Nolan Creek flow: Potential changes related to upstream influences

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Acknowledgements

Assistance toward the preparation of this report is gratefully acknowledged to persons of: The United States Geological Survey, The United States Department of Agriculture - Agricultural Research Service, The Texas Commission on Environmental Quality, The City of Killeen, The City of Harker Heights, The City of Nolanville, The City of Belton, Bell County Clear Water Underground Water Conservation District, Bell County Water Conservation and Improvement Districts 1,3, and 6, Texas A&M AgriLife Extension, and Texas A&M AgriLife Research.

Executive Summary:

The City of Belton is considering the development of Nolan Creek for recreational purposes; specifically, installing engineered channel modifications to support kayaking. Nolan Creek discharge through Belton depends primarily upon upstream natural base flow, permitted wastewater outfalls, and permitted diversions. Increasing population and water demand is driving interest and movement toward water conservation through wastewater recycling (i.e., wastewater outfall diversion and re-use). This could potentially affect Nolan Creek flow and Belton's proposed engineered channel modifications. Historic flow records, wastewater discharge data, permitted diversion data, and known proposed changes were evaluated for this report. United States Geological Survey gauging between 1974 and 1982 reported the lowest average daily discharge for Nolan Creek at Belton as 13 million gallons per day (MGD), greater than the engineered channel design minimum flow requirement of 10 MGD. An average monthly flow budget, based on Nolan Creek estimated base flow, permitted wastewater discharges, and permitted diversions data, indicates that, under current conditions, flow should not fall below minimum channel design requirements if currently planned upstream diversions are implemented. Engineered channel modifications offer services beyond the designed intent.

Nolan Creek Watershed Description

The Nolan Creek Watershed (NCW) encompasses approximately 135 square miles and consists of three named streams; North Nolan Creek, South Nolan Creek, and Nolan Creek (Figure 1) collectively classified by the United States Geological Survey (USGS) as Stream Segment 1218. The flow travels easterly through Bell County, Texas, starting in Killeen at an elevation of 870 feet and descends 420 feet, over 29 miles, until joining the Leon River. Average slope is 14.5 feet per mile or 0.0027 foot per foot. The main stem begins approximately two miles northwest of Belton at the convergence of North and South Nolan Creeks. The main stem flows southeast for approximately 9 miles, through the City of Belton, to its confluence with the Leon River, two miles east of Belton. North Nolan Creek originates approximately 11 miles northwest on the Fort Hood Military Reservation. South Nolan Creek originates approximately 17 miles west, in Killeen (TSHA 2010). The majority of Nolan Creek flow originates from two main sources:

natural base flow and wastewater outfalls from the upstream cities of Killeen, Harker Heights, and Nolanville along South Nolan Creek. Also affecting the flow reaching Belton are several water right diversions. Natural diversions, un-permitted diversions and evaporative loss were not considered in this report. As Bell County's population increases, Nolan Creek flow will be affected through changes in upstream wastewater discharge, wastewater recycling, wastewater diversions, and other permitted water right diversions. Population growth may however, increase wastewater discharge and offset re-use, recycling, and other diversions.

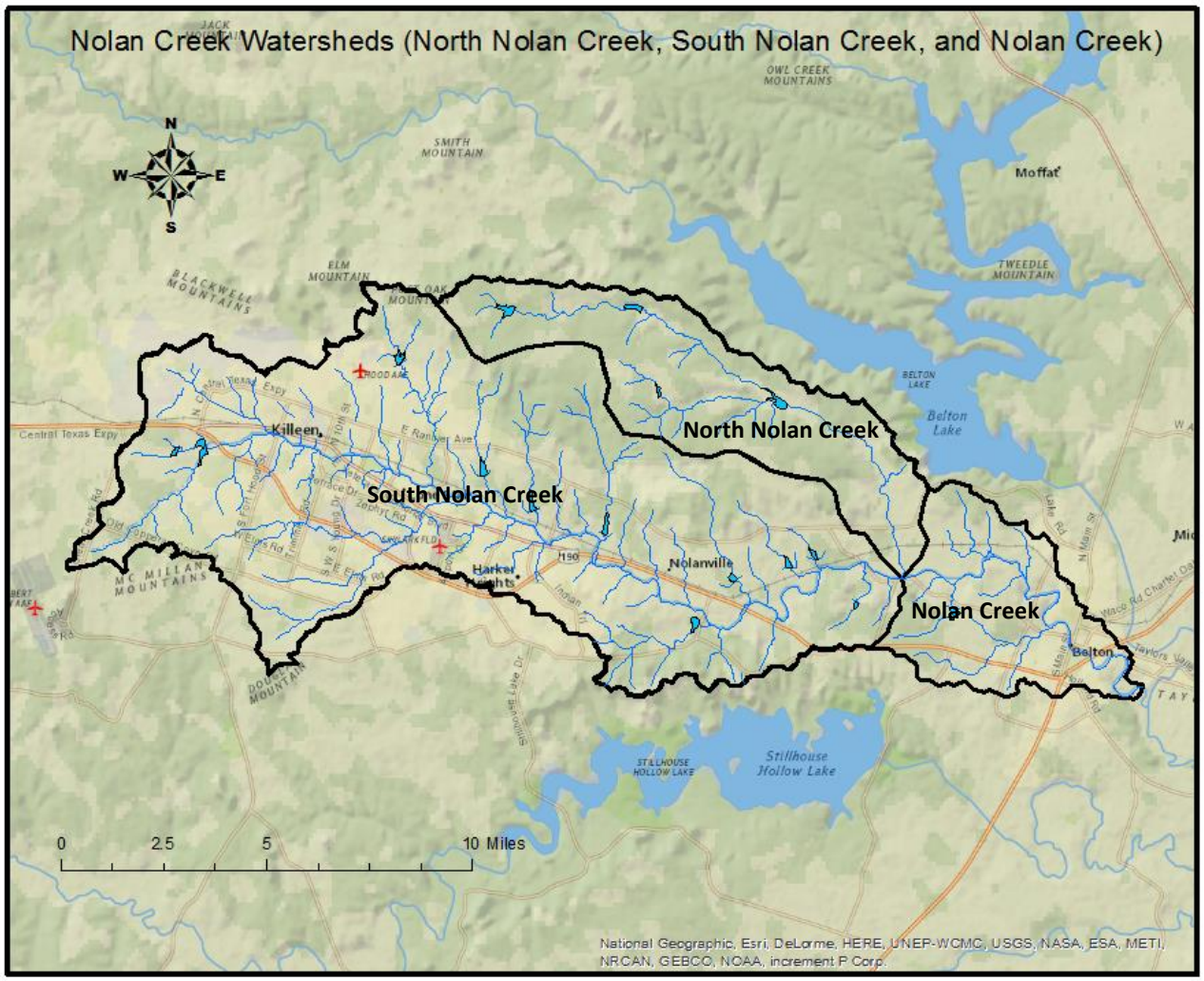

Figure 1. Nolan Creek Watersheds – North Nolan Creek, South Nolan Creek, and Nolan Creek.

Due to the geology of the NCW, Nolan Creek exhibits flashy runoff and sometimes extreme flooding, following heavy rainfall events. Historic downstream damage and loss-of-life due to these events led to the construction of upstream flood control structures (PL566 dams) which were installed in the 1950s and 60s. Fourteen of 17 planned impoundments were built (Figure 2). Bell County Water Control and Improvement District (WCID) #6 management provided information regarding the operation of these structures. Each has a 24" overflow conduit that restricts discharge when water is temporarily impounded during storm runoff events. In the past 15 years, WCID#6 management has never observed flow from any of the structures, except following flood events. It may be reasonably assumed that any base flow or wastewater discharge upstream of the structures is intercepted before reaching the Nolan Creek main channel.

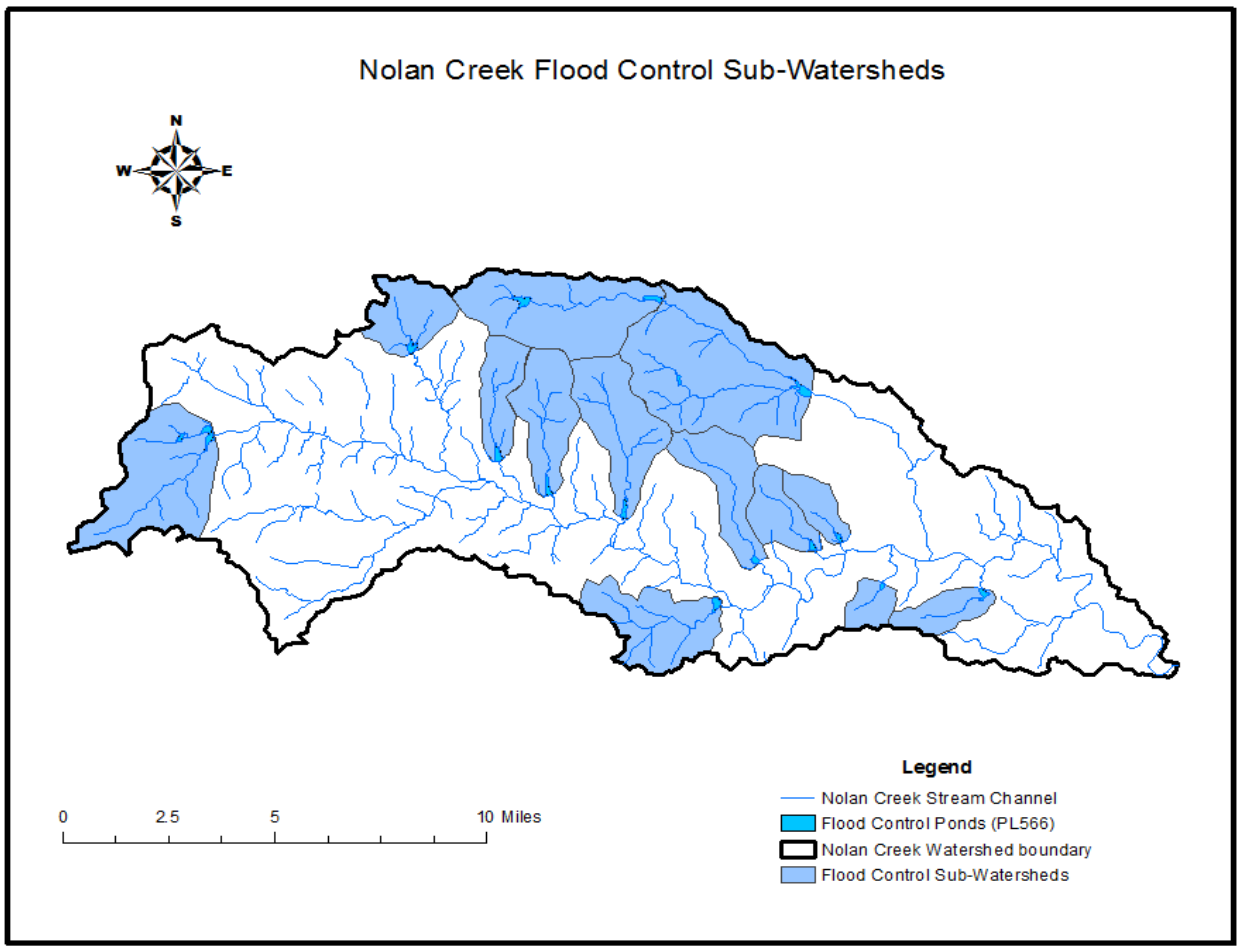

Figure 2. Nolan Creek Watershed sub-watershed containing flood control (PL566) structures

Recreation

Texas A&M University conducted a recreational use attainability analysis in 2010 that assessed 31 streams in the Brazos River Basin. Watershed characteristics, population trends, land use, historic flows, and primary recreational uses for each stream were described. The analysis determined that fishing and kayaking held the greatest recreational potential for Nolan Creek (Winemiller et al. 2010). Nolan Creek has been reported appropriate for whitewater kayaking with Class II—III rapids present during higher flows (Daniel 2004). The American Whitewater association describes Class II rapids as: "*straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers.*" Class III rapids are described as: *"rapids with moderate, irregular waves which may be difficult to avoid and which can swamp an open boat. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found."* "Higher flows" were not defined in terms of discharge rates but recommended put-in at Backstrom Crossing and take-out at Confederate Park were given.

Plans developed for the City of Belton by Recreation Engineering and Planning (Boulder, CO) incorporate environmental, public safety, and recreation requirements using natural-appearing engineering solutions (Lacy 2013). A minimum operational flow range between 10 and 15 million gallons per day (MGD) is required to support recreational kayaking (Lacy 2013). In addition to its primary boating use, the engineered design will contribute to the overall attractiveness of the area, promoting human health and wellbeing. Engineered structures within heavily used park areas will provide protection to the natural banks from foot traffic. Hardened banks may be thought of as "sacrifice areas", inviting use while protecting natural riparian areas. During high flows, the engineered structures will also protect park areas against erosion and bank failure.

Flow Records

The United States Geological Survey operated a gauging station on Nolan Creek 3.1 miles upstream from its convergence with the Leon River, at Interstate Highway 35 (USGS 2014*a*). Average daily flow was measured at this location for almost 9 years, from January 1974 to November 1982. Figure 3 is a raster hydrograph depicting average daily flow for the entire period. Low flow conditions of less than 10 cubic feet per second (cfs) are apparent during periods in 1977, 1978, and 1980. The lowest average daily flow recorded during the period of record was 8.6 cfs or 13.6 MGD. A flow duration curve describing the percentage of the time that stream discharge equaled or exceeded the rate is shown in Figure 4. Note the lowest recorded flow from this dataset never fell below the planned stream channel engineering design's lower minimum operational flow requirement of 10 MGD.

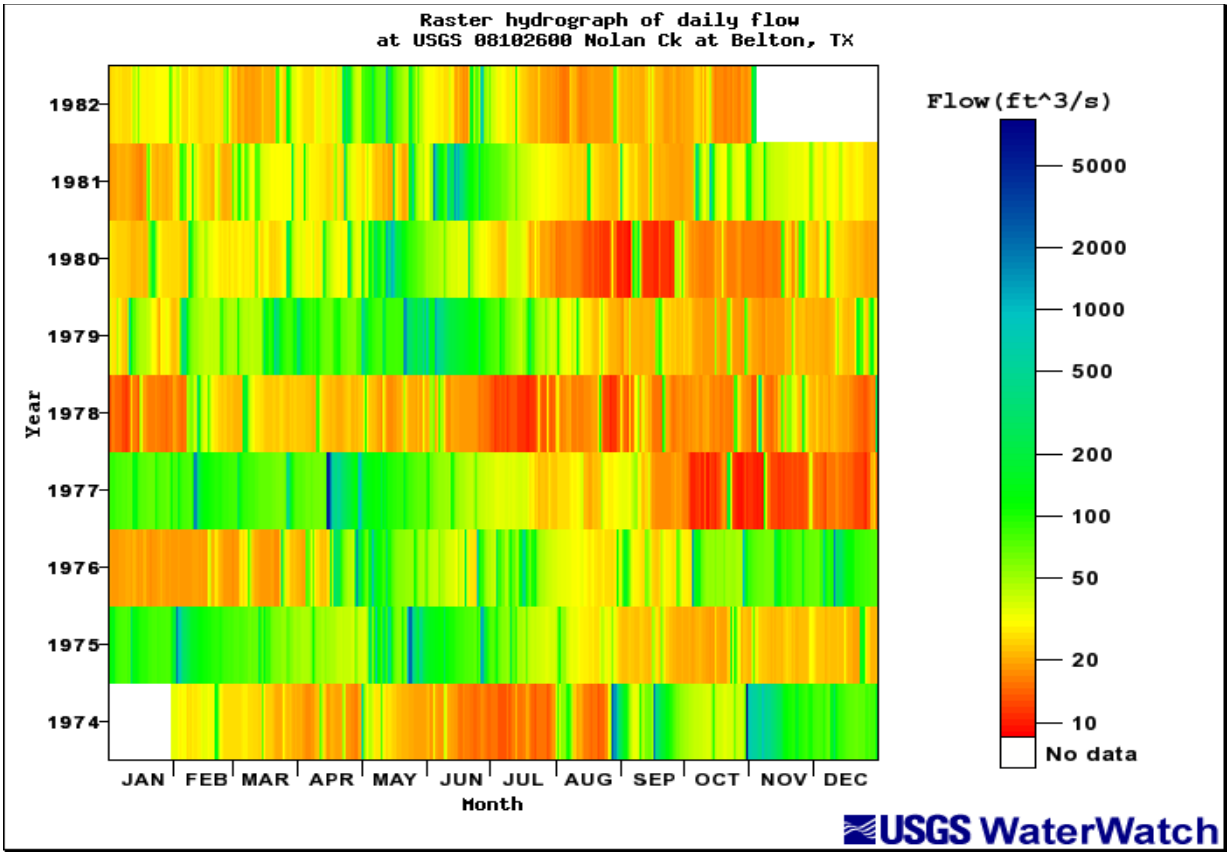

Figure 3. Raster hydrograph representing average daily flow recorded at USGS gauging station 08102600, Nolan Creek at Belton, Texas. Gauge operational between 31 January 1974 and 3 November 1982.

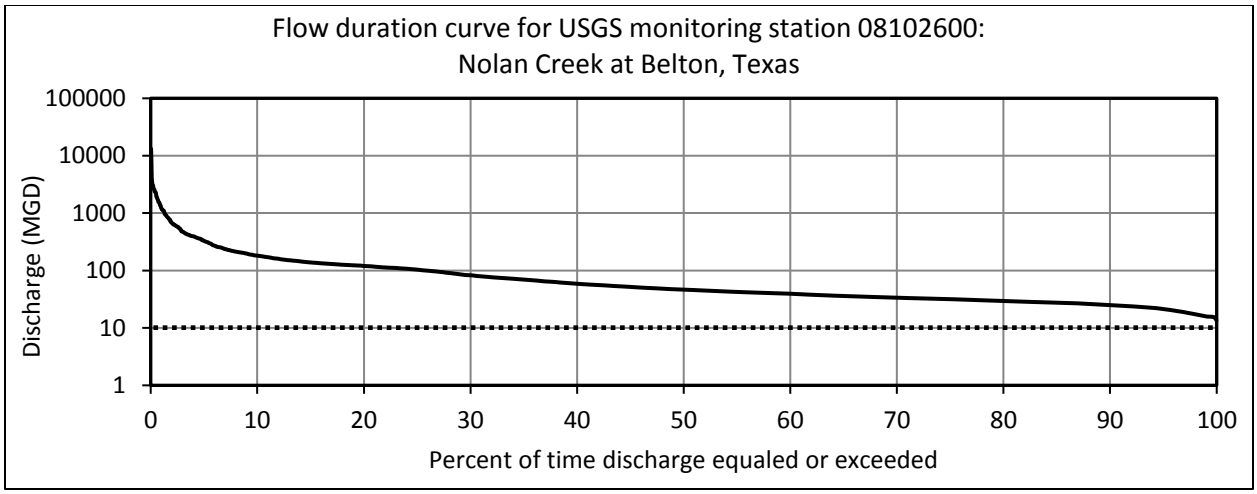

Figure 4. Flow duration curve based on USGS gauging station 08102600, Nolan Creek at Belton, Texas between 31 January 1974 and 3 November 1982. Dashed line indicates channel design minimum flow requirement.

No other extended flow records exist for Nolan Creek; however, The Texas Commission on Environmental Quality (TCEQ) collects occasional stream flow data as part of its surface water quality monitoring effort (See Flow Characterization page 15 and Flow Budget page 16). These measurements are often collected during low flow and are available through TCEQ open records.

The City of Belton, in cooperation with upstream municipalities, installed a flood alert system in 2011 in response to an extreme flood event occurring in 2010. The system has successfully provided early warning of several high water events since its installation. In addition to its primary function, the system has potential to provide useful stream flow records. The 5 gauging stations positioned along the main channel in South Nolan Creek and Nolan Creek report stream levels from Killeen to Belton. Currently the system is configured to report twice a day and during rising stream levels. The data is "pushed" (i.e., one way communication) from the gauge to a centralized server, via radio communication, and delivered to safety personnel during flood events through an internet web-page. Currently, logged data is minimal. The system could be re-programmed to log hourly (or other appropriate interval) data from select locations. Stream levels may be converted to useful flow rates by establishing stage-discharge relationships. Continuous data could then be used to determine and advertise minimum and appropriately safe flows for kayaking and other recreational activities. Additionally, over time, stream flow records would become an invaluable data set to assist with future water availability studies.

Natural Base Flow

Natural base flow data for NCW is sparse. Several springs within NCW are documented in three published references but few report flow data (Table 1). Brune (2002) reports flow from 16 springs, 4 within the NCW, measured in 1974 or 1975, during dry conditions. The average reported flow from documented springs was 0.06 MGD. Unfortunately, without knowledge of in-channel spring location and discharge volume, this value is not useful except for general interest. Personal communication with land owners and city officials reported small flows present during all but the driest of years, on at least three tributaries of South Nolan Creek.

In-channel springs and seeps control Nolan Creek's natural base flow. Output depends upon recharge driven by seasonal weather patterns and is therefore subject to seasonal fluctuation. Data from local springs, required to estimate Nolan Creek base flow fluctuation, was unavailable or incomplete at the time of this report. Ten years of average monthly discharge, reported from Barton Springs in Austin, Texas (USGS 2014*b*) was used as a surrogate to estimate seasonal fluctuation of Nolan Creek base flow (Figure 5). Fluctuation, expressed as a percentage of the total, was applied to Nolan Creek estimated base flow to account for expected seasonal variation. Base flow accounts for about 35% of average Nolan Creek flow (See Flow Budget page 15).

Table 1. Documented springs within the Nolan Creek Watershed including: spring name, stream, reference, location/comment, and reported flows. Flows unit are Liters per second.

Spring Name	Stream	Reference	Location / Comment	Flow
Nolan Spring	Nolan	a	North side of Nolan Creek near Confederate Park, Belton	2.5 L/s
Willow Springs	South Nolan	a	Flow into South Nolan, north of McMillian Mountains	na
McDaniel Springs	North Nolan	a	Within Camp Arrowhead on Fort Hood Reservation	5.7, 1.6 L/s
Ransomer Spring	South Nolan	a	8 km NW of Nolanville on Fort Hood Reservation	1.3 L/s
Keel Spring	North Nolan	b	Location unknown	na
Crawford Spring	South Nolan	b	Location unknown	na
Shelton Springs	Nolan	b	Flows off bluff across from Harris Park, Belton	na
Seven Oaks Springs	South Nolan	c	Headwater of South Nolan Creek, Killeen	na
Slaughter Spring	South Nolan	d	Below overflow of PL566, PC - G. Grandy: WCID#6	na
Mahler Spring	North Nolan	d	In channel, confluence of N and S Nolan. PC - A. Owen	na
Average discharge				2.8 L/s (0.06 MGD)

References: a – Brune 1981, b – Tyler 1936, c – CTCOG 1975, d – Personal Communication

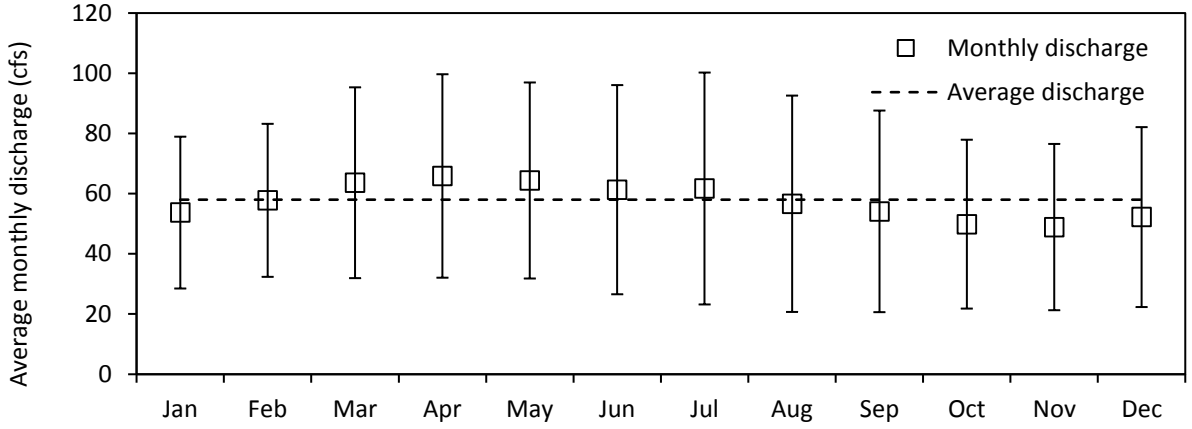

Figure 5. Average monthly discharge from Barton Springs, Austin, Texas between January 2000 and December 2011, illustrating seasonal fluctuation. Bars indicate one standard deviation from the mean.

Permitted Wastewater Outfalls

The NCW contains 7 wastewater outfalls permitted by the National Pollution Discharge Elimination System (NPDES) which is managed in Texas by the TCEQ. These outfalls represent wastewater treatment plant discharge from Fort Hood's Liberty Village housing area, the Belton Lake Outdoor Recreational Area (BLORA), and the cities of Killeen, Harker Heights, and Nolanville (Figure 6). Average monthly discharge data for all facilities, except Killeen, were obtained by interviewing individual plant managers. Average monthly discharge data for Killeen's two active wastewater plants were obtained through TCEQ open records.

The Fort Hood Liberty Village plant (NPDES 13358-001), managed by Fort Hood Universal Services, is permitted at 0.09 MGD and discharges between 0.04 and 0.06 MGD, on average. Discharge drains to an un-named flood control structure, which in turn drains to the large flood control structure named "Pershing Lake" near the junction of HW190 and the Fort Hood Main Gate. This plant contributes no measurable flow to Nolan Creek.

American Water Operations and Management Inc., is contracted by Fort Hood's Department of Public Works to manage the wastewater facility located near BLORA (NPDES 14994-001). The plant is permitted at 0.03 MGD and discharges an average of 0.01 MGD. The plant is physically located in the Leon River Watershed, on the shore of Lake Belton, just outside the Nolan Creek Watershed. The discharge is pumped over the ridge into the North Nolan Creek watershed and empties onto the ground north of North Nolan Road and evaporates before reaching North Nolan Creek. This plant contributes no measurable flow to Nolan Creek.

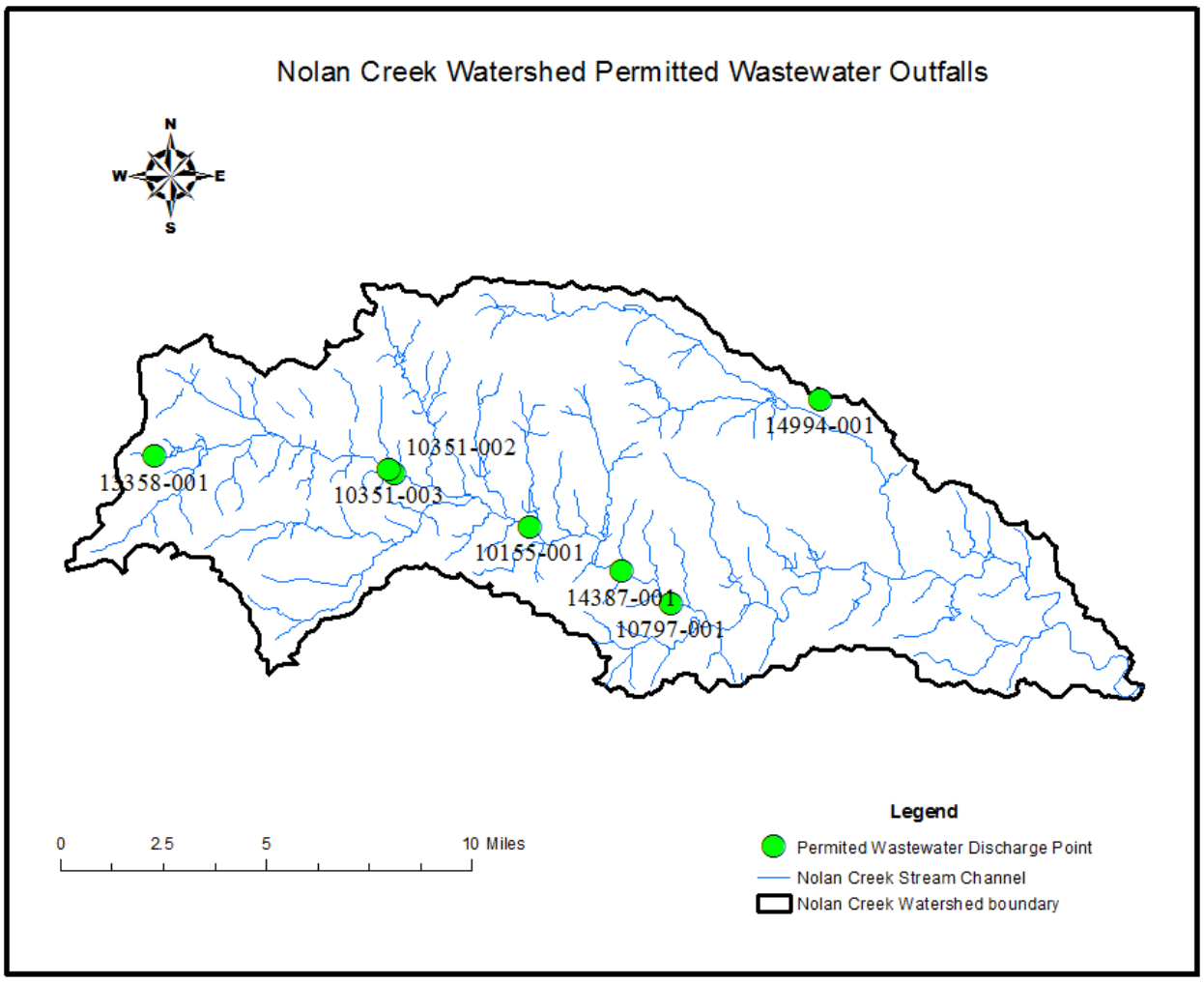

Figure 6, Nolan Creek NPDES permitted wastewater outfalls.

Bell County WCID #1 manages three wastewater treatment plants operating in Killeen.

Main Plant #1 (NPDES 10351-2) is the eastern most plant located on 38th Street. It is permitted at 18 MGD and discharges an average of 11.3 MGD into South Nolan Creek, based on 2009-2013 discharge records (Figure 7). This facility is responsible for almost half of the average daily Nolan Creek flow (~46%).

Killeen Main Plant #2 (NPDES 10351-001) is the western most plant located on 38th Street. This is an older facility permitted at 6 MGD and currently averages 0 MGD because the plant is off-line.

Killeen South Plant (NPDES 14387-001) is permitted at 6 MGD and discharges an average of 2.9 MGD into South Nolan Creek, based on 2009-2013 discharge records (Figure 8), accounting for about 12% of the average daily Nolan Creek flow. The facility is physically located in the Lampasas River Watershed but discharge is pumped into the NCW. The outfall is located between the Harker Heights and Nolanville wastewater outfalls on South Nolan Creek.

The City of Harker Heights manages its own wastewater treatment plant (NPDES 10155-001). The plant is permitted at 3 MGD, and discharges an average of 2.0 MGD, based on 2006 to 2014 discharge records (Figure 9). This facility contributes about 8% of the average daily flow to Nolan Creek.

Bell County WCID #3 operates the City of Nolanville's waste water treatment facility (NPDES 10797-001). The plant is permitted at 0.68 MGD and discharges an annual average of 0.24 MGD into South Nolan Creek (Figure 10). This amounts about 1% of the average daily flow to Nolan Creek.

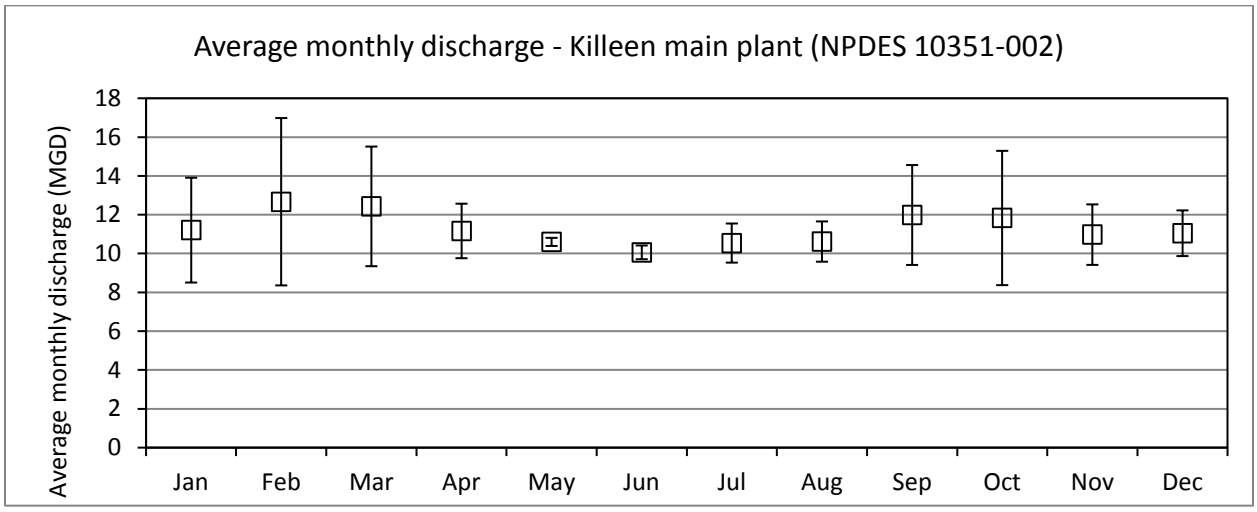

Figure 7. Average monthly discharge (MGD) by Killeen main wastewater treatment facility (NPDES 10351-001) between January 2009 and December 2013. Bars indicate one standard deviation from the mean.

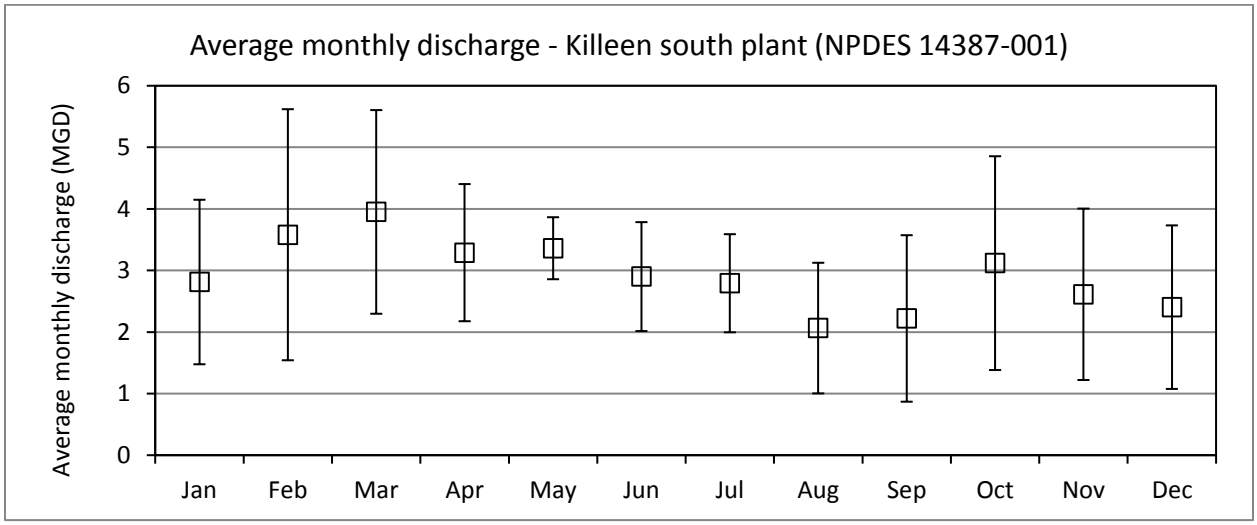

Figure 8. Average monthly discharge (MGD) by Killeen south wastewater treatment facility (NPDES 14387-001) between January 2009 and December 2013. Bars indicate one standard deviation from the mean.

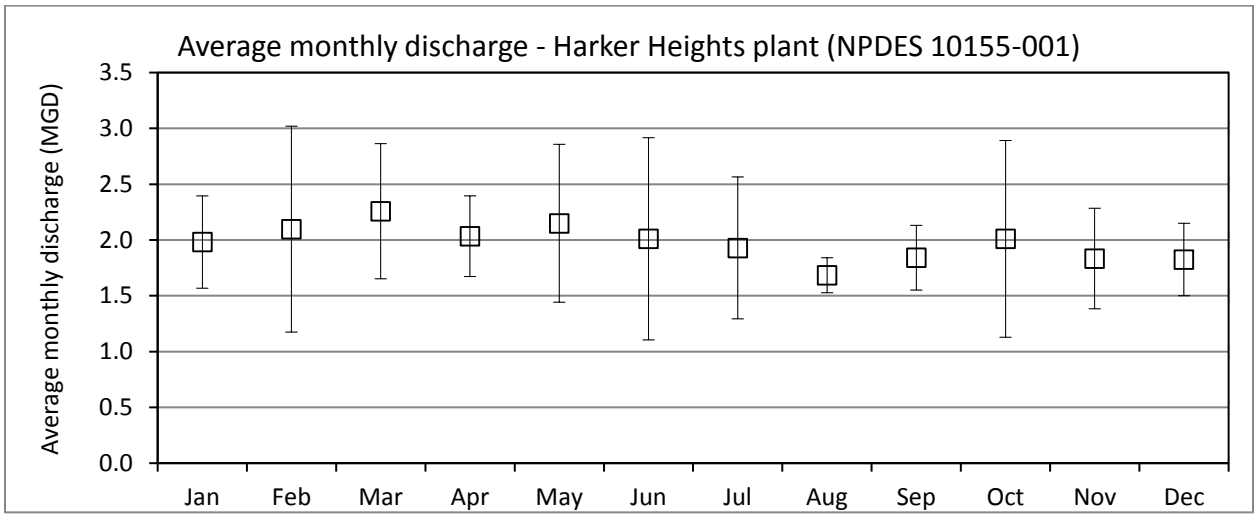

Figure 9. Average monthly discharge (MGD) by Harker Heights wastewater treatment facility (NPDES 10155-001) between August 2008 and June 2014. Bars indicate one standard deviation from the mean.

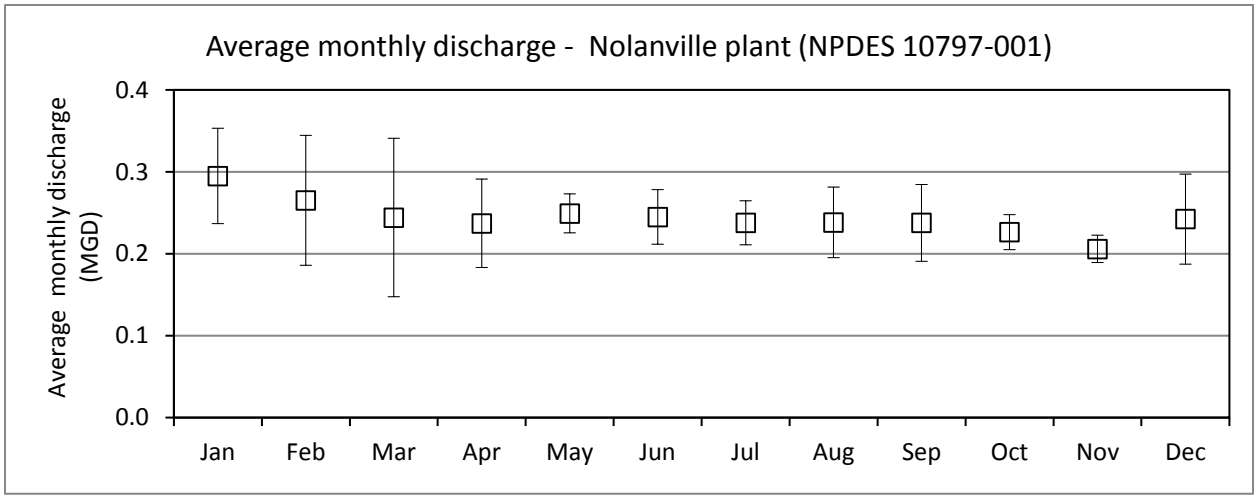

Figure 10. Average monthly discharge (MGD) by Nolanville wastewater treatment facility (NPDES 10797-001) between January 2011 and July 2014. Bars indicate one standard deviation from the mean.

Diversions

Surface water in Texas is owned by the state and held in trust for its citizens. The state grants the right to use this water to anyone, with permission. There are "exempt uses" described in the Texas Water Code, which do not require a permit. The most common exemption is Domestic and Livestock (D&L); water used for livestock, to meet household needs, or to irrigate a yard or home garden. Landowners along Texas rivers and streams can divert surface water for D&L use, without a permit. Diverters may impound 200 acre-feet, or less, over 12 consecutive months.

Non-exempt surface water diversions require a water right permit, issued and managed by the TCEQ. Because there are physical limits to the amount of water which can be permitted, water rights are granted on a "first come, first served" basis. The right specifies the volume of water which may be used annually and has an assigned priority date, which determines seniority. There is no guarantee that water will be available and regardless of the priority date, D&L users have seniority over other permitted uses. (Texas A&M AgriLife Extension 2014).

The TCEQ uses a Water Availability Model (WAM), the Water Rights Analysis Package, to estimate the amount of water available in a stream, under a specified set of conditions. Model output is used to recommend granting or denial of water right applications. At the time of this report, the WAM output for the Brazos River Basin, which includes the NCW, is under revision and currently unavailable. The WAM may be useful for estimating NCW minimum flows, and therefore of interest to the City of Belton, when it becomes available.

There are 10 upstream permitted diversions within NCW (Figure 11). These include diversion permits for 3 reservoirs, 1 mining operation, and 7 irrigation operations. Total permitted diversion amount is 837 acre feet (217 mg) per year, or an average of 0.6 MGD (Table 2). Note that permitted diversion amount may not reflect actual diversion. Amounts may be less than permitted maximum and not utilized uniformly over time. For example, irrigation diversions are not typically utilized year round and are more likely to be tapped during the growing season under dry weather conditions. Exempt water rights were not considered; data were unavailable. Totaled diversion amounts account for about -2% (i.e., loss) of average daily Nolan Creek flow.

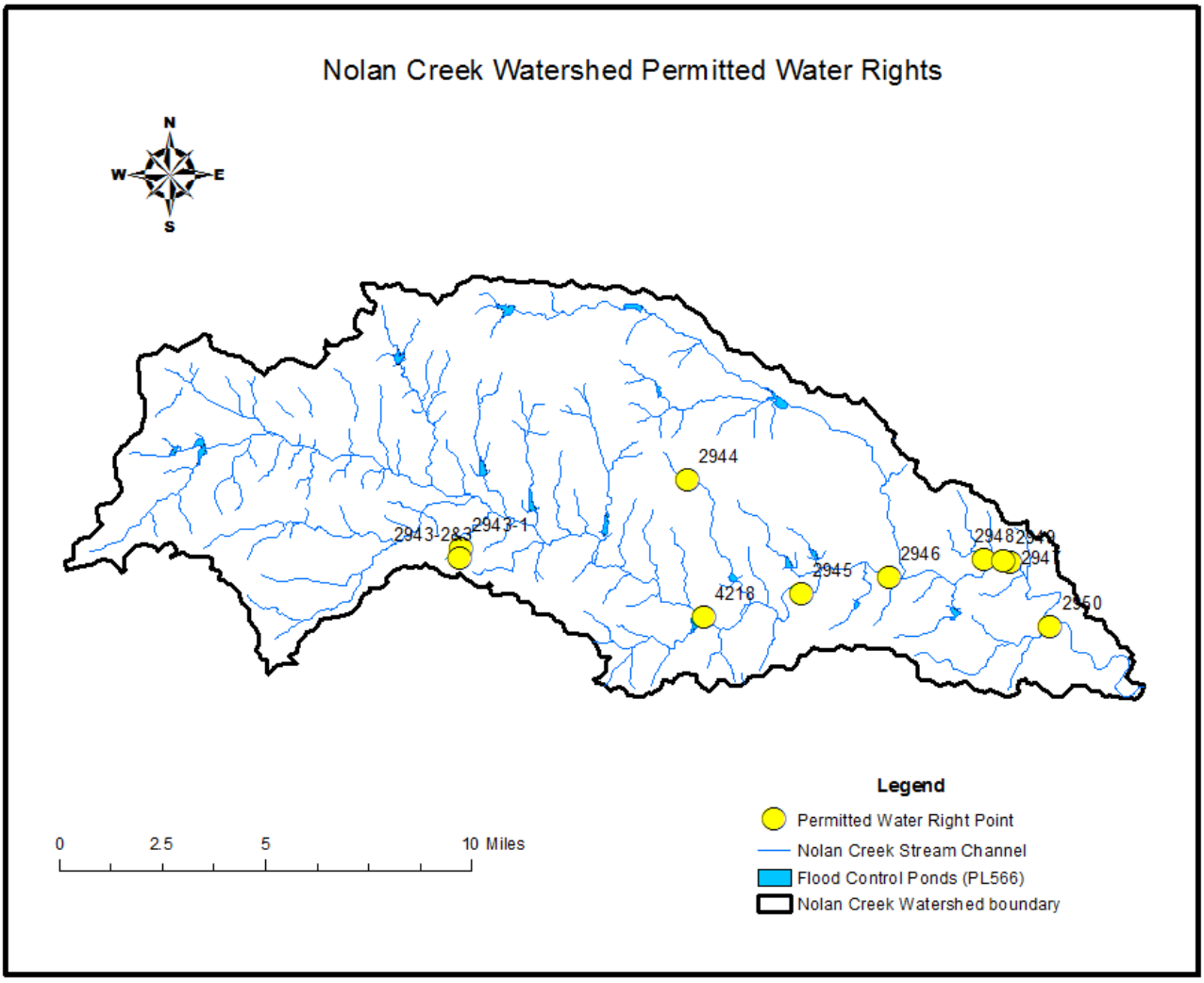

Figure 11. Nolan Creek Watershed Texas Water Right permitted diversions.

Table 2. Permitted water right ID number, owner, use, and maximum diversion amount (acre feet per year)

WR ID	Owner	Use	Amount
2943-1	City of Killeen & Killeen Willows INC - Golf course, Res1	Irrigation	20
2943-2&3	City of Killeen & Killeen Willows INC - Golf course, Res 2&3	Irrig., Rec.	121
2944	Franklin Limestone Company	Mining	138
2945	Glenn Baird	Irrigation	36
2946	J B Siebenlist	Irrigation	24
2947	P E Powell	Irrigation	11
2948	C E Dickson	Irrigation	278
2949	C E Dickson	Irrigation	37
4218	M D Connell	Irrigation	172
TOTAL			837

Flow Characterization

TCEQ personnel measured flow in conjunction with monthly water quality monitoring, from May through December, 2013, at 9 locations along Nolan Creek. Five of the 8 measurements were taken during periods with no rainfall occurrence 7 to 10 days prior to the measurement and represent good estimates of base flow, plus upstream discharges and diversions.

Creek flow characterization was determined through a "seepage run" analysis described by Riggs (1972). TCEQ personnel measured stream flow in conjunction with water quality measurements, monthly from May through December, at 9 locations along Nolan Creek, above Belton. The average discharge for each monitoring point was plotted over the course of the stream to examine gains and losses between each point (Figure 12). Figure 13 shows each monitoring point in relation to wastewater outfalls and permitted diversions. It is apparent that the Killeen main plant (10351-001) contributes a large portion of the flow with a significant gain between points 11915 and 18828. The stream shows a loss, due to natural seepage or an unknown diversion, between points 18827 and 11910. There is a gain from Killeen south plant and Nolanville wastewater outfalls beyond monitoring point 11911. The stream continues to gain flow, most likely from tributaries and natural in-channel sources, as it continues toward Belton. For example, observable outflow from an un-named in-channel spring near the confluence of South Nolan Creek and Nolan Creek has been reported (Personal communication: A. Owen, Texas A&M AgriLife Research – Blackland, 2014). Finally, there is a slight decrease in flow between monitoring points 11905 and 14237 that is attributable to permitted diversions.

Flow Budget

Nolan Creek base flow was estimated by subtracting 2013 average monthly wastewater outfall volumes and average permitted diversions from water quality monitoring station flow volume collected on 2013 dates with no significant rainfall in the preceding week (5 measurements). The value was also adjusted to reflect seasonal variation using available spring flow variation data. The final estimate ranged between 3.76 and 11.85 MGD (Table 3). Greatest base flow may be expected in the spring to early summer and lowest during the winter months.

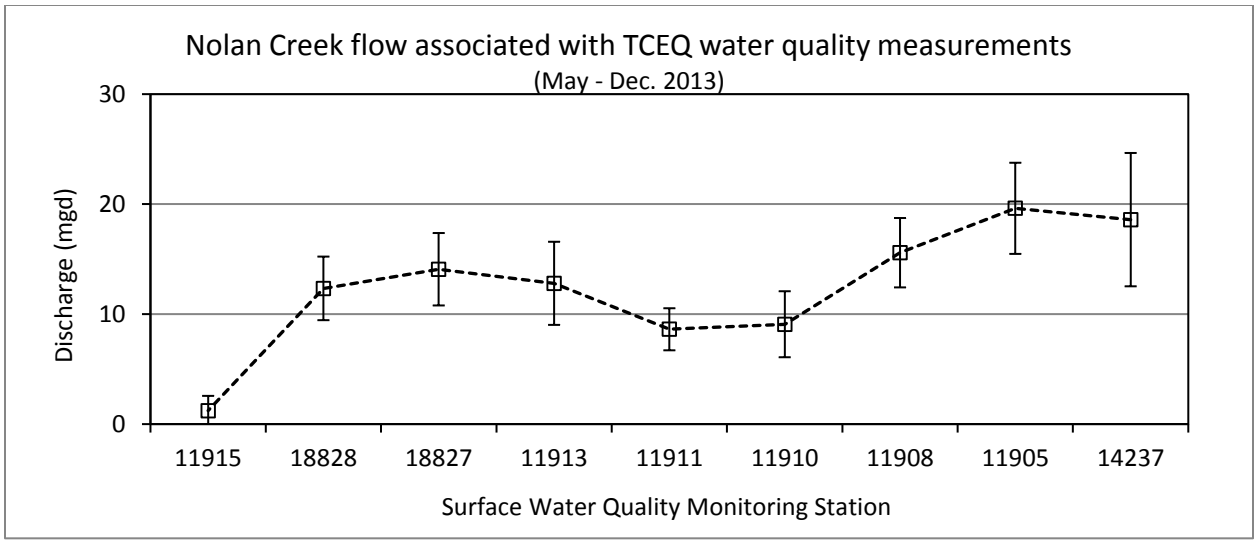

Figure 12. Monthly flow along Nolan Creek measured during TCEQ surface water quality monitoring in 2013.

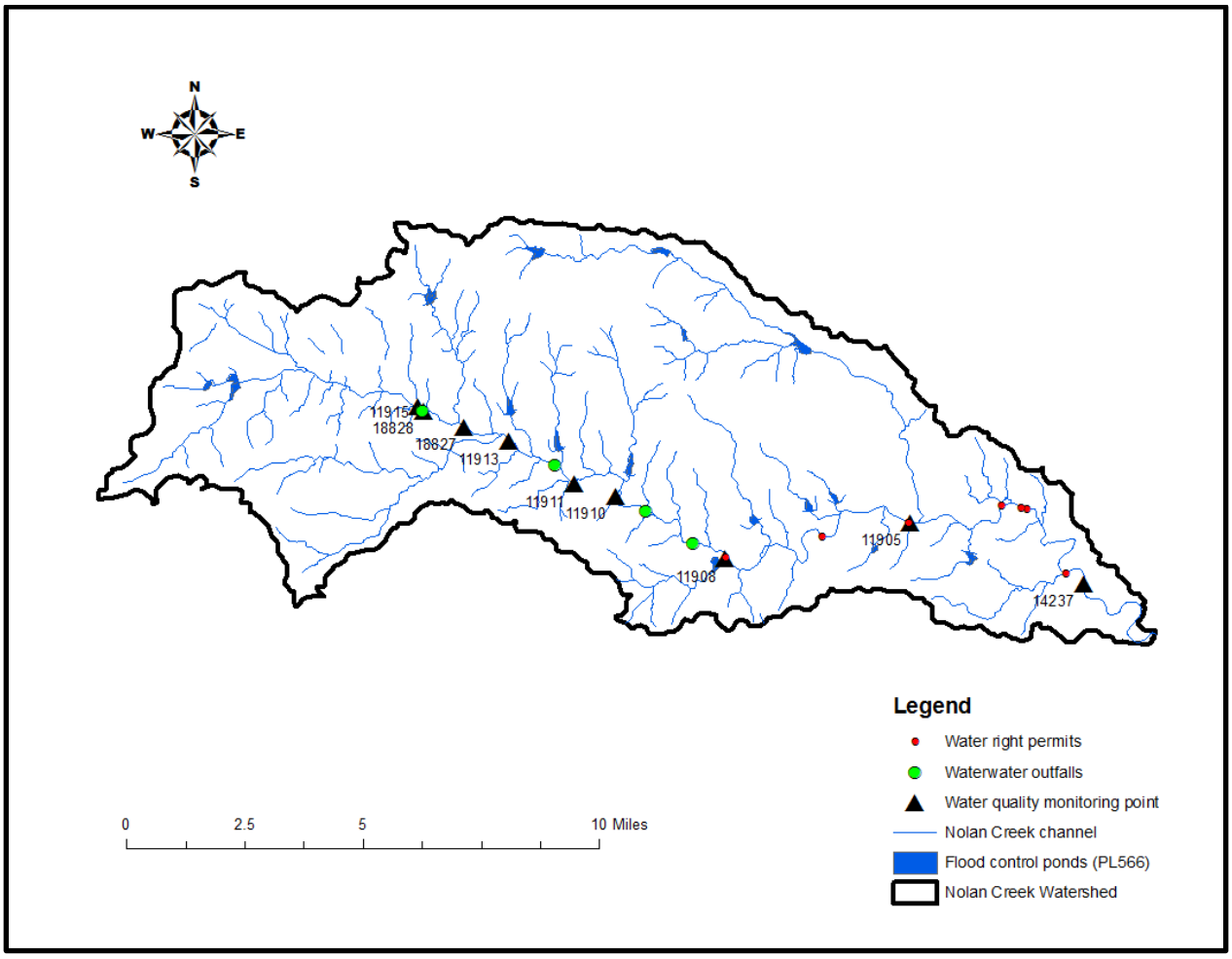

Figure 13. TCEQ surface water quality monitoring locations along Nolan Creek.

A Nolan Creek average monthly flow budget was determined by summing upstream estimated base flow, known permitted wastewater discharges, and permitted diversions. Irrigation diversions fluctuate with seasonal demand and adjusted accordingly. Total monthly flow averages ranged between 20.1 and 27.0 MGD. Percent flow contributions, by source were: 35% base flow, 46% Killeen main plant, 12% Killeen south plant, 8% Harker Heights plant, and 1% Nolanville plant. Diversions accounted for -2% (Table 3). Based on available data, the current minimum expected flow (19 MGD) easily exceeds the minimum flow requirement for the City of Belton's engineered channel plans (10-15 MGD). This estimate should be used with caution as it is based on one year of data and may not be representative over time.

Table 3. Nolan Creek average monthly water budget derived from estimated base flow, wastewater discharge (Killeen, Harker Heights, Nolanville), and permitted diversions.

Month	Base Flow*	Killeen main	Killeen south	Harker Heights	Nolanville	Permitted diversions	TOTAL
Jan	6.91	11.21	2.81	1.98	0.30	-0.25	22.96
Feb	9.10	12.67	3.58	2.10	0.27	-0.25	27.46
Mar	11.55	12.43	3.95	2.26	0.24	-0.25	30.18
Apr	11.85	11.16	3.29	2.03	0.24	-0.25	28.32
May	10.41	10.60	3.36	2.15	0.25	-0.75	26.02
Jun	10.61	10.06	2.90	2.01	0.25	-0.75	25.07
Jul	9.27	10.54	2.79	1.93	0.24	-0.75	24.02
Aug	9.14	10.62	2.06	1.68	0.24	-0.75	22.99
Sep	8.27	11.99	2.22	1.84	0.24	-0.75	23.81
Oct	4.41	11.83	3.12	2.01	0.23	-0.75	20.85
Nov	3.76	10.97	2.61	1.83	0.21	-0.25	19.14
Dec	5.77	11.05	2.40	1.83	0.24	-0.25	21.04
Average	8.42	11.26	2.93	1.97	0.24	-0.50	24.32
% of total	35%	46%	12%	8%	1%	-2%	

*Base flow estimated by subtracting upstream flow totals from downstream flow measurements, taken during periods with no rainfall, and adjusted for seasonal variation using available spring flow data.

Planned and Potential Flow Budget Changes

With growing populations and increasing water demand, diversion and recycling of wastewater discharge has gained attention. Interviews with wastewater managers from Killeen and Harker

Heights revealed plans to implement some re-use and recycling diversions that will directly affect Nolan Creek flow. A plan to divert 0.5 MGD from Killeen main plant to irrigate a golf course will likely be implemented in the future, but no specific date has been set. A permit to discharge 2 MGD from Killeen south plant into the Lampasas River Watershed, rather than to Nolan Creek, has been approved and "will commence in the near future". The City of Harker Heights has considered a wastewater diversion from its plant to irrigate a soccer field but costs to implement the project are too high at the current time. Known projected changes, if implemented could reduce Nolan Creek flow by 10-11% (Table 4). Based on available data, the current minimum expected flow with planned and proposed reductions (17 MGD) exceeds the minimum flow requirement for the City of Belton's engineered channel plans (10-15 MGD). Additional flow reductions due to future water right permits for the NCW are unknown. TCEQ is currently revising the WAM for the Brazos River Watershed to assist granting of future Texas water right permits. Population growth and associated wastewater discharge increases could offset future diversions.

Table 4. Known planned and proposed wastewater recycling or diversions directly affecting Nolan Creek flow, based on 2013 data.

	Current	Planned	Planned	Proposed	
Month	Base flow, discharges, and diversions	Killeen main	Killeen south	Harker Heights	TOTAL
Jan	22.96	0.00	-2.00	0.00	20.96
Feb	27.46	0.00	-2.00	0.00	25.46
Mar	30.18	-0.50	-2.00	-0.50	27.18
Apr	28.32	-0.50	-2.00	-0.50	25.32
May	26.02	-0.50	-2.00	-0.50	23.02
Jun	25.07	-0.50	-2.00	-0.50	22.07
Jul	24.02	-0.50	-2.00	-0.50	21.02
Aug	22.99	-0.50	-2.00	-0.50	19.99
Sep	23.81	-0.50	-2.00	-0.50	20.81
Oct	20.85	0.00	-2.00	0.00	18.85
Nov	19.14	0.00	-2.00	0.00	17.14
Dec	21.04	0.00	-2.00	0.00	19.04
Average	24.32	-0.29	-2.00	-0.29	21.74
% of Total	100%	-1.2%	-8.2%	-1.2%	89.4%

Summary

- Engineered channel design requires between 10 and 15 MGD to support kayaking
- Engineered design offers aesthetic, environmental, and safety value beyond main intent
- USGS gauged Nolan Creek from 1974 to 1982; lowest observed flow was 13.6 MGD
- Belton Flood Alert System can be configured to support recreation and flow analyses
- Current estimated monthly base flow ranges between 3.8 MGD and 11.9 MGD
- Current permitted monthly wastewater discharge ranges between 14.6 and 18.8 MGD
- Current averaged monthly diversion ranges between 0.25 and 0.75 MGD
- Current un-permitted diversion amounts are unknown
- Current estimated monthly flow budget ranges between 18.7 and 24.0 MGD
- Planned wastewater diversions may reduce current flow budget 2.0 to 3.0 MGD
- Population increase and associated wastewater increases could offset diversions

- Current estimated monthly flow, with planned and proposed re-use/recycling diversions, ranges between 17.1 and 27.2 MGD. This value exceeds the City of Belton's engineered channel design minimum flow requirement of 10 to 15 MGD, indicating the loss of sufficient flow to support kayaking is unlikely, based on available data.

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APPENDIX A

USGS Stream Gauge 08102600 at Belton, Texas

UNITED STATES
DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY
Water Resources Division

Description prepared 5/1/74
by EEW
Reviewed 5/30/74
by WDR
District review 10/1/74
by LGS

Station No. 08102600

Description of Gaging Station on NOLAN CREEK AT BELTON, TEX.

Location.--Lat 31°03'06", long 97°27'25", Bell County (determined from USGS topographic map, Belton Quadrangle, 1965 edition, scale 1:24,000). on left bank, 43 ft downstream from centerline of downstream service road of Interstate Highway 35, 86 ft from left end of bridge, 0.5 miles southeast of the courthouse at Belton, and 3.1 miles upstream from mouth.

Drainage area.--112 sq mi. Measured on USGS topographic maps, scale 1:24,000.

Establishment and history.--Jan. 30, 1974, to _____: On Jan. 30, 1974, the USGS established a recording bubble gage.

Gage.--Digital punch tape recorder in tandem with graphic water-stage recorder housed in a 4 x 6 ft metal shelter on 6 x 6 ft concrete base 4 ft high.
Recorder will function from 1.92 to about 32 ft.
Datum of gage is 480.84 ft above mean sea level, datum of 1929.

Elevation of various features above datum of gage:

Top of 2-inch orifice cap	2.05
Floor of shelter house	27.2
Top of instrument shelf	31.2

Bubble gage:

Recorder is operated by a 35-foot (maximum range manometer) bubble gage. Plastic tubing from shelter to orifice is encased in 3/4-inch pipe except the orifice end which consists of 21 ft of 2-inch pipe anchored securely to solid rock streambed, a 90° ell with a 24-inch nipple turned downstream.

Orifice is located 12 ft upstream and 198 ft to right of centerline of gage shelter.

Outside gage:

Enameled gage sections, USGS type mounted on 6-inch channel iron with wood backing facing Interstate Highway 35 are located as follows:

13.6-16.9	1 ft downstream and 103 ft to the right of centerline of gage shelter.
17.0-20.3	2 ft downstream and 91.5 ft to right of centerline of gage shelter.
20.4-23.7	79 ft to the right of centerline of gage shelter.
23.8-27.3	1 ft upstream and 35.5 ft to the right of centerline of gage shelter.

Wire-weight gage:

A type A wire-weight gage is attached to downstream side of bridge at gage opposite sounding station 112. It is used as base gage below 13.6 ft.

Elevation of check bar by levels	15.90 ft
Elevation of check bar by dial	15.90 ft

Control.--Low-water control is solid rock with wock rubble 45 ft below orifice and is fairly stable. Medium-and high-water control is bed and banks with trees on right bank and small growth on left bank.

Discharge measurements.--Wading: Low-water measurements (below 5.0 ft) can be made by wading in area of orifice.

Bridge.--Medium: Stage measurements (5.0 to 13.0 ft) can be made from upstream side of downstream service road at gage. Initial point for sounding is the streamward face of the left abutment. Stations are marked every 5 ft with ceramic markers glued to walkway, one every 10 ft, two each 50 ft, and three at the 100-foot stations.

Bridge.--High: Stage measurements (above 13 ft) can be made from upstream side of bridge on Interstate Highway 35 about 200 ft above gage. Initial point for sounding is the streamward face of left abutment. Stations are marked every 10 ft with ceramic markers glued to upstream walkway, one every 10 ft, two each 50 ft, and three at the 100-foot stations.

Floods.--Historical information begins in 1900. Highest stages since that date occurred in 1913, 1921, and 1957. All were about the same stage, according to Mr. E. W. Cline born in Bell County 1896. Mr. Cline's brother agrees to the above statement.
According to Mr. P. P. Wilhit, born April 1900 and living in Belton since 1926, says the 1957 flood was highest since his arrival in Belton.
Elevation of the 1957 and 1965 floods by levels to high-water mark located in house of Mrs. Robert Brown 100 ft below gage is 24.5 ft. Mrs. Brown indicated she has lived at this location since 1952. She indicated the 1957 and 1965 floods were the highest since that time and they were about the same elevation.

Point of zero flow.--Not determined at this time, but should be checked when possible.

Winter flow.--Little or no ice effect.

Regulation.--Flow partly regulated by 13 floodwater-retarding structures with a total combined drainage area of 47.4 sq mi and a total combined storage capacity of 15,715 ac-ft (May 1974).

Diversion and return water.--Numerous diversions upstream for irrigation, amounts unknown. Discharges made into creek by Fort Hood Reservation, and cities of Killeen, Harker Heights, and Nolanville, amounts unknown.

Accuracy.--Records for all stages should be good.

Cooperation.--Construction and operation of gage financed 50% by USGS, 41% by Brazos River Authority, and 9% by the Texas Water Development Board.

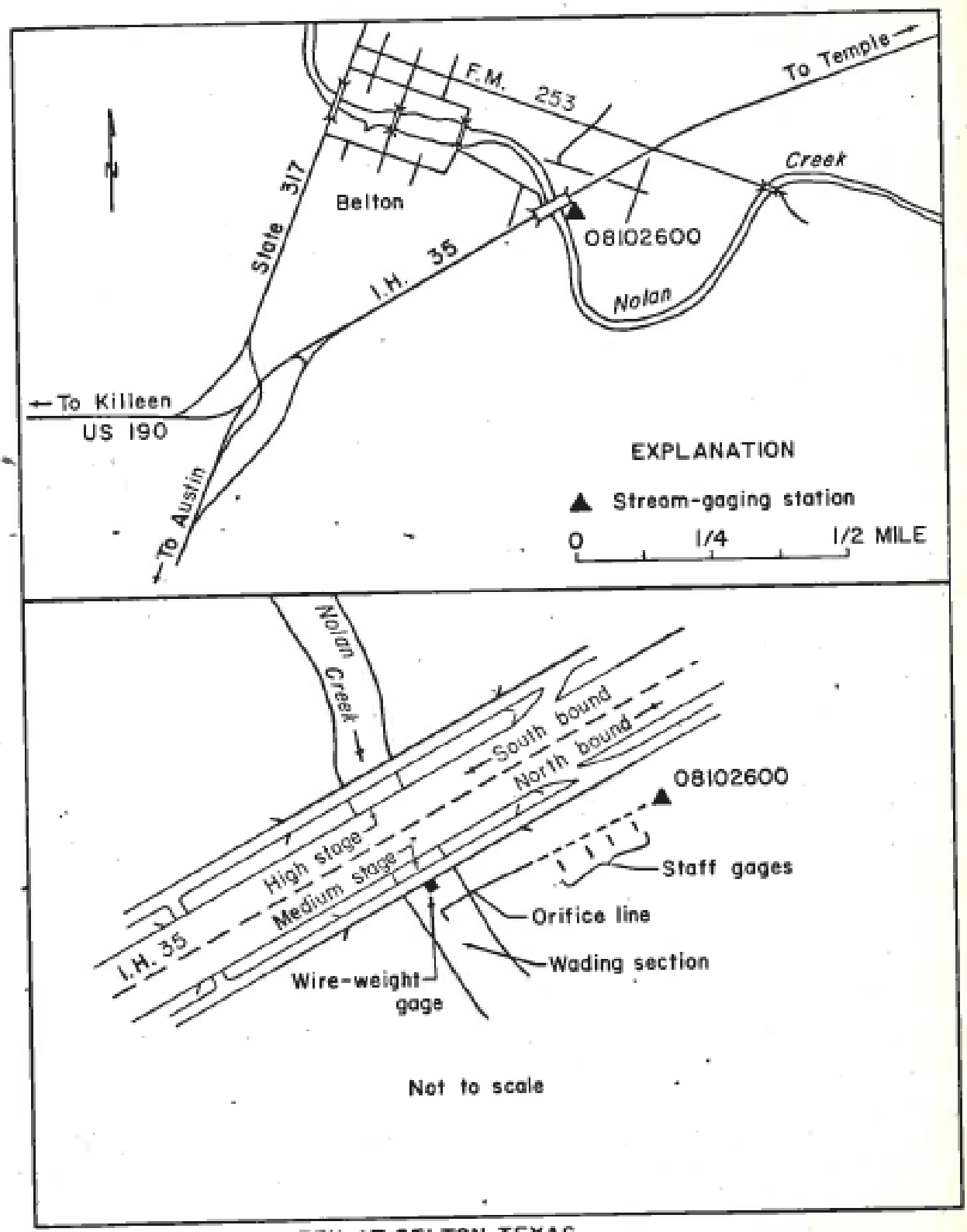
Classification.--(-C2--R532).

Justification.--Station needed to coordinate QW samples (collected by Brazos River Authority) with discharge in order to determine quality of water above Belton Sewage Disposal Plant.

Reference Marks.--RM-1 (Estab. 1-30-73). Standard USGS WR bronze tablet set on downstream walkway on the left end of downstream service road 36 ft upstream and 86 ft to the right of centerline of gage shelter. Elevation above zero of gage 17.32 ft.
RM-2 (Estab. 1-30-73). Standard USGS WR bronze tablet set in solid rock outcrop located 160 ft to the right of centerline of gage shelter.

USCGS C240. 0.2 mile south along U.S. Highway 190 from post office at Belton, Bell County, at a concrete bridge over Nolan Creek, in the top of the east end of the south abutment, and 17.4 ft east of the centerline of the highway. A standard disk, stamped "C 240 1953". Elevation above mean sea level 522.781 ft (datum of 1929 adjusted 1953). Elevation above zero of recording gage 24.63 ft. For sea level datum of gage, see "Gage" paragraph.

Aerial photo.--Aerial photo no. AWW-5GG-182 was taken 12-5-65. Photo obtained from the U.S. Department of Agriculture.



08102600 NOLAN CREEK AT BELTON, TEXAS

APPENDIX B

Killeen: monthly wastewater discharge 2009-2013

Main Plant (No. 10351-002)

South Plant (No. 14387-001)

Date	Main plant (No. 10351-002) Discharge (MGD)	South plant (No. 14387-001) Discharge (MGD)
1/31/2009	7.6	3.1
2/28/2009	9.0	3.1
3/31/2009	10.5	3.6
4/30/2009	10.8	3.5
5/31/2009	10.8	na
6/30/2009	10.0	3.5
7/31/2009	9.8	3.3
8/31/2009	10.3	3.3
9/30/2009	11.8	4.3
10/31/2009	17.7	5.8
11/30/2009	13.2	4.6
12/31/2009	12.3	4.4
1/31/2010	14.6	4.6
2/28/2010	19.9	6.9
3/31/2010	16.5	6.6
4/30/2010	13.1	4.7
5/31/2010	10.7	4.0
6/30/2010	9.9	3.6
7/31/2010	11.2	3.7
8/31/2010	11.8	1.1
9/30/2010	15.8	1.2
10/31/2010	11.7	1.0
11/30/2010	11.4	1.0
12/31/2010	10.9	1.0
1/31/2011	12.9	1.1
2/28/2011	12.7	1.3
3/31/2011	10.2	2.3
4/30/2011	9.3	3.3
5/31/2011	10.4	3.0
6/30/2011	10.1	1.7
7/31/2011	9.1	2.6
8/31/2011	9.2	2.7
9/30/2011	9.1	2.4
10/31/2011	8.8	2.5
11/30/2011	9.8	1.6
12/31/2011	11.6	1.3
1/31/2012	11.1	1.9
2/29/2012	12.0	3.4
3/31/2012	15.1	4.4

Date	Main plant (No. 10351-002) Discharge (MGD)	South plant (No. 14387-001) Discharge (MGD)
6/30/2012	10.6	2.2
7/31/2012	11.3	1.6
8/31/2012	11.5	0.9
9/30/2012	12.8	0.8
10/31/2012	9.8	3.0
11/30/2012	9.2	2.8
12/31/2012	9.2	2.7
1/31/2013	9.9	3.3
2/28/2013	9.8	3.3
3/31/2013	9.9	2.9
4/30/2013	11.7	1.6
5/31/2013	10.8	3.5
6/30/2013	9.7	3.5
7/31/2013	11.2	2.9
8/31/2013	10.3	2.4
9/30/2013	10.4	2.4
10/31/2013	11.3	3.4
11/30/2013	11.4	3.0
12/31/2013	11.2	2.7

APPENDIX C

Harker Heights: monthly wastewater discharge 2006-2014

Single Plant (No. 10155-001)

Harker Heights Wastewater Plant (No. 10155-001)

Month	Average Flow MGD
June-06	1.61
July-06	1.56
August-06	1.44
September-06	1.67
October-06	1.63
November-06	1.52
December-06	1.63
January-07	2.43
February-07	1.82
March-07	2.89
April-07	2.76
May-07	3.86
June-07	4.23
July-07	3.29
August-07	1.83
September-07	1.70
October-07	1.59
November-07	1.62
December-07	1.70
January-08	1.62
February-08	1.77
March-08	2.15
April-08	1.91
May-08	1.86
June-08	1.52
July-08	1.33
August-08	1.61
September-08	1.56
October-08	1.62
November-08	1.54
December-08	1.58
January-09	1.68
February-09	1.49
March-09	1.76
April-09	1.80
May-09	1.96
June-09	1.65
July-09	1.61
August-09	1.66
September-09	2.40
October-09	4.17
November-09	2.87
December-09	2.59
January-10	2.71
February-10	4.33
March-10	3.32
April-10	2.42

Month	Average Flow MGD
May-10	1.87
June-10	1.74
July-10	1.89
August-10	1.63
September-10	2.16
October-10	1.68
November-10	1.86
December-10	1.88
January-11	2.18
February-11	2.12
March-11	1.84
April-11	1.83
May-11	1.93
June-11	1.82
July-11	1.75
August-11	1.79
September-11	1.85
October-11	1.87
November-11	1.53
December-11	1.69
January-12	1.66
February-12	1.94
March-12	2.57
April-12	1.85
May-12	1.60
June-12	1.60
July-12	1.59
August-12	1.58
September-12	1.66
October-12	1.61
November-12	1.76
December-12	1.69
January-13	1.89
February-13	1.63
March-13	1.87
April-13	1.96
May-13	2.14
June-13	1.91
July-13	2.41
August-13	1.93
September-13	1.73
October-13	1.91
November-13	1.97
December-13	1.84
January-14	1.68
February-14	1.68
March-14	1.66
April-14	1.74
May-14	1.98

APPENDIX D

Nolanville: monthly wastewater discharge 2012-2014

Single Plant (No. 10709-001)

Bell County WCID #3
Waste Water Treatment Plant
700,000 gpd capacity / 675,000 gpd capacity

monthly flow avg. / highest daily flow / rainfall for month / monthly BOD avg.

YEAR 2011	YEAR 2012	YEAR 2013	YEAR 2014
Jan.378/.452/4.4”/3.25	.292/.342/3.1”/4	.249/.374/4.85”/2	.261/.329/0”/2.4
Feb.346/.514/.75”/4.25	.290/.500/.4.05”/1.75	.157/.217/1.5”/2.25	.268/.320/.50”/2.2
Mar.235/.438/0”/2.2	.380/.750/.7.45”/3.6	.153/.201/2”/2.75	.209/.243/3.0”/2.5
Apr..189/.300/.25”/2.25	.293/.367/.5”/.75	.193/.326/1”/3.5	.274/.300/1.37”/2.7
May.236/.434/2.5”/2.25	.260/.410/2.5”/2.6	.277/.373/9.75”/3.8	.224/.300/5.6”/4.4
Jun..216/.295/.5”/2.2	.293/.340/2.5”/2.25	.237/.302/1.2”/2.5	.234/.304/3.2”/2.7
Jul.201/.291/0”/3.25	.263/.459/4.5”/3.75	.236/.371/4”/3.25	.251/.390/1.25”/3.8
Aug..202/.397/0”/2.5	.286/.392/2.5”/2.8	.227/.302/3”/2.4	
Sep..203/.222/.05”/2.8	.291/.405/3.01”/4.25	.219/.242/5.33”/3.8	
Oct..231/.286/3.5”/2.5	.203/.363/.26”/4	.245/.326/8”/2.0	
Nov.224/.277/.5”/2.5	.203/.267/0”/ 2.5	.191/.268/3.5”/2.7	
Dec.278/.408/2.5”/4.4	.270 /.436/.85”	.179/.214/1.2”/2.0	

ANNUAL AVERAGES

monthly flow avg. / highest monthly flow / rainfall for year / yearly BOD avg.

YEAR 2011	YEAR 2012	YEAR 2013	YEAR 2014
.245/.360/1.24”/2.9	.277/.419/2.6”/2.9	.214/.293/39.33”/2.75	

APPENDIX E

TCEQ Surface Water Quality Monitoring

Nolan Creek: Stream Segment 1218

May to December 2013

Stream Segment ID	Station ID	Date	Time	Flow (cfs)
1218	14237	5/8/2013	7:17	24
1218	14237	6/4/2013	7:22	35
1218	14237	7/10/2013	7:38	17
1218	14237	8/6/2013	6:42	26
1218	14237	9/11/2013	7:12	37
1218	14237	10/8/2013	7:11	19
1218	14237	11/13/2013	7:37	32
1218	14237	12/12/2013	7:36	45
1218	11905	5/8/2013	7:41	34
1218	11905	6/4/2013	7:51	34
1218	11905	7/10/2013	8:03	17
1218	11905	8/6/2013	7:05	31
1218	11905	9/11/2013	7:33	35
1218	11905	10/8/2013	7:32	26
1218	11905	11/13/2013	7:58	34
1218	11905	12/12/2013	8:05	37
1218	11908	5/8/2013	8:02	31
1218	11908	6/4/2013	8:18	27
1218	11908	7/10/2013	8:20	17
1218	11908	8/6/2013	7:26	28
1218	11908	9/11/2013	7:50	18
1218	11908	10/8/2013	7:47	23
1218	11908	11/13/2013	8:16	25
1218	11908	12/12/2013	8:23	28
1218	11910	5/8/2013	8:18	10
1218	11910	6/4/2013	8:42	18
1218	11910	7/10/2013	8:38	9
1218	11910	8/6/2013	7:42	13
1218	11910	9/11/2013	8:05	13
1218	11910	10/8/2013	8:03	11
1218	11910	11/13/2013	8:33	19
1218	11910	12/12/2013	8:40	22
1218	11911	5/8/2013	8:34	10
1218	11911	6/4/2013	8:56	18
1218	11911	7/10/2013	8:56	12
1218	11911	8/6/2013	7:56	14
1218	11911	9/11/2013	8:18	12
1218	11911	10/8/2013	8:15	11
1218	11911	11/13/2013	8:46	18
1218	11911	12/12/2013	8:54	14
1218	11913	5/8/2013	8:52	24
1218	11913	6/4/2013	9:14	26
1218	11913	7/10/2013	9:16	10
1218	11913	8/6/2013	8:14	17
1218	11913	9/11/2013	8:34	16
1218	11913	10/8/2013	8:31	19
1218	11913	11/13/2013	9:04	22
1218	11913	12/12/2013	9:13	28

Stream Segment ID	Station ID	Date	Time	Flow (cfs)
1218	18827	5/8/2013	9:21	19
1218	18827	6/4/2013	9:56	18
1218	18827	7/10/2013	9:45	18
1218	18827	8/6/2013	8:40	21
1218	18827	9/11/2013	9:02	21
1218	18827	10/8/2013	8:59	21
1218	18827	11/13/2013	9:30	27
1218	18827	12/12/2013	9:39	33
1218	11915	5/8/2013	10:06	3
1218	11915	6/4/2013	10:23	3
1218	11915	7/10/2013	10:22	2
1218	11915	8/6/2013	9:32	3
1218	11915	9/11/2013	9:38	3
1218	11915	10/8/2013	9:36	3
1218	11915	11/13/2013	10:05	5
1218	11915	12/12/2013	10:20	3
1218	14237	5/8/2013	7:17	24
1218	14237	6/4/2013	7:22	35
1218	14237	7/10/2013	7:38	17
1218	14237	8/6/2013	6:42	26
1218	14237	9/11/2013	7:12	37
1218	14237	10/8/2013	7:11	19
1218	14237	11/13/2013	7:37	32
1218	14237	12/12/2013	7:36	45
1218	11905	5/8/2013	7:41	34
1218	11905	6/4/2013	7:51	34
1218	11905	7/10/2013	8:03	17
1218	11905	8/6/2013	7:05	31
1218	11905	9/11/2013	7:33	35
1218	11905	10/8/2013	7:32	26
1218	11905	11/13/2013	7:58	34
1218	11905	12/12/2013	8:05	37
1218	11908	5/8/2013	8:02	31
1218	11908	6/4/2013	8:18	27
1218	11908	7/10/2013	8:20	17
1218	11908	8/6/2013	7:26	28
1218	11908	9/11/2013	7:50	18
1218	11908	10/8/2013	7:47	23