from the box structure adjacent to the Victoria Barge Canal through two 96-inch diameter pipes and lifts water into the Main Canal System, from which Dow/UCC pumps water for its use and GBRA pumps water for delivery to its municipal and industrial customers. Under single-year contracts, GBRA sometimes delivers water for irrigation use via the Main Canal and various lateral canals and turn-outs.

3.3.3 Lower Basin New Appropriation

GBRA has an application pending before TCEQ for P12482, which will authorize diversions of 189,484 ac-ft/year at a maximum rate of 500 cfs from the same diversion point as GBRA's Lower Basin Water

Rights. The maximum combined diversion rate of GBRA's Lower Basin Water Rights and the New Appropriation is 622 cfs (i.e., the maximum diversion rate under the Lower Basin Water Rights). This application was filed in 2009, declared administratively complete in 2017, and is currently in technical review. P12482 will be issued subject to adopted TCEQ environmental flow standards. The GBRA Lower Basin New Appropriation is a recommended water management strategy in the 2022 State Water Plan.

3.3.4 Mid-Basin Supply Project (Phase 2)

In 2020, TCEQ issued Water Use Permit No. 12378 (P12378) to GBRA authorizing diversion of 75,000 ac-ft/year at a maximum rate of 500 cfs from the Guadalupe River in a diversion reach extending from the San Marcos River confluence to the Gonzales/DeWitt County line. P12378 includes special conditions providing for limitation or suspension of diversions to meet adopted environmental flow standards. Under these special conditions, no diversions are allowed that would cause flow passing the Gonzales streamflow gaging station or the point of diversion to fall below the applicable seasonal subsistence level ranging from 180 cfs to 210 cfs. Additional special conditions require diversion restrictions for passage of seasonal base and pulse flows. See discussion of other aspects of this project in **Section 3.2.4**.

3.3.5 Certificate of Adjudication No. 18-3863, As Amended

A portion of Certificate of Adjudication No. 18-3863, as amended, was acquired by GBRA from the Womack family and is often casually identified as the "Womack Right." Under this certificate, GBRA is authorized to divert up to 3,000 ac-ft/year at maximum rate of 17.0 cfs (up to 18.05 cfs if the Womack family is not diverting concurrently) from one or more locations within a diversion reach of the Guadalupe River extending from New Braunfels to the GBRA Saltwater Barrier and Diversion Dam.

3.4 Groundwater Development

GBRA has obtained groundwater production and export permits from the Gonzales County Underground Water Conservation District (GCUWCD) for 15,000 ac-ft/year as part of its Carrizo Groundwater Supply Project. Seven wells have been completed, and surface facilities, raw water collection pipelines, a water treatment plant, and treated water transmission facilities are under construction. In May 2022, GBRA submitted applications to GCUWCD for new permits and permit amendments supporting production and export of an additional 9,000 ac-ft/year from the Carrizo Aquifer to meet rapidly growing customer needs. Recognizing the potential for long-term changes in surface water/groundwater interactions (i.e., reductions in aquifer discharge into surface watercourses and increased aquifer recharge from surface watercourses due to aquifer drawdown associated with groundwater production), GBRA is considering inclusion of its groundwater development projects as covered activities.

In preparation of the South Central Texas Regional Water Plans, technical consultants have applied groundwater models including production associated with recommended water management strategies (aka. planned projects) to assess changes in aquifer flux and associated changes in streamflow. The 2021 South Central Texas Regional Water Plan reports reductions in Guadalupe River and San Marcos River flows of about 15 cfs and 23 cfs, respectively, due to all planned projects drawing from the Carrizo

Aquifer. Estimating GBRA's portion of the possible reduction in the total flux due to its projects is difficult and would need to consider:

1) GBRA's groundwater withdrawals as a portion of the total aquifer withdrawals;

2) Locations of withdrawals relative to the Carrizo Aquifer outrcrop and water courses;

3) Well field operations as a function of time and duration;

4) Temporal and spatial distribution of recharge estimates; and

5) Other factors.

Further research may be appropriate, as the recent 2021 Joint Planning Desired Future Conditions Explanatory Report for Groundwater Management Area 13 (LRE Water 2022) expressed some skepticism about the ability of the Groundwater Availability Model (GAM) to simulate surface water groundwater interactions.

3.5 Water Discharges

The inclusion of existing and planned wastewater treatment plant and other facility discharges as covered activities in the GRHCP will be determined in consultation with GBRA. Specific facilities are therefore not discussed in this technical memorandum. However, **Section 5** does discuss the proposed modeling approach for existing and planned wastewater treatment plants that are selected as covered activities.

4.0 WATER QUANTITY AND QUALITY DATA AND RELEVANT ENVIRONMENTAL FLOW STUDIES BY ENVIRONMENTAL FLOW CONTROL POINT

The USGS, state agencies, and regional cooperating entities including GBRA have maintained streamflow gaging stations and collected water quality data throughout the Guadalupe River Basin for decades. Streamflow gaging stations and water quality sampling provide the fundamental records of historical streamflow quantity and quality that form the bases for modeling of water available for impoundment, diversion, and use subject to the prior appropriation doctrine and for modeling water quality for regulation of discharges as defined in TCEQ rules. Similarly, records from streamflow gaging stations, considered in combination with biological and water quality data, form the basis for assessment of flow regimes deemed adequate to support sound ecological environments. Ultimately, such environmental flow regimes, balanced by other factors through a public rulemaking process, form the basis for environmental flow standards adopted by TCEQ. These environmental flow standards, in turn, serve to limit future appropriations of surface water for impoundment and diversion in order to preserve and protect the aquatic and riparian environments of Texas, as well as the State's coastal marshes and estuarine systems.

Texas' instream environmental flow standards are typically specified for each season of the year and include subsistence, base, and pulse flow regime components, which appear in water use permits and are applied as flow passage requirements in daily operations. These flow regime components are defined in TCEQ rules as follows:

Subsistence – the minimum streamflow needed during critical drought periods to maintain tolerable water quality conditions and to provide minimal aquatic habitat space for the survival and recolonization of aquatic organisms.

Base – the range of average flow conditions, in the absence of significant rainfall events, that may vary depending on current weather patterns.

Pulse – relatively short-duration, high flows within the stream channel that occur during or immediately following a storm event.

Texas estuarine environmental flow standards, on the other hand, generally establish a reasonably protective long-term flow regime and may affect the magnitude of new appropriations, but do not appear in water use permits or directly affect daily operations.

Historical streamflow and water quality records representative of the Guadalupe River and its major tributaries, segmented by 10 USGS streamflow gaging stations or control points, are summarized in upstream to downstream order in **Sections 4.1** through **4.10**. Included in the summaries are notations of the potential presence of covered species and/or covered activities to be addressed in the GRHCP. As second party take participants in the GRHCP have yet to be determined, only GBRA covered activities are directly addressed in Section 4. Clearly, covered activities involving impoundment, diversion, or discharge in any segment of the river will affect flows at multiple downstream control points. These effects are addressed through hydrologic modeling as discussed in Section 5. References to key data sources, reports, and research studies with information that may be relevant to assessing species impacts is also provided in these sections.

Figure 1 shows the locations of the control points discussed herein, and **Table 1** provides a concise summary of relevant information for each control point and associated stream segment. **Appendix A** includes the following four figures for each control point using currently available data:

a) Annual streamflow volume (ac-ft) with 10-year moving average and non-parametric statistics including median daily flow (cfs) and percentage of zero flow days.

b) Daily streamflow frequency with superimposed TCEQ environmental flow standards including ranges of seasonal subsistence, base, and pulse flows.

c) Dissolved oxygen (milligrams per liter, mg/L) and concurrent streamflow observations with trendline and with superimposed TCEQ surface water quality standard and range of seasonal subsistence environmental flow standards.

d) Temperature (degrees Fahrenheit, ºF) and concurrent streamflow observations for summer and all seasons with trendlines and with superimposed TCEQ surface water quality standard and range of seasonal subsistence environmental flow standards.

Table 1. Control Point Information Summary

USGS Streamflow Gaging Station Name	USGS#	First Full Year of Record	Number of Full Years of Record	Drainage Area (sq. mi.)	Uncontrolled Drainage Area (sq. mi.)	Approximate Percentage of Drainage Area Uncontrolled	WAM Primary Control Point?	Known Covered Species Occurrence within Segment?	GBRA Covered Activity within Segment?	TPWD Ecologically Significant Segment?	TCEQ Stream Segment	TCEQ 2020 303(d) List[1]	TCEQ Aquatic Life Uses
Guadalupe River at Comfort, TX	08167000	1940	81	839	839	100	Yes	Yes	No	Yes	1806		Exceptional
Guadalupe River near Spring Branch, TX	08167500	1923	98	1,315	1,315	100	Yes	Yes	No	Yes	1806	B	Exceptional
Blanco River at Wimberley TX	08171000	1929	92	355	355	100	Yes	Yes	No	Yes	1813		Exceptional
San Marco River at Luling TX	08172000	1940	81	838	838	100	Yes	Yes	Yes	Yes	1808		High
Plum Creek near Luling, TX	08173000	1931	90	309	309	100	Yes	No	Yes	No	1810		High
Guadalupe River at Gonzales, TX	08173900	1997	24	3,490	2,058	59	No	Yes	Yes	Yes	1803		High
Sandies Creek near Westhoff, TX	08175000	1960	61	549	549	100	Yes	No	No	No	1803B	B, DO, IFC, IMC	Intermediate
Guadalupe River at Cuero, TX	08175800	1964	57	4,934	3,502	71	Yes	Yes	No	No	1803		High
Guadalupe River at Victoria, TX	08176500	1935	86	5,198	3,766	72	Yes	Yes	Yes	Yes	1803		High
Guadalupe River near Tivoli, TX	08188800	2001	20	10,128	7,494	74	Yes	Yes	Yes	Yes	1802		High

[1] B = Bacteria in water; DO = Depressed dissolved oxygen in water; IFC = Impaired fish community in water; IMC = Impaired microbenthic community in water

4.1 Guadalupe River at Comfort

The Guadalupe River at Comfort (USGS# 08167000) is near the upstream extent of the GBRA 10-county statutory district in Kendall County, very near the Kerr County line. Typical of the Texas Hill Country and Edwards Plateau Eco-Region, annual and daily flows here are highly variable and subject to large floods and extended periods of drought. As shown in Appendix A, lower flows were more prevalent 1940-1970 and 2010-2020, while higher flows were common 1970-2010. Median streamflow at this location is 106 cfs, and the river ceases to flow about 1.1 percent of the time. TCEQ associates exceptional aquatic life uses with the river segment including this control point and TPWD considers it an ecologically significant stream segment based on high water quality, exceptional aquatic life, and high aesthetic value. Observed dissolved oxygen levels have occasionally fallen below the surface water quality standard, but a trendline suggests that they are unlikely to violate the standard with flows in the subsistence range. Observed temperatures have never exceeded the surface water quality standard, and trendlines suggest that they are unlikely to violate the standard with flows in the subsistence range.

This control point is at the lower end of the known current distribution and proposed critical habitat of the Guadalupe fatmucket, within the known current distribution and proposed critical habitat of the Guadalupe orb, and within the historical distribution of the false spike (USFWS 2019). Host fishes for the glochidia of the Guadalupe fatmucket and Guadalupe orb are included among the focal fish species and habitat guilds identified by the Guadalupe, San Antonio, Mission, & Aransas Rivers and Mission, Copano, Aransas, & San Antonio Bays Basin & Bay Expert Science Team (GSA BBEST), and plots relating percentage of maximum weighted usable habitat area to discharge for four habitat guilds of fish species at this site are available (GSA BBEST 2011). Two adaptive management studies led by the San Antonio River Authority (SARA) and focused on instream data collection and potential methodologies for validation or refinement of TCEQ environmental flow standards include aquatic sampling near the Guadalupe River at Comfort (SARA et al. 2017, 2015).

No existing GBRA covered activities that affect water flow and/or water quality have been identified upstream of the Guadalupe River at Comfort.

4.2 Guadalupe River near Spring Branch

The Guadalupe River near Spring Branch (USGS# 08167500) is located in Comal County between the upstream extent of Canyon Reservoir and the Kendall County line. Typical of the Texas Hill Country and Edwards Plateau Eco-Region, annual and daily flows here are highly variable and subject to large floods and extended periods of drought. As shown in Appendix A, lower flows were more prevalent 1920-1970 and 2010-2020, while higher flows were common 1970-2010. Median streamflow at this location is 147 cfs, and the river ceases to flow about 1.4 percent of the time. TCEQ associates exceptional aquatic life uses with the river segment including this control point, and TPWD considers it an ecologically significant stream segment based on high water quality, exceptional aquatic life, high aesthetic value, and riparian conservation areas such as Guadalupe River State Park. TCEQ's current 303(d) list prepared pursuant to the Clean Water Act includes notation of bacteria in water impairment in the Guadalupe River near this control point, but downstream of the Comfort control point. Observed dissolved oxygen levels have only occasionally fallen below the surface water quality standard, and a trendline suggests that they are unlikely to violate the standard with flows in the subsistence range. Observed temperatures have only once exceeded the surface water quality standard, and trendlines suggest that they are unlikely to violate the standard except at the lowest of flows (less than 0.1 cfs) within the subsistence range.

This control point is located at the downstream end of the known current distribution and proposed critical habitat of Guadalupe orb and within the historical distribution of the Guadalupe fatmucket and false spike (USFWS 2019). Host fishes for the glochidia of the Guadalupe fatmucket and Guadalupe orb are included among the focal fish species and habitat guilds identified by the GSA BBEST, and plots relating percentage of maximum weighted usable habitat area to discharge for three habitat guilds of fish species at this site (GSA BBEST 2011).

No existing GBRA covered activities that affect water flow and/or water quality have been identified upstream of the Guadalupe River near Spring Branch.

4.3 <u>Blanco River at Wimberley</u>

The Blanco River at Wimberley (USGS# 08171000) is in central Hays County near the upstream extent of the outcrop of the Edwards Aquifer. Typical of the Texas Hill Country and Edwards Plateau Eco-Region, annual and daily flows here are highly variable and subject to large floods and extended periods of drought. As shown in Appendix A, lower flows were more prevalent 1930-1970 and 2010-2020, while higher flows were common 1970-2010. Median streamflow at this location is 54 cfs, and the river has not ceased to flow during the period of record of the gaging station. TCEQ associates exceptional aquatic life uses with the river segment including this control point, and TPWD considers it an ecologically significant stream segment based on high water quality, exceptional aquatic life, and high aesthetic value. Observed dissolved oxygen levels have infrequently fallen below the surface water quality standard, but a trendline suggests that they are unlikely to violate the standard with flows in the subsistence range. Similarly, observed temperatures have infrequently exceeded the surface water quality standard, and trendlines suggest that they are likely to violate the standard with flows below the subsistence range.

The Fern Bank salamander is known to occur at Fern Bank Springs approximately 6 miles downstream of this control point, as well as in springs within Cypress Creek approximately 5.5 miles upstream of the control point (Devitt et al 2019).

No existing GBRA covered activities that affect water flow and/or water quality have been identified upstream of the Blanco River at Wimberley.

4.4 <u>San Marcos River at Luling</u>

The San Marcos River at Luling (USGS# 08172000) is located in the city of Luling on the Caldwell/Guadalupe County line. Streamflows are somewhat less variable at this location in the Post Oak Savannah Eco-Region than those typical of the Texas Hill Country due to the influence of baseflow from San Marcos Springs, the second largest spring system in Texas. As shown in Appendix A, flows have been reasonably consistent throughout the period of record, including during an extended period of severe drought 1947-1956. Median streamflow at this location is 212 cfs, and the river has not ceased to flow during the period of record. TCEQ associates high aquatic life uses with the river segment including this control point, and the TPWD considers it an ecologically significant stream segment based on endangered/threatened/unique species communities and riparian conservation areas including Palmetto State Park. Observed dissolved oxygen levels have never fallen below the surface water quality standard and a trendline suggests that they are unlikely to violate the standard with flows in the subsistence range. Similarly, observed temperatures have never exceeded the surface water quality standard, and trendlines suggest that they are unlikely to violate the standard except in the event of flows that fall well below the subsistence range.

This control point is within the known current distribution and proposed critical habitat of Guadalupe orb and within the historical distribution of the false spike (USFWS 2019). Host fishes for the glochidia of the Guadalupe orb are included among the focal fish species and habitat guilds identified by the GSA BBEST, but plots relating percentage of maximum weighted usable habitat area to discharge for habitat guilds of fish species at this site are not available (GSA BBEST 2011). Two adaptive management studies led by SARA and focused on instream data collection and potential methodologies for validation or refinement of TCEQ environmental flow standards include aquatic sampling near the San Marcos River at Luling (SARA et al. 2017, 2015).

GBRA covered activities near and upstream of the San Marcos River at Luling include run-of-river diversions (see **Section 3.3.1**), which are treated at the Luling Water Treatment Plant and delivered for municipal use by the cities of Luling and Lockhart. As these run-of-river diversions are not firm (i.e., reliable without shortage during a repeat of the drought of record), GBRA may consider acquisition of additional run-of-river water rights and/or development of an ASR project relatively near the Luling Water Treatment Plant. An additional GBRA covered activity affecting the San Marcos River downstream of the Luling control point involves changes in surface water/groundwater fluxes associated with the Carrizo Groundwater Supply Project presently under construction, as well as its planned expansion (**Section 3.4**).

4.5 Plum Creek near Luling

Plum Creek near Luling (USGS# 08173000) is located northeast of the city of Luling in southern Caldwell County within the Post Oak Savannah Eco-Region with much of its upstream watershed in the Texas Blackland Prairies Eco-Region. Annual and daily flows here are variable and appear to be increasing somewhat over time, perhaps due to land development and discharge of treated effluent. As shown in Appendix A, the most severe drought period occurred in the late 1940s and early 1950s. Median streamflow at this location is 7.4 cfs, and the stream ceases to flow about 1.4 percent of the time. TCEQ associates high aquatic life uses with the stream segment including this control point. Observed dissolved oxygen levels have infrequently fallen below the surface water quality standard, but a trendline suggests that they are unlikely to violate the standard with flows in the subsistence range. Observed temperatures have never exceeded the surface water quality standard, and trendlines suggest that they are unlikely to violate the standard with flows in the subsistence range.

The segment of Plum Creek at and upstream of this control point is not identified as being within the current distribution or proposed critical habitat of the freshwater mussels species that may be covered by the GRHCP (USFWS 2019). There is potential one or more of the species may occur in portions of Plum Creek.

GBRA covered activities upstream of the Plum Creek near Luling control point include discharges from the following wastewater treatment facilities: Buda, Shadow Creek, Sunfield, Lockhart Larremore Street, and Lockhart FM 20.

4.6 Guadalupe River at Gonzales

The Guadalupe River at Gonzales (USGS# 08173900) is in central Gonzales County, 4.4 miles downstream of the San Marcos River confluence in the Post Oak Savannah Eco-Region. Note that the next upstream Guadalupe River control point is located near Spring Branch, over 160 river miles upstream. Hence, the Guadalupe River in this segment upstream of Gonzales traverses the Edwards Plateau, Texas Blackland Prairies, and Post Oak Savannah Eco-Regions. As shown in Appendix A, the period of record is substantially shorter than that for other streamflow gaging stations considered herein. Median streamflow at this location is 840 cfs, and the river has never ceased to flow during the available period of record. Development of natural streamflows for the TCEQ Water Availability Model (WAM) in this river segment was based in part on operator log records for GBRA's H-5 hydropower facilities. Such records may be useful in evaluation of covered activities and conservation measures in this segment. Base flows are very strong here due to the influences of Comal and San Marcos Springs, the two largest spring systems in Texas. TCEQ associates high aquatic life uses with the river segment including this control point, and the TPWD considers it an ecologically significant stream segment based on endangered/threatened/unique species communities. Observed dissolved oxygen levels have never fallen below the surface water quality standard and a trendline suggests that they are unlikely to violate the standard with flows in the subsistence range. Similarly, observed temperatures have never exceeded the surface water quality standard, and trendlines suggest that they are unlikely to violate the standard with flows in the subsistence range.

This control point is within the known current distribution and proposed critical habitat of Guadalupe orb and false spike, and the entire Guadalupe River segment between Gonzales and Spring Branch is within the historical distribution of these species (USFWS 2019). The historical distribution of the Guadalupe fatmucket extends from just downstream of Seguin upstream to Spring Branch and beyond (USFWS 2019). Host fishes for the glochidia of the Guadalupe orb and Guadalupe fatmucket are included among the focal fish species and habitat guilds identified by the GSA BBEST, and plots relating percentage of maximum weighted usable habitat area to discharge for five habitat guilds of fish species at this site are available (GSA BBEST 2011). Information supplementing that of the GSA BBEST, including alternative habitat guilds and comparisons of available and quality habitat, is available in Hardy (2011). The red shiner, a host fish for the glochidia of the false spike (USFWS 2019), was found to be the most common fish sampled on the Guadalupe River below Gonzales in a comprehensive instream flow study of the Gonzales reach of the Guadalupe River (BIO-WEST 2017). This study includes not only plots relating percentage of maximum weighted usable habitat area to discharge for six habitat guilds of fish species, but more importantly the results of four mussel sampling events at flows ranging from 101 cfs to 796 cfs. These results suggest that subsistence flows of about 130 cfs, which are substantially less than those in the TCEQ environmental flow standards (i.e. 180-210 cfs) would likely be adequate to support the freshwater mussel populations in the Guadalupe River study reach (BIO-WEST 2017). Finally, two adaptive management studies led by SARA and focused on instream data collection and potential methodologies for validation or refinement of TCEQ environmental flow standards include aquatic sampling near the Guadalupe River at Gonzales (SARA et al. 2017, 2015).

Many GBRA activities have been identified on the Guadalupe River between Gonzales and the next upstream control point at Spring Branch. These covered activities include the operations of Canyon Dam and Reservoir and the operations and maintenance of six hydropower dams and reservoirs on the Guadalupe River (**Sections 3.1.1** and **3.1.2**), as well as planned diversions under P12378 associated with Phase 2 of GBRA's Mid-Basin Water Supply Project (**Sections 3.3.4** and **3.2.4**). Canyon Reservoir operations in this stream segment that are considered potential covered activities include GBRA direct diversions from the reservoir (i.e., Western Canyon WTP), GBRA downstream diversions (e.g., Regional Raw Water Delivery System and Guadalupe Power Partners Water Delivery System), and customer downstream diversions (e.g., New Braunfels Utilities, Canyon Regional Water Authority, Georgia-Pacific, Springs Hill Water Supply Corporation, etc.).Additional GBRA covered activities include discharges from the Stein Falls Wastewater Treatment Plant near New Braunfels (**Section 3.5**) and changes in surface water/groundwater fluxes associated with the Carrizo Groundwater Supply Project presently under construction, as well as its planned expansion (**Section 3.4**).

4.7 Sandies Creek near Westhoff

Sandies Creek near Westhoff (USGS# 08175000) is located in western DeWitt County near the Gonzales County line within the Post Oak Savannah Eco-Region. As shown in Appendix A, annual and daily flows here are variable and can be quite limited during dry years. Median streamflow at this location is 8.7 cfs, and the stream ceases to flow about 0.5 percent of the time. TCEQ associates intermediate aquatic life uses with the stream segment including this control point. TCEQ's current 303(d) list prepared pursuant to the Clean Water Act includes notations of bacteria, depressed dissolved oxygen, fish community, and macrobenthic community impairments in Sandies Creek from the Guadalupe River confluence upstream. Observed dissolved oxygen levels have frequently fallen below the surface water quality standard within and above the subsistence flow range. Observed temperatures have never exceeded the surface water quality standard, and trendlines suggest that they are unlikely to violate the standard with flows in the subsistence range.

No covered species are known to occur in Sandies Creek at or upstream of this control point.

No existing GBRA covered activities that affect water flow and/or water quality have been identified on Sandies Creek.

4.8 Guadalupe River at Cuero

The Guadalupe River at Cuero (USGS# 08175800) is in central DeWitt County 4.2 miles downstream of the Sandies Creek confluence in the Texas Blackland Prairies Eco-Region. As shown in Appendix A, the period of record is somewhat shorter than that for many other streamflow gaging stations considered herein. Median streamflow at this location is 980 cfs, and the river has never ceased to flow during the available period of record. Base flows are strong here due to the influences of Comal and San Marcos Springs, the two largest spring systems in Texas, as well as the large upstream watershed. TCEQ associates high aquatic life uses with the river segment including this control point. Observed dissolved oxygen levels have infrequently fallen below the surface water quality standard, but a trendline suggests that they are very unlikely to violate the standard with flows in the subsistence range. Observed temperatures have never exceeded the surface water quality standard, and trendlines suggest that they are unlikely to violate the standard unless summer flows fall below approximately 20 cfs, well below the seasonal subsistence flow standards.

This control point is within the current distribution and proposed critical habitat of Guadalupe orb and false spike (USFWS 2019). One host fish for the glochidia of the Guadalupe orb is included among the focal fish species and habitat guilds identified by the GSA BBEST, and plots relating percentage of maximum weighted usable habitat area to discharge for three habitat guilds of fish species at this site are available (GSA BBEST 2011). The red shiner, a host fish for the glochidia of the false spike (USFWS 2019), was found to be the most common fish sampled on the Guadalupe River below Gonzales (BIO-WEST 2017). A comprehensive instream flow study of the Gonzales reach of the Guadalupe River was completed by BIO-WEST in 2017. This study includes not only plots relating percentage of maximum weighted usable habitat area to discharge for six habitat guilds of fish species, but more importantly the results of four mussel sampling events at flows ranging from 101 cfs to 796 cfs. These results suggest that subsistence flows less than those in the TCEQ environmental flow standards would likely be adequate to support the freshwater mussel populations in the Guadalupe River study reach (BIO-WEST 2017). Finally, two adaptive management studies led by SARA and focused on instream data collection and potential methodologies for validation or refinement of TCEQ environmental flow standards include aquatic sampling downstream of the Guadalupe River downstream of Gonzales and upstream of Cuero (SARA et al. 2017, 2015).

No existing GBRA covered activities that affect water flow and/or water quality have been identified on the Guadalupe River between the Cuero and Gonzales control points. Even though the authorized Guadalupe River diversion reach in P12378 (**Section 3.3.4**) for GBRA's Mid-Basin Water Supply Project (**Section 3.2.4**) extends from the San Marcos River confluence downstream to the Gonzales/DeWitt County line, current planning suggests that this diversion is likely to be located upstream of the Gonzales control point.

4.9 Guadalupe River at Victoria

The Guadalupe River at Victoria (USGS# 08176500) is in central Victoria County about 15 miles upstream of the Coleto Creek confluence in the Western Gulf Coastal Plain Eco-Region. As shown in Appendix A, lower flows were more prevalent 1930-1970 and 2010-2020, while higher flows were common 1970-2010. The most severe period of drought occurred 1947-1956. Median streamflow at this location is 973 cfs, and the river has never ceased to flow during the available period of record. Base flows are strong here due to the influences of Comal and San Marcos Springs, the two largest spring systems in Texas, as well as the large upstream watershed. TCEQ associates high aquatic life uses with the river segment including this control point. Observed dissolved oxygen levels have never fallen below the surface water quality standard, and a trendline suggests that they are very unlikely to violate the standard with flows in the subsistence range. Similarly, observed temperatures have never exceeded the surface water quality standard, and trendlines suggest that they are very unlikely to violate the standard with flows in the subsistence range.

This control point is located at the downstream end of the known current distribution and proposed critical habitat of Guadalupe orb and false spike, while the historical distribution of these species extended further downstream (USFWS 2019). One host fish for the glochidia of the Guadalupe orb is included among the focal fish species and habitat guilds identified by the GSA BBEST, and plots relating percentage of maximum weighted usable habitat area to discharge for three habitat guilds of fish species at this site are available (GSA BBEST 2011). Information supplementing that of the GSA BBEST, including alternative habitat guilds and comparisons of available and quality habitat, is available in Hardy (2011). The red shiner, a host fish for the glochidia of the false spike (USFWS 2019), was found to be the most common fish sampled on the Guadalupe River below Gonzales (BIO-WEST 2017).

Diversions under CA18-5486 from the Guadalupe River about 0.8 miles downstream of the FM 447 crossing to augment storage in Coleto Creek Reservoir are potentially a covered activity. No other GBRA covered activities have been identified on the Guadalupe River between the Cuero and Victoria control points.

4.10 Guadalupe Estuarine System

Downstream of Victoria, the Guadalupe River meanders about 50 river miles through the Gulf Coast Prairies Eco-Region and the Guadalupe delta to its outfall in Guadalupe Bay. The GBRA Saltwater Barrier and Diversion Dam is located approximately 10 miles upstream from the mouth of the river, GBRA's diversion gates are about 550 feet upstream of the Saltwater Barrier, the Guadalupe River near Tivoli streamflow gaging station (USGS# 08188800) is about 200 feet upstream of the diversion gates, and the San Antonio River confluence is about 0.4 miles upstream of the gage. It is noted that the San Antonio River Basin contributes a significant component of the freshwater inflows to the Guadalupe Estuary. As a result, hydrologic modeling scenarios will address surface and groundwater uses in the San Antonio River Basin. Bayous in the Guadalupe delta, including Schwings, Hog, and Goff bayous, deliver local runoff and Guadalupe River overflows into Mission Lake, the northernmost water body in the Guadalupe estuarine system. Historical freshwater inflows to the Guadalupe estuary derived from two source reports (TWDB 2010 and HDR 2019) are summarized in Appendix A. Lower freshwater inflows were more prevalent 1940-1970 and 2010-2020, while higher flows were common 1970-2010. The most severe period of drought occurred 1947-1956. Median annual freshwater inflow is about 2.04 million ac-ft/year, and inflows have never ceased during the available period of record. Base inflows are strong here due to the influences of Comal and San Marcos Springs, treated effluent from San Antonio, and the large upstream watershed. Discharges from these two springs, after accounting for channel losses, have averaged about 9 percent of historical freshwater inflow and exceeded 20 percent during 1956.

TCEQ has not adopted instream environmental flow standards for a measurement point coincident with the Guadalupe River near Tivoli streamflow gaging station (USGS #08188800) that are comparable to those for other control points discussed herein. It has, however, adopted seasonal freshwater inflow regimes with defined allowable impairments applicable to the consideration of applications for new appropriations. Spring and Summer Seasons freshwater inflow standards were derived using *Rangia* clams and Eastern oysters (*Crassostrea virginica*), respectively, as focal species. During other seasons, the adopted instream environmental flow standards applicable to inland measurement locations or control points are deemed adequate to support a sound ecological environment in the estuarine system. Research sampling performed after the adoption of freshwater inflow standards found live *Rangia* clams to be uncommon in Mission Lake and found none in Guadalupe Bay (Black et al. 2015).

TCEQ associates high aquatic life uses with the Guadalupe River segment between the Victoria and Tivoli control points. Observed dissolved oxygen levels have occasionally fallen below the surface water quality standard in the Guadalupe River upstream of the Tivoli streamflow gaging station, but a trendline suggests that they are very unlikely to violate the standard at low flows. Observed temperatures in this segment of the river have never exceeded the surface water quality standard, and trendlines suggest that they are very unlikely to violate the standard at low flows.

Freshwater inflows to the Guadalupe estuary may affect the abundance of habitat and certain foods (e.g., blue crab, wolfberry) as well as the availability of drinking water for wintering whooping cranes. Key information regarding investigations of potential linkages between freshwater inflows, marsh community dynamics, and whooping cranes may be found in Slack et al. (2009). More recent research linking seasonal freshwater inflows for a range of water use scenarios to the abundance of blue crabs in the Guadalupe estuary is available in (Scheef et al. 2019). Water use scenarios evaluated by Scheef et al. (2019) ranged from the natural condition to full use of surface water and Edwards Aquifer groundwater rights without return flows.

Several GBRA covered activities are associated with the Guadalupe River immediately downstream of the streamflow gaging station near Tivoli (USGS #08188800) and affect freshwater inflows to the Guadalupe estuary which may, in turn, affect transient salinity gradients within the estuarine system. These activities include the Saltwater Barrier and Diversion Dam (**Section 3.1.4**), the Calhoun Canal System supplied by the Lower Basin Water Rights (**Section 3.3.2**), off-channel storage for the Port Lavaca Water Treatment Plant (**Section 3.2.1**), the planned Lower Basin Storage Project (**Section 3.2.2**), and the planned Lower Basin New Appropriation and associated off-channel storage (**Sections 3.3.3** and **3.2.3**).

5.0 MODELING APPROACH AND PROCEDURES

The purpose of the modeling efforts and data analyses proposed in this technical memorandum is to complete the species impact assessments needed to determine the potential for take of covered species from GRHCP covered activities that affect water flow and/or water quality. As illustrated in **Figure 2**, besides water usage, return flows, climate conditions, surface/groundwater interactions, and sediment in reservoirs are all inputs to the water quantity model that will determine flow estimates. In turn, these flow estimates, and temperature conditions are inputs to the water quality model that will be used in the species/habitat assessment models. In analyzing the model results and assessing species impacts, it is important to consider that environmental flow standards and water quality standards provide baselines and/or reference points for comparison purposes and/or may regulate flows and water quality parameters, which in turn may limit potential impacts to covered species.

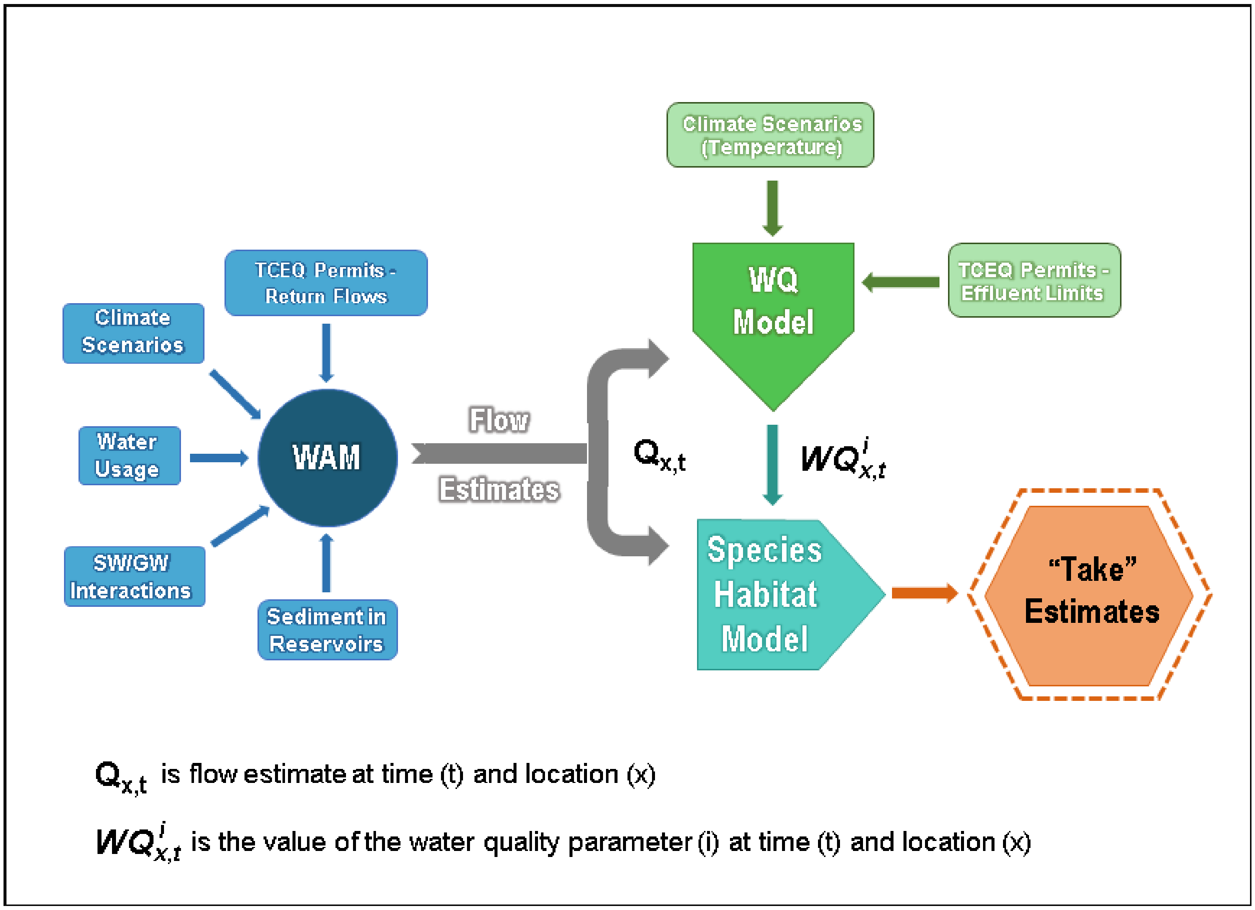

Figure 2. GRHCP Modeling Approach.

5.1 Surface Water Modeling

The GRHCP will use simulated daily regulated streamflow estimates under alternative conditions to support water quality modeling and aquatic habitat, species abundance, or other evaluations potentially useful for assessment of take along with other parameters to determine existing and future impacts to species of concern from water management activities of the GBRA and second parties. Regulated streamflows are the streamflows resulting from all significant water management activities (diversions, return flows, reservoir operations, etc.) in the Guadalupe and San Antonio (GSA) River Basin.

5.1.1 Model Selection

Alternative scenarios, which affect water quantity, as well as water quality and other aquatic habitat parameters, will be simulated using the TCEQ's WAM for the GSA River Basin. The GSA WAM includes a hydrologic period of record of 1934-1989 and simulates all consumptive surface water rights on a monthly timestep in strict accordance with the prior appropriations doctrine (first in right, first in time).

The GSA WAM was selected as the model for developing estimates of daily regulated streamflows under the various alternative scenarios for the following reasons:

- The GSA WAM is used by TCEQ to evaluate water right applications in the GSA River Basin and is a widely accepted tool for simulating basin-wide hydrology in the basin.
- The GSA WAM was used in the development of environmental flow standards in the GSA River Basin.
- The GSA WAM can provide monthly regulated streamflow estimates at specific locations throughout the entire basin.
- Monthly streamflow output from the GSA WAM can easily be disaggregated into daily streamflow estimates using historical daily flow patterns.
- The GSA WAM simulates all existing surface water rights and major reservoir operations in the basin and can easily be modified to simulate assumed hydrologic and water management conditions in the alternative scenarios.
- No other GSA basin model exists. The development of a basin model that would include all water management activities in the basin in a separate modeling platform such as RiverWare would require a significant effort and would not result in significantly different daily regulated streamflow estimates.

5.1.2 Modeling Approach

The GSA WAM will be modified as necessary to represent the appropriate hydrologic conditions with respect to surface water use, sediment conditions in reservoirs, return flows, Edwards Aquifer spring flows, and future climate change in the basin. Regulated streamflows at selected locations will be extracted from GSA WAM output and will be used to support water quality modeling and aquatic habitat, species abundance, or other evaluations potentially useful for assessment of take of each aquatic covered species.

Detailed steps of the proposed approach are presented as follows and are illustrated in **Figure** .

1. Modify GSA WAM to simulate the appropriate hydrological conditions with respect to surface water use, sediment conditions in reservoirs, return flows, Edwards Aquifer springflows and future climate change in the basin. Modeling assumptions to be used in modifying the GSA WAM are further detailed in Section 5.1.4.
2. Extract monthly time series of simulated regulated streamflow at selected locations from GSA WAM output for the 1934-1989 model period of record.
3. Disaggregate monthly time series of simulated regulated streamflows at selected locations to daily streamflow values for 1934-1989 period of record of the GSA WAM.
4. Develop daily simulated streamflow frequency and statistics from 1934-1989 daily timeseries for use in water quality modeling and determination of impacts to species.

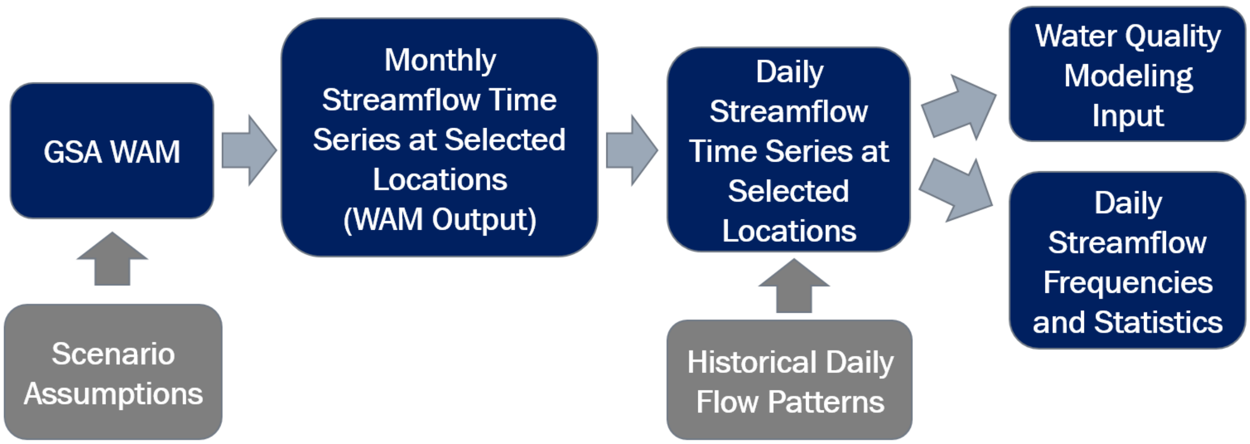

Figure 3. Process Diagram of Surface Water Quantity Modeling Approach.

5.1.3 Scenarios

Proposed surface water modeling scenarios are provided in **Table 2** and further described below. The initial scenarios will be completed first followed by the subsequent scenarios once the modeling assumptions have been determined.

Initial Scenarios

- **Reference –** A "Current Conditions" run based on year-2020 water use, sediment in reservoirs, and return flows and one set of Edwards Aquifer springflows pursuant to the current Edwards Aquifer Habitat Conservation Plan (EAHCP). This scenario is intended to serve as the environmental baseline for the GRHCP impact analysis. Should the results of this initial Reference Scenario indicate the need to refine the assessment of GBRA's current activities, a Supplemental Reference Scenario (see Scenario 6 in **Table 2**) may be simulated (e.g., "Current Conditions excluding GBRA", in cooperation with GBRA.

Table 2. Summary of Surface Water Model Scenarios and General Surface Water Modeling Assumptions

	Scenario	Scenario Purpose	Flow and Related Attributes	Covered Activities (GBRA and 2nd Parties)		Other Entities		Large Dams or Other Existing Infrastructure/ Sediment Conditions	Conservation Measures	Climate Change
				Water Use & Operations	Return Flows	Water Use & Operations	Return Flows			
Initial Scenarios										
1	Reference	Baseline for HCP impact analysis	Current conditions with current covered activities	Yes/Current	Yes/Current	Yes/Current	Yes/Current	Yes/Current	No	No
2	Covered Activities	Impact Analysis and Take Estimates	Future conditions with future covered activities	Yes/Future	Yes/Future	Yes/Future[a]	Yes/Future[a]	Yes/Future	No	No
Subsequent Scenarios										
3	Climate Change	Assess feasibility of future mitigation efforts	Use future evaporation, precipitation, and streamflow projections (TBD)	Yes/Future	Yes/Future	Yes/Future	Yes/Future	Yes/Future	No	Yes
4	Conservation Strategy	Assess extent to which conservation measures mitigate take	Proposed future operations plus conservation flows and restoration	Yes/Future	Yes/Future	Yes/Future	Yes/Future	Yes/Future (Other than infrastructure to be removed – e.g., dams removed for HCP)	Yes	TBD
5	Conservation Strategy with Alternatives	Assess extent to which alternative conservation measures mitigate take	Proposed future operations plus conservation flows and restoration for alt. conservation strategies	Yes/Future	Yes/Future	Yes/Future	Yes/Future	Yes/Future (Other than infrastructure to be removed – e.g., dams removed for HCP)	Yes	TBD
6	Supplemental Reference (if needed), Natural Flows[b], Climate Change #2, or Other Scenario TBD	Current conditions excluding GBRA (if needed), Compare GRHCP conservation measures, additional climate change scenario, other	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

[a] Scenario 2 model run will include all projected water use (e.g., GBRA, 2nd party stakeholders, other entities) to fully estimate future flow conditions in the river, allow for a direct comparison with the baseline scenario (which also includes all water users), and address 2nd party users that may become interested in GRHCP participation after model runs are completed. GBRA's water use and associated effects, as well as 2nd party use/effects, would be pro-rated to determine each entity's contribution to species effects.

[b] Estimating natural flows does not require a WAM run. If natural flow information is used for comparing conservation measures or similar purposes, the Project Team proposes to use natural flow information that has been developed previously for the Guadalupe River Basin.

- **Covered Activities –** A "Future Conditions" run based on projected 2070 water use, projected 2070 sediment in reservoirs, and projected 2070 return flows with consideration given to conservation and reuse and one set of Edwards Aquifer springflows pursuant to the current EAHCP. Note that this model run will be based on a *projected 2070 water use* and not on *full authorized 2070 use of water rights*. This approach was selected because projected use best represents the activity or activities that are *reasonably certain* to result in incidental take as per the HCP Handbook (USFWS and National Marine Fisheries Service 2016). The Covered Activities scenario based on projected water use is considered to be the best representation of 2070 conditions and assessing take of covered species. Additionally, this approach is supported by the 2070 projected water demand estimates used by the South Central Texas (Region L) Regional Water Planning Group and the TWDB to develop water management strategies for the 2022 State Water Plan. In this plan - where water demand is defined as the needs (for both surface and groundwater) of all water user groups during the repeat of the drought of record – the 2070 projected water demand for the GRHCP Plan Area is estimated to be approximately 450,000 acre-feet/year, which is considerably less than full authorized 2070 use of water rights of approximately 700,000 acre-feet/year.

  For the "Future Conditions" based on the above for the years 2030, 2040, 2050, and 2060, are anticipated to be developed through interpolation between the 2020 and 2070 data. Analyzing the data in increments can be of significant value in determining and documenting the likelihood of take over time. Note that take coverage permitted under the plan will be capped at the projected water use amounts described by this scenario. Should additional water usage be needed (e.g., water usage consistent with fully authorized use of water rights), an amendment to the plan will be required.

<u>*Subsequent Scenarios*</u>

- **Climate Change** – Because of widely divergent predictions of future precipitation across Global Climate Models (GCMs), the uncertainty associated with selecting a single representative model is high and difficult to defend. Additionally (in part because of this) permittees are not required to quantify and offset the impacts of climate change. Rather, the impacts of climate change must be addressed as part of the Conservation Strategy. The climate change scenario will assess the effectiveness of conservation actions in addressing potential future scenarios that would be particularly problematic for at-risk species (e.g., less precipitation during summer months). The model can also help GBRA ensure that any future water commitments (such as minimum flow requirements) are achievable. Modifications are expected to include adjustments to the natural streamflow and net evaporation historical datasets included in the GSA WAM. Aquifer recharge and springflows are not expected to be modified.

- **Conservation Strategy –** This scenario can be based off a Covered Activities run modified to reflect potential conservation measures to assess the extent to which conservation measures mitigate take. Modifications may also include climate change.

- **Conservation Strategy with Alternatives –** An additional conservation strategy run modified to reflect potential alternative conservation measures to assess the extent to which different conservation measures mitigate take. This run can be used to help prioritize different conservation alternatives. Modifications may also include climate change.

- **Other Scenario** – An additional scenario may be modeled to consider supplemental reference conditions (if needed), an alternative climate change scenario, or other factors to be determined.

5.1.4 Modeling Assumptions

5.1.4.1 Surface Water Use

Surface water consumptive use by existing water rights in the GSA WAM will be adjusted based on current and projected future conditions. GBRA covered activities will be integrated into the GSA WAM where applicable and GBRA operations will be simulated assuming the current and future assumed water use provided in **Table 3**.

Current water use of non-GBRA major water rights with authorized diversion amounts greater than 5,000 ac-ft/year will be estimated using reported water use for 2010-2020. Future water use by non-GBRA entities will be estimated by use type as follows:

- Municipal – Municipal use will be projected by extrapolating current water use levels to 2070 levels using projected county population estimates and/or water user group demand projections from the 2022 State Water Plan.

- Industrial – Industrial use is assumed to remain constant from 2020 to 2070 unless specific information is provided by industrial user(s).

- Irrigation – Irrigation use is assumed to remain constant from 2020 to 2070.

Table 3. Summary of GBRA Current and Future Covered Activities

Water Right ID	Consumptive Use Amount (ac-ft/yr)			Storage Capacity (ac-ft)			Notes
	Authorized	Current[a]	Future	Authorized	Current	Future	
Lower Basin Water Rights							
CA 18-5173	2,500	1,600	2,500	See CA18-5178			Water rights are also authorized to divert from one or more points on the perimeter of the small reservoir created by GBRA's Saltwater Barrier and Diversion Dam authorized under Certificate of Adjudication No. 18-5484 pursuant to Amendment D of each of the rights. CA18-5173 through CA18-5177 are authorized to use storage specified in CA18-5178.
CA 18-5174	1,870	1,200	1,870	See CA18-5178			
CA 18-5175	940	600	940	See CA18-5178			
CA 18-5176	9,944	4,800	9,944	See CA18-5178			
CA 18-5177	51,247	24,500	51,247	See CA18-5178			
CA 18-5178	106,000	9,700	106,000	150,000	0	40,000	
CA 18-5484	---	---	---	600	600	600	Authorization for Saltwater Barrier impoundment
Subtotal	**172,501**	**45,400[b]**	**172,501[b]**	**--**	**--**	**--**	---
Canyon Reservoir Water Right							
CA 18-2074	120,000	42,800[c]	Firm Yield[d]	386,200	376,553[e]	370,804[e]	Use amount limited to 450,000 ac-ft/yr in any 5-year period. Diversion is authorized from the perimeter of Canyon Reservoir, as releases through the dam for use downstream, and at downstream diversion points on the Guadalupe River. Total authorized storage is 740,900 ac-ft with a conservation storage capacity of 386,200 ac-ft.
San Marcos River / Luling Water Rights							
CA 18-3896	2,800	600	2,800	0	0	0	
Permit No. 3600	750	500	750	0	0	0	
Permit No. 5234	1,022	1,000	1,022	0	0	0	
Subtotal	**4,572**	**2,100**	**4,572**	**--**	**--**	**--**	---
Mid-Basin Water Rights							
CA 18-3863	3,000	3,000[f]	3,000	See CA18-5178			"Womack" Water Right. Authorized to use storage specified in CA18-5178.
Permit No. 12378	75,000	0	75,000	125,000	0	5,000[g]	Water right includes diversion reach from confluence of Guadalupe and San Marcos Rivers to Gonzales County line.
Hydropower Water Rights (Non-Consumptive)							
Permit No. 4167	0	0	0	0	0	0	Canyon Reservoir
CA 18-5172	0	0	0	> 0	> 0	> 0	Lake Gonzales (H-4) and Lake Wood (H-5). Authorized to impound an unspecified volume of water below "normal maximum operating levels" specified in ft-msl.
CA 18-5488	0	0	0	> 0	> 0	> 0	Lake Dunlap (TP-1), Lake McQueeney (TP-3), Lake Placid (TP-4), and Meadow Lake (Nolte, TP-5). Authorized to impound an unspecified volume of water below "normal maximum operating levels" specified in ft-msl.

a-Current water use estimates based on average annual reported use from 2010-2020 unless otherwise noted.

b-Includes Dow water use.

c-Assumes 4,400 ac-ft/yr of Canyon Reservoir supplies are delivered to Coleto Creek pump station. Value is 2010-2021 average of annual contract deliveries.

d-The firm yield of Canyon Reservoir will be calculated under future conditions. Firm yield amount will assume no supplies are delivered to Coleto Creek pump station.

e-Reported 2020 and 2070 conservation storage in 2016 South Central Texas Regional Water Plan.

f-Full use of water right was reported by GBRA for 2020 and 2021. It is assumed GBRA will continue to fully utilize water right since it has been amended for use in mid-basin service area.

g-Mid-Basin pre-sediment and wetland storage.

5.1.4.2 Sediment Conditions

Sediments conditions will be updated for the major reservoirs in the basin to represent current and future conditions using storage volume and surface area relationships from the year-2020 and year-2070 versions of the 2016 South Central Texas (Region L) WAM unless otherwise noted. **Table 4** provides the authorized and estimated current and future conservation pool capacities of major reservoirs with more than 5,000 ac-ft of authorized storage in the GSA River Basin.

Table 4. Summary of Authorized and Estimated Current and Future Conservation Pool Capacities of Major Reservoirs in the Guadalupe and San Antonio River Basins

Major Reservoir	Authorized Conservation Pool Capacity (ac-ft)	Current Conservation Pool Capacity (ac-ft)	Future Conservation Pool Capacity (ac-ft)
Canyon	386,200	376,553	370,804
Medina	237,874	237,874[a]	237,874[a]
Calaveras	63,200	62,222	61,262[b]
Coleto	35,084	32,913	30,198[c]
Braunig	26,500	26,401	26,311[d]

a-A 1995 survey of Medina Lake completed by TWDB calculated a conservation pool capacity of 254,843 ac-ft, approximately 17,000 ac-ft greater than the authorized capacity. For modeling purposes, it is assumed that storage in the reservoir cannot exceed the authorized storage capacity under current and future conditions.
b-No 2070 conservation pool storage is reported in the 2016 Region L WAM and no recent surveys are readily available. Therefore, an annual sedimentation rate of 19.2 ac-ft/yr was calculated using the authorized storage and impoundment date (1969) and 2020 conservation pool capacity to estimate the 2070 conservation pool capacity.
c-No 2070 conservation pool storage is reported in the 2016 Region L WAM and no recent surveys are readily available. Therefore, an annual sedimentation rate of 54.2 ac-ft/yr was calculated using the authorized storage and impoundment date (1980) and 2020 conservation pool capacity to estimate the 2070 conservation pool capacity.
d-No 2070 conservation pool storage is reported in the 2016 Region L WAM and no recent surveys are readily available. Therefore, an annual sedimentation rate of 1.8 ac-ft/yr was calculated using the authorized storage and impoundment date (1964) and 2020 conservation pool capacity to estimate the 2070 conservation pool capacity.

5.1.4.3 Return Flows

Return flows in the GSA River Basin comprise a significant portion of the available and regulated streamflow at some locations in the basin, especially during drought conditions. Current levels of return flows will be estimated using an average of historical return flow discharges for 2010-2020.

Increases in effluent between 2020 and 2070 will be estimated by applying the projected county population percent increases from the 2022 State Water Plan to the estimated current effluent levels. Future return flow discharges will be estimated by assuming 75% of the current effluent will continue to be discharged (assumed 25% reduction from reuse and conservation) and 50% of wastewater flows in excess of current levels will be discharged (50% reuse and conservation of any future increases in effluent). The future return flows will be further reduced by the supply amount of reuse water management strategies included in the 2022 State Water Plan.

5.1.4.4 Edwards Aquifer Springflows

All scenarios will assume Edwards Aquifer springflows pursuant to the current EAHCP. The Edwards Aquifer Authority has just begun a six-year planning process to renew the incidental take permit that will include modeling Edwards Aquifer spring flow projections under the effects of climate change. The GRHCP team will continue to monitor the EAHCP permit renewal process to evaluate how it may affect the GRHCP model scenarios.

5.1.4.5 Climate Change

Climate change scenarios will consider observed trends in historical data and projections from existing climate models to derive scaling factors for adjustment of the existing naturalized flow and net evaporation datasets included in the GSA WAM to simulate anticipated 2070 conditions. The potential also exists for future water use to be affected by climate change. However, these adjustments would come with a high level of uncertainty as some portion of these future increases from climate change are expected to be offset with future conservation measures. Therefore, adjustments to future water use to account for projected climate change are not proposed as part of the climate change scenario evaluations.

Observed and naturalized streamflow, rainfall, evaporation, and temperature in contributing watersheds of up to four WAM primary control points will be evaluated to identify the presence of trends in the historical data. The current GSA WAM includes a period of record of 1934-1989. Naturalized streamflow at the four selected primary control points will be extended to 2021 using simplified, conservative procedures previously developed by HDR (HDR 2008). Rainfall, evaporation, and temperature for the four selected control points will be extended to 2021 using readily available data.

These observed trends will be projected to year 2070 for comparison with year 2070 projected streamflow, rainfall, and temperature based on climate model results. One set of scaling factors will be developed to adjust the existing natural streamflow and net evaporation datasets in the GSA WAM for projected 2070 conditions. It is assumed that Edwards Aquifer springflows and return flows will not be adjusted for climate change scenarios. Further details of the adjustments for climate change will be provided in a subsequent technical memorandum.

5.1.4.6 Model Output

For evaluation purposes, monthly simulated regulated flows for the 1934-1989 period from the GSA WAM for the six scenarios will be disaggregated to daily regulated flows using readily available historical gaged flow patterns at selected locations throughout the Guadalupe River Basin. These identified locations are listed in **Table 5**. Streamflow statistics required for water quality modeling, such as the 7Q2, will be calculated from the 1934-1989 daily timeseries of regulated flows that are representative of the inflow or headwater of each segment to be modeled using QUAL-TX.

Table 5. Summary of Streamflow Locations for WAM Regulated Flow Extraction

Location	USGS Gage#	WAM Control Point ID	WAM Primary Control Point[1]
Guadalupe River at Comfort, TX	08167000	CP01	Yes
Guadalupe River at H5 Dam	N/A	CP06	Yes
San Marcos River at Luling TX	08172000	CP10	Yes
Plum Creek near Luling, TX	08173000	CP11	Yes
Guadalupe River at Gonzales, TX	08173900	GRGONZ	No
Guadalupe River at Victoria, TX	08176500	CP15	Yes
Guadalupe River near Tivoli, TX	08188800	CP38	Yes

[1]WAM primary control points have naturalized streamflows calculated from gaged streamflow. WAM secondary control points are located at ungaged control points and naturalized flows are computed at these locations within the WAM simulation using naturalized flows at nearby primary control points.

5.2 Water Quality Modeling

5.2.1 Goal

The goal of the water quality (WQ) modeling is to provide concentration estimates of key water quality constituents of concern for the covered species discussed herein to assess impacts on those covered species and develop take estimates. The WQ modeling will utilize critical-condition flows developed from the WAM runs mentioned in the previous section. The WQ modeling will also utilize return flow estimates from WAM that reflect future human population increases, conservation, and reuse in the basin. The key WQ constituents to be considered in the modeling are dissolved oxygen (DO), temperature, and ammonia (NH_3). Additional constituents may be identified later in this project and reviewed if they can be investigated with available models.

As stated earlier, the sole purpose of the modeling efforts and data analysis proposed in this technical memorandum is to complete the species impact assessments needed to determine the potential for take of covered species from GRHCP covered activities that affect water flow and/or water quality. In analyzing the model results and assessing species impacts, it is important to consider that environmental flow standards, water quality standards, and wastewater effluent limits provide baselines and/or reference points for comparison purposes and/or may regulate flows and water quality parameters, which in turn may limit potential impacts to covered species.

5.2.2 Preferred Model

To adequately estimate take of covered species in the Guadalupe-Blanco River Basin ("Basin"), it is desirable to use existing WQ models that already 1) have reasonably extensive coverage of the streams in the Basin; and 2) have been set up to simulate critical low-flow conditions. Through the Texas Pollutant Discharge Elimination System (TPDES) program, the TCEQ has developed multiple QUAL-TX models in the Basin to evaluate waste loads from existing permittees under low-flow conditions (typically 7Q2). The WQ modeling effort will utilize these QUAL-TX models.

Unlike the basin-scale TCEQ WAM models, TCEQ QUAL-TX models are much smaller and are oriented towards an individual permittee or groups of neighboring permittees. A typical TCEQ QUAL-TX model would cover one or several stream reaches and would generally begin near the permitted outfalls and end some distance downstream where the water quality has either recovered to background water quality conditions or is trending towards recovery. For this reason, the spatial extents of TCEQ QUAL-TX models are not uniform. Models of large dischargers tend to cover longer sections of streams because the waste loads take longer to assimilate. On the other hand, models of smaller dischargers tend to cover shorter distances. Stream sections that have no permitted dischargers may have no coverage by TCEQ QUAL-TX models. Also, very small dischargers may not be modeled by TCEQ if best professional judgment determines that their water quality impacts are unlikely to violate ambient water quality standards.

As a result, the coverage of TCEQ QUAL-TX models is irregular. Therefore, the water quality modeling will adopt a targeted approach that focuses on streams that can assess impacts from GBRA's covered activities. The Project Team reached out to TCEQ for the TCEQ QUAL-TX models for the following types of permittees

1. Wastewater treatment plants (WWTPs) owned and/or operated by GBRA – The models for these permittees simulate direct water quality impacts of GBRA's covered wastewater treatment activities.

2. Largest dischargers in the basin – The models associated with these permittees tend to cover long portions of streams in the basin. Even though the streams may not receive direct discharges from GBRA's covered wastewater treatment activities, they may be situated downstream of other covered activities, such as reservoir releases and hydropower generation, that alter the flow regime. These models will be used to assess water quantity impacts on water quality brought about by GBRA's other covered activities.

A detailed discussion on the received TCEQ QUAL-TX models and their coverage is provided in the next subsections.

5.2.2.1 Overview of QUAL-TX models received from TCEQ

Figure 4 shows the spatial extents of QUAL-TX models received from TCEQ. The stream reaches covered by QUAL-TX models are colored in **red**. The TPDES permittees in the basin are shown as **orange** dots and are sized according to their average discharge rate (in million gallons per day [MGD]) according to discharge monitoring records from EPA's ECHO database. Permittees that are related to GBRA are highlighted with black circles. Also shown are the different zones of the Edwards Aquifer (i.e., contributing, recharge and transition zones). More detailed, zoomed-in views of **Figure 4** are provided in **Figure 5** through **Figure 9**.

As mentioned above, water quality modeling will adopt a targeted approach that uses selected models to assess impacts of GBRA's covered activities.

Table 6 lists five focus areas for the water quality modeling, which were identified based on clusters of GBRA-related permits and available TCEQ QUAL-TX models.

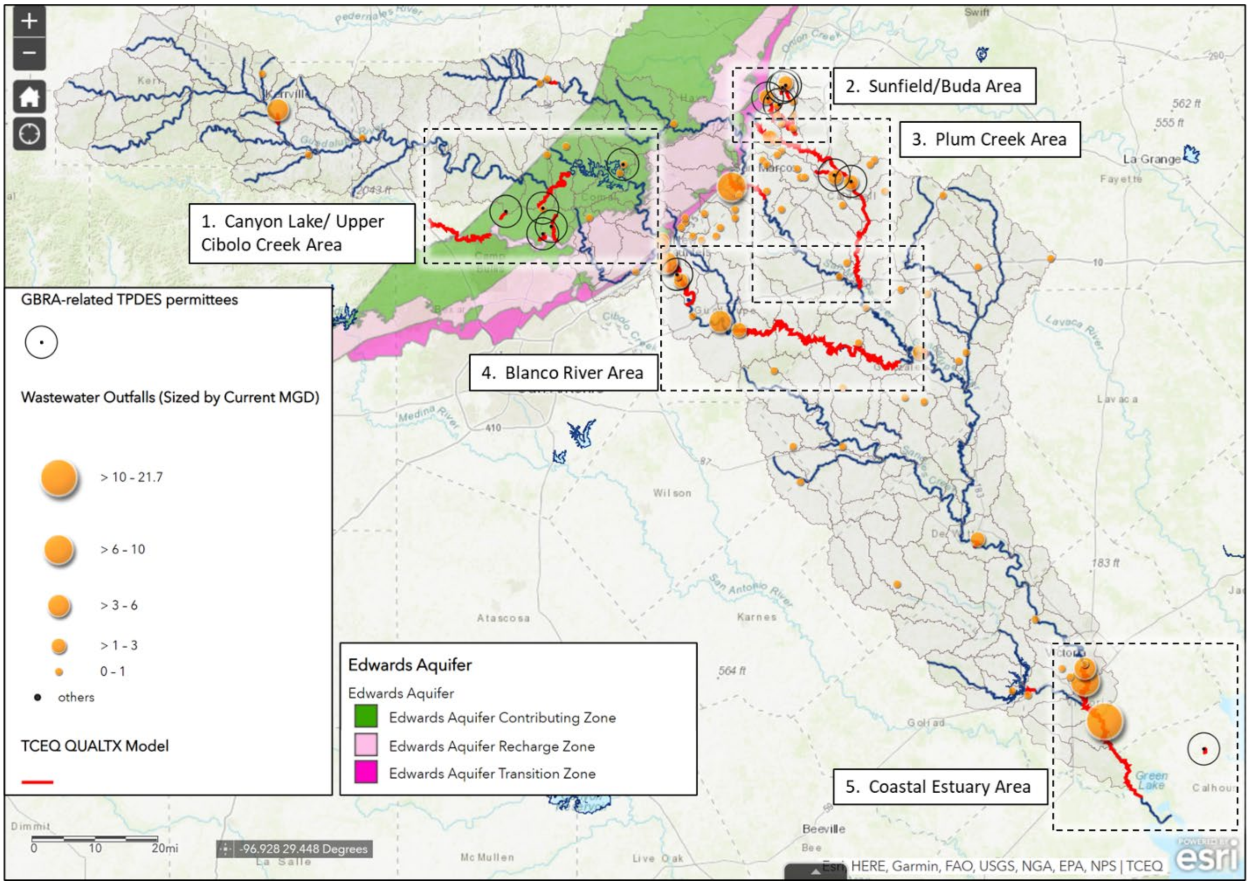

Figure 4. Spatial extents of QUAL-TX models received from TCEQ.

Table 6. List of water quality modeling focus areas.

#	Water quality modeling focus areas
1	Canyon Lake/Upper Cibolo Creek Area
2	Sunfield/Buda Area
3	Plum Creek Area
4	Blanco River Area
5	Coastal Estuary Area

Detailed descriptions of each of the above areas and the available models and GBRA-related permittees are provided in the following subsections.

5.2.2.2 Canyon Lake/Upper Cibolo Creek Area

The Canyon Lake/Upper Cibolo Creek Area is located mostly in the contributing zone of the Edwards Aquifer. It is a rapidly developing area with several new housing developments. **Figure 5** shows the extents of the TCEQ QUAL-TX models and locations of GBRA-related permittees in the area.

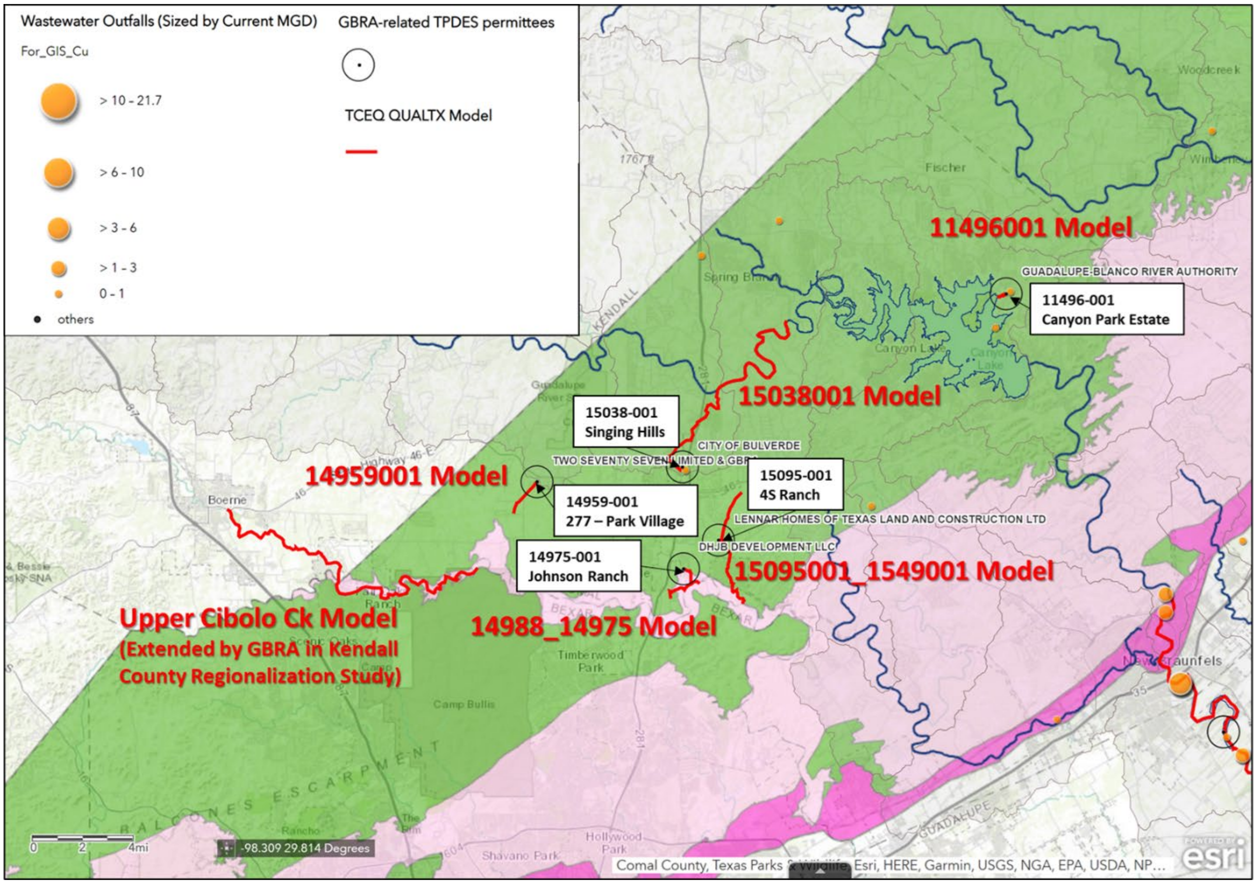

Figure 5. GBRA-related permittees and TCEQ QUAL-TX models in the Canyon Lake/Upper Cibolo Creek Area.

Table 7 shows a summary of the names of the TCEQ QUAL-TX models and the GBRA-related permittees in the Canyon Lake/Upper Cibolo Creek area. In 2018, GBRA conducted a WWTP regionalization study for northern Kendall County and developed an extended model of Upper Cibolo Creek. This model may potentially be used to evaluate impacts of a future GBRA-operated regional wastewater treatment plant.

There are a total of five (5) QUAL-TX models that simulate the impacts of five (5) existing GBRA-related permittees in this area. In addition, there is one (1) QUAL-TX model that can potentially be used to simulate the impacts of one (1) potential regional plant discharging into Upper Cibolo Creek.

Table 7. Summary of the received QUAL-TX models and the GBRA-related permittees in the Canyon Lake/Upper Cibolo Creek Area

TCEQ QUAL-TX Model	GBRA-related permit number	Facility Name	Name of GBRA-related Permittee
1495001	14959-001	277-Park Village	Two Seventy Seven Limited and GBRA
14988001_14975001	14975-001	Johnson Ranch	DHJB Development LLC
15095001_1549001	15095-001	4S Ranch	Lennar Homes of Texas and Construction Ltd
15038001	15038-001	Singing Hills	City of Bulverde
11496001	11496-001	Canyon Park Estate	Guadalupe Blanco River Authority
Upper Cibolo Ck Model	(Potential Future Regional Plant)		

5.2.2.3 Sunfield/Buda Area

The Sunfield/Buda Area is located near the border of Travis and Hays counties. It is also a rapidly developing area in the Greater Austin Metropolitan Area. **Figure 6** shows the extents of the TCEQ QUAL-TX models and locations of GBRA-related permittees in the area.

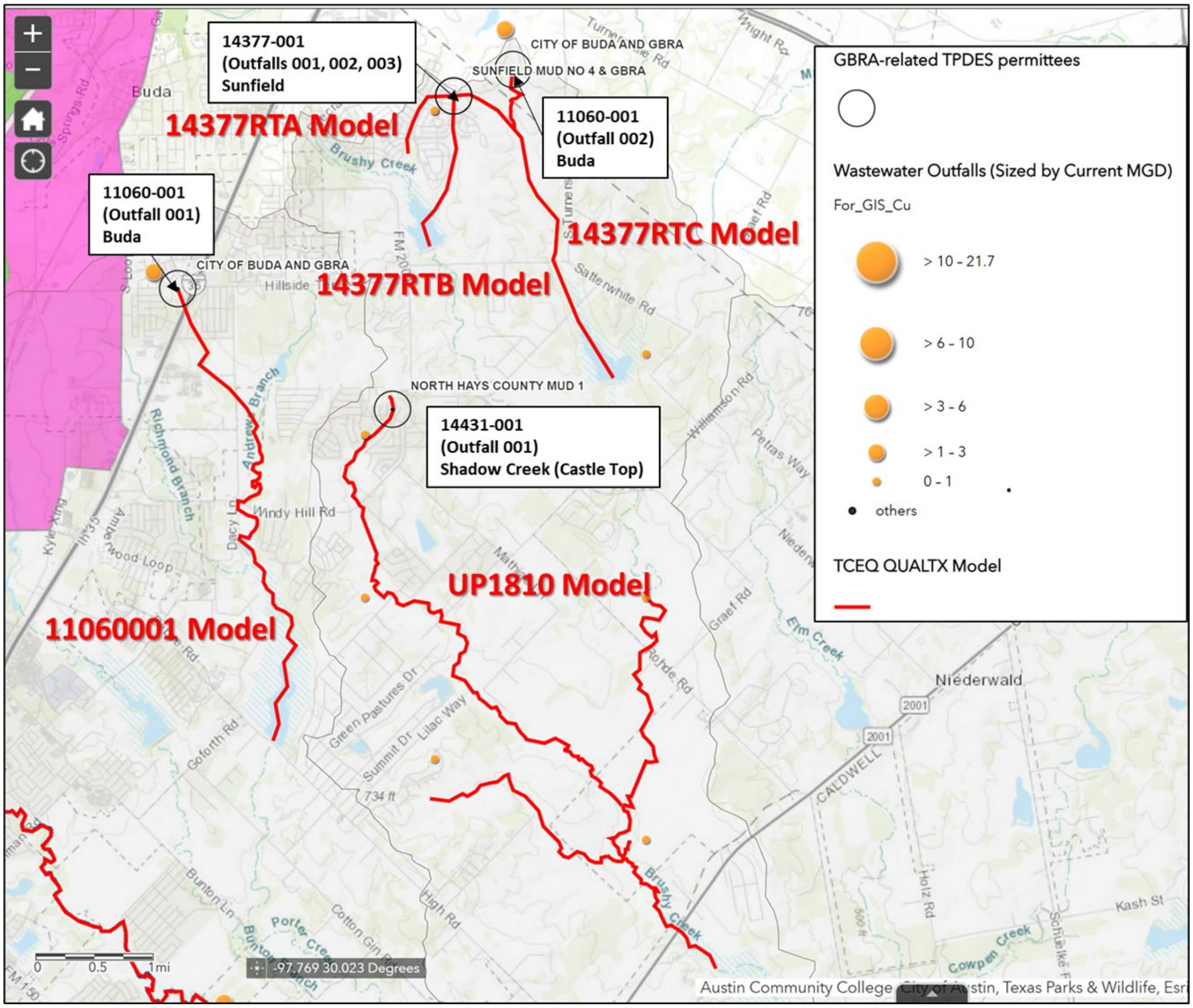

Figure 6. GBRA-related permittees and TCEQ QUAL-TX models in the Sunfield/Buda Area.

A summary of the received QUAL-TX models and the GBRA-related permittees in the Sunfield/Buda area is shown in

Table 8.

There are a total of five (5) QUAL-TX models that simulate the impacts of three (3) existing GBRA-related permittees in this area. However, some of the permittees have multiple outfalls and so the total number of GBRA-related permitted outfalls simulated is six (6).

Table 8. Summary of the received QUAL-TX models and the GBRA-related permittees in the Sunfield/Buda area

TCEQ QUAL-TX Model	GBRA-related permit number	Facility Name	Name of GBRA-related Permittee
11060001	11060-001 (Outfall 1)	Buda	City of Buda and GBRA
14377RTA	14377-001 (Outfall 1)	Sunfield	Sunfield MUD No.4 and GBRA
14377RTB	14377-001 (Outfall 2)	Sunfield	Sunfield MUD No.4 and GBRA
14377RTC	14377-001 (Outfall 3) 11060-001 (Outfall 2)	Sunfield Buda	Sunfield MUD No.4 and GBRA City of Buda and GBRA
UP1810	14431-001	Shadow Creek (Castle Top)	North Hays County MUD 1

5.2.2.4 Plum Creek Area

The Plum Creek Area is to the south of the Sunfield/Buda area and is centered around Lockhart, TX. It extends from Kyle, TX to the confluence with the Guadalupe River. **Figure 7** shows the extents of the TCEQ QUAL-TX models and locations of GBRA-related permittees in the area.

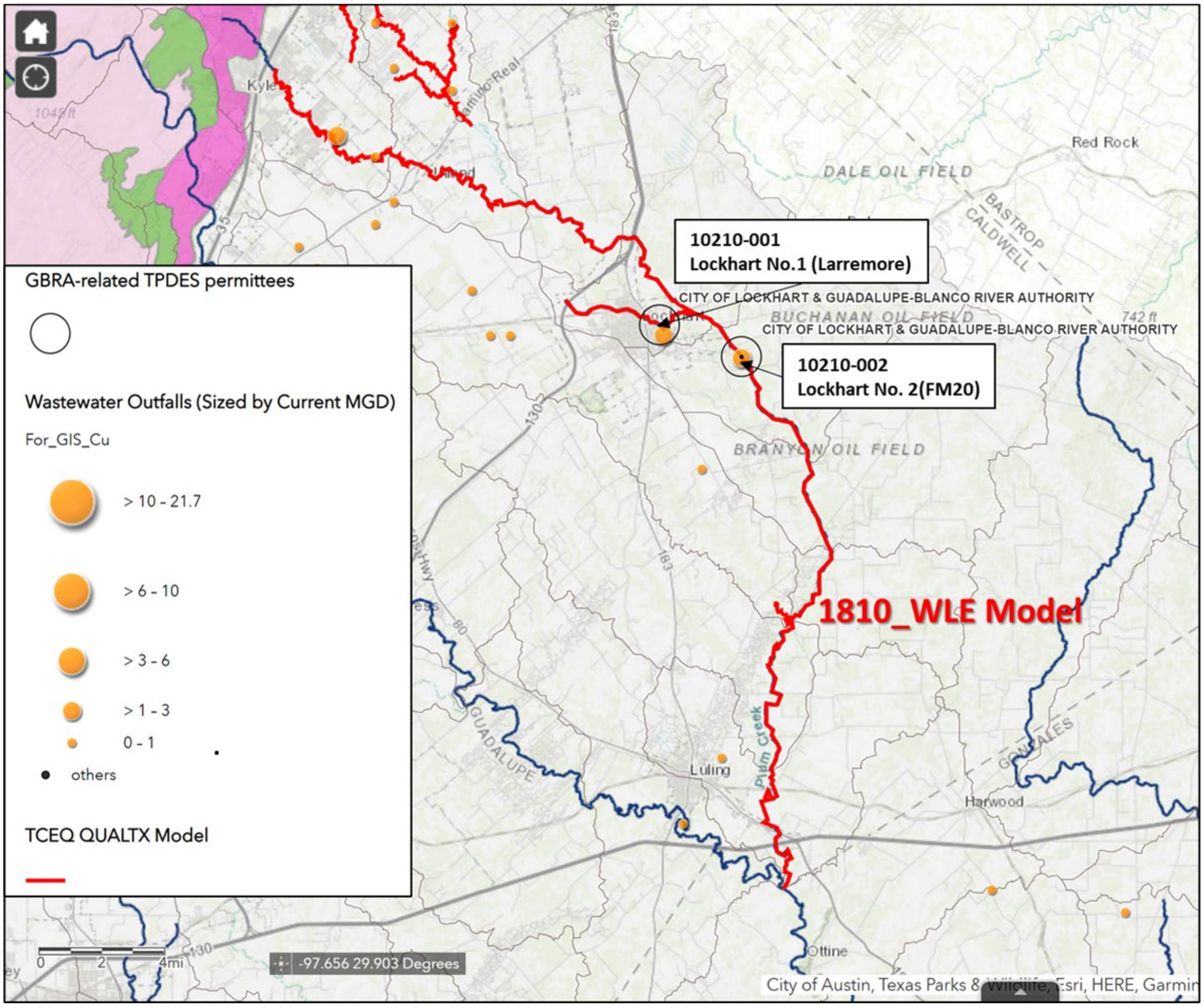

Figure 7. GBRA-related permittees and TCEQ QUAL-TX models in the Plum Creek area.

A summary of the received QUAL-TX models and the GBRA-related permittees in the Plum Creek area is shown in **Table 9**. There is only one (1) QUAL-TX model that simulates the impacts of two (2) existing GBRA-related permittees in this area.

Table 9. Summary of the received QUAL-TX models and the GBRA-related permittees in the Plum Creek area

TCEQ QUAL-TX Model	GBRA-related permit number	Facility Name	Name of GBRA-related Permittee
1810_WLE	10210-001 10210-002	Lockhart No.1 (Larremore) Lockhart No.2 (FM20)	City of Lockhart & GBRA City of Lockhart & GBRA

5.2.2.5 Blanco River Area

The Blanco River Area is situated downstream of Canyon Lake dam to the confluence with the Guadalupe River. **Figure 8** shows the extents of the TCEQ QUAL-TX models and locations of GBRA-related permittees in the area.

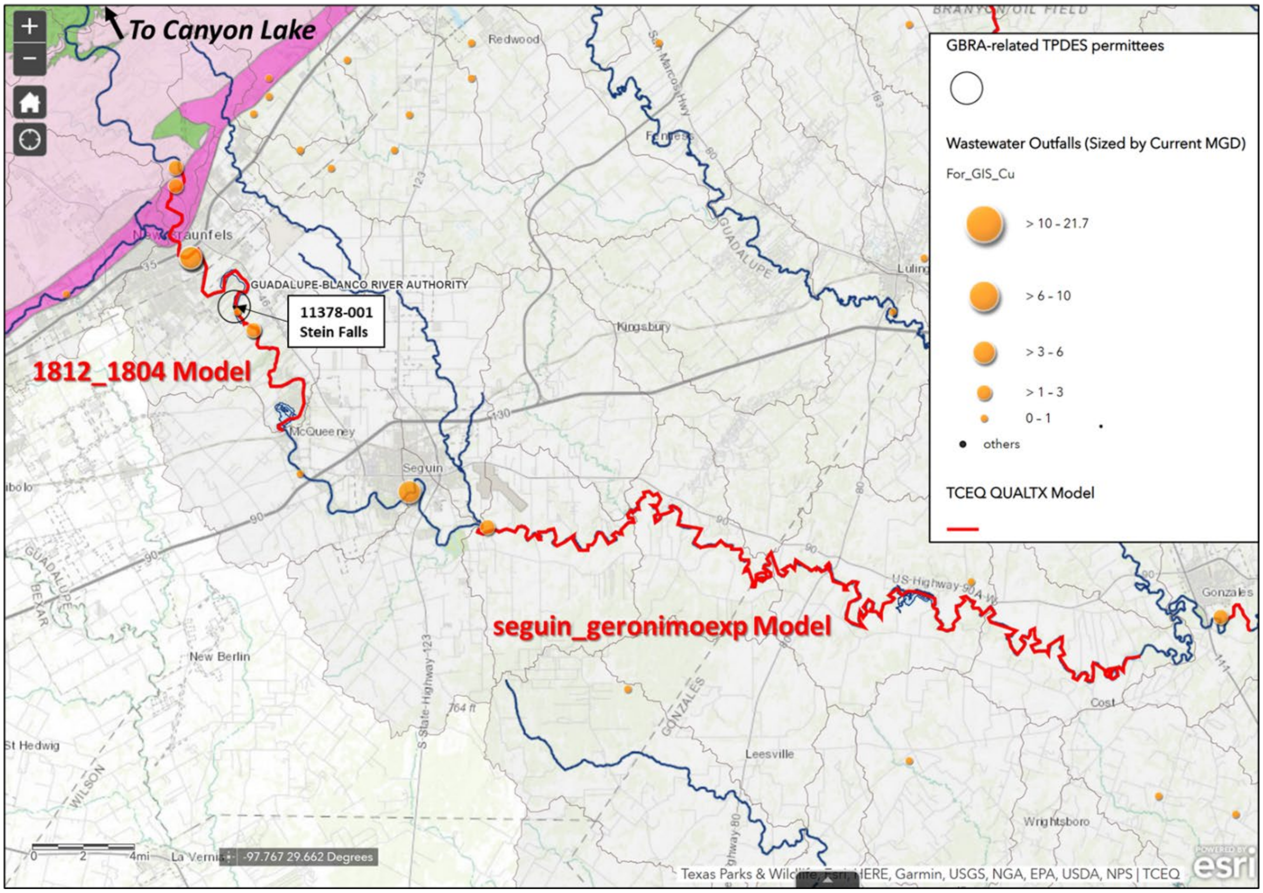

Figure 8. GBRA-related permittees and TCEQ QUAL-TX models in the Blanco River area.

A summary of the received QUAL-TX models and the GBRA-related permittees in the Blanco River area is shown in **Table 10**. There are two (2) QUAL-TX models. One of them (1812_1804 model) simulates the impacts of one (1) existing GBRA-related permittee in this area. The other QUAL-TX model (seguin_geronimoexp) does not receive any direct discharges from GBRA-related TPDES permittees. However, it is downstream of Canyon Lake and has several GBRA covered activities (hydropower facilities) within its spatial extent that can impact water quantity. Therefore, this model will also be simulated to identify impacts of water quantity changes on water quality.

Table 10. Summary of the received QUAL-TX models and the GBRA-related permittees in the Blanco River area

TCEQ QUAL-TX Model	TPDES number of GBRA-related permit	Facility Name	Name of GBRA-related Permittee
1812_1804	11378-001 (Outfall 001 and 002)	Stein Falls	GBRA
Seguin_geronimoexp	-	-	-

5.3 Coastal Estuary Area

The Coastal Estuary Area is situated approximately between Victoria, TX and Tivoli, TX**. Figure 9** shows the extents of the TCEQ QUAL-TX models and locations of GBRA-related permittees in the area.

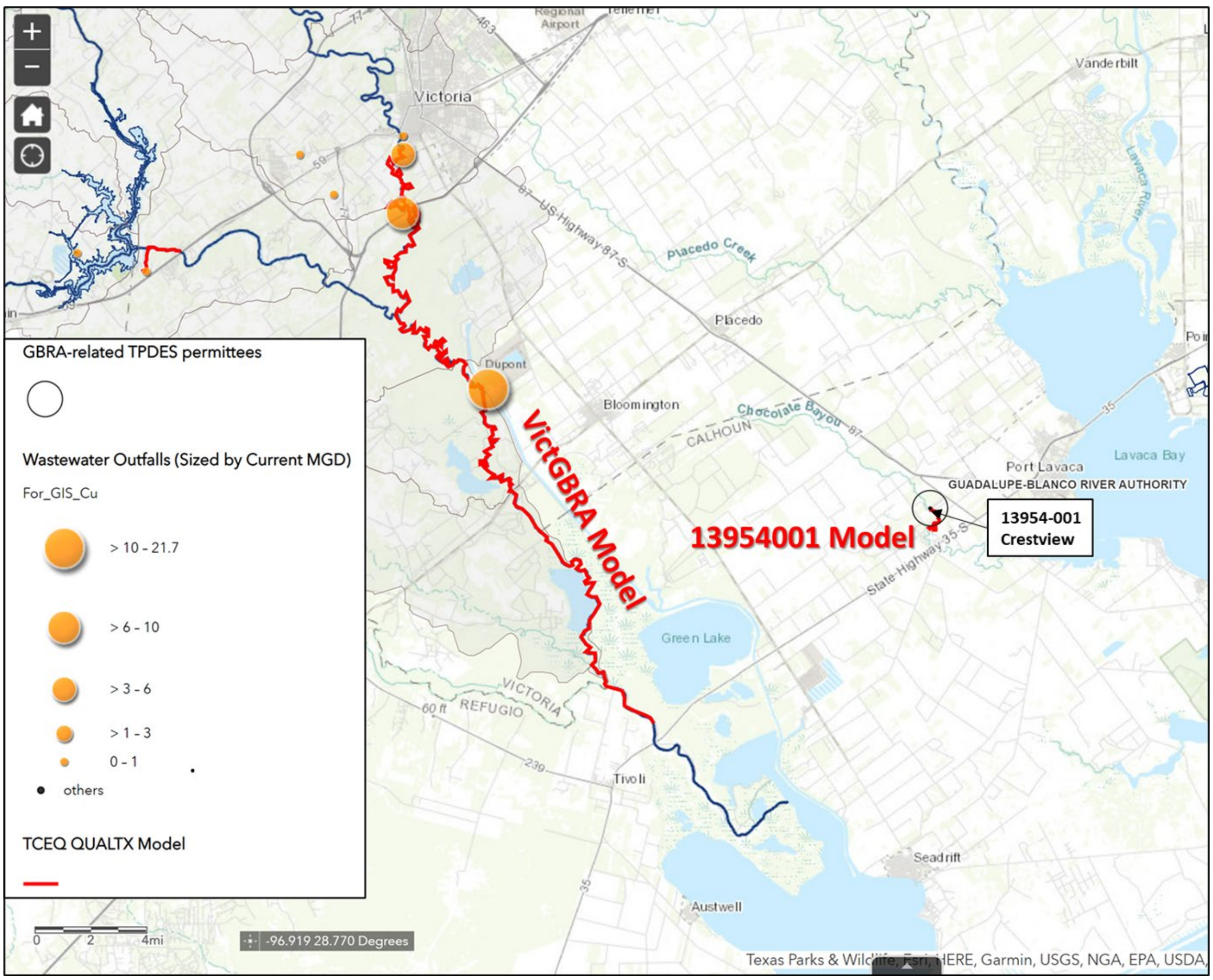

Figure 9. GBRA-related permittees and TCEQ QUAL-TX models in the Coastal Estuary area.

5.3.1 Capabilities and Limitations

Because of their role in regulating waste loads, QUAL-TX models developed by TCEQ are configured to simulate DO, NH_3, and 5-day carbonaceous biochemical oxygen demand ($CBOD_5$). Under TCEQ's configuration, water temperature is an input variable and not a state variable. This means the user will have to develop the temperature conditions for input into the WQ model. TCEQ QUAL-TX models cannot predict water temperature as a function of factors such as air temperature, streamflow, etc. Instead, TCEQ QUAL-TX models will be used to predict temperature effects (as determined by the climate change scenarios) on DO, NH_3 and $CBOD_5$ in the streams.

TCEQ QUAL-TX models are also steady-state models, which means they require inputs that are constant over time. Because WAM flow estimates are time-variable, they would need to be processed to develop representative critical low flows for input into the QUAL-TX models. For instance, monthly flow estimates from WAM may be discretized into daily flows to calculate the 7Q2 critical flow.

For the other water quality constituents that are yet to be determined, further review will be performed to determine whether they can be feasibly modeled by QUAL-TX within project time and budget constraints.

5.3.1.1 Model Inputs

The WQ modeling will incorporate inputs from both the WAM model and effluent limits from TCEQ to simulate water quality constituents (as shown in **Figure 10**).

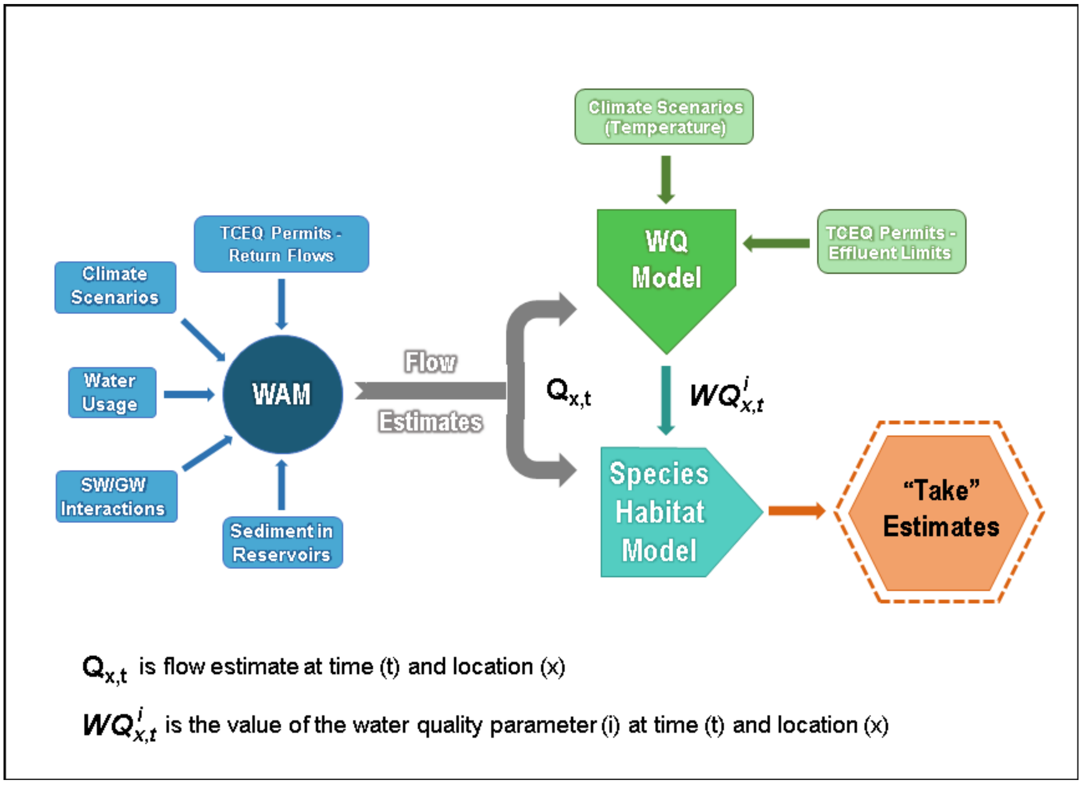

Figure 10. Inputs into the water quality modeling.

Water quality modeling will be performed at streams where TCEQ QUAL-TX models are available. The WQ modeling effort will not extend to unmodeled streams.

Figure 11 shows a hypothetical example of a modeled stream reach – which is depicted by the green meandering line. QUAL-TX model will use WAM flow estimates at the head of the reach to develop the headwater flow boundary condition. For each of the permitted outfalls along the modeled reach, the QUAL-TX model will use return flows estimated from the WAM model and effluent limits from the TCEQ permits to determine the waste loads.

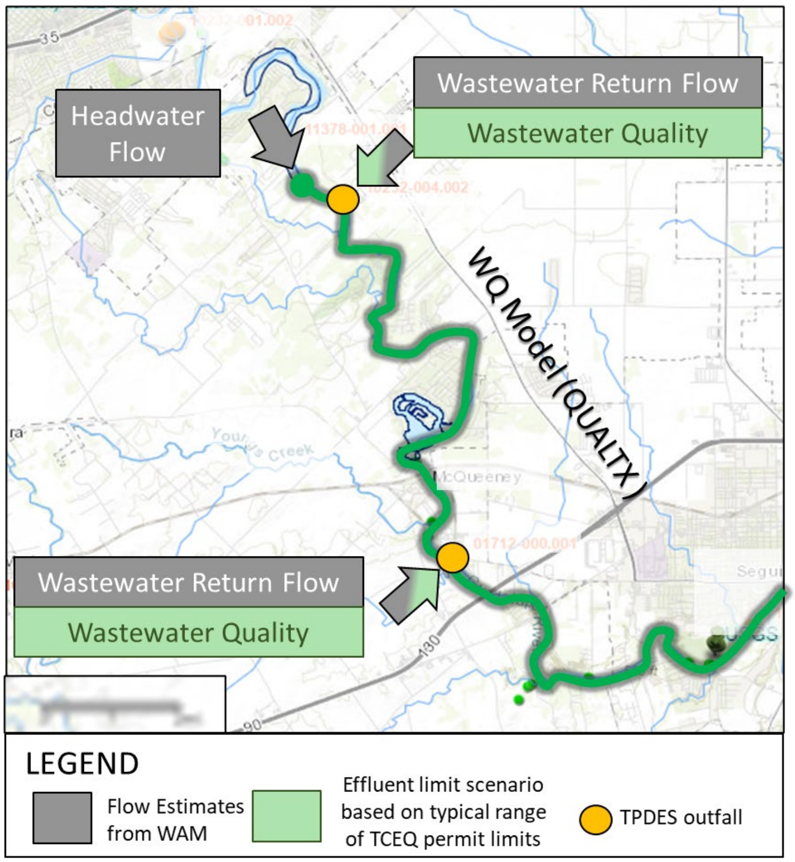

Figure 11. Concept of using WAM flow estimates and TCEQ effluent limits in QUAL-TX simulation

5.3.2 Model Outputs

From each modeling scenario, QUAL-TX will generate predictions of concentrations of water quality constituents along each modeled stream reach. **Figure 12** shows an example of the predicted streamflow and concentrations for DO, NH_3 and $CBOD_5$. (Note: TCEQ grants a 0.2 mg/L tolerance for DO standards when evaluating model results; therefore, if the modeled critical DO is 4.8 mg/L and the DO standard for the stream segment is 5 mg/L, TCEQ would still consider the DO standard to be met. The lower red-dashed line on **Figure 12** represents the DO tolerance.) It can be observed that streamflow increases where return flows enter via TPDES outfalls. Concentrations of NH_3 and $CBOD_5$ also tend to increase near the outfalls, but decline further downstream due to natural assimilation.

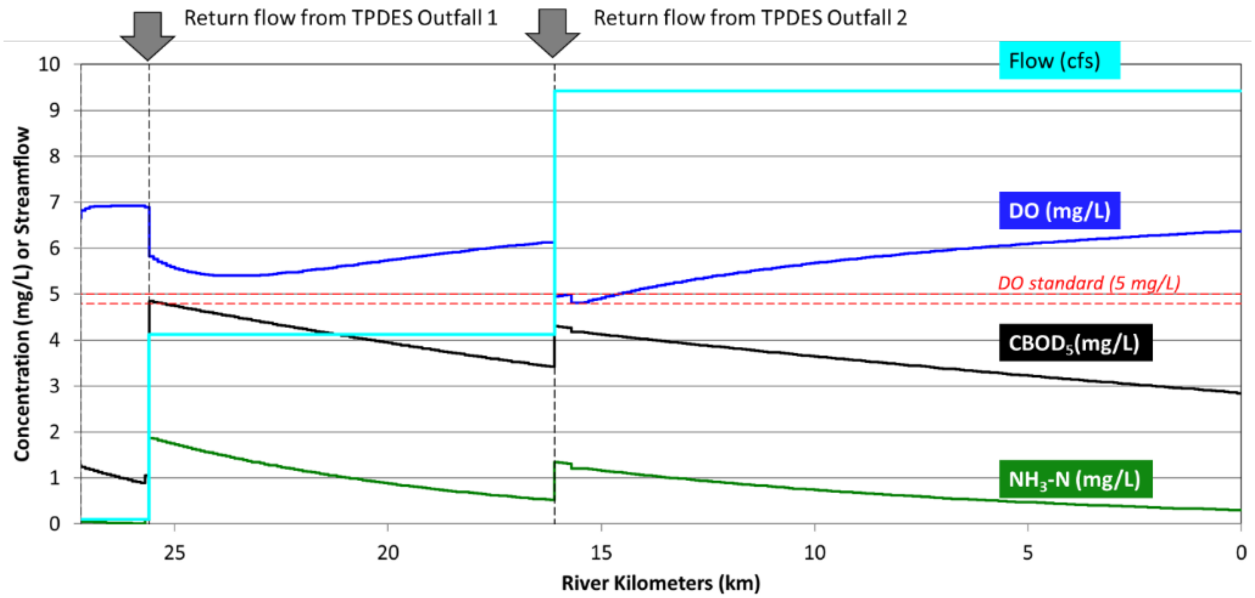

Figure 12. Example of water quality predictions from QUAL-TX.

Model outputs can be mapped to stream locations so that water quality predictions can be viewed spatially (see **Figure 13**). The maps or shapefiles of predicted water quality concentrations will be overlaid on species habitat/distribution map layers and used in the development of take estimates.

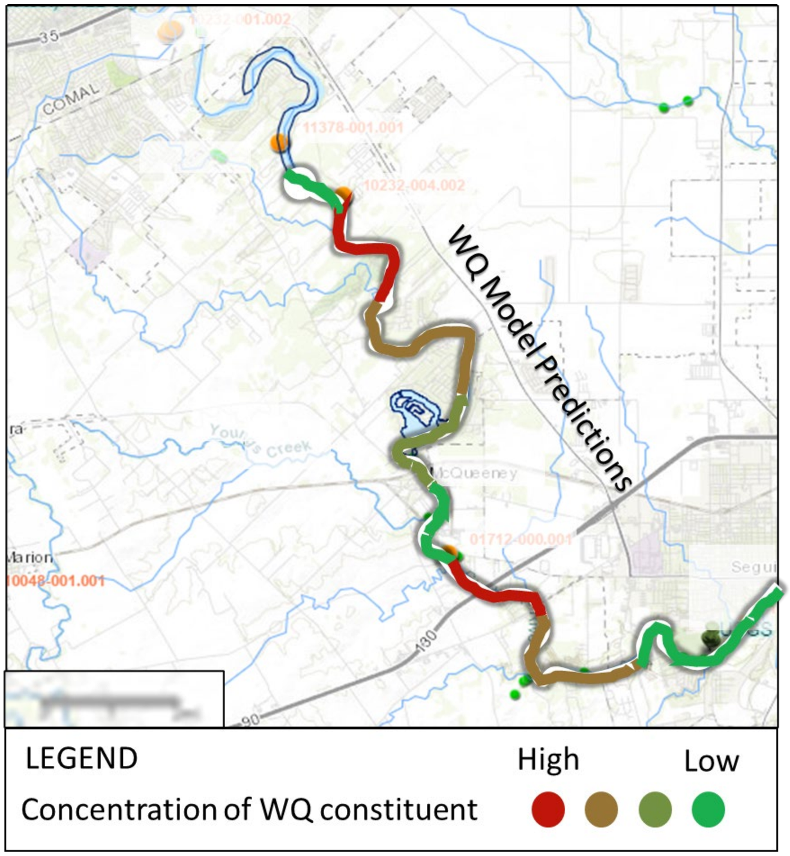

Figure 13. Conceptual illustration of mapping of predicted concentrations of water quality constituents from QUAL-TX

5.3.3 Future Effluent Limits

Future effluent discharge flow limits will be estimated based on the return flow estimates from the WAM scenarios. However, since WAM does not simulate water quality, future water quality effluent limits (i.e., concentrations limits for $CBOD_5$, NH_3-N, and DO) will need to be determined before running the QUAL-TX models. It is proposed that two water quality effluent limit scenarios be simulated for every future WAM scenario to capture the range of water quality effects from GBRA-covered activities.

- Future Effluent Limit Scenario 1: All GBRA-related wastewater treatment plants discharge at the same set of water quality effluent limits issued in their permits by TCEQ in 2022. Due to TCEQ's anti-backsliding rule, the water quality effluent limits cannot be less stringent than what is in the current permit.

- Future Effluent Limit Scenario 2: All GBRA-related wastewater treatment plants discharge at the most stringent set of effluent limits issued by TCEQ as of 2022. This set is 5 mg/L $CBOD_5$, 1 mg/L as NH_3-N, and 6 mg/L DO (TCEQ Modeling Standard Operating Procedures, 2018).

Future Effluent Limit Scenario 1 is expected to reflect an equal or higher waste load than Future Effluent Limit Scenario 2. Therefore, Scenario 1 is expected to result in more impact on covered species. However, Scenario 1 may not necessarily be realistic, because any effluent limits issued by regulatory agencies would have to comply with prevailing ambient water quality standards. For example, if Scenario 1 causes a violation of DO standards, it is likely that TCEQ will curtail the effluent limits to protect the DO standard. Nonetheless, Scenario 1 is a useful bounding scenario for assessing whether take can occur under the assumption that no additional effort is spent to improve treatment processes. If take does not occur, then no further consideration is needed. However, if take occurs, then the results from Future Effluent Limit Scenario 2 will need to be considered.

Future Effluent Limit Scenario 2 represents the scenario where GBRA-related permittees improve their treatment process technology to comply with the most stringent effluent set issued by TCEQ. Future Effluent Limit Scenario 2 evaluates whether take can occur even when GBRA does its best to improve treatment technology for its facilities.

Scenarios

The water quality modeling scenarios to be simulated by the QUAL-TX models will be consistent with the proposed WAM scenarios with the addition of two future effluent limit subscenarios per future WAM scenario to capture the range of potential water quality effluent limits.

5.3.4 Modeling Needs

A summary of the modeling needs discussed in this section is provided in **Table 11**. One of the most important modeling needs is gathering the TCEQ QUAL-TX models in the Basin. A request was made to TCEQ on May 9, 2022, for the models. As there are a total of 49 TCEQ water quality segments and 99 TPDES outfalls in the Basin, getting all the models and setting them up for simulation can be very time-consuming and labor-intensive for both the TCEQ and the project team. The project team will therefore work with the TCEQ to identify models that capture the most important water quality segments and outfalls in the Basin for the take assessment. It is anticipated that between 10 and 20 TCEQ QUAL-TX models can be feasibly utilized in this water quality study. Note that a typical QUAL-TX model may include multiple outfalls and water quality segments.

Projected water demand and wastewater return flows will also be needed to inform the WAM and QUAL-TX modeling for future scenarios. These may be inferred from population projections developed for the Basin by sources such as the Texas Water Development Board. Further discussion may be needed to identify how these trends can be reflected in the WAM and QUAL-TX inputs.

Existing permit effluent limits for each outfall are also needed. It is anticipated that these limits would be reflected in the TCEQ QUAL-TX models and thus an additional request to TCEQ would likely not be required. Existing permit effluent limits can also be accessed and downloaded from the EPA ECHO database website without requesting through TCEQ.

Table 11. Summary of Water Quality Modeling Needs

Water Quality Modeling Need	Information Provider	Comment
Projected water demand and wastewater return flows	Project Team/GBRA	Needed to inform the WAM and QUAL-TX modeling for future scenarios.
TCEQ QUAL-TX models in the Guadalupe-Blanco River Basin.	TCEQ	Request for models has been sent by Project Team to TCEQ on 5/9/2022. Awaiting TCEQ compilation of information. Because of the size of the request, Project Team can help TCEQ focus their efforts by prioritizing which streams are the most important. As models are received from TCEQ, Project Team will evaluate coverage of available QUAL-TX models in the Basin.
Existing effluent limits in permits in the Basin.	TCEQ	Existing effluent limits should be reflected in TCEQ QUAL-TX models. If not available, then Team will download them from EPA ECHO database.
Baseline and Future headwater flows for QUAL-TX models	Project Team/WAM modeling	Team will evaluate how to develop critical headwater flow from WAM simulations.
Future return flows for QUAL-TX models	Project Team/WAM modeling	Team will evaluate how to develop representative return flows from population, conservation, and reuse projections and WAM simulations.
Future temperature conditions for QUAL-TX models	Project Team	Team will develop appropriate water temperature conditions to reflect climate change for WQ simulation.
Additional constituents for evaluation in WQ Modeling.	Project Team/GBRA	Once received, additional WQ constituents will be reviewed for feasibility of modeling using QUAL-TX.

6.0 SUMMARY AND CONCLUSION

The above information summarizes the GRHCP Project Team's assessment of existing information and studies on environmental flows and water quality in the Guadalupe River Basin, identifies GBRA's existing and planned activities that affect water flows and/or quality, and presents the Team's proposed approach for conducting water quantity and quality modeling/analyses for the GRHCP. The sole purpose of the proposed modeling and data analysis efforts is to complete the species impact assessments needed to determine the potential for take, as defined by the ESA, of the following covered species from the covered activities that affect water flow and/or water quality: three freshwater mussels, three salamanders, and the whooping crane. Based on the results of the proposed modeling and impact/take assessments, the model results may also help to develop appropriate conservation measures related to water quantity and water quality.

The proposed water quantity modeling involves analyzing the flow scenarios listed below using TCEQ's WAM for the Guadalupe/San Antonio River Basin, modified as necessary to represent current (year-2020) and future (year-2070) hydrologic conditions with respect to surface water use, sediment conditions in reservoirs, return flows, Edwards Aquifer spring flows in the Guadalupe and San Antonio River Basins, and future climate change. The following model runs are proposed:

- Reference, or “Current Conditions,” based on year-2020 water use, sediment in reservoirs, and return flows and one set of Edwards Aquifer springflows pursuant to the current EAHCP.

- Covered Activities, a “Future Conditions” run based on projected 2070 water use, projected 2070 sediment in reservoirs, and projected 2070 return flows with consideration given to conservation and reuse and one set of Edwards Aquifer springflows pursuant to the current EAHCP. As discussed in **Section 5.1.3**, this model run will be based on a *projected 2070 water use* and not on *full authorized 2070 use of water rights* to represent a likely (or reasonably certain) scenario based on projected 2070 water use. The 2070 scenario based on projected water use is considered to be more representative of 2070 conditions and more meaningful for assessing take of covered species and addressing ESA compliance than a worst-case scenario based on full authorized 2070 use of water rights. Future conditions for 5-year and/or 10-year increments may also be developed through interpolation between the 2020 and 2070 data to assist in determining and documenting the likelihood of take over time.

- Climate Change, a “Future Conditions” run (as described above) modified to reflect climate change to assess the feasibility of future mitigation efforts.

- Conservation Strategy, a “Future Conditions” run (as described above) modified to reflect potential conservation measures to assess the extent to which conservation measures mitigate take.

- Conservation Strategy with Alternatives, a “Future Conditions” run (as described above) modified to reflect potential alternative conservation measures to assess the extent to which such alternative conservation measures mitigate take.

- Other Scenario, an additional scenario may be modeled which may consider supplemental reference conditions, natural flow, an alternative climate change scenario, or other factors to be determined.

The above-described WAM runs are proposed after reviewing available data, considering approved water use projections based on regional water plans, and considering the most meaningful scenarios for assessing take of covered species and addressing ESA compliance. Further description of the proposed water flow/quantity modeling is provided in **Section 5.1**.

The proposed water quality modeling is intended to provide concentration estimates of key water quality constituents of concern for the covered species discussed herein to assess impacts on those covered species and develop take estimates. The water quality modeling will be performed with TCEQ’s QUAL-TX models developed for the Basin and will utilize critical-condition flows developed from the WAM runs outlined above, as well as return flow estimates from WAM that reflect future human population increases, conservation, and reuse in the basin. Dissolved oxygen (DO), temperature, and ammonia (NH_3) will be the key water quality constituents to be considered in the modeling, with other constituents being considered based on need and availability of existing models. From each of the four modeling scenarios listed above, QUAL-TX will generate predictions of concentrations of water quality constituents along each modeled stream reach.

Further description of the proposed water quality modeling is provided in **Section 5.2**, including a summary of modeling needs in **Section 5.3.5**.

In analyzing the modeling results and assessing species impacts, it is important to:

1) continually maintain focus on the purpose of the modeling and impact assessments (to determine species impacts and take estimates);
2) consider the scale at which the analysis is being conducted (Guadalupe River Basin – landscape scale); and
3) consider the timeframe in which impacts/take may occur from a covered activity (e.g., using the model results, at what point or in what year do effects to streamflows and/or water quality reach a level that results in take).

It is also important to consider that environmental flow standards, water quality standards, and wastewater effluent limits provide baselines and/or reference points for comparison purposes and/or may regulate flows and water quality parameters, which in turn may limit potential impacts to covered species.

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Appendix A

Control Point Water Flow and Quality Summaries

Figure A1. Guadalupe River at Comfort (USGS 08167000) Annual Streamflow

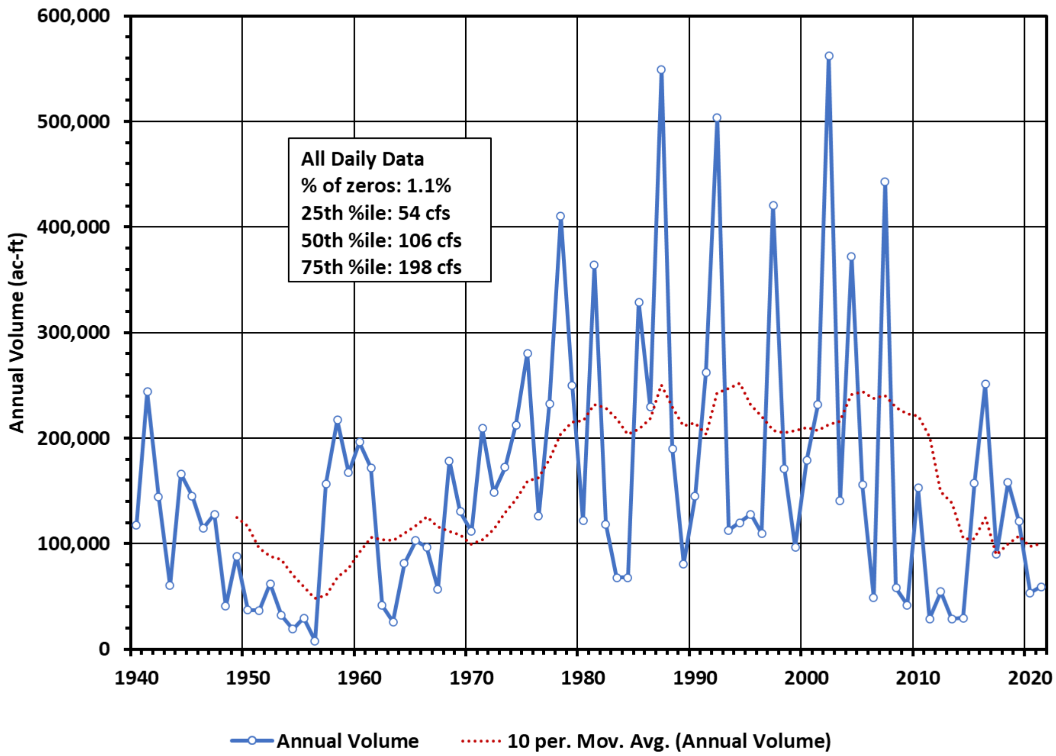

Figure A2. Guadalupe River at Comfort (USGS 08167000) Daily Streamflow Frequency

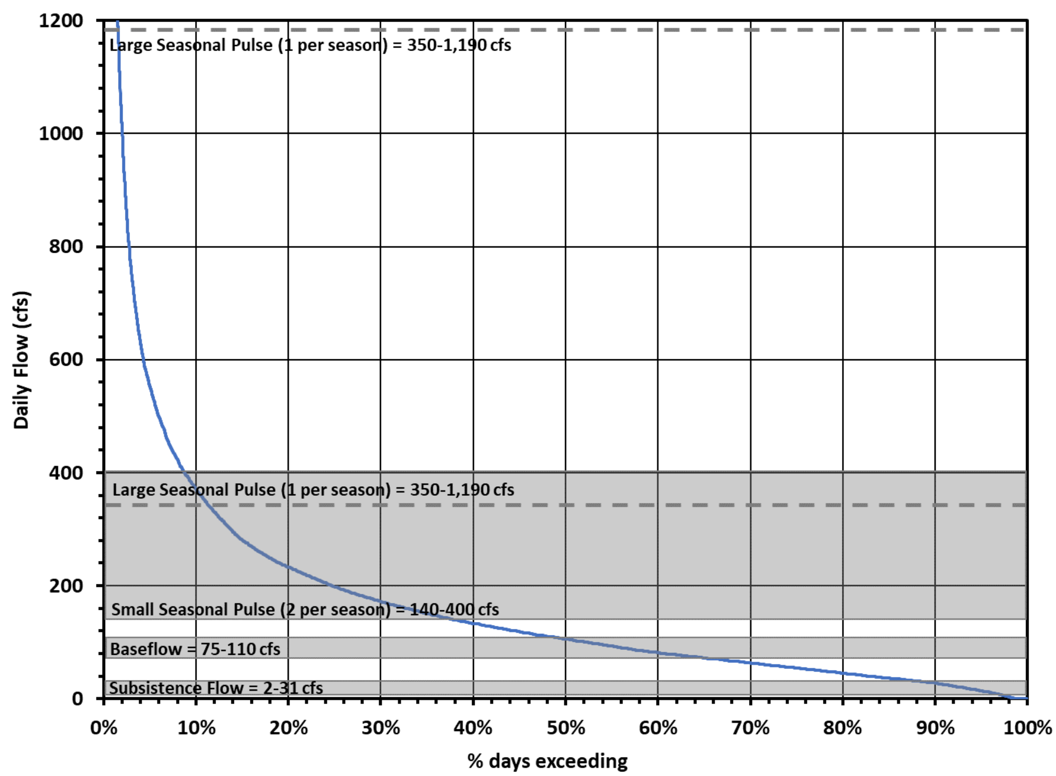

Figure A3. Guadalupe River at Comfort Dissolved Oxygen

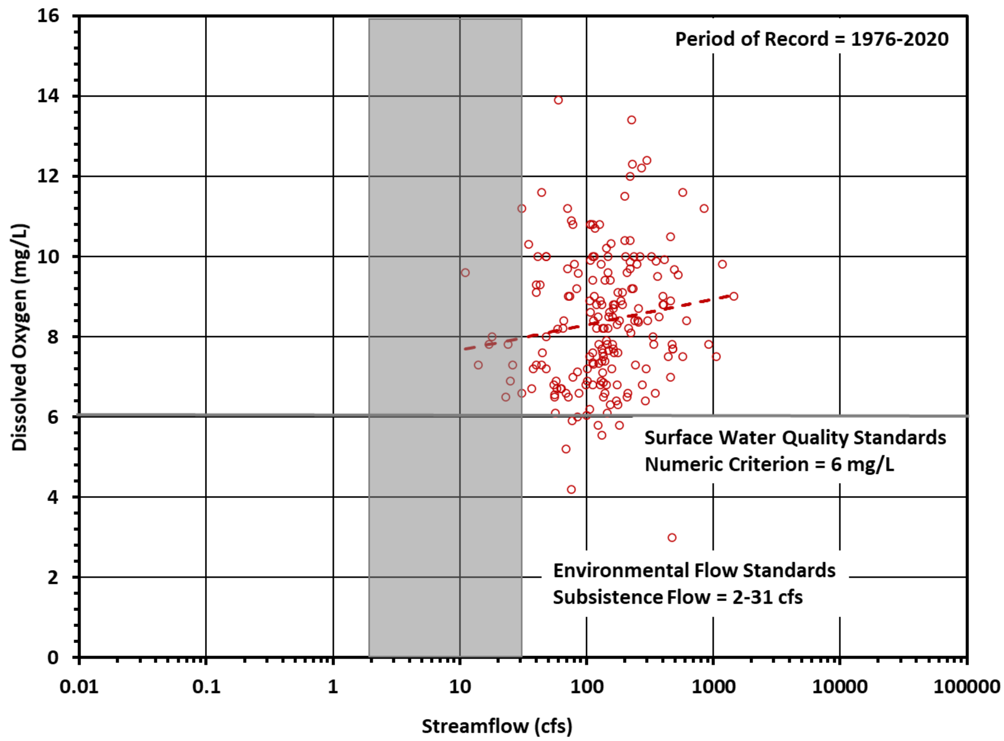

Figure A4. Guadalupe River at Comfort Temperature

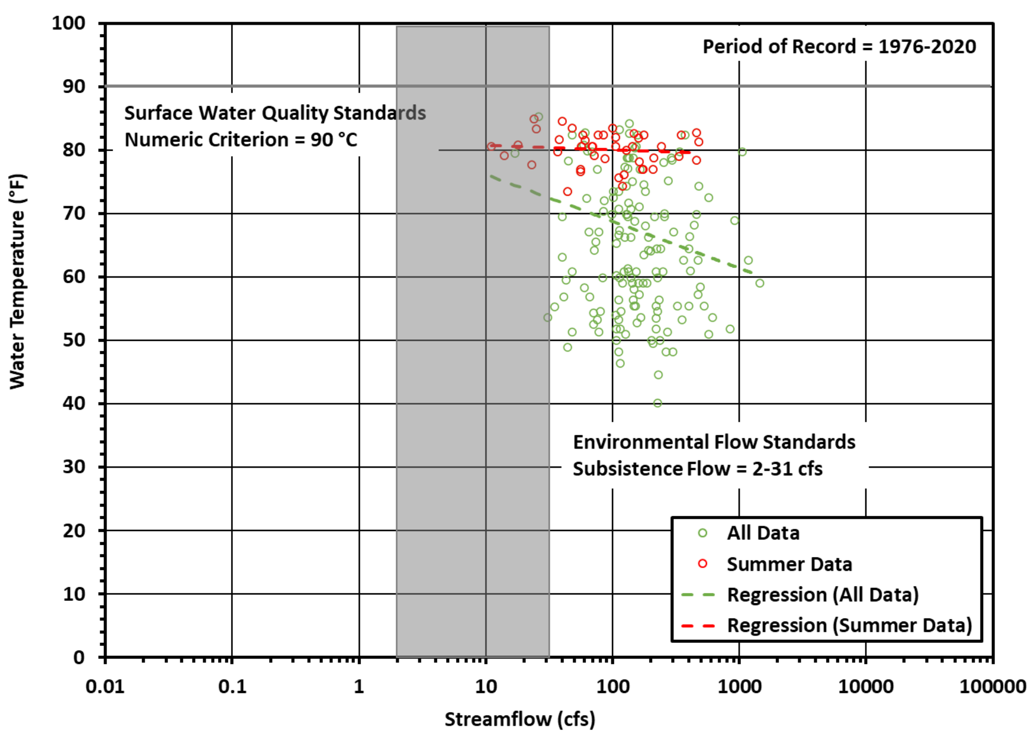

Figure A5. Guadalupe River near Spring Branch (USGS 08167500) Annual Streamflow

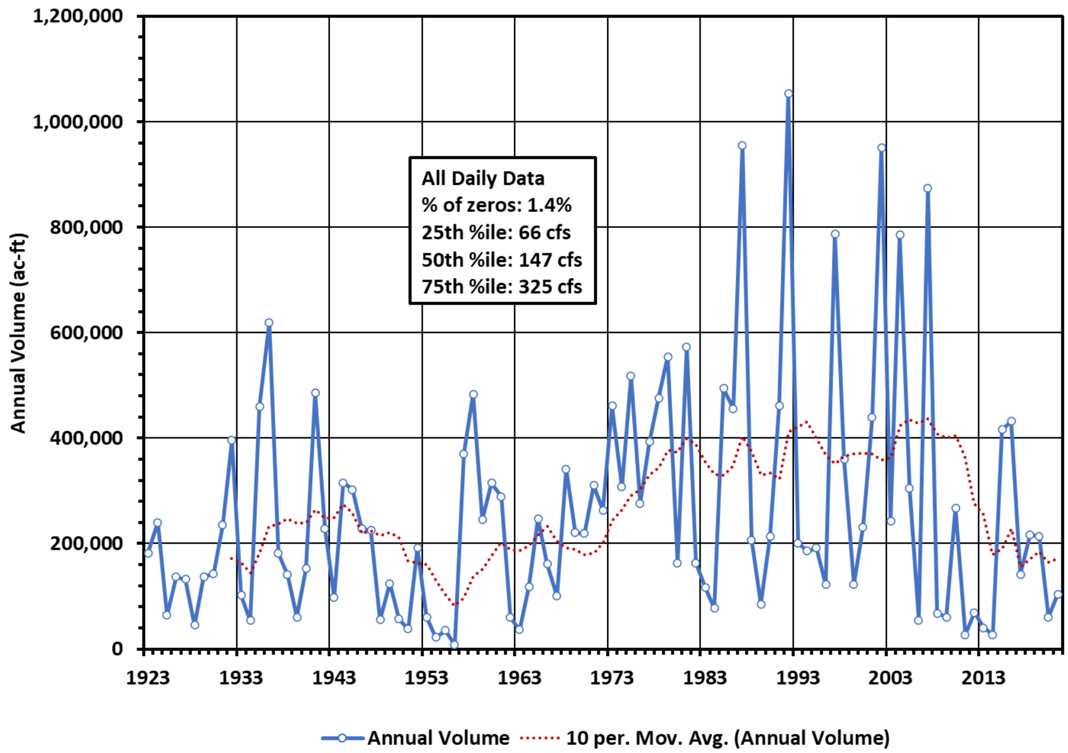

Figure A6. Guadalupe River near Spring Branch (USGS 08167500) Daily Streamflow Frequency

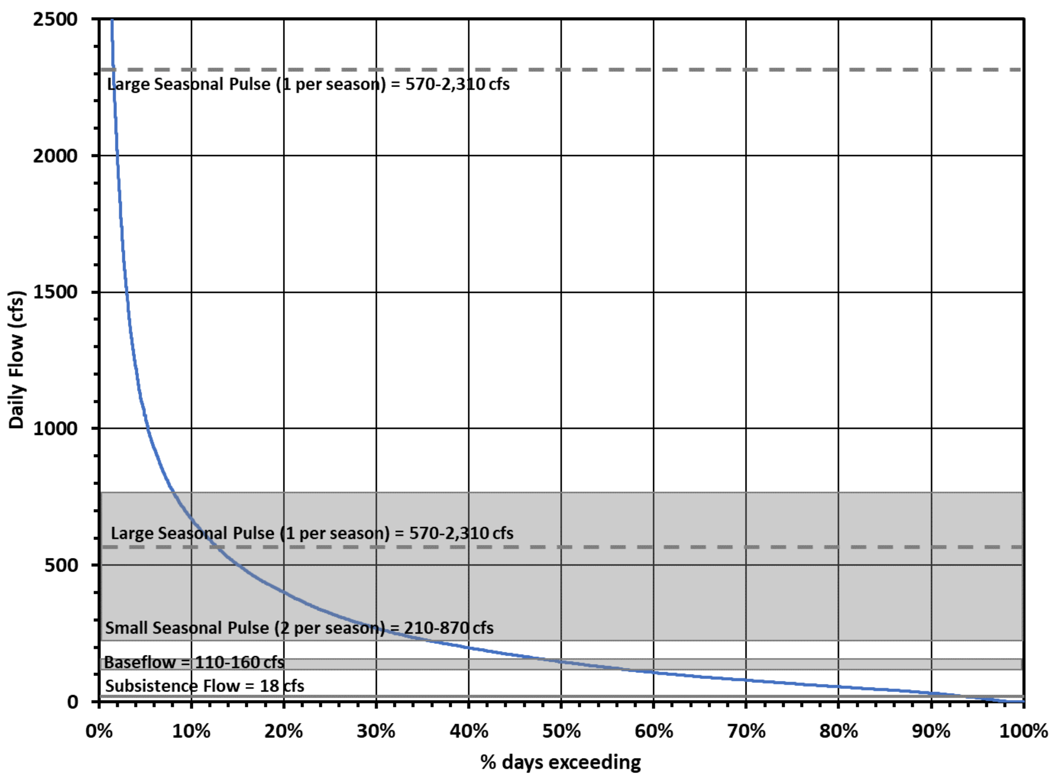

Figure A7. Guadalupe River near Spring Branch Dissolved Oxygen

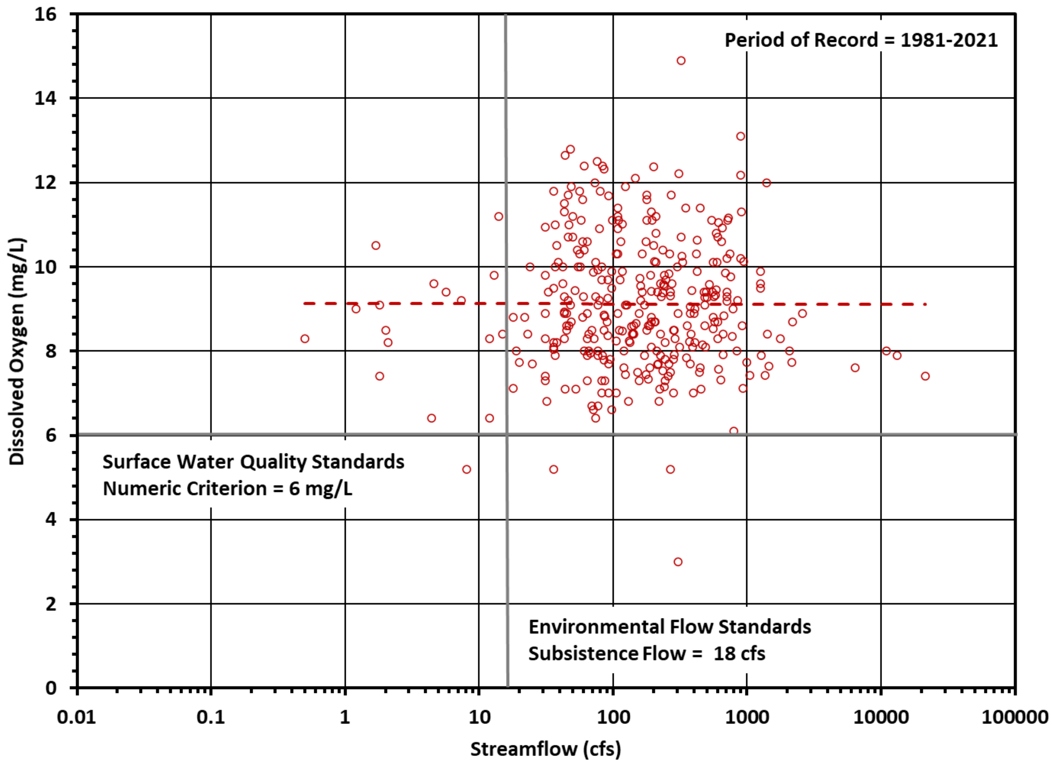

Figure A8. Guadalupe River near Spring Branch Temperature

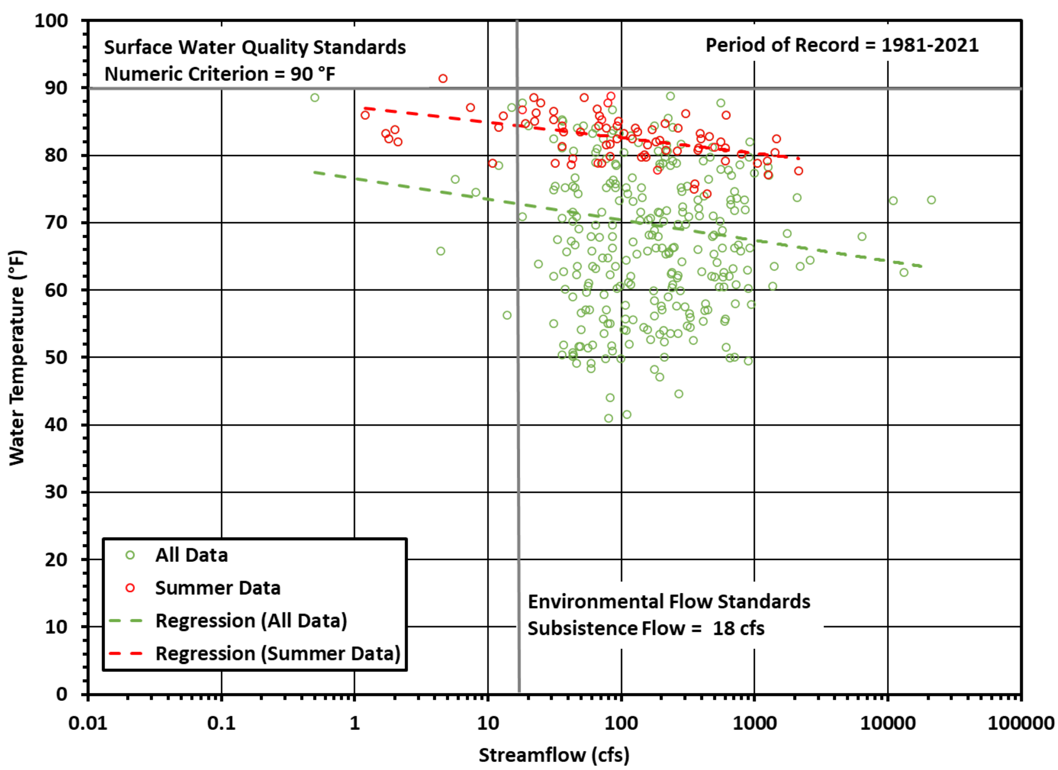

Figure A9. Blanco River at Wimberley (USGS 08171000) Annual Streamflow

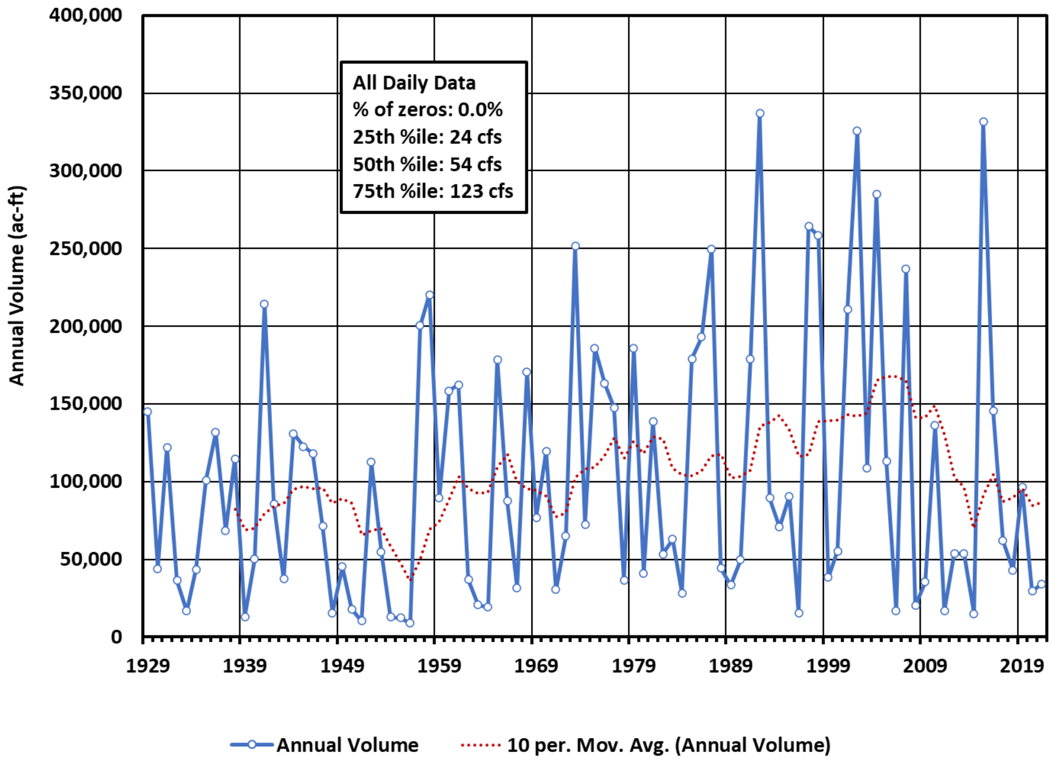

Figure A10. Blanco River at Wimberley (USGS 08171000) Daily Streamflow Frequency

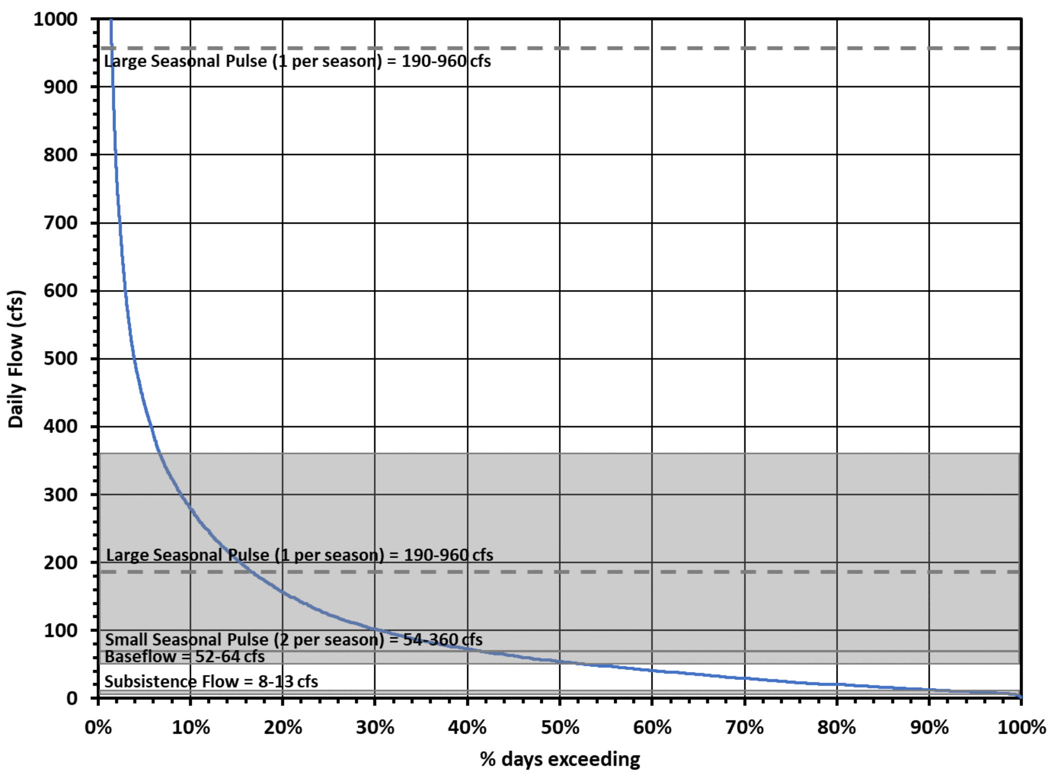

Figure A11. Blanco River at Wimberley Dissolved Oxygen

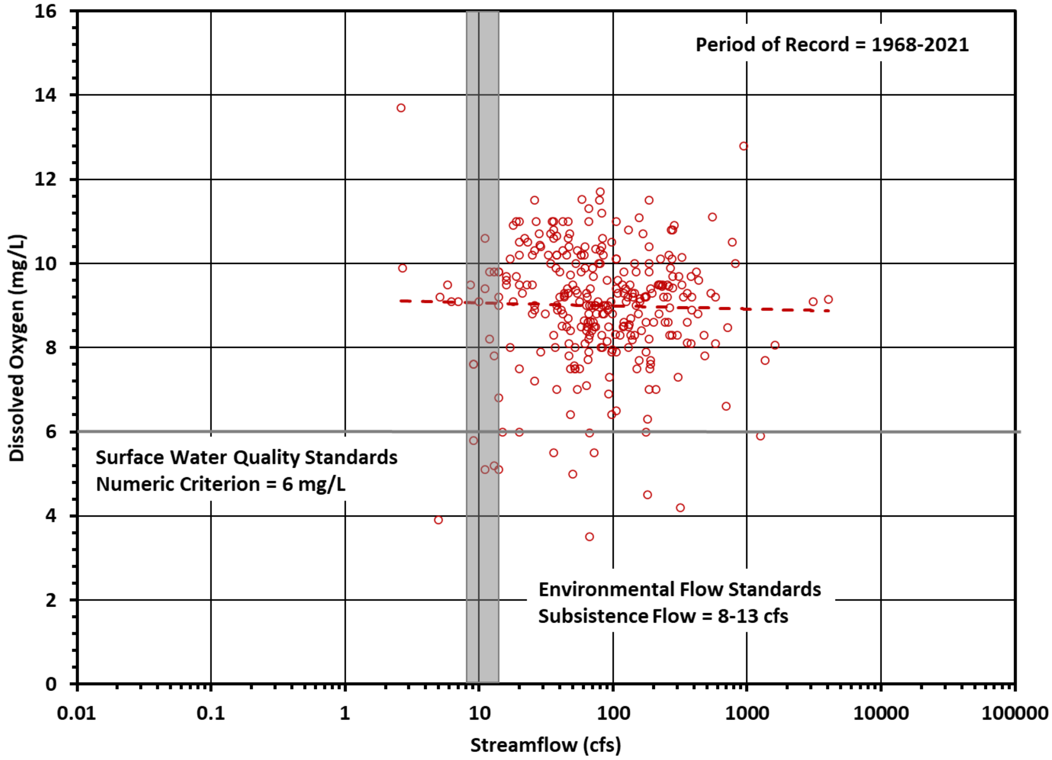

Figure A12. Blanco River at Wimberley Temperature

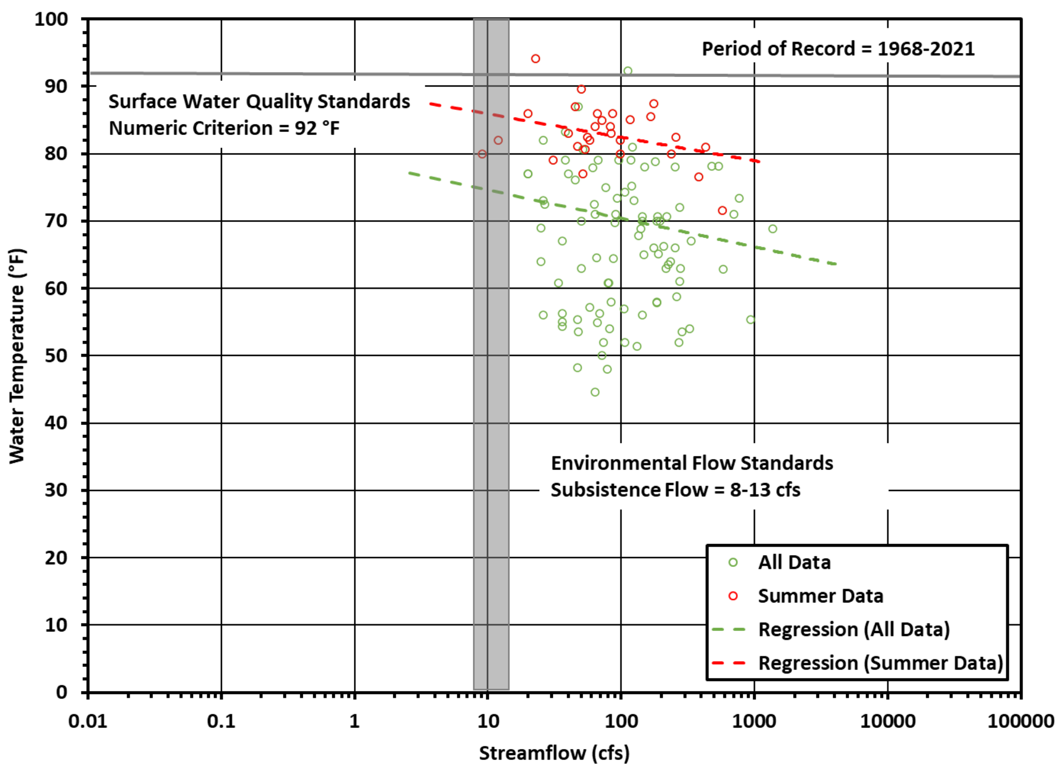

Figure A13. San Marcos River at Luling (USGS 08172000) Annual Streamflow

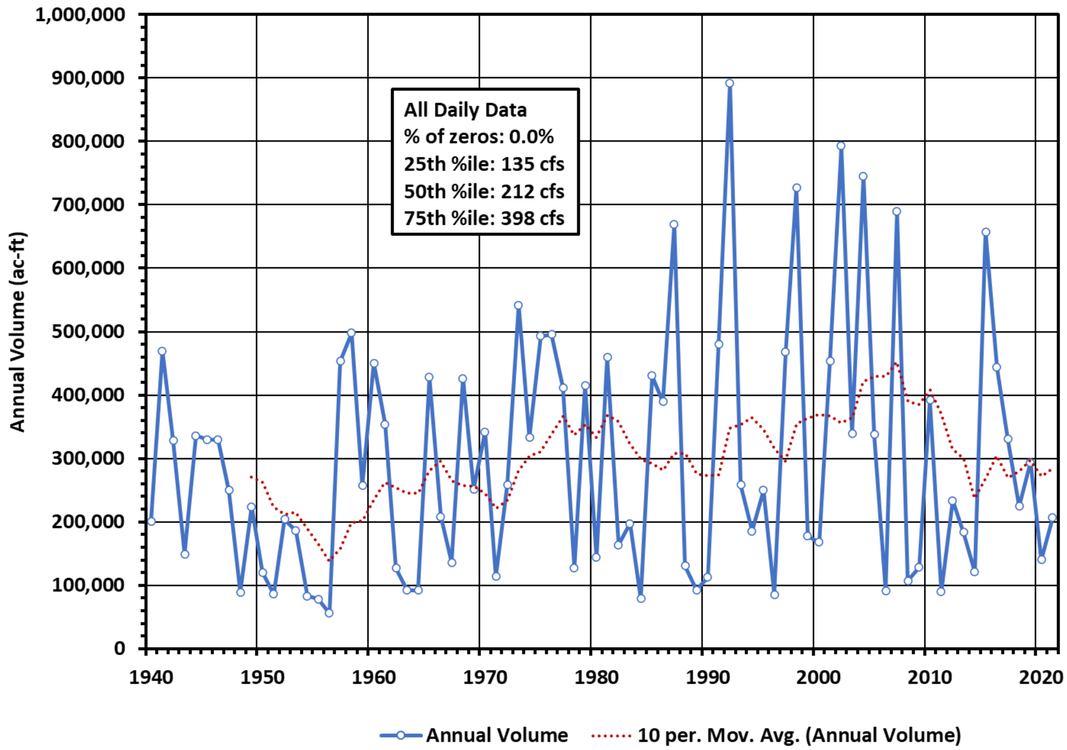

Figure A14. San Marcos River at Luling (USGS 08172000) Daily Streamflow Frequency

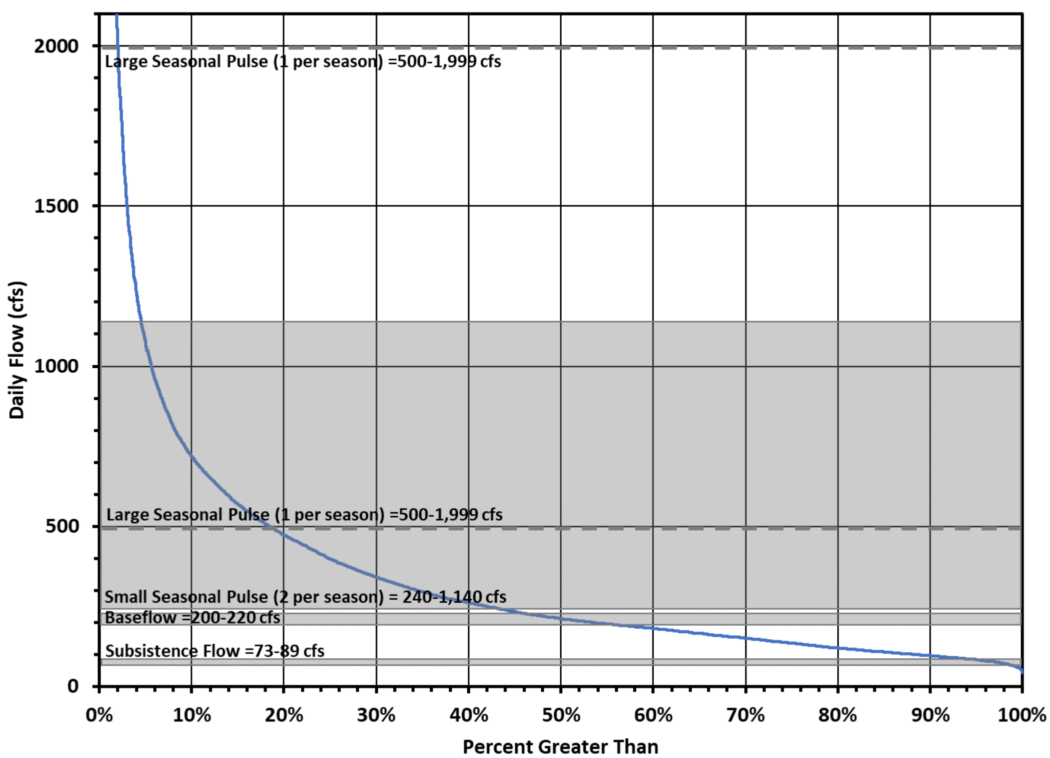

Figure A15. San Marcos River at Luling Dissolved Oxygen

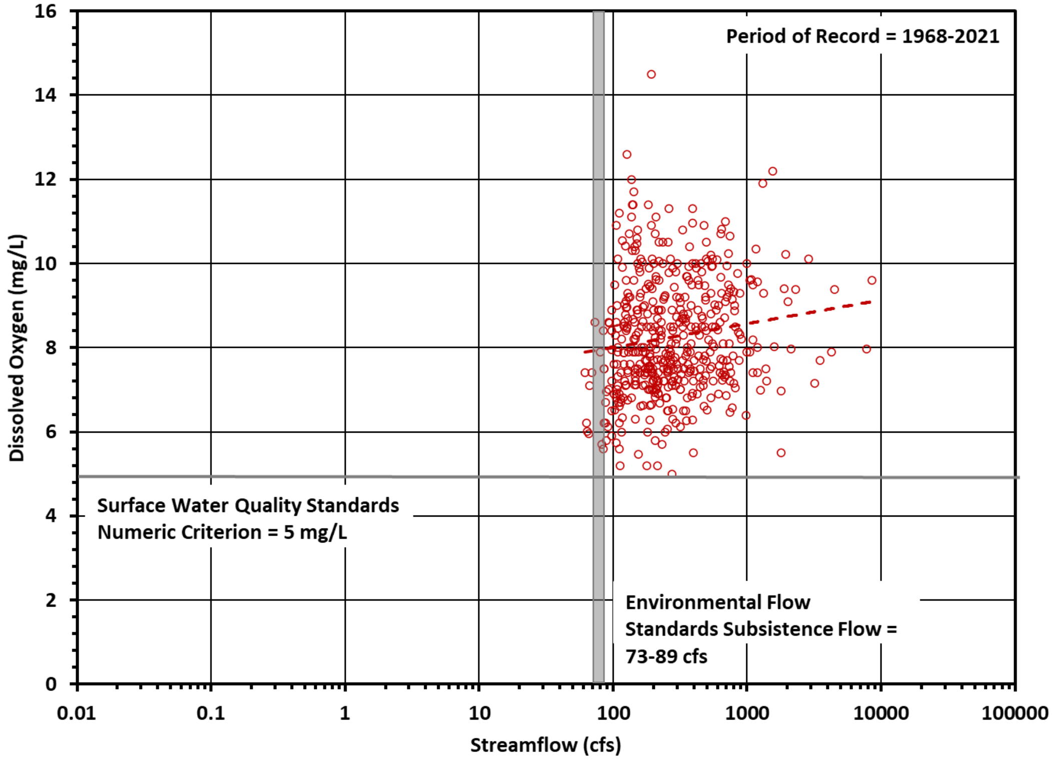

Figure A16. San Marcos River at Luling Temperature

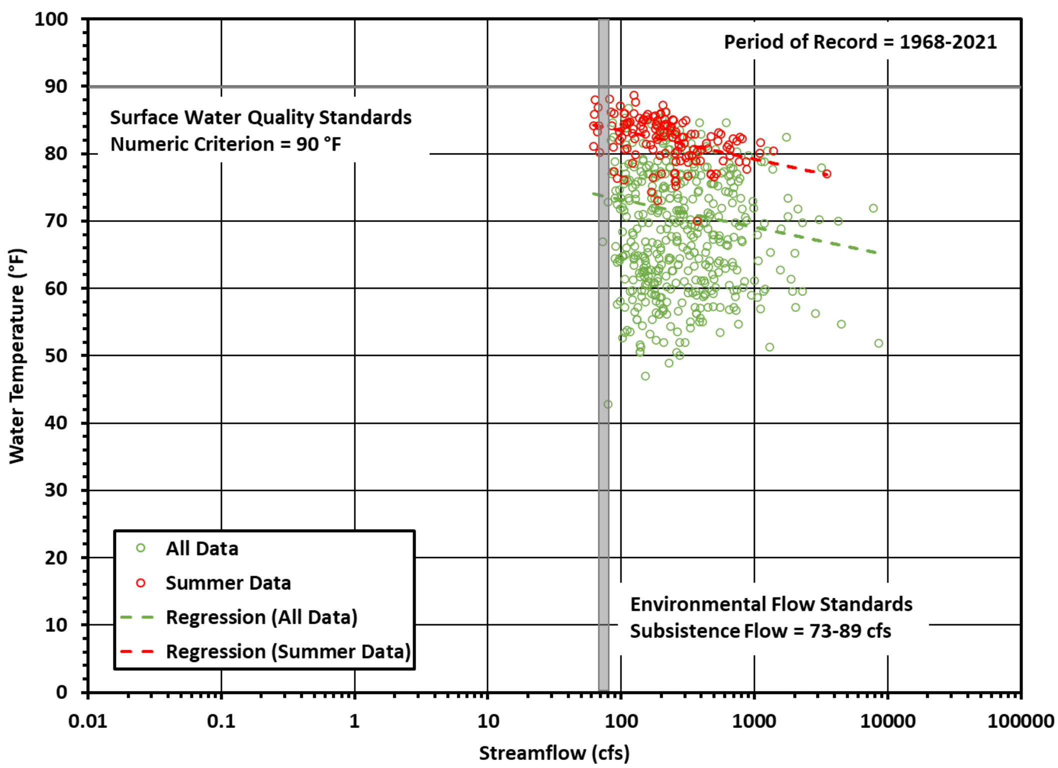

Figure A17. Plum Creek near Luling (USGS 08173000) Annual Streamflow

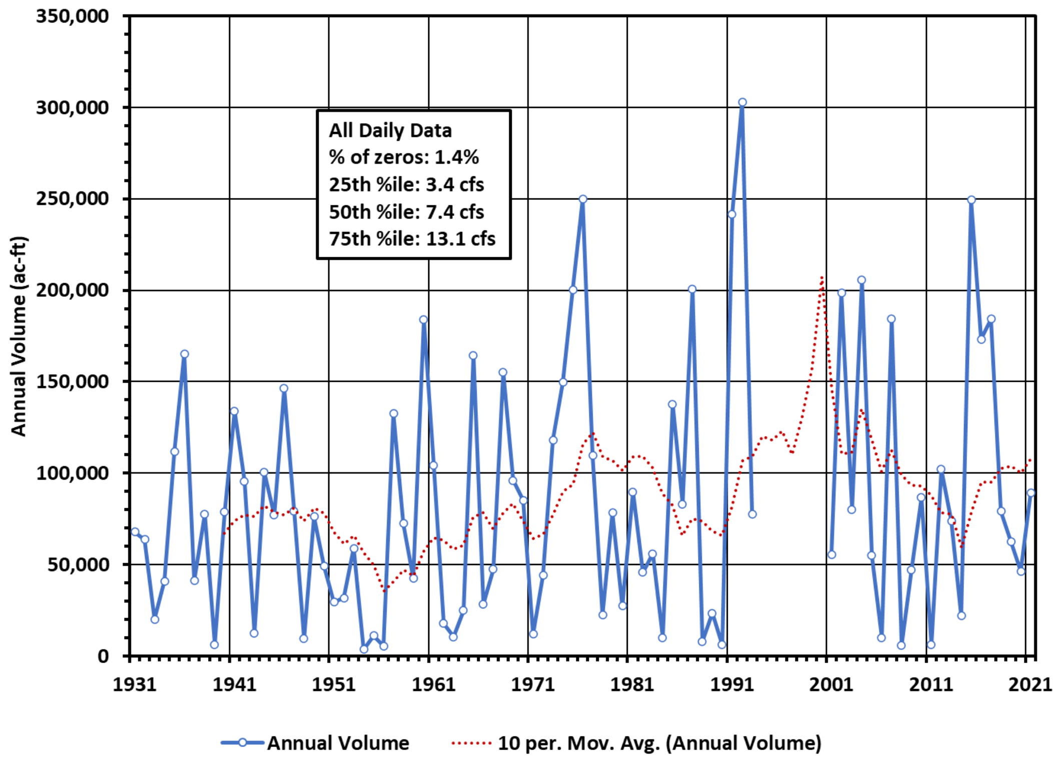

Figure A18. Plum Creek near Luling (USGS 08173000) Daily Streamflow Frequency

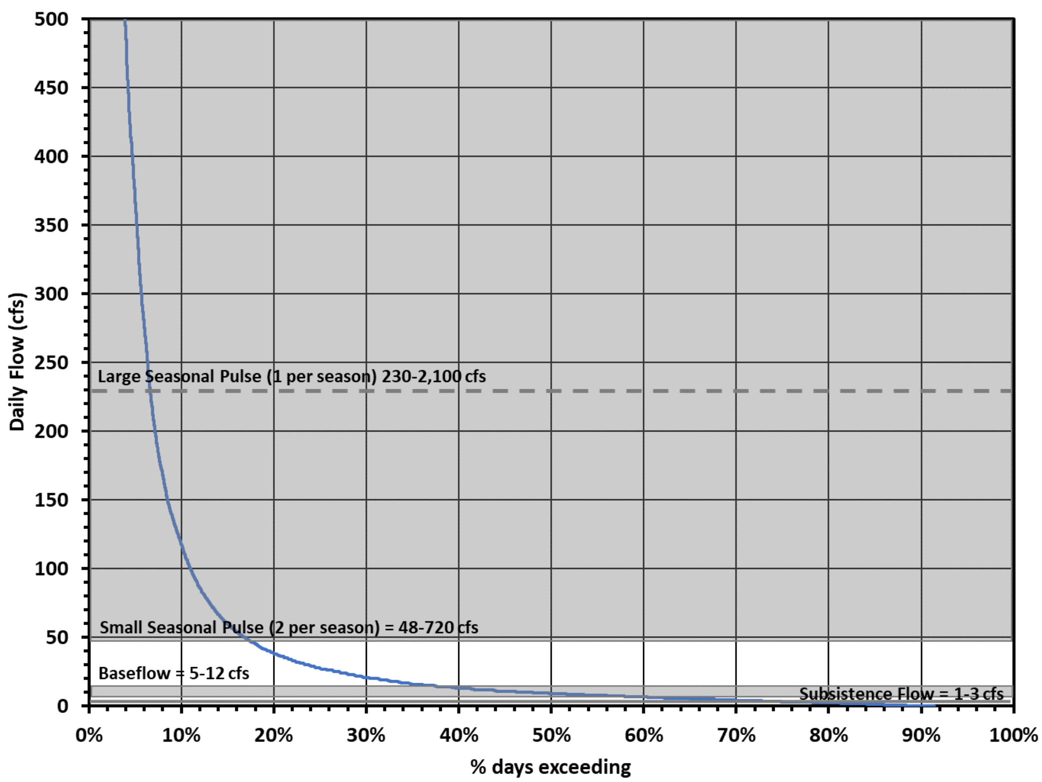

Figure A19. Plum Creek near Luling Dissolved Oxygen

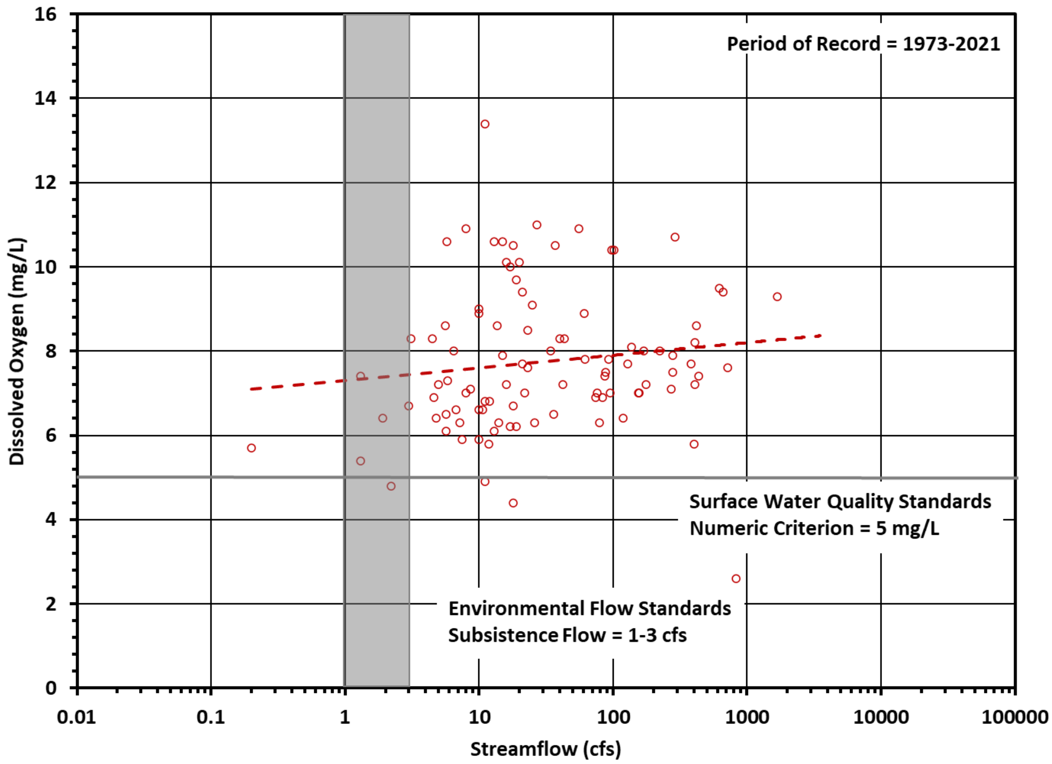

Figure A20. Plum Creek near Luling Temperature

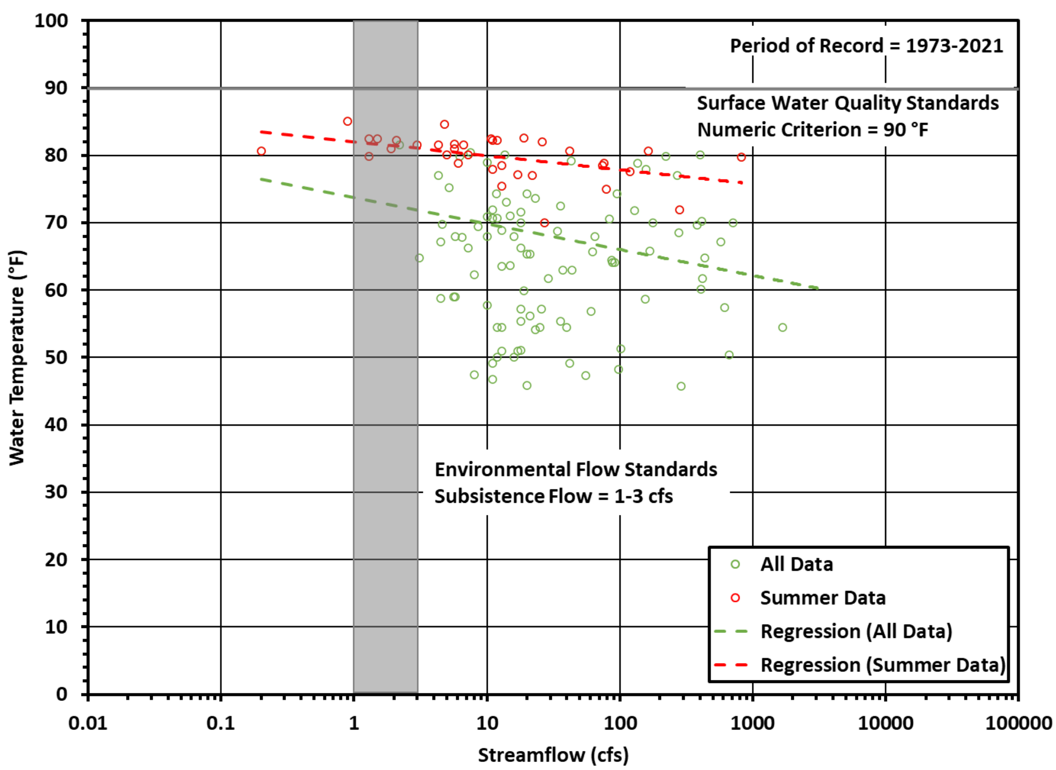

Figure A21. Guadalupe River at Gonzales (USGS 08173900) Annual Streamflow

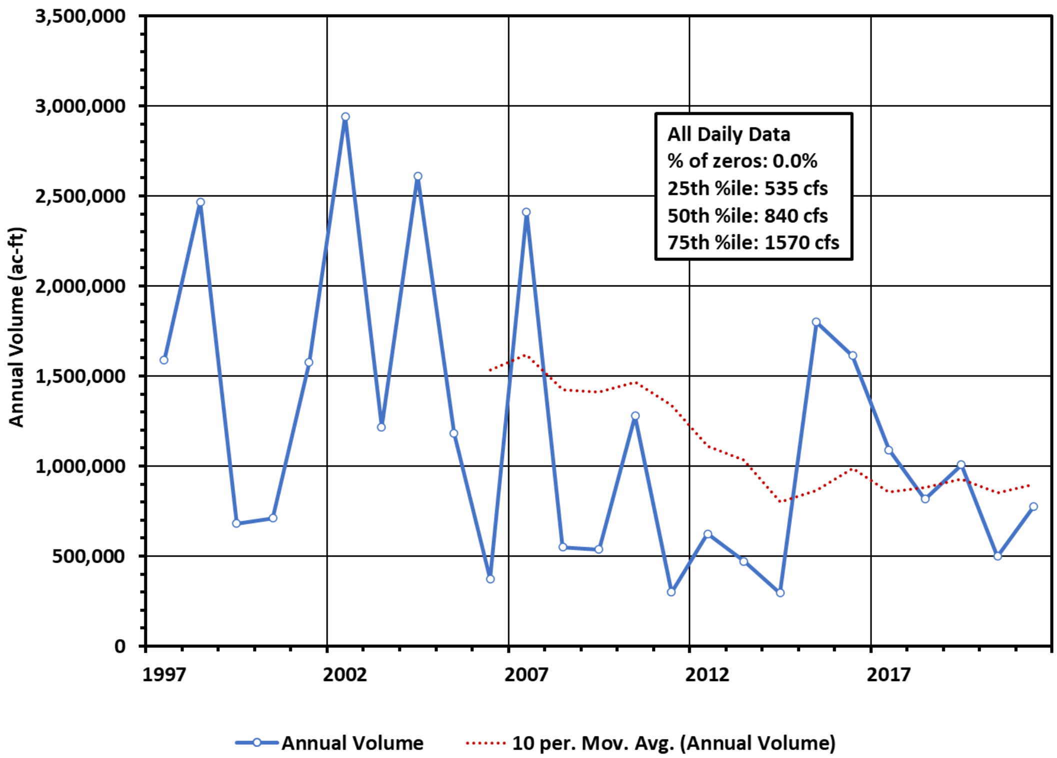

Figure A22. Guadalupe River at Gonzales (USGS 08173900) Daily Streamflow Frequency

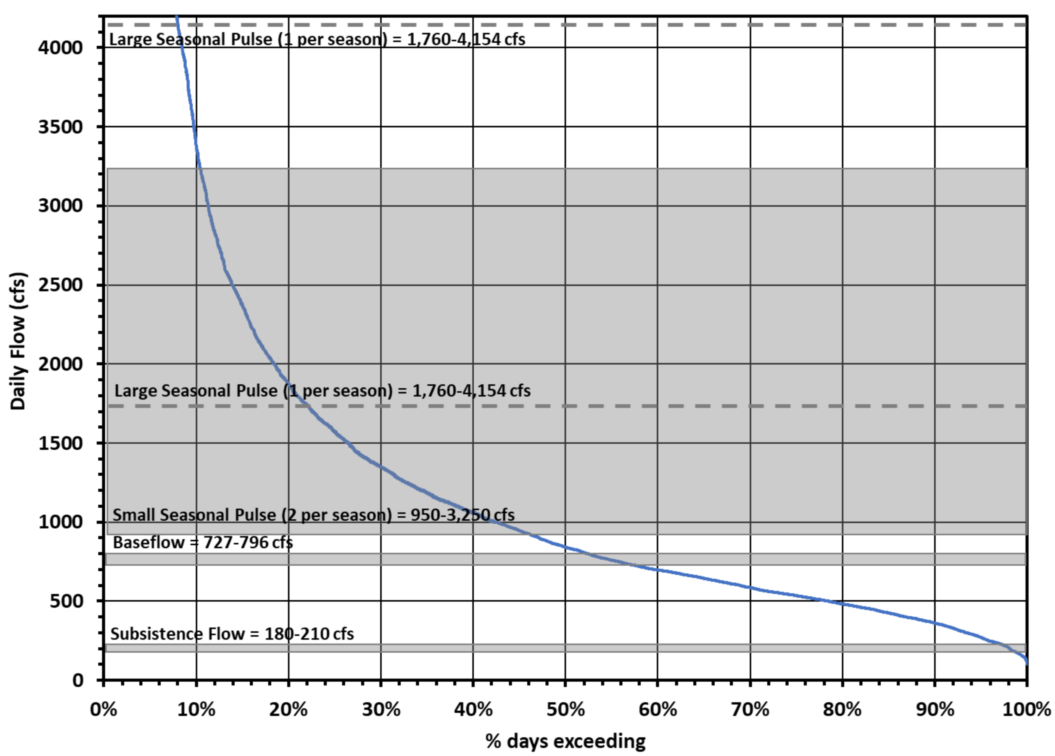

Figure A23. Guadalupe River at Gonzales Dissolved Oxygen

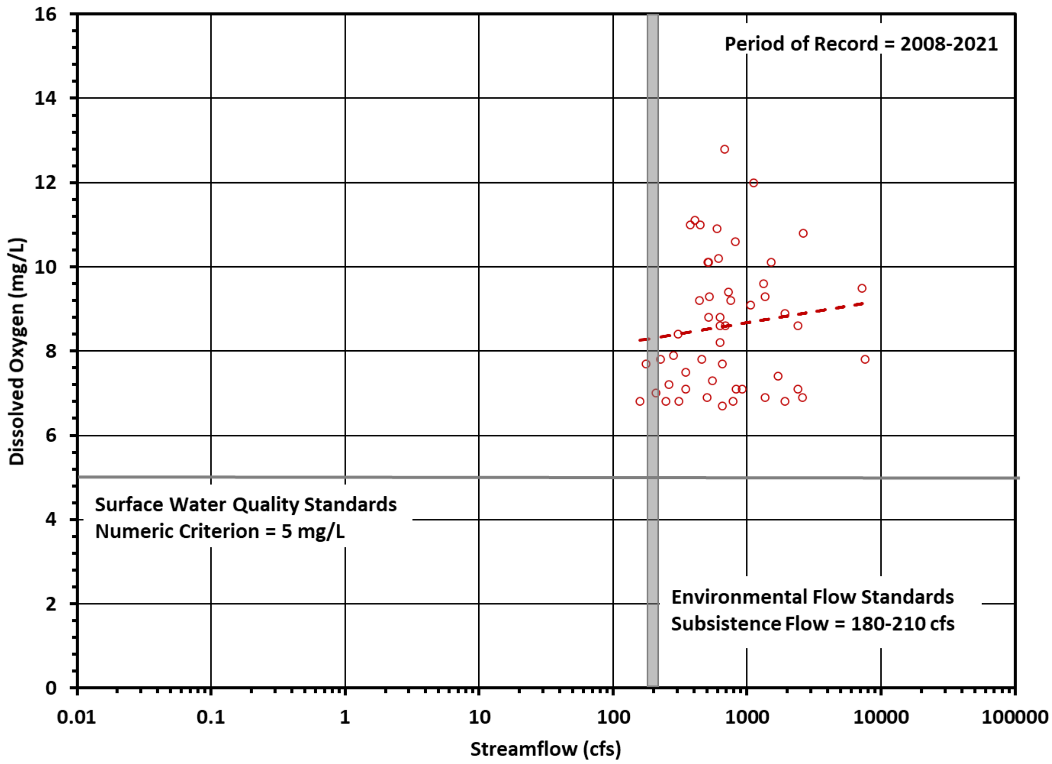

Figure A24. Guadalupe River at Gonzales Temperature

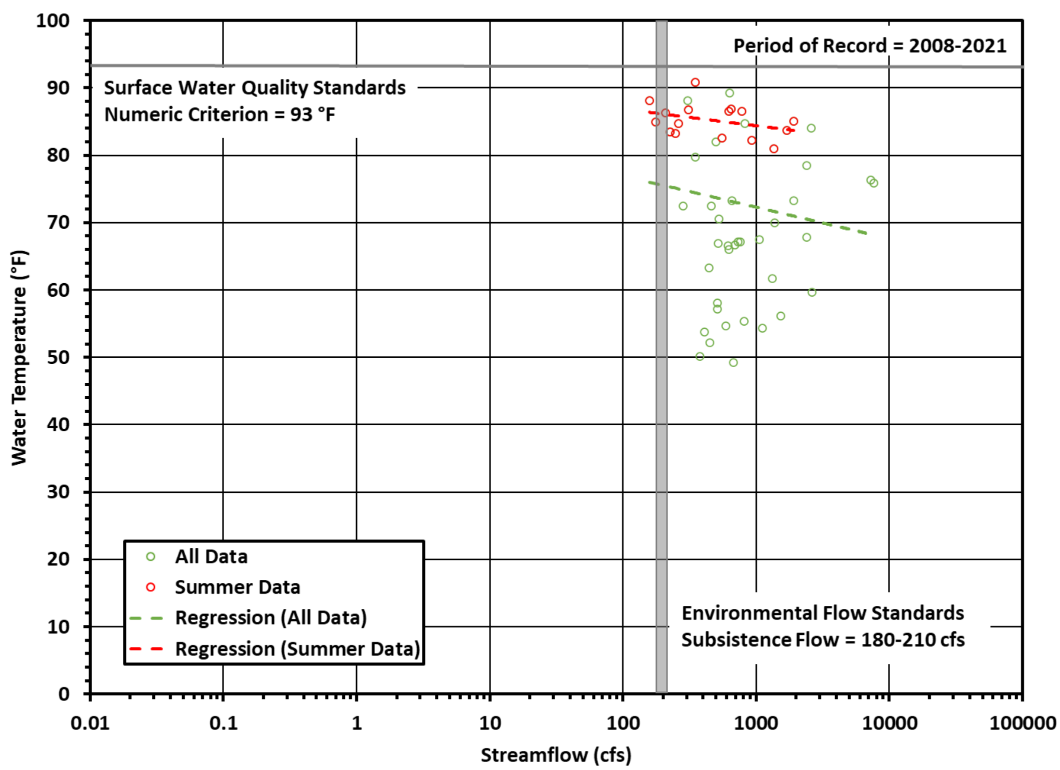

Figure A25. Sandies Creek near Westhoff (USGS 08175000) Annual Streamflow

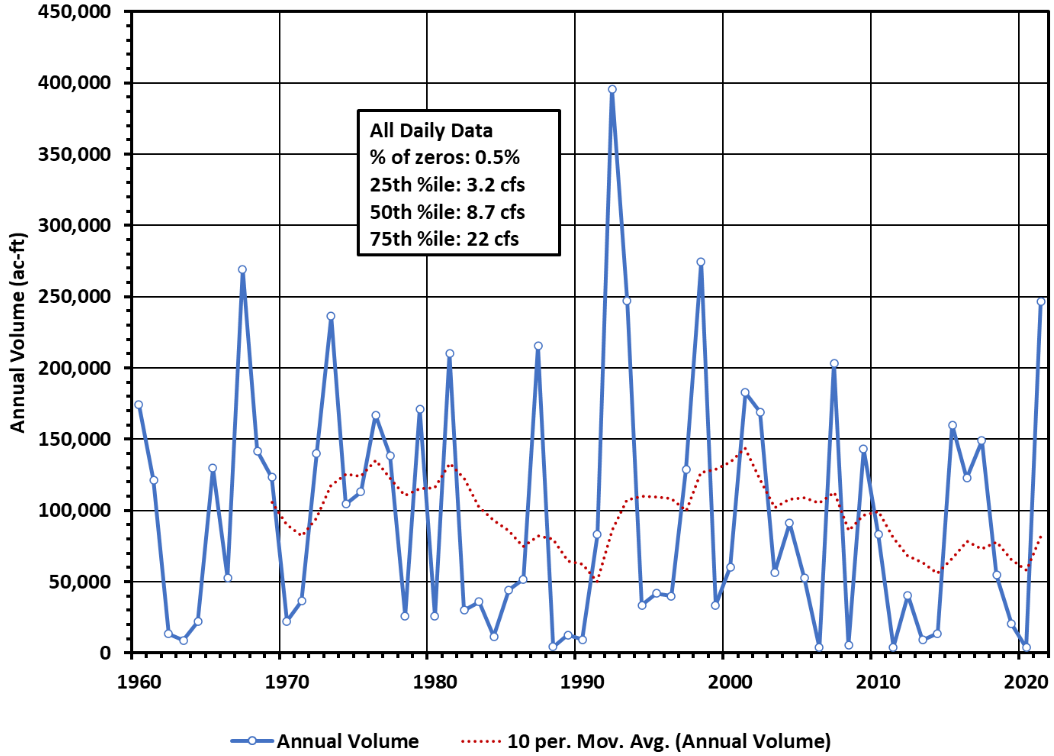

Figure A26. Sandies Creek near Westhoff (USGS 08175000) Daily Streamflow Frequency

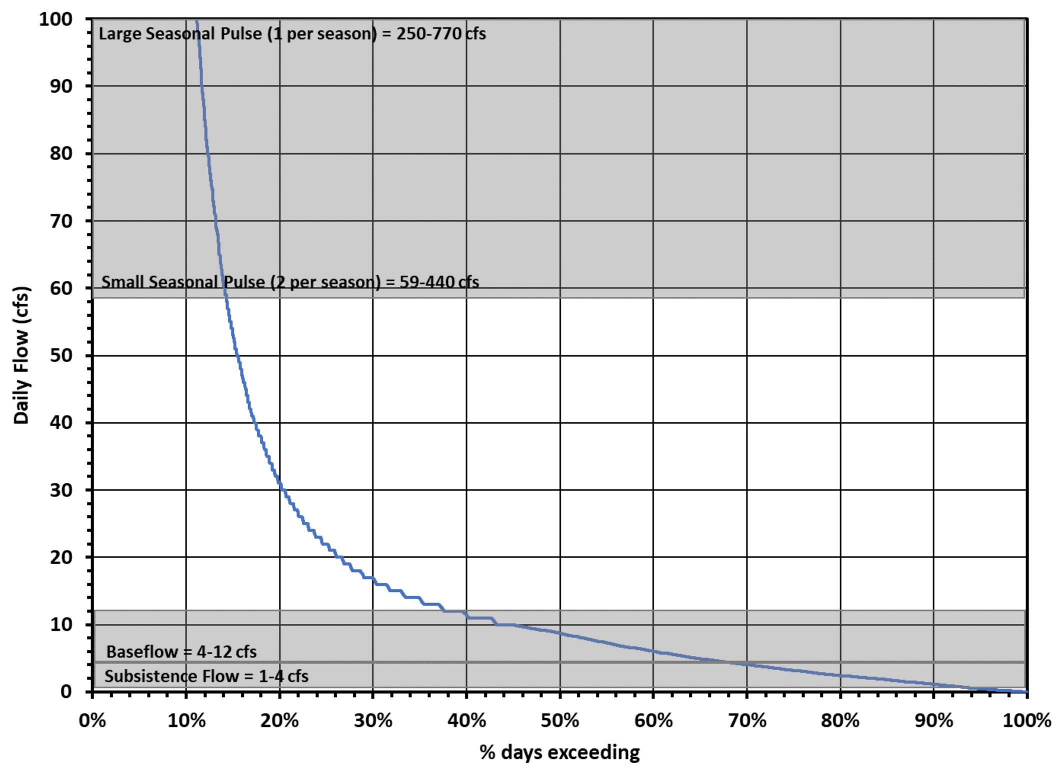

Figure A27. Sandies Creek near Westhoff Dissolved Oxygen

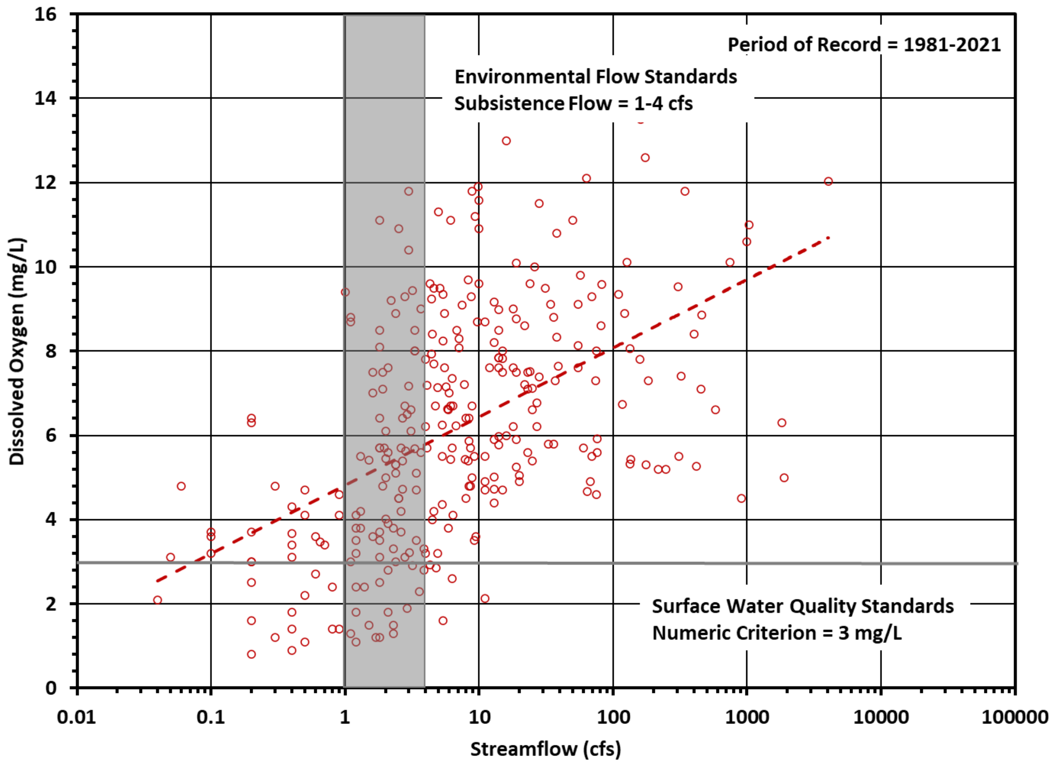

Figure A28. Sandies Creek near Westhoff Temperature

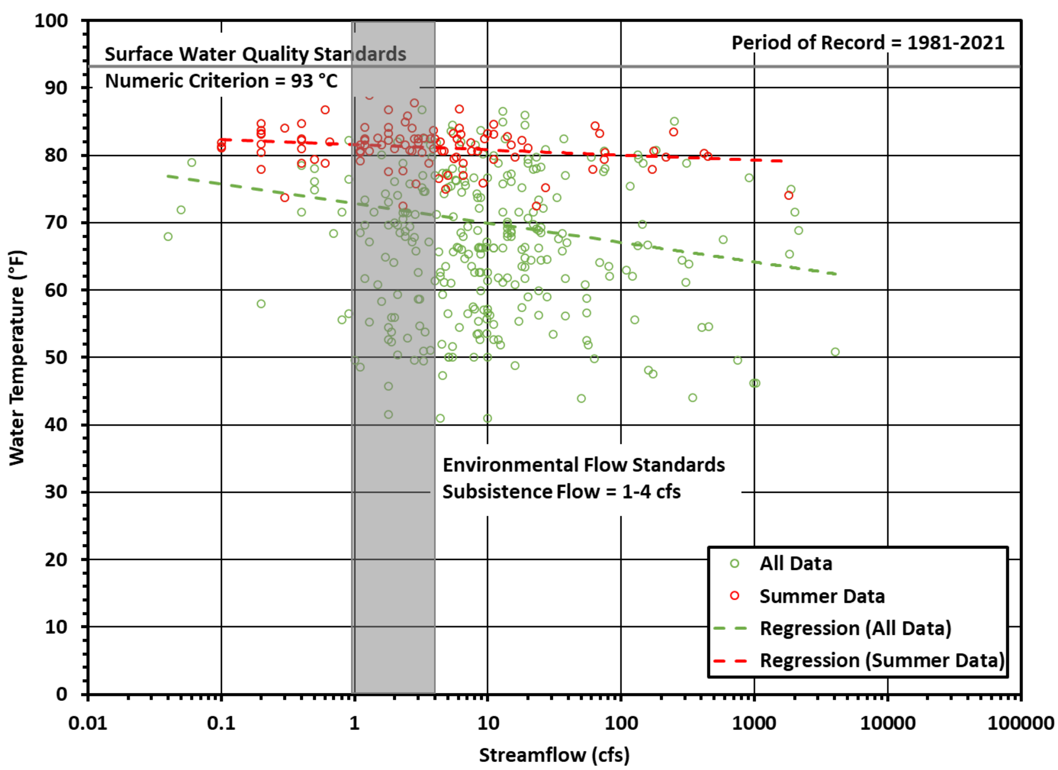

Figure A29. Guadalupe River at Cuero (USGS 08175800) Annual Streamflow

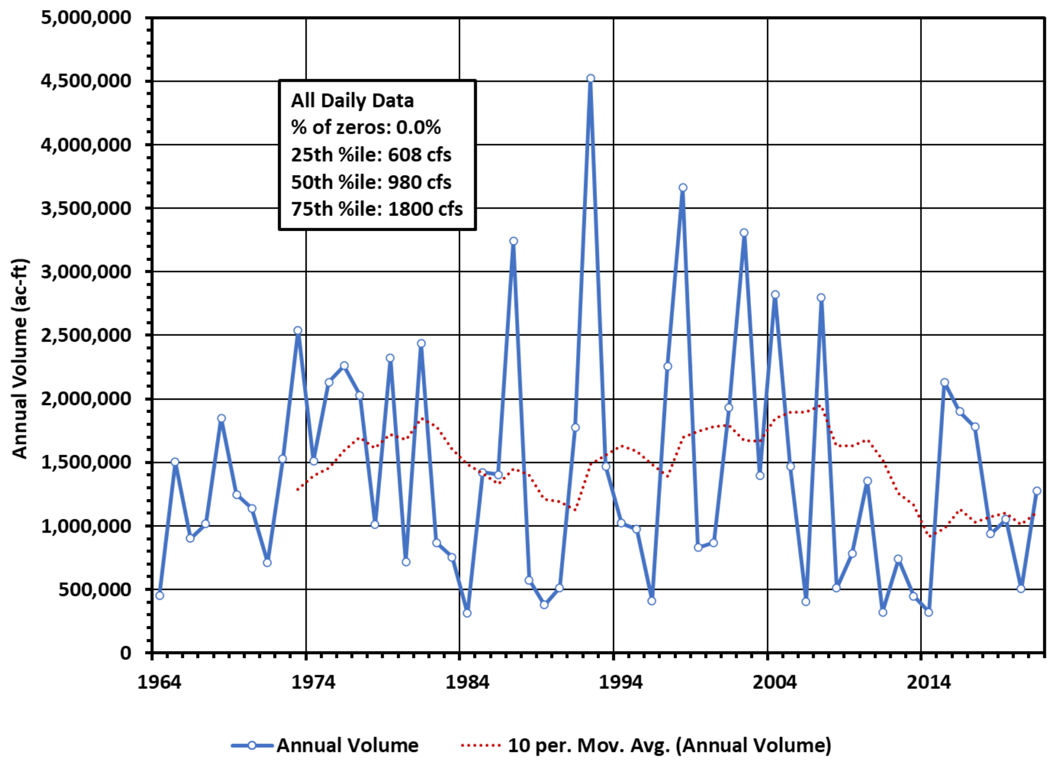

Figure A30. Guadalupe River at Cuero (USGS 08175800) Daily Streamflow Frequency

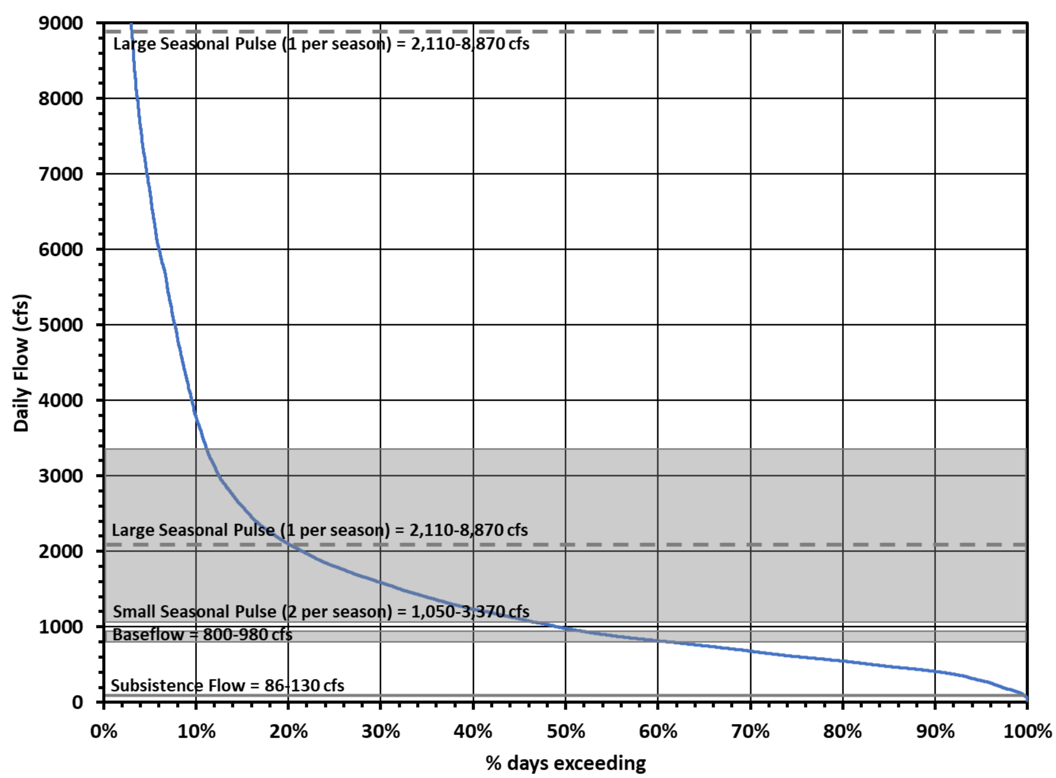

Figure A31. Guadalupe River at Cuero Dissolved Oxygen

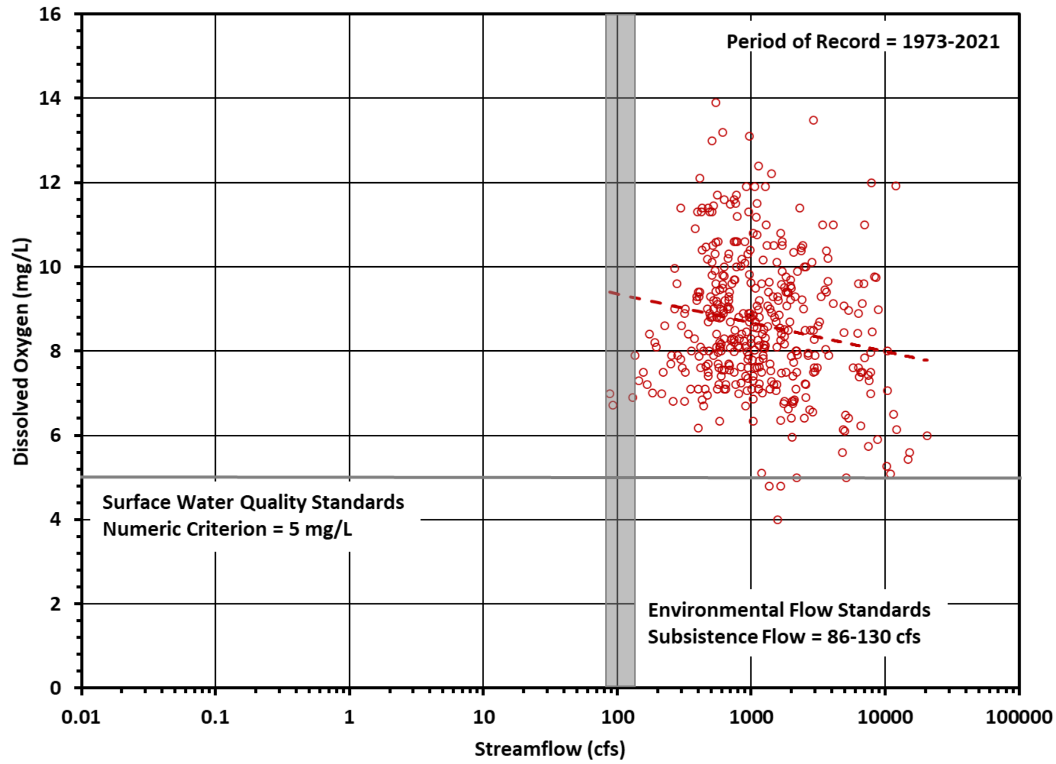

Figure A32. Guadalupe River at Cuero Temperature

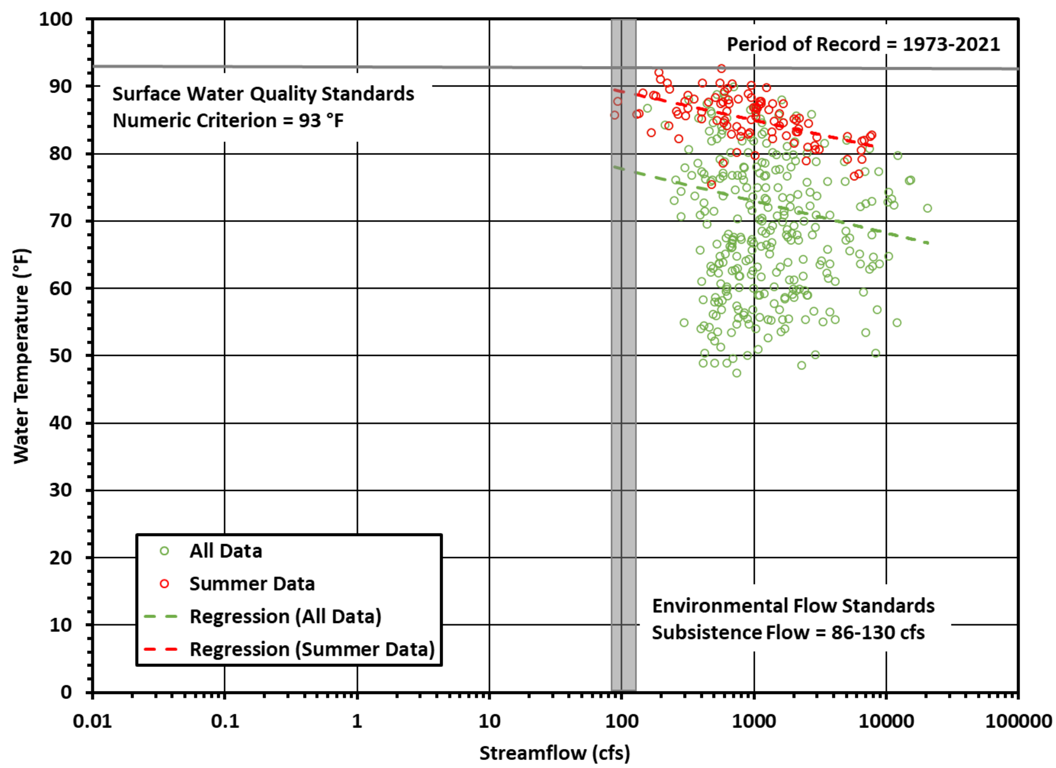

Figure A33. Guadalupe River at Victoria (USGS 08176500) Annual Streamflow

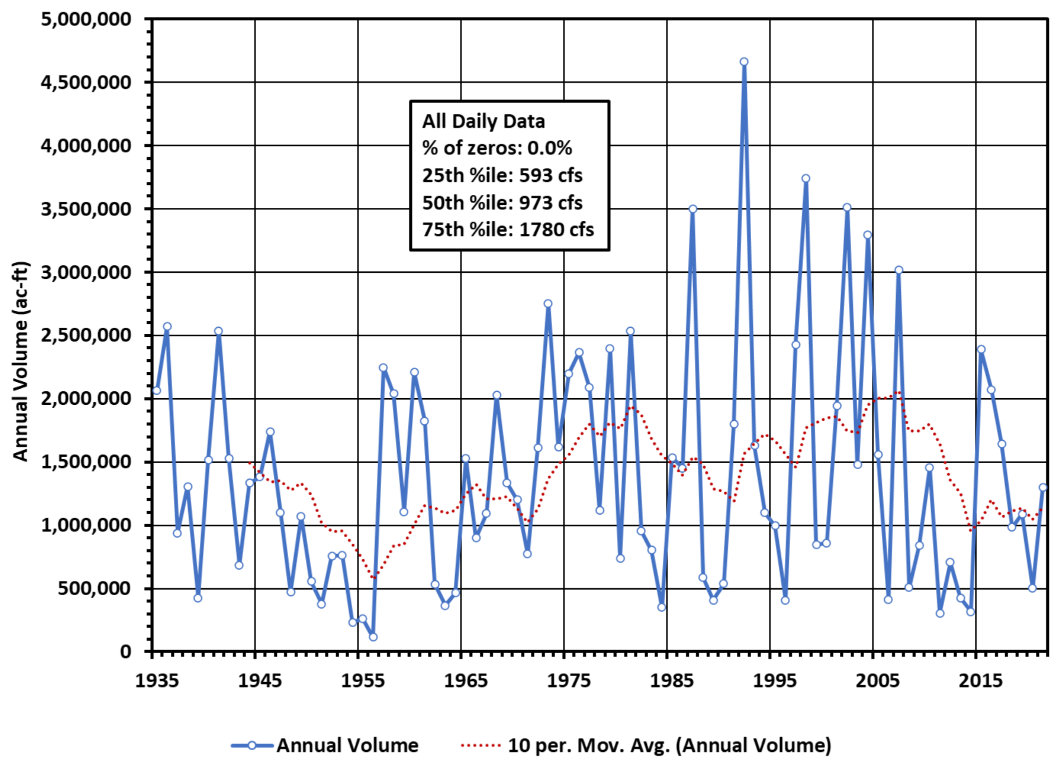

Figure A34. Guadalupe River at Victoria (USGS 08176500) Daily Streamflow Frequency

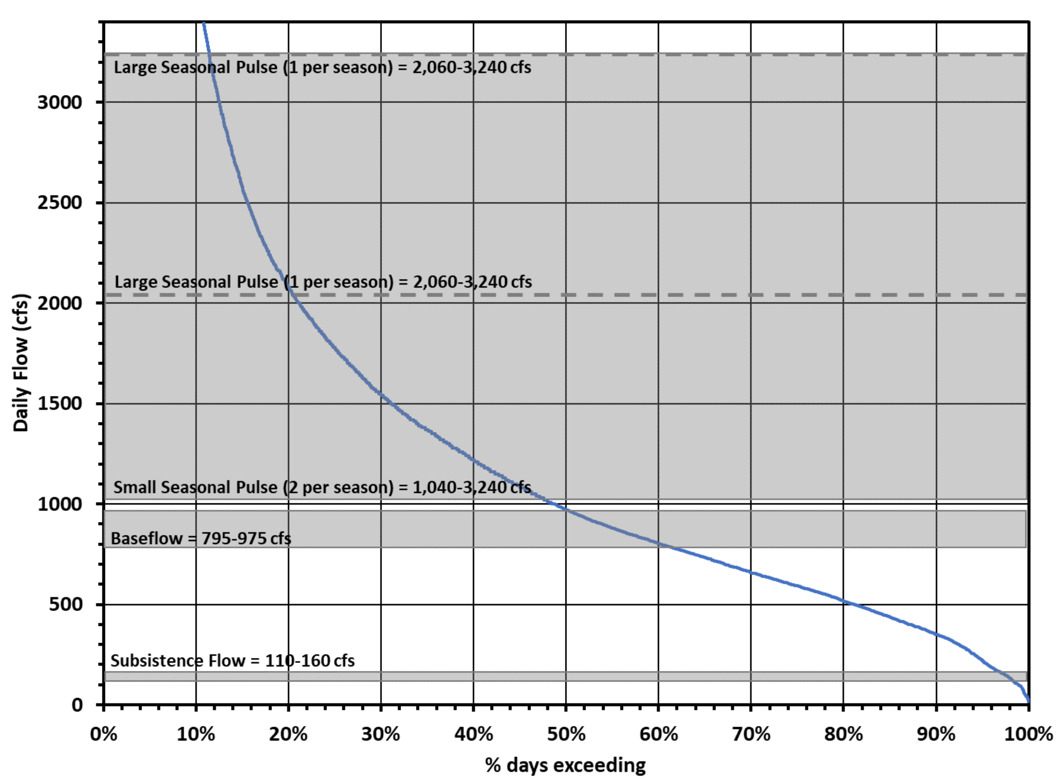

Figure A35. Guadalupe River at Victoria Dissolved Oxygen

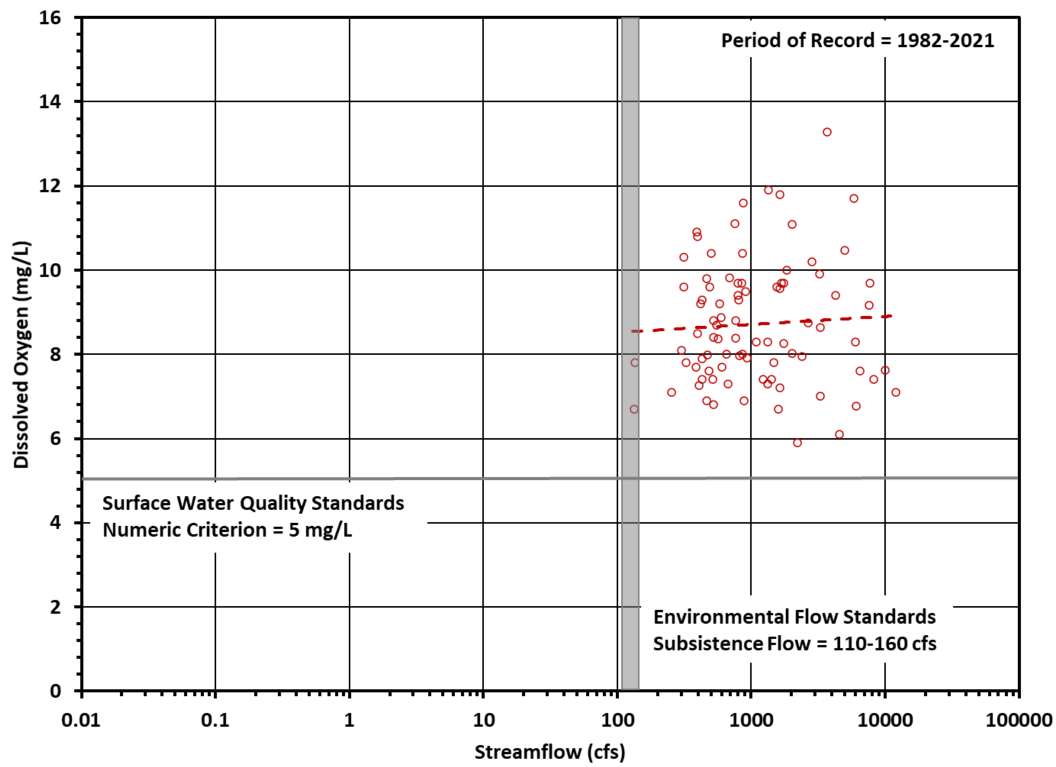

Figure A36. Guadalupe River at Victoria Temperature

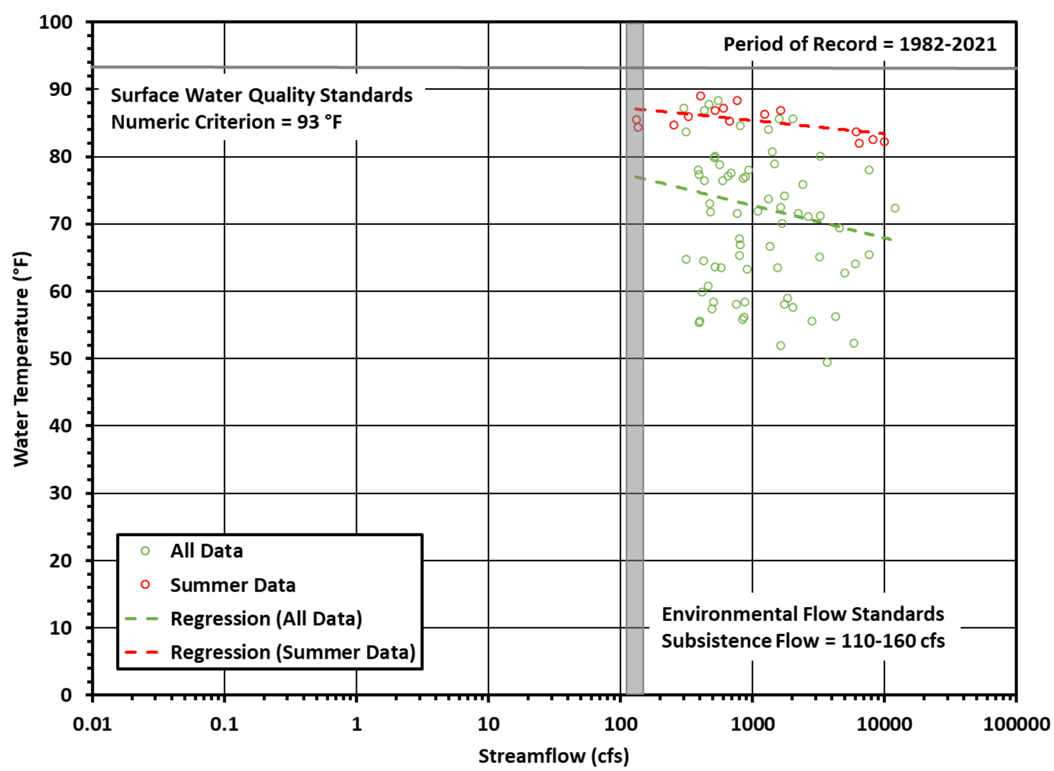

Figure A37. Guadalupe Estuary Total Freshwater Inflow

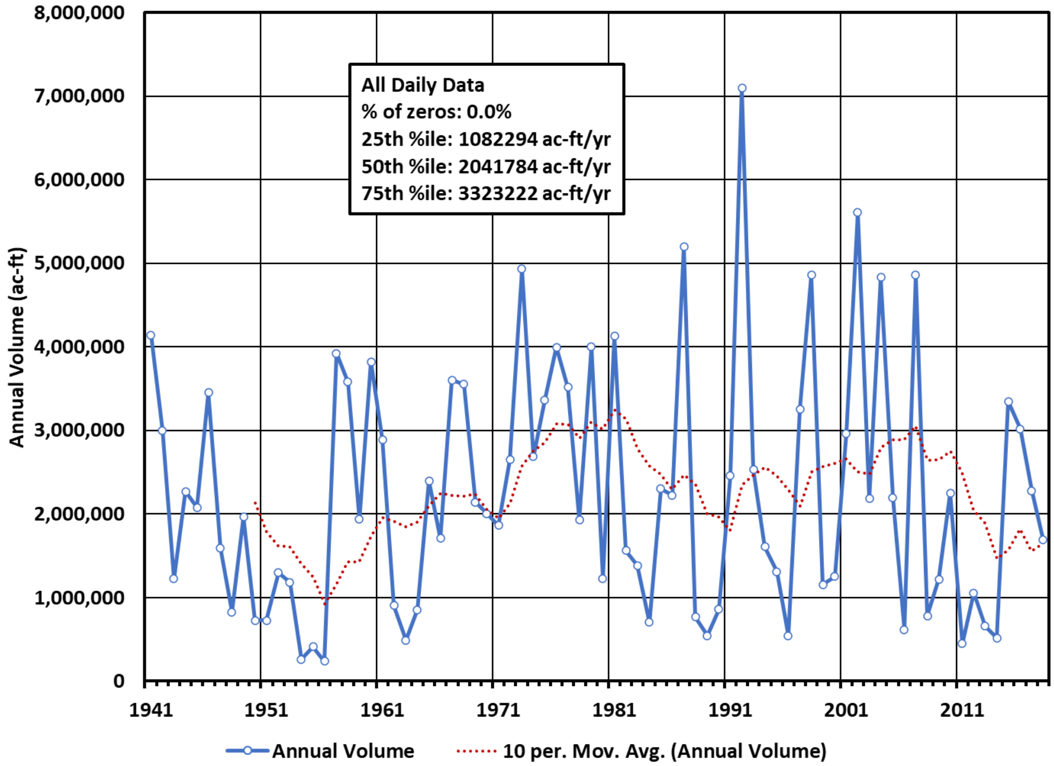

Figure A38. Guadalupe Estuary Annual Streamflow Frequency

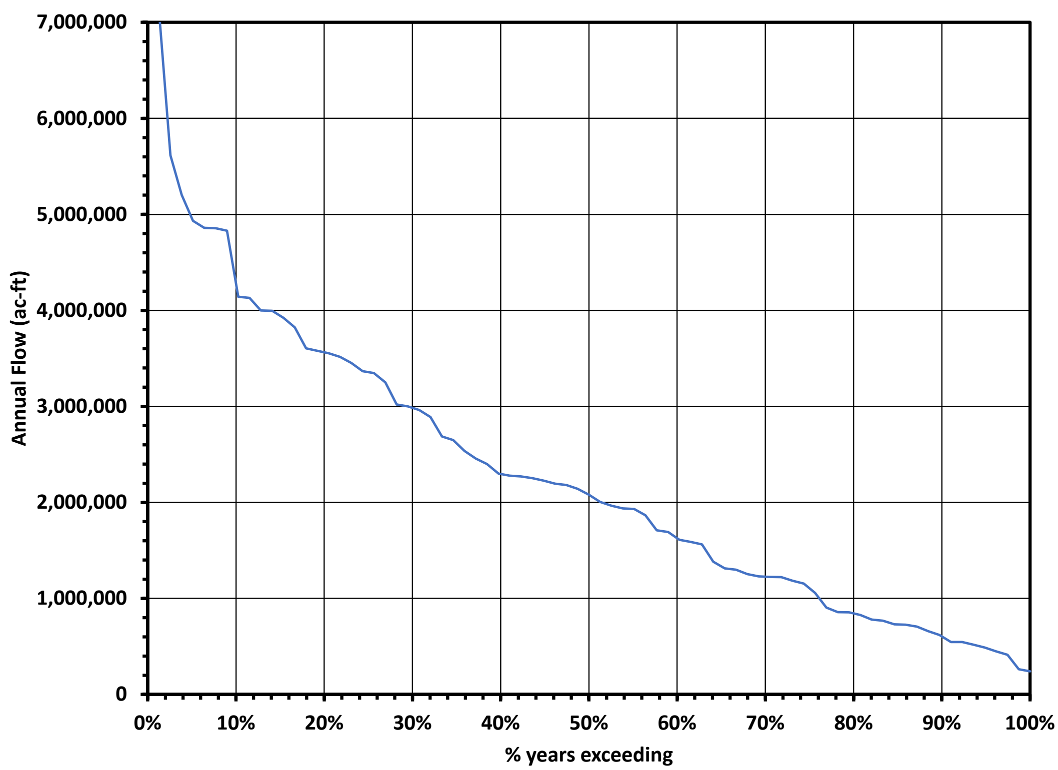

Figure A39. Guadalupe River near Tivoli (USGS 08188800) Dissolved Oxygen

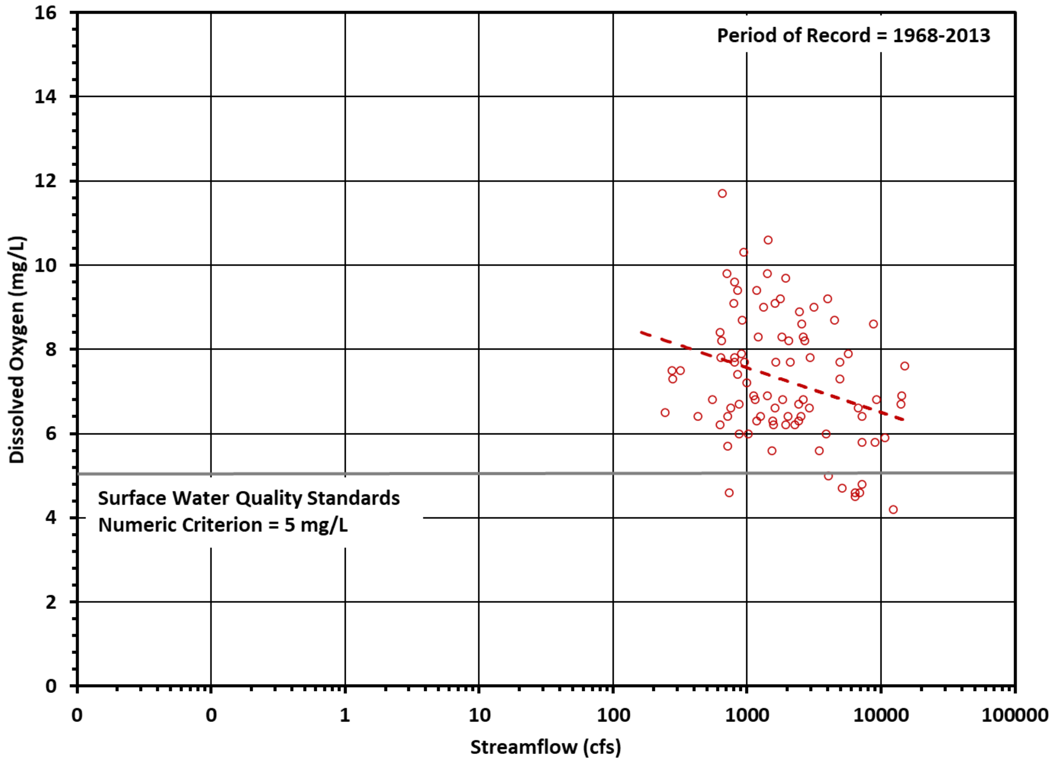

Figure A40. Guadalupe River near Tivoli (USGS 08188800) Temperature