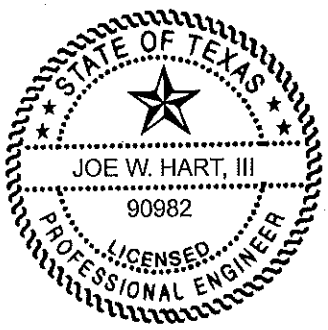
CITY OF CANTON

PWS #2340001

GRAND SALINE CREEK RESERVOIR STUDY

JUNE 20, 2017



June 20, 2017

Prepared by:

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INTRODUCTION AND SCOPE

The City of Canton retained Johnson and Pace Incorporated (JPI) to perform a study for a potential water supply reservoir on the Grand Saline Creek in Van Zandt County. The potential water supply reservoir is referred to as the Grand Saline Creek Reservoir in this report. The purpose of this report is to determine if the Grand Saline Creek Reservoir is a suitable long-term water supply solution for the City of Canton.

In 2009, Gary Burton Engineering Inc. prepared a long-term water study for the City of Canton. The report concluded that the City of Canton would not be able to service a future population with the City's existing water supply. The long-term water study evaluated purchasing the raw or treated water versus constructing a proposed reservoir near the City of Canton. The study concluded that the construction of a reservoir with an intake pump station and pipeline would be the least cost prohibitive option. A reservoir on the Grand Saline Creek was determined to be a potential option due to its proximity to the City of Canton and a large watershed. In 2016, JPI began the study for the Grand Saline Creek Reservoir for the City of Canton. The viability of the reservoir will determine if the City of Canton should submit a water right application to the Texas Commission of Environmental Quality (TCEQ) to establish a priority date. JPI determined that the following items would be required to determine the viability of the Grand Saline Creek Reservoir:

1. Aerial Imagery and LiDAR Survey for the study limits
2. A Firm Yield analysis using the TCEQ's Water Availability Model (WAM)
3. A preliminary Hydrologic and Hydraulic analysis of the Reservoir

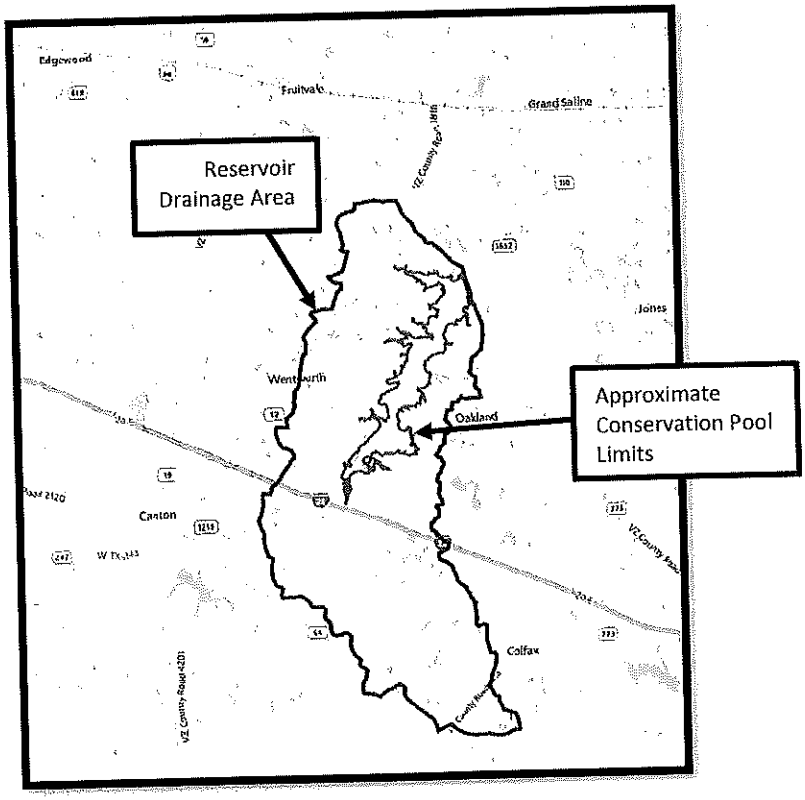

Figure 1. Grand Saline Creek Reservoir Location

AERIAL IMAGERY AND LIDAR SURVEY

JPI retained Dallas Aerial Survey Inc. (DAS) to provide Aerial Imagery and LiDAR Survey for the study limits. The study limits included 8,000 acres in the Grand Saline Creek Watershed. DAS flew the Aerial Imagery and the LiDAR at the same time on January 24, 2017. The flight date was determined because of the maximum ground surface availability that occurs when the leaves drop in the winter months. The Aerial Imagery was flown at 10 cm GSD with the UltraCam Lp digital aerial camera. LiDAR Survey was captured with the Riegl VQ-480 Sensor, and this provided a Digital Elevation Model (DEM) in LAS format. The LiDAR Survey Data was collected at a rate of 300,000 pulses per second, with 15 returns per pulse, and this corresponded to 1 point per meter.

The Aerial Imagery was ortho-rectified to produce digital imagery with a 6-inch pixel resolution. Planimetric features were developed from the study area that included roadways, bridges, buildings, creeks, rivers, lakes, ponds, railroads, transmission lines, power poles and fences. A digital terrain model (DTM) was derived from the LiDAR Survey points. Breaklines were then digitized from both the imagery and the LiDAR Survey points. Contours were generated from the breaklines and the LiDAR survey points and shown at 2.0' intervals.

JPI provided the essential ground control surveying that was necessary to determine the elevation and horizontal position of all control points required for the completion of LiDAR processing by Dallas Aerial Survey Inc. (DAS). Horizontal and vertical control was established by (GPS) techniques. Such control complied with the National Map Accuracy Standards. JPI furnished DAS with 14 control point locations, along with a list of coordinates and elevations for each point.

On April 21, 2017, JPI received the Aerial Imagery, topographic mapping data, and LiDAR survey points a DVD disc from DAS.

RESERVOIR DAM SITE ANALYSIS

JPI created CAD drawings and maps of the study limits from the information that was supplied by DAS. The first task was to generate a study limits map to identify reservoir dam locations. The study limits map included the Aerial Imagery, 2.0' contour lines, highlighted structures, and labeled infrastructure. The study limits map is titled "Overall Reservoir Site Map". Due to the map's large size it is included in a separate submittal.

JPI designated 3 potential reservoir dam locations, Site A, Site B, and Site C, along the Grand Saline Creek. After meeting with the City of Canton, Site A and Site C were selected for the preliminary Hydrologic and Hydraulic analysis and Reservoir Firm Yield Analysis.

Once the dam site locations were chosen, JPI extracted and processed the 2.0' interval contour lines from the DAS files. The contour lines of the Grand Saline Creek were used to generate stage-storage tables, also known as elevation-area tables, for the reservoir dam options. The Stage-Storage Tables for Site A and Site C can be found in Appendix A.

The next step was to determine a range of conservation pool elevations (also known as normal pool elevation). The 420.0' conservation pool elevation was evaluated for this study. By utilizing the survey information provided by DAS, it was determined that a conservation pool of 420.0' would permanently

retain water in the Texas Department of Transportation's (TxDOT) Right of Way (R.O.W.) of Interstate 20 and Farm to Market 1255. For this reason, the 420.0' conservation pool elevation was not included in the preliminary Hydrologic and Hydraulic Analysis and Reservoir Firm Yield Analysis.

The 416.0' conservation pool elevation was evaluated for this study. By utilizing the survey information provided by DAS, it was determined that a conservation pool of 416.0' would permanently retain water on the existing electrical substation located southeast of the intersection of Van Zandt County Roads 1213 and 1211. The lowest edge of the electrical substation pad is at elevation 415.1'. The existing electrical substation will need to be modified or relocated to accommodate a conservation pool elevation of 416.0'. An exhibit of the existing electrical substation can be found in Figure 2 below.

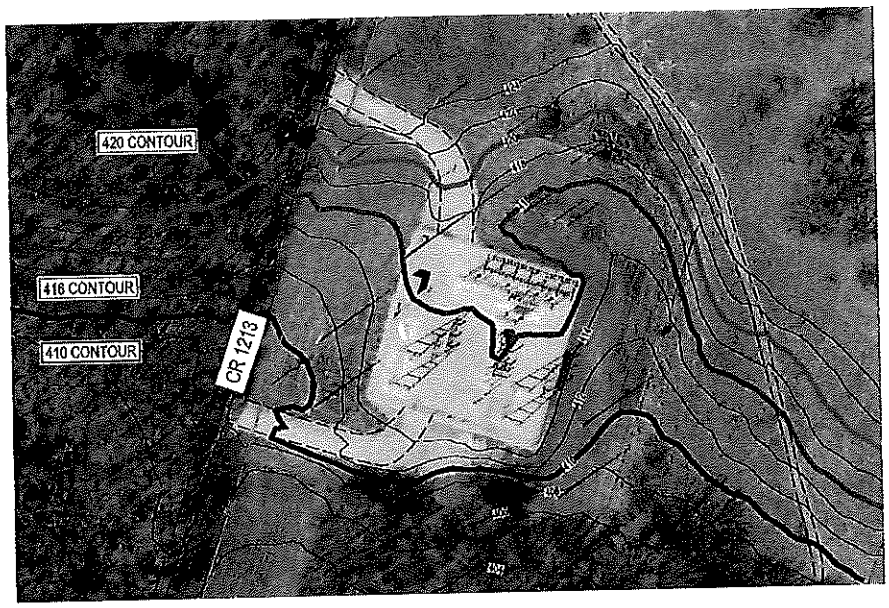

Figure 2. Existing Electrical Substation

The 410.0' conservation pool elevation was evaluated for this study, and it was determined that the 410.0' elevation did not retain water on the previously mentioned existing structures. However, the conservation pool elevation options of 410.0' and 416.0' will impact existing county roads, electric transmission lines, a gas transmission pipeline, abandoned oil/gas well, and existing water systems. The features are displayed on the study limits map is titled "Overall Reservoir Site Map". A future study will be needed to determine the logistical and financial impacts of the previously mentioned conflicts.

It was concluded that the conservation pool elevations of 410.0' and 416.0' would be included in the preliminary Hydrologic and Hydraulic Analysis and Reservoir Firm Yield Analysis.

PRELIMINARY HYDROLOGIC ANALYSIS

JPI prepared a preliminary Hydrologic Model of the Grand Saline Creek watershed at the location of the proposed dam locations Site A and Site C. The watershed for each dam location was generated based on 5.0' interval contour maps provided by the Texas Natural Resources Information System (TNRIS). The watershed area of Site A was calculated to be 33.48 square miles. The watershed area of Site C was calculated to be 28.62 square miles. A watershed map for Site A and Site C can be found in Appendix B.

The watershed areas for Site A and Site C were utilized in the Reservoir Firm Yield Analysis. The watershed area for Site A was utilized for the Hydrologic Model due to the larger size of the watershed area. The Hydrologic Model was developed using HEC-HMS Software (Version 4.2) by the U.S. Army Corp of Engineers. The design storm for the Reservoir was determined to be the Probable Maximum Flood (PMF) event, and the TCEQ's guidelines for design storm development titled "Hydrologic and Hydraulic Guidelines for Dams in Texas" were utilized in the PMF development. The 100 year-24 hour storm event was also analyzed to determine impacts to existing infrastructure.

Storm durations from 3 hours to 72 hours were analyzed using the TCEQ PMF rainfall distributions to determine the maximum water surface elevation in the Reservoir from the resulting storms. To determine the rainfall distributions, the total rainfall depths were estimated from the Texas Percent Maximum Precipitation publication. The estimated total rainfall depth values are preliminary, and they are subject to revision with the final design documents for the Reservoir. The rainfall depth for the 100 year-24 hour event was determined based on the maps provided by Technical Paper No. 40 (TP-40). The total rainfall depths can be found in Table 1:

Table 1. PMF Rainfall Depths

Storm Duration (HR)	Total Rainfall Depth (IN)
100 Year - 24 Hour	10.0
3	20.9
6	25.7
12	34.9
24	42.1
48	43.8
72	43.8

Uniform infiltration losses of 0.12 inch per hour were adopted based upon a preliminary review USGS Soil Maps and the NRCS Hydrologic Soil Groups and Uniform Infiltration (Loss) Rates. An initial loss of 0.75 inch was used for the 100-year-24 hour storm event, and no initial loss was used for the PMF. A unit hydrograph for the Grand Saline Creek Reservoir watershed areas using the Snyder Method. The Cp and Ct values were developed based on drainage studies in the surrounding East Texas area. The Cp and Ct values are subject to revision with the final design documents for the Reservoir.

PRELIMINARY HYDRAULIC ANALYSIS

JPI prepared a preliminary Hydraulic Model of the Grand Saline Creek watershed at the location of the proposed dam location Site A. The dam location at Site A was utilized for the Hydraulic Model due to the larger size of the watershed area. The conservation pool elevations of 410.0' and 416.0' were analyzed for the preliminary analysis using rating tables generated by HEC-HMS 4.2. The result printouts can be found in Appendix C

To maintain a conservation pool elevation of 410.0', a 150' wide spillway was set at elevation 410.0' to convey the 100 year-24 hour storm event. The water elevation for the 100 year – 24 hour storm event is 415.3'. A 600' wide emergency spillway was set at elevation 416.0' to convey larger and less frequent storm events. The PMF storm produced a water surface elevation of 421.8'. To account for wave action and other factors, the top of dam was determined to be at a minimum 3' higher than the PMF water surface elevation. In this scenario, top of dam was set at elevation 425.0'. There are no habitable structures at or below the 425.0' elevation.

To maintain a conservation pool elevation of 416.0', a 300' wide spillway was set at elevation 416.0' to convey the 100 year-24 hour storm event. The water elevation for the 100 year – 24 hour storm event is 419.7'. A 600' wide emergency spillway was set at elevation 420.0' to convey larger and less frequent storm events. The PMF storm produced a water surface elevation of 425.0'. To account for wave action and other factors, the top of dam was determined to be at a minimum 3' higher than the PMF water surface elevation. In this scenario, top of dam was set at elevation 428.0'. It appears that there is one habitable structure below the 428.0' elevation. On the ground field survey will have to be performed to validate this structure elevation.

RESERVOIR FIRM YIELD ANALYSIS

Surface water right applications submitted to the TCEQ are, as a part of the permitting process, reviewed and analyzed by TCEQ staff for sufficient water availability to fulfill the beneficial use requirements and for impacts to senior water rights. The TCEQ Water Availability Model (WAM) is the computer modeling system used to analyze surface water right applications. The TECQ WAM simulates all existing state surface water rights and environmental flow requirements within a river basin over the monthly hydrologic period of record. The WAM for the Sabine River Basin was used for the firm yield analysis.

Hoffpauir Consulting PLLC conducted the simulation of the WAM to determine the firm yield of the Reservoir. The Reservoir Locations Site A and Site C were analyzed for firm yield water supply. Modeling assumptions and other considerations are given in the report "Firm Yield Analysis of the Grand Saline Creek Reservoir Site", and the report is included in Appendix D. Table 2 presents the firm yield for Sites A and C with top of conservation pools at elevations 410.0' and 416.0'

Table 2: Estimated Firm Yields of the Proposed Grand Saline Reservoir

Site	Max Elevation feet	Storage Capacity acre-feet	Average Annual Streamflow acre-ft per year	**Estimated Firm Yield ac-ft per year**	**Estimated Firm Yield MGD**
A	416.0	17,162	17,942	**3,803**	**3.40**
A	410.0	9,549	17,942	**2,503**	**2.23**
C	416.0	10,613	15,338	**2,362**	**2.11**
C	410.0	5,137	15,338	**1,263**	**1.13**

For additional information and discussion related to the Estimated Firm Yields, Pending Amendment to Certificate 05-4658, and the Non-Firm Supply option please refer to the attached report in Appendix D.

CURRENT GROUND WATER SUPPLY

There are 3 wells that supply ground water to the public water system. According to the City of Canton, the 3 wells have a capacity of 597 gallons per minute (GPM) or 0.86 million gallons per day (MGD). During peak operation of the wells, it is expected that the wells will operate only 12 hours a day to allow the ground water level to recover. The water supply safe yield from the wells is half its capacity. This correlates to a yield of 299 GPM or 0.43 MGD for the ground water wells.

The wells pull from the Carrizo Formation and Wilcox Group aquifers. Due to the interrelated nature of the aquifers, they are commonly considered as the Carrizo-Wilcox aquifer.

CURRENT SURFACE WATER SUPPLY

The City of Canton owns two surface water reservoirs, Old City Lake and Mill Creek Lake. The City has 50 acre-feet per year available from Old City Lake, but it was concluded in Gary Burton's 2009 Report that it would be infeasible to use Old Creek Lake to supplement the current water supply. The City has a yield of 1,500 acre-feet per year that is available from Mill Creek Lake according to the water rights certificate of adjudication. The water rights certificate of adjudication is included in Appendix E.

The City of Canton currently has a request into the TCEQ for a Water Reuse Permit. According to the 2016 TWDB Region D North East Texas Regional Water Plan, the City of Canton has 323 acre-feet per year of potential indirect use if the TCEQ approves the permit application. This report assumes that the TCEQ will allow the permit for reuse.

Table 3 is a summary of the current water supply sources for the City of Canton.

Table 3: City of Canton Current Water Supply

Source	Capacity (MGD)	Capacity (Acre-Feet/Year)
Ground Water Wells	0.43	482
Mill Creek Reservoir	1.34	1,500
Proposed Indirect Reuse	0.29	323
Totals	2.06	2,305

CITY OF CANTON POPULATION AND WATER DEMAND

According to the 2010 Census, the estimated population for the City of Canton is 3,581. According to the 2004 Comprehensive Plan, the City of Canton, in its current configuration and zoning, can support a population of 34,268. The City of Canton is within 60 miles of downtown Dallas and within 37 miles of downtown Tyler. The location between major population centers, proximity to Interstate 20, and the continued growth of the Canton Trade Days primes the City of Canton for future growth. Future growth of the City of Canton can be justified by the recent growth rates of cities around Dallas. The populations of the cities of Forney, Celina, and Princeton have more than doubled in the past 25 years. Population growth, which was developed from U.S. Census Bureau data, of Forney, Celina, and Princeton can be viewed in Figure 3.

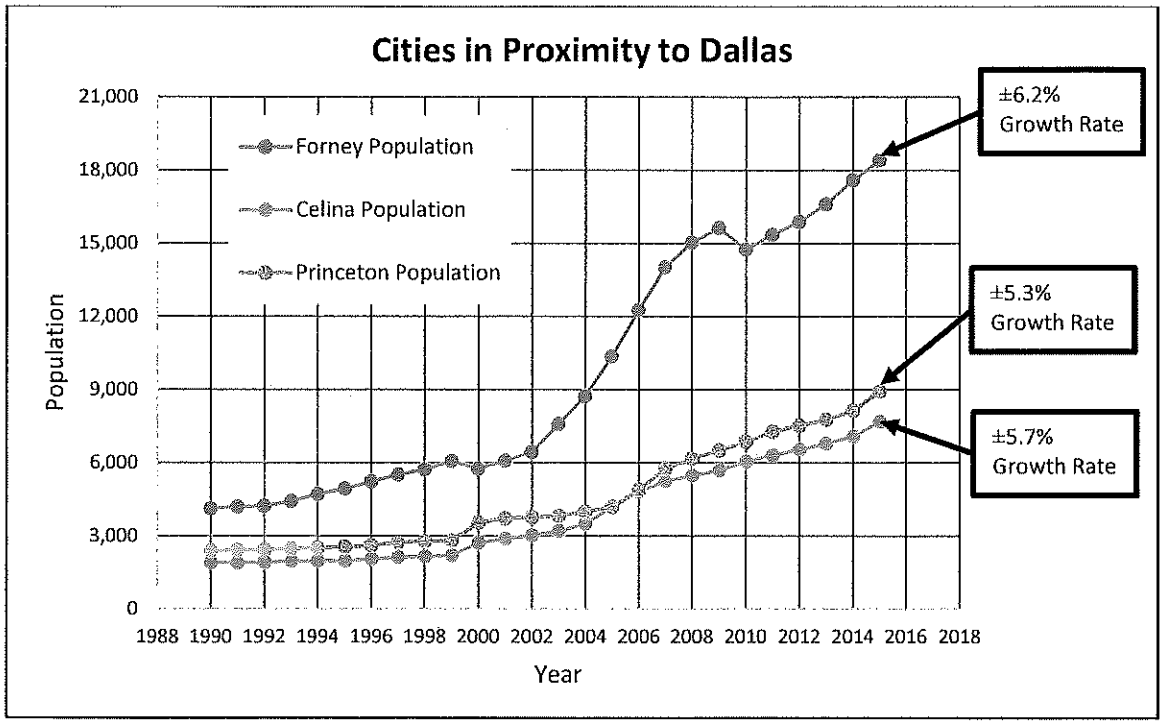

Figure 3. Cities in Proximity to Dallas

According to the Water User Group (WUG) Entity Detailed GPCD Report created by the TWDB, the City of Canton had a usage rate of 224 gallons per capita daily (GPCD) in 2011. The usage rate was not adjusted due to the population surges that occur during the Canton Trade Days. The WUG usage rate was utilized to establish the population size that the City of Canton's current and potential water supply can support. JPI calculated the potential population served based on the current and proposed water supply numbers. The values can be found in Table 5. A breakdown of the water supply calculations can be found in Appendix F.

Table 5: City of Canton Current and Proposed Water Availability

Source	Capacity (Acre-Feet/Year)	Capacity (MGD)	Potential Population Served
Current Water Supply	2,305	2.06	9,196
Proposed Water Supply with Proposed Grand Saline Creek Reservoir (Site A – 410.0')	4,808	4.29	19,152
Proposed Water Supply with Proposed Grand Saline Creek Reservoir (Site A – 416.0')	6,108	5.45	24,330

Opinion and methodology differ greatly when predicting at what year the City of Canton will reach a population of 24,330. Assuming a 2017 population of 3,581 and utilizing a geometric growth rate equation with a growth rate of 3.7%, The City of Canton will reach a population of 24,313 in the year 2070. If the City of Canton grows at the same rate as the City of Forney, which is unlikely, the City of Canton will reach a population of 24,791 in the year 2049. The calculations for these projections can be found in Appendix F. Detailed population projections are beyond the scope for this report.

CONCLUSION

The report concludes that the hydraulic effects of the Reservoir can be mitigated and that the Reservoir has the capacity to serve the future growth of the City of Canton for many decades in the future. The Grand Saline Creek Reservoir should be considered the most viable option for the long-term water supply strategy for the City of Canton which is consistent with the recommendations from the 2009 Long Term Water Study Report. The recommendation of this report is that the City of Canton should submit a water right application to the TCEQ to establish a priority date for the Grand Saline Creek Reservoir.

APPENDIX A: STAGE-STORAGE TABLES

GRAND SALINE CREEK RESERVOIR (SITE A)

STAGE (ELEV)	AREA (SQ FT)	AREA (ACRES)	STORAGE (ACRE-FT)
382	22,068	1	0
383	34,056	1	1
384	46,043	1	2
385	69,516	2	3
386	92,988	2	5
387	140,523	3	7
388	188,058	4	11
389	697,406	16	21
390	1,206,754	28	43
391	3,019,452	69	92
392	4,832,150	111	182
393	6,129,328	141	308
394	7,426,506	170	463
395	8,674,351	199	648
396	9,922,195	228	862
397	11,119,755	255	1,103
398	12,317,314	283	1,372
399	14,379,440	330	1,679
400	16,441,566	377	2,032
401	20,897,275	480	2,461
402	25,352,984	582	2,992
403	27,995,193	643	3,604
404	30,637,401	703	4,277
405	32,672,654	750	5,004
406	34,707,906	797	5,777
407	38,012,989	873	6,612
408	41,318,071	949	7,523
409	44,132,945	1,013	8,503
410	46,947,818	1,078	9,549
411	49,706,344	1,141	10,658
412	52,464,870	1,204	11,831
413	55,272,900	1,269	13,068
414	58,080,929	1,333	14,369
415	60,832,254	1,397	15,734
416	63,583,578	1,460	17,162
417	66,451,684	1,526	18,655
418	69,319,789	1,591	20,213
419	72,481,176	1,664	21,841
420	75,642,562	1,737	23,541
421	79,237,920	1,819	25,319
422	82,833,277	1,902	27,179
423	86,397,534	1,983	29,121
424	89,961,790	2,065	31,146
425	94,040,417	2,159	33,258
426	98,119,044	2,253	35,464
427	101,744,938	2,336	37,758
428	105,370,831	2,419	40,135
429	109,607,364	2,516	42,603
430	113,843,897	2,613	45,167
431	118,399,617	2,718	47,833
432	122,955,336	2,823	50,604
433	127,314,467	2,923	53,476
434	131,673,598	3,023	56,449
435	136,383,993	3,131	59,526
436	141,094,388	3,239	62,711
437	145,733,195	3,346	66,003
438	150,372,001	3,452	69,402
439	154,501,567	3,547	72,902
440	158,631,133	3,642	76,496

GRAND SALINE CREEK RESERVOIR (SITE C)

STAGE ELEV	AREA SQ FT	AREA ACRES	STORAGE ACRE-FT
387	3,487	0	0
388	6,973	0	0
389	40,409	1	1
390	73,844	2	2
391	104,731	2	4
392	135,617	3	7
393	276,059	6	12
394	416,500	10	19
395	913,212	21	35
396	1,409,923	32	61
397	2,147,296	49	102
398	2,884,668	66	160
399	4,581,439	105	246
400	6,278,210	144	370
401	10,375,080	238	561
402	14,471,949	332	847
403	16,783,004	385	1,205
404	19,094,058	438	1,617
405	20,798,614	477	2,075
406	22,503,170	517	2,572
407	25,351,803	582	3,121
408	28,200,436	647	3,736
409	30,499,250	700	4,410
410	32,798,063	753	5,137
411	35,079,733	805	5,916
412	37,361,402	858	6,747
413	39,727,771	912	7,632
414	42,094,140	966	8,571
415	44,478,233	1,021	9,565
416	46,862,326	1,076	10,613
417	49,299,119	1,132	11,717
418	51,735,912	1,188	12,877
419	54,220,629	1,245	14,093
420	56,705,345	1,302	15,366
421	60,038,463	1,378	16,706
422	63,371,580	1,455	18,123
423	66,303,512	1,522	19,611
424	69,235,444	1,589	21,167
425	72,735,151	1,670	22,797
426	76,234,857	1,750	24,507
427	79,288,159	1,820	26,292
428	82,341,461	1,890	28,147
429	85,900,625	1,972	30,078
430	89,459,788	2,054	32,091
431	93,290,859	2,142	34,189
432	97,121,930	2,230	36,374
433	100,775,069	2,313	38,646
434	104,428,208	2,397	41,001
435	108,301,271	2,486	43,443
436	112,174,334	2,575	45,974
437	115,831,985	2,659	48,591
438	119,489,635	2,743	51,292
439	122,900,194	2,821	54,074
440	126,310,753	2,900	56,935

APPENDIX B: WATERSHED MAPS

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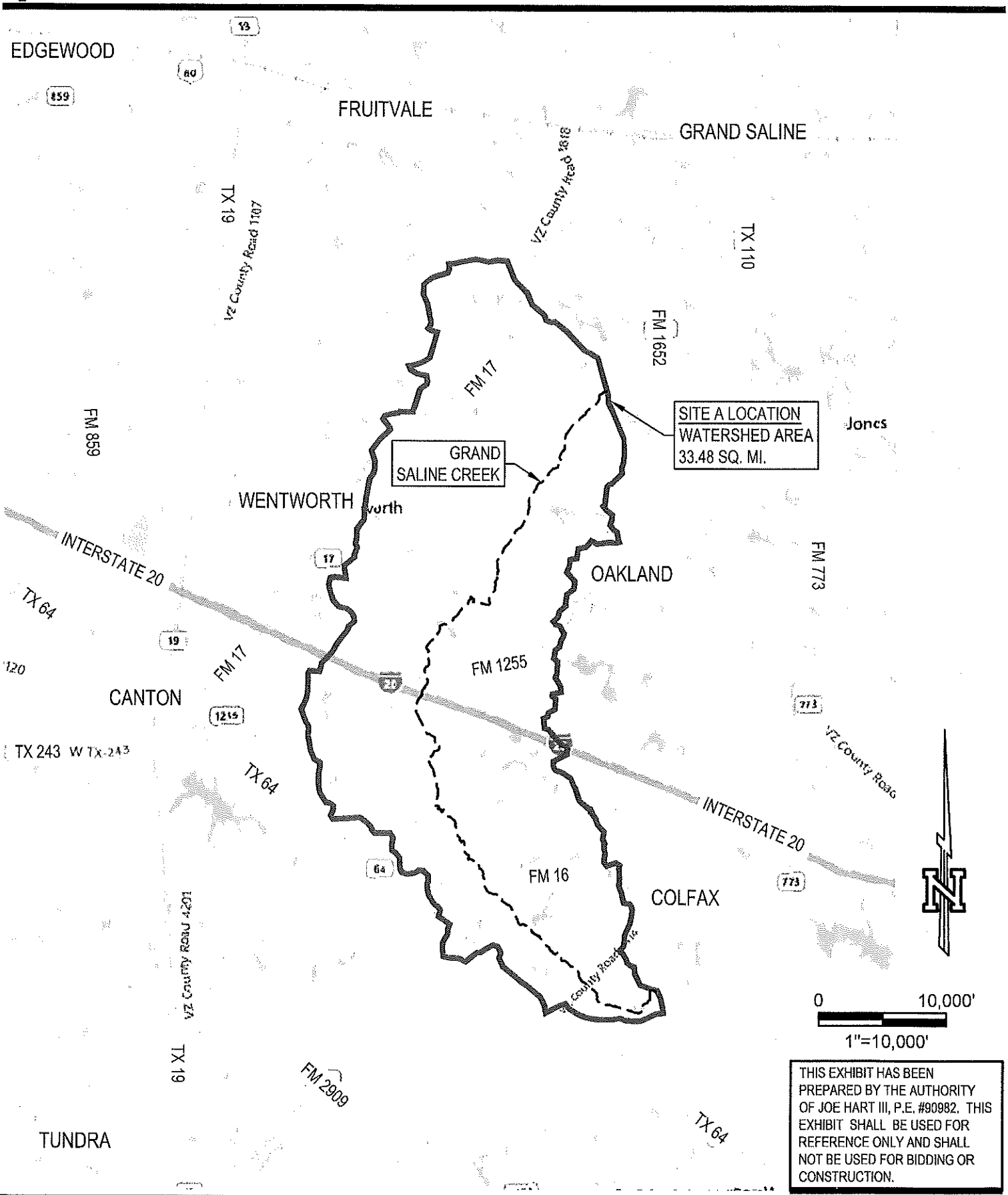

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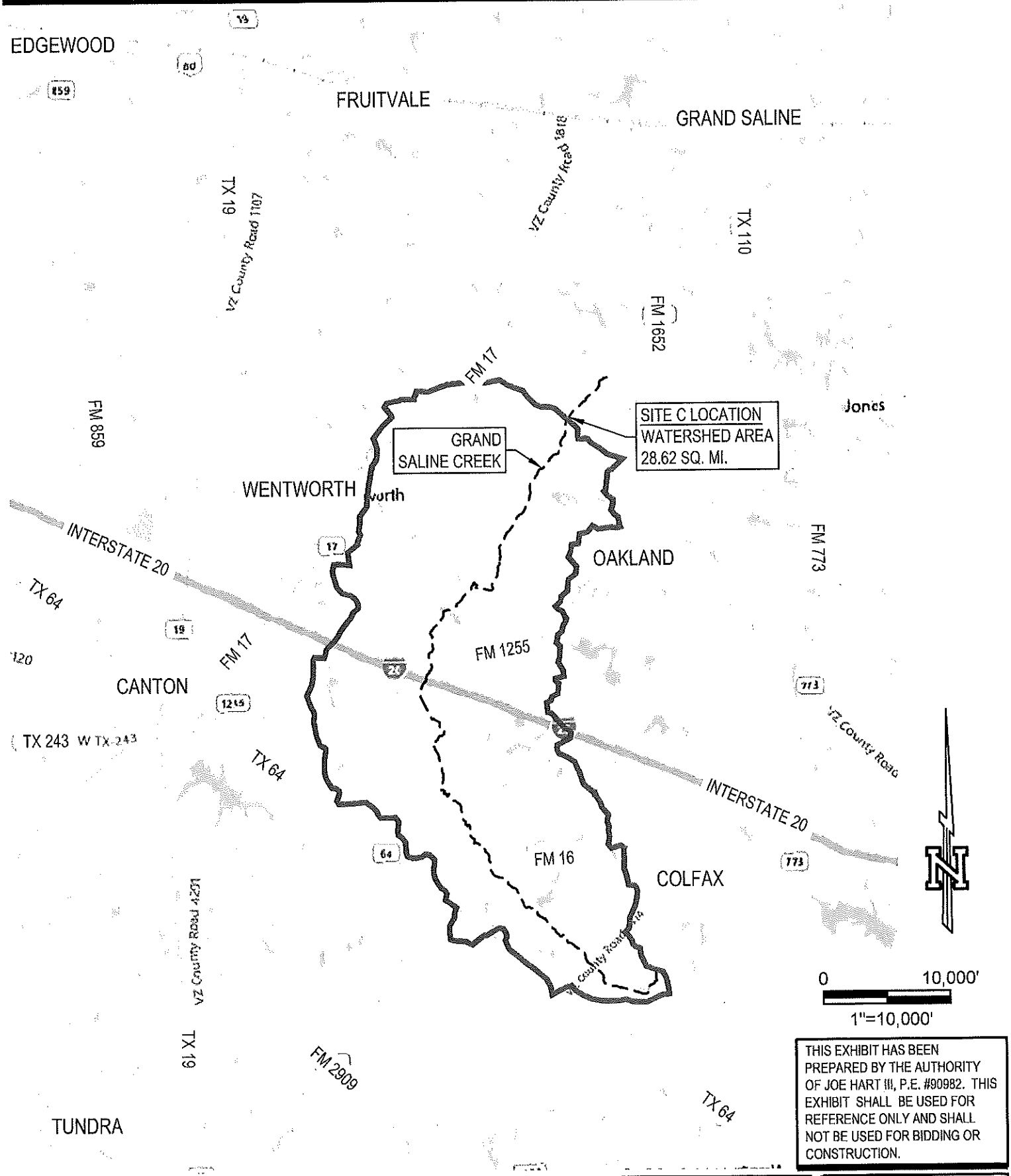
TBPE F-4691

SITE A - WATERSHED MAP

Grand Saline Creek Reservoir Study

DRAWN BY: AWR	DATE: JUNE 20, 2017
CHECKED BY: JWH	SCALE: 1" = 10,000'
JOB NUMBER: 4228-001	
SHEET NO.:	Exhibit B-1

 Filename: F:\Land Development\4228 Canton\4228-001 Grand Saline Ck Water Right\CAD\CIVIL\WATERSHED MAP.dwg



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TBPE F-4691

SITE C - WATERSHED MAP

Grand Saline Creek Reservoir Study

DRAWN BY: AWR	DATE: JUNE 20, 2017
CHECKED BY: JWH	SCALE: 1" = 10,000'
JOB NUMBER: 4228-001	
SHEET NO.: Exhibit B-2	

APPENDIX C: HYDROLOGIC MODEL AND HYDRAULIC MODEL

OID	STORM_TYPE	PMP_03	PMP_06	PMP_12	PMP_24	PMP_48	PMP_72
1	Local	20.93	25.7	34.9	42.1	43.8	43.8
2	General	14.1	24.03	28.26	30.32	38.67	39.63
3	Tropical	19.92	24.73	33.57	40.44	43.4	43.5

From TCEQ GRIDDED PMP TOOL

Project: GRAND_SALINE Simulation Run: 100-24
Reservoir: GS Reservoir

Start of Run:	01Jan2000, 00:00	Basin Model:	Grand Saline Creek
End of Run:	07Jan2000, 00:00	Meteorologic Model:	100-24
Compute Time:	20Jun2017, 09:27:59	Control Specifications:	6 Days

Volume Units:IN

Computed Results

Peak Inflow:	9876.4 (CFS)	Date/Time of Peak Inflow:	01Jan2000, 22:40
Peak Discharge:	4769.9 (CFS)	Date/Time of Peak Discharge	02Jan2000, 06:40
Inflow Volume:	7.45 (IN)	Peak Storage:	16178.1 (AC-FT)
Discharge Volume	7.26 (IN)	Peak Elevation:	415.3 (FT)

*1 Normal Pool set at 410.0' Emergency Spillway Set at 416.0'
150' Principal Spillway
600' Emergency Spillway

Project: GRAND_SALINE Simulation Run: 24-HR PMP
Reservoir: GS Reservoir

Start of Run:	01Jan2000, 00:00	Basin Model:	Grand Saline Creek
End of Run:	07Jan2000, 00:00	Meteorologic Model:	24-HR PMP
Compute Time:	20Jun2017, 09:29:32	Control Specifications:	6 Days

Volume Units:IN

Computed Results

Peak Inflow:	43514.7 (CFS)	Date/Time of Peak Inflow:	01Jan2000, 14:50
Peak Discharge:	15881.8 (CFS)	Date/Time of Peak Discharge	01Jan2000, 18:20
Inflow Volume:	39.51 (IN)	Peak Storage:	26860.0 (AC-FT)
Discharge Volume	23.22 (IN)	Peak Elevation:	421.8 (FT)

#1

Project: GRAND_SALINE Simulation Run: 100-24
Reservoir: GS Reservoir

Start of Run:	01Jan2000, 00:00	Basin Model:	Grand Saline Creek
End of Run:	07Jan2000, 00:00	Meteorologic Model:	100-24
Compute Time:	20Jun2017, 09:36:28	Control Specifications:	6 Days

Volume Units:IN

Computed Results

Peak Inflow:	9876.4 (CFS)	Date/Time of Peak Inflow:	01Jan2000, 22:40
Peak Discharge:	5592.3 (CFS)	Date/Time of Peak Discharge	02Jan2000, 05:20
Inflow Volume:	7.45 (IN)	Peak Storage:	23051.7 (AC-FT)
Discharge Volume	7.33 (IN)	Peak Elevation:	419.7 (FT)

*Z Normal Pool Set at 416.0', Emergency Spillway set at 420.0'
300' Principal Spillway
600' Emergency Spillway

Project: GRAND_SALINE Simulation Run: 24-HR PMP
Reservoir: GS Reservoir

Start of Run:	01Jan2000, 00:00	Basin Model:	Grand Saline Creek
End of Run:	07Jan2000, 00:00	Meteorologic Model:	24-HR PMP
Compute Time:	20Jun2017, 09:32:57	Control Specifications:	6 Days

Volume Units:IN

Computed Results

Peak Inflow:	43514.7 (CFS)	Date/Time of Peak Inflow:	01Jan2000, 14:50
Peak Discharge:	20907.7 (CFS)	Date/Time of Peak Discharge	01Jan2000, 18:20
Inflow Volume:	39.51 (IN)	Peak Storage:	33187.4 (AC-FT)
Discharge Volume	26.94 (IN)	Peak Elevation:	425.0 (FT)

*Z

APPENDIX D: FIRM YIELD ANALYSIS OF THE GRAND SALINE CREEK RESERVOIR SITE

Firm Yield Analysis

of the

Grand Saline Creek Reservoir Sites

Prepared by:

Richard Hoffpauir, PhD, PE
Hoffpauir Consulting, PLLC

May 31, 2017

1. Summary

Grand Saline Creek is located in Van Zandt County, Texas and is a tributary of the Sabine River in the portion of the basin upstream of Toledo Bend Reservoir. Two potential reservoir sites were analyzed for firm yield water supply. The Texas Commission on Environmental Quality (TCEQ) Water Availability Model (WAM) for the Sabine River Basin was used for the firm yield analysis. Modeling assumptions were made regarding existing water rights in the basin and preliminary reservoir sizes on Grand Saline Creek.

Results of the firm yield analysis are presented and discussed in further detail in section 11 of this report. Modeling assumptions and other considerations are given in the remaining sections. Table 1 presents the estimated firm yield for Sites A and C with top of conservation pools at elevations 416' and 410'. The results of additional scenarios are presented in section 11. Other considerations, such as instream flow requirements for Grand Saline Creek, may reduce the estimated firm yield and are discussed in the report.

Table 1. Estimated Firm Yields of the Proposed Grand Saline Reservoir

Site	Max Elevation, feet	Storage Capacity, ac-ft	Average Annual Streamflow, ac-ft per year	**Estimated Firm Yield, ac-ft per year**
A	416	17,162	17,942	3,803
A	410	9,549	17,942	2,503
C	416	10,613	15,338	2,362
C	410	5,137	15,338	1,263

2. Purpose of Analysis

The primary purpose of the analysis is to calculate estimated firm yields of the proposed Grand Saline Reservoir at two sites and with varying top of conservation elevations. The estimated firm yields are developed using the TCEQ WAM, which will also be used by the state agency for review of the permit application if submitted. Additionally, the report serves as documentation of the WAM modeling assumptions and discussion of other considerations pertinent to developing firm yield estimates.

3. Water Availability Model

Surface water right applications submitted to the TCEQ are reviewed and analyzed by TCEQ staff for sufficient water availability to fulfill beneficial use requirements and for impacts to senior water rights. The TCEQ WAM is the computer modeling system used to simulate surface water right applications. The WAM consists of basin specific input files and supporting geographic information, and a generalized simulation model known as the Water Rights Analysis Package (WRAP). The WAM simulates all existing state surface water rights and environmental flow requirements in priority order within a river basin over a monthly hydrologic period of record. The most recently published Sabine River Basin input files are dated 7/6/2015, and the most recently published version of WRAP is dated August 2015. Both were used in this analysis.

The WAM input files consist of a water management scenario for existing water rights and a period of record of hydrologic conditions over which the water management scenario is evaluated. The full authorization version of the Sabine River Basin WAM was used for the firm yield analysis of the proposed Grand Saline reservoir sites. The full authorization WAM assumes all water rights are utilized at their authorized diversion volumes and storage capacities. No return flows are included in the simulation unless required by permitting conditions. Environmental instream flow requirements, also known as Senate Bill 3 e-flow standards, are included in the WAM. Instream flow requirements are discussed in section 6 of this report.

The Sabine WAM hydrologic conditions are represented by monthly naturalized streamflow volumes at 18 stream gages and monthly net evaporation minus precipitation volumes for calculation of reservoir evaporation at 20 locations across the basin. The hydrologic period of record encompasses 59 calendar years from January 1940 through December 1998. The drought of record for the Sabine River Basin begins with the summer of 1950 and ends with the flood event in the spring of 1957. The drought of record is used to calculate reservoir firm yield.

4. Location of the Reservoir Sites

The proposed reservoir sites are located on Grand Saline Creek in Van Zandt County, Texas and northeast of the City of Canton. Two sites are considered in this report, and hereafter referred to Site A and Site C. The upstream contributing drainage area of Site A is 33.48 square miles and is downstream of Site C. The upstream contributing drainage area of Site C is 28.62 square miles. Figure 1 shows the location of the two sites relative to the City of Canton as well as other pertinent features contained in the TCEQ WAM.

The WAM indicates that there are 2 existing senior water rights with 3 diversion points located upstream of the reservoir sites near the headwaters of Grand Saline Creek. Certificate of Adjudication 05-4685 has a time priority of August 30, 1976 and allows for the impoundment of up to 200 ac-ft of storage with no diversion from the stream. Certificate of Adjudication 05-4684 has a time priority of November 6, 1972 and allows for the impoundment of up to 160 ac-ft of storage with no diversion from the stream, and additionally, the impoundment of up to 200 ac-ft of storage with 27 ac-ft/yr of diversion for irrigation purposes.

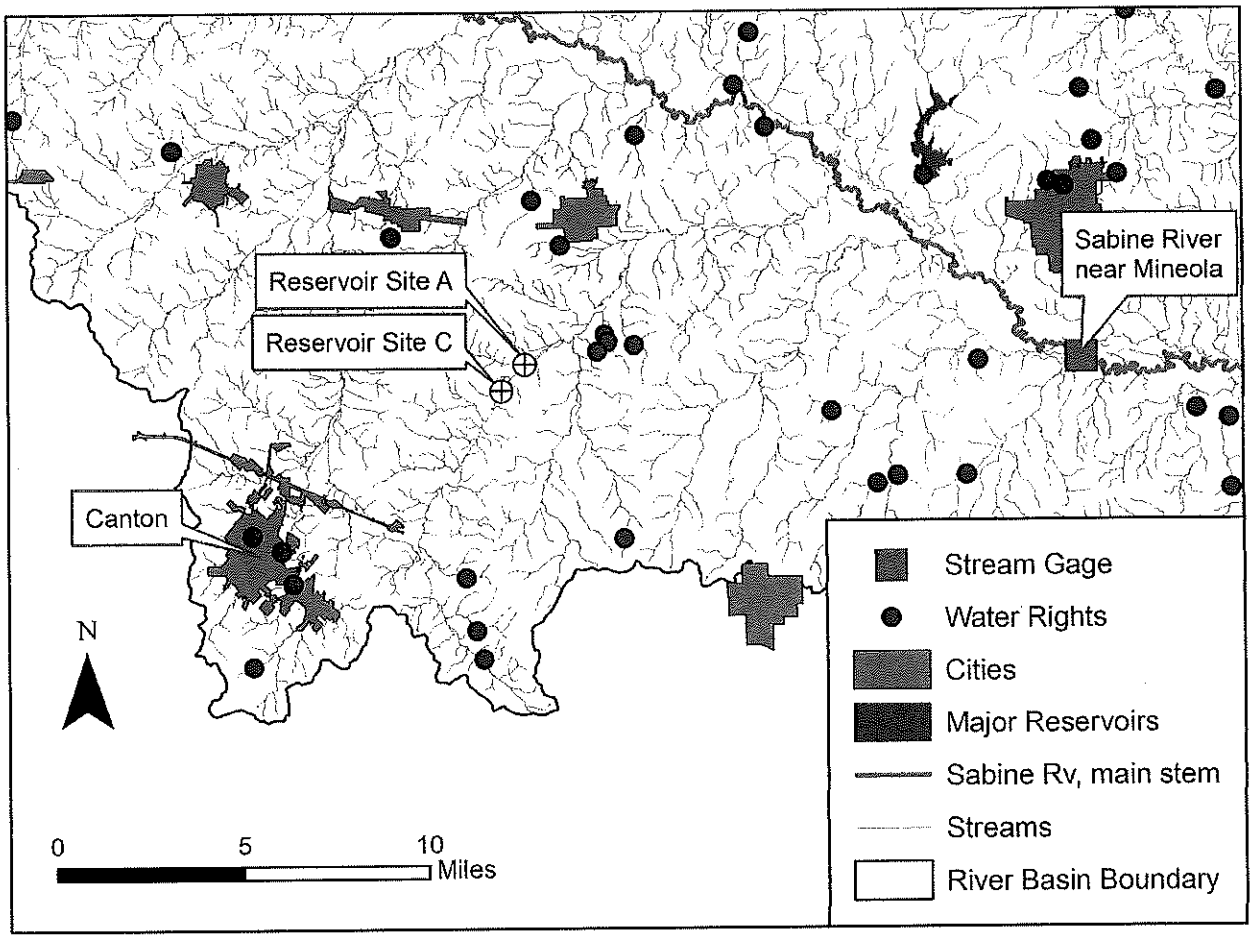

Figure 1. Location of the Proposed Sites on Grand Saline Creek

5. WAM Hydrology at Reservoir Sites

Two new control points were added to the WAM at the location of the reservoir sites. The next downstream control point in the WAM is located on the main stem of the Sabine River at the United States Geological Survey (USGS) stream gage 08018500 near Mineola, Texas. There are no stream gages on Grand Saline Creek in the WAM to provide local naturalized flows to the existing water rights or the proposed reservoir sites. Naturalized flows on Grand Saline Creek are synthesized in the WAM using the naturalized flow record of the Mineola gage.

The standard WAM option for transferring naturalized hydrology from gaged to ungaged locations is the drainage area ratio method. The incremental gains in drainage area and naturalized flows between the Mineola gage and the upstream USGS stream gage 08017410 for the Sabine River near Wills Point are calculated. The incremental naturalized flows are then distributed to the ungagged control points using the ratio of the drainage area at the ungagged locations and the incremental drainage area between the stream gages. This method was used to obtain monthly naturalized flows at the proposed reservoir sites on Grand Saline Creek.

Figure 2 shows the time series of annual naturalized flows which were calculated in the WAM for Site A using the drainage area ratio transfer method described above. The annual naturalized flows were aggregated from the monthly naturalized flows. The monthly naturalized flows at Site A are shown in Figure 3. The monthly time series of flows exhibit extreme variability and is typical for small watersheds. The monthly flow exceedance curves for both Site A and Site C are shown in Figure 4. Flows near or equal to zero ac-ft per month are indicated in Figure 4.

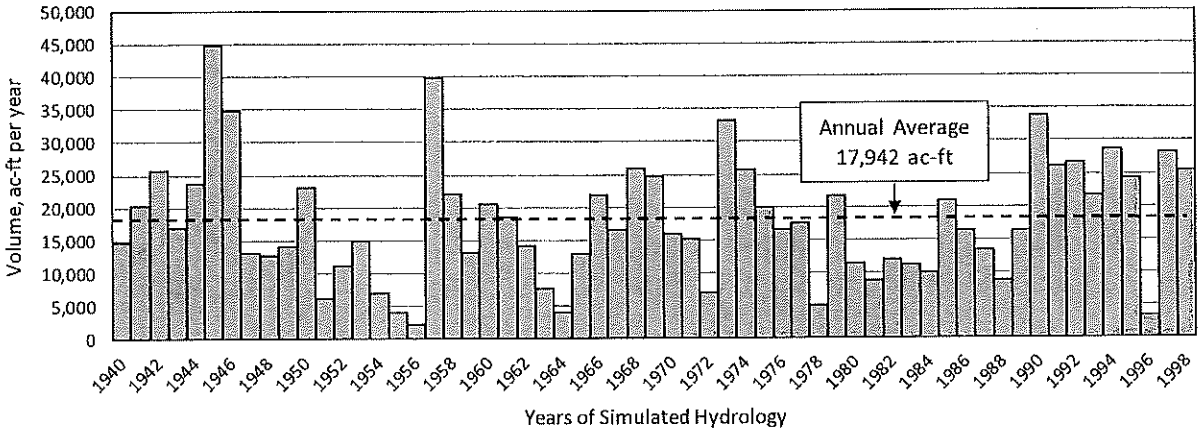

Figure 2. Annual Naturalized Flow Volumes at Site A

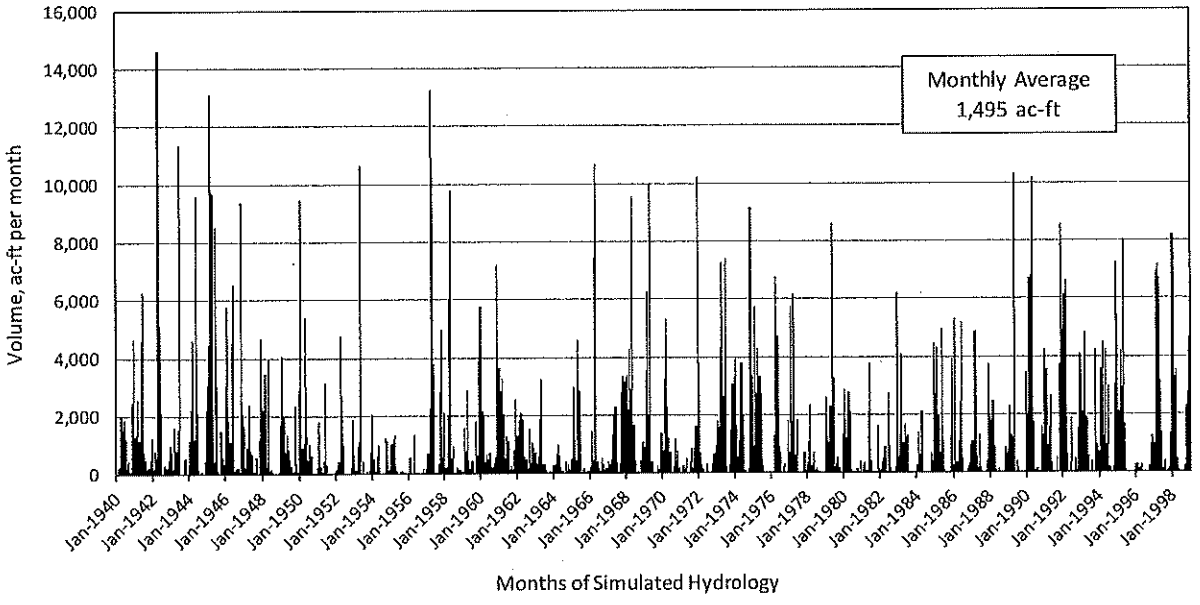

Figure 3. Monthly Naturalized Flow Volumes at Site A

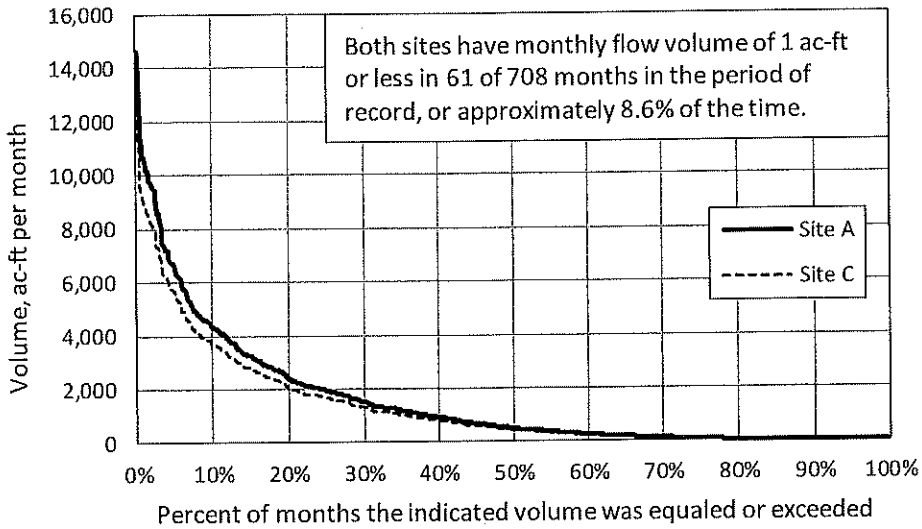

Figure 4. Monthly Flow Exceedances at Sites A and C.

6. Environmental Instream Flow Requirements

Environmental instream flow requirements are special conditions typically applied to new water right permits. If streamflows are flowing into the upstream end of a reservoir, for example, then some or all inflows may have to be passed through the dam to meet downstream instream flow requirements should downstream flows be insufficient. Two types of instream flows are discussed below and are considered in the Grand Saline firm yield analysis. First, the e-flow standards pursuant to Senate Bill 3 are described and are applicable along the main stem of the Sabine River. Secondly, a local instream flow requirement along Grand Saline Creek could be considered in the TCEQ permitting process for maintaining water quality, channel morphology, or aquatic habitat prior to the confluence with the Sabine River.

6.1 Senate Bill 3 E-Flow Standards

All new authorizations for surface water are subject to environmental flow requirements, also known as environmental flow standards, as established for each river basin in Texas under the direction of House Bill (HB) 3 and Senate Bill (SB) 3 of the 80th Legislature, 2007. The pertinent environmental flow standards for the Sabine River Basin are found in the Texas Administrative Code[1], Title 30, Part 1, Chapter 298, Subchapter C.

The SB3 e-flow standards for the Sabine River Basin consist of a seasonally varying subsistence flow, base flow, and high flow pulse requirements. The three tiers of flow requirements are defined in TAC §298.1 as follows. Subsistence flows are "the minimum streamflow needed during critical drought periods to maintain tolerable water quality conditions and to provide minimal

[1] http://www.sos.state.tx.us/tac/

aquatic habitat space for the survival and recolonization of aquatic organisms." Base flows are "the range of average flow conditions, in the absence of significant rainfall events, that may vary depending on current weather patterns." High flow pulses are "relatively short-duration, high flows within the stream channel that occur during or immediately following a storm event."

The USGS stream gage 08020000 for the Sabine River near Gladewater is the first downstream location from the reservoir sites where the SB3 e-flow standards are applied. Though an actual water right permit will be conditioned to only adhere to the e-flow standards at the first downstream e-flow gage, the WAM analysis will consider all downstream e-flow gages per TCEQ guidelines[2] on implementation of e-flows. Downstream from the Gladewater gage, e-flow standards which are applicable to the Grand Saline firm yield analysis include USGS gage 08022040 for the Sabine River near Beckville and USGS gage 08030500 for the Sabine River near Ruliff. The e-flow standards are provided in table format in TAC §298.280.

TAC §298.285 provides a threshold for exempting water right permits from subjugation to the pulse flow requirements. A water right with authorization to store or divert less than 10,000 ac-ft per year are exempt from pulse flow consideration in the e-flow standards. Only the subsistence and base flow requirements are applicable. All scenarios analyzed for the Grand Saline Reservoir with storage capacity of less than 10,000 ac-ft were modeled without SB3 pulse flow requirements at Gladewater, Beckville, and Ruliff.

6.2 Instream Flow Requirement on Grand Saline Creek

New authorizations for storage and diversion can be assigned a special condition in their water right permit which requires the bypass of inflows for maintaining water quality, channel morphology, or aquatic habitat in their local watershed. Instream flow requirements are calculated and assigned during TCEQ review of the water right permit application. However, a simplified instream flow requirement for Grand Saline Creek was considered in some firm yield scenarios.

For the purposes of firm yield sensitivity to an instream flow requirement on Grand Saline Creek, some scenarios were assigned a 1 cfs instream flow requirement. For the scenarios with the requirement, inflows are passed through the dam if water was flowing in the creek and only up to an amount sufficient to meet 1 cfs of streamflow immediately downstream of the dam. Stored water held in the reservoir was not modeled as being released to maintain 1 cfs of streamflow when no inflows are present. For reference, 1 cfs is equal to approximately 724 ac-ft per year or 60.3 ac-ft per month.

[2]https://www.tceq.texas.gov/assets/public/permitting/watersupply/water_rights/eflows/revised_draft_sb3_implementation_guidelines.pdf

7. Municipal Demand Distribution

The TCEQ WAM for the Sabine River Basin assumes a generalized monthly distribution for municipal demands. This distribution was applied to withdrawals from the proposed reservoir on Grand Saline Creek during the firm yield analysis. The distribution is given in the table below.

Table 2. WAM Monthly Municipal Demand Distribution, % of annual total

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
6.0%	5.5%	6.5%	6.3%	7.6%	8.2%	10.7%	11.4%	11.5%	11.5%	8.4%	6.4%

8. Elevation – Surface Area – Capacity Relationship

Data were provided by Johnson & Pace Incorporated regarding the conservation pool elevation, surface area, and storage capacity at Sites A and C. The values in Table 3 are abbreviated selections from the data for the two sites. Additional data points were used in the WAM simulations to more fully represent the elevation – area – capacity relationship.

Table 3. Elevation – Surface Area – Capacity for Sites A and C

Stage Elevation, feet	Site A		Site C	
	Capacity, ac-ft	Area, acres	Capacity, ac-ft	Area, acres
416	17,162	1,460	10,613	1,076
415	15,734	1,397	9,565	1,021
410	9,549	1,078	5,137	753
405	5,004	750	2,075	477
400	2,032	377	370	144
395	648	199	35	21
389	21	16	1	1
383	1	1	0	0

9. Priority Date

All simulation scenarios of the Grand Saline Reservoir assumed a 2017 priority date for appropriation of streamflow. The actual priority date will depend on the date in which the water right permit is declared administratively complete by TCEQ. Regardless, the 2017 priority date makes this project the junior-most water right in the simulation.

10. Pending Amendment to Certificate 05-4658

The Sabine River Authority holds Certificate of Adjudication 05-4658 which authorizes the impoundment of 4,477,000 ac-ft of water within Toledo Bend Reservoir and up to 750,000 ac-ft/yr of diversion from the stored waters of the reservoir at a March 5, 1958 priority date. Special condition 5.I. of the certificate states that the authorization is "subordinate to the present and future water requirements of that portion of the Sabine River Watershed lying upstream of the point known as Stateline." The Sabine River Authority filed Application No. 05-4658B on February 14, 2003 to amendment the certificate. One of the requests in Application No. 05-4658B is the removal of the upstream subordination in special condition 5.I. The application is still pending at TCEQ as of the date of this report.

Reservoir firm yield scenarios were created both with and without the Toledo Bend subordination being applied to the impoundment of water on Grand Saline Creek. The subordination of the Toledo Bend right does not exempt a new water right from considering the water availability needs of other senior water rights downstream of Toledo Bend. Likewise, the SB3 e-flow standard below Toledo Bend for the Sabine River near Ruliff are applicable per TCEQ modeling guidelines. Water availability effects of senior rights downstream of Toledo Bend and all SB3 e-flow standards were considered in the WAM in all scenarios.

11. Results

Reservoir firm yields for Sites A and C are shown in Table 4. Two maximum conservation pool elevation assumptions were made for Site A. Three maximum conservation pool elevations assumptions were made for Site C. The additional elevation of 415' for Site C was considered because the storage capacity is below 10,000 ac-ft. Therefore, the scenario would be exempt from the pulse flow requirements in the SB3 e-flow standards. All scenarios include SB3 e-flow standards. Scenarios on rows 2, 4, and 5 are exempt from pulse flow requirements, whereas scenarios on rows 1 and 3 are not. Table heading "With Subordination" refers to the subordination of the Toledo Bend water right as discussed in section 10 of this report. Table headings "Without IFR" and "With IFR" refer to the 1 cfs instream flow requirement on Grand Saline Creek at the dam site as discussed in section 6.2.

Though scenarios on rows 2, 4, and 5 are exempt from pulse flow requirements, additional simulations were made with the pulse flow requirements activated. No differences in firm yield were found when the pulse flow requirements were activated. Because the TCEQ WAM is a monthly simulation, the effects of the pulse flow requirements may not be fully reflected in the finding of no difference in firm yields. Pulses are high streamflows immediately following storm events and may persist for hours, days, or weeks. A monthly time step resolution may not fully capture the effects of these short duration events with regard to upstream water availability constraints.

Table 4. WAM Estimated Firm Yield of the Proposed Reservoir on Grand Saline Creek

Site	Max Elevation, feet	Storage Capacity, ac-ft	Reservoir Firm Yields, ac-ft per year				
			With SB3 Environmental Flow Standards				
			With Subordination		Without Subordination		
			Without IFR	With IFR	Without IFR	With IFR	
A	416	17,162	3,803	3,624	1,019	1,017	*Row 1*
A	410	9,549	2,503	2,333	373	371	*2*
C	416	10,613	2,362	2,187	396	394	*3*
C	415	9,565	2,180	2,006	315	314	*4*
C	410	5,137	1,263	1,150	64	63	*5*
			Column D	*E*	*F*	*G*	

Figure 5 shows the storage content trace for Sites A and C corresponding to the firm yield results in scenario D1 (*column D – row 1 of Table 4)* and scenario D3. The firm yield is determined as the maximum diversion demand from the reservoir that can be fully met without shortage. The drought of the 1950's is the constraining sequence for determining firm yield in the 1940 – 1998 period of record. Reservoir storage content is drawn down to zero while fully meeting the demands listed in Table 4. Hydrologic data are not available for the WAM covering the more recent drought which occurred after 2010. It is unknown if the more recent drought would be more constraining to the firm yield calculation than the drought of the 1950's.

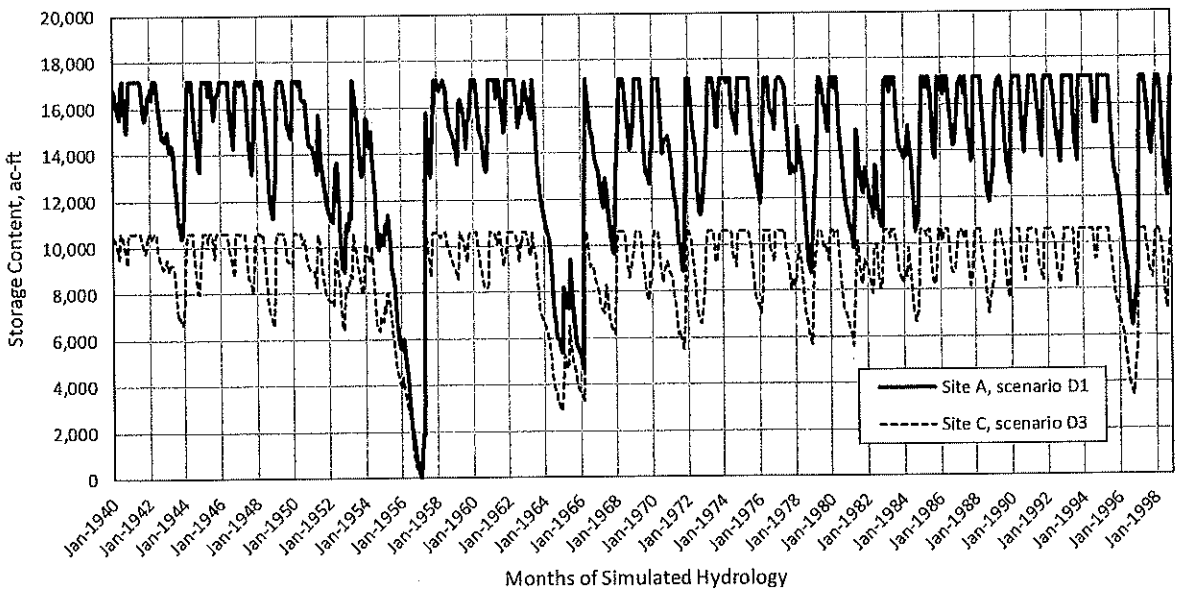

Figure 5. Site A and C Reservoir Storage Content for the WAM Period of Record

12. Non-Firm Supply Option

In 2013, TCEQ granted water right permit No. 5821, Lake Ralph Hall, to the Upper Trinity Regional Water District. Under this permit, water can be diverted from the reservoir on a non-firm basis in an amount up to 45,000 ac-ft per year. As reservoir storage decreases to certain trigger levels, diversions from the reservoir must be reduced to approximately 34,050 ac-ft per year. The later amount is considered the reservoir's firm yield when operated with a non-firm (interruptible) supply component. The larger non-firm amount was allowed because the permittee holds alternative water supplies that may be used when reservoir storage decreases and diversions are curtailed to the equal the firm yield.

The concept of a non-firm and firm yield supply component for the Grand Saline Reservoir was explored with two additional scenarios. An unlimited number of possible storage triggers and curtailment amounts could be developed for the purposes of calculating a non-firm and firm yield supply. However, for the purposes of illustrating the concept, a 30% diversion reduction was assumed when reservoir storage content dropped to approximately 30% remaining. For Site A operated with 416' top of conservation elevation and 17,162 ac-ft of capacity, diversion from the reservoir was reduced by 30% when storage content dropped below 5,000 ac-ft. For Site C operated with 416' top of conservation elevation and 10,613 ac-ft of capacity, the 30% diversion reduction trigger was set to 3,200 ac-ft of storage content.

Table 5 shows the results of considering a non-firm supply when reservoir storage contents are above the trigger level. Results in rows 1 and 3 are equivalent to scenarios D1 and D3 in Table 4. Rows 2 and 4 show the additional non-firm supply (column V) gained by reducing the firm yield (column Y). Columns W and X provide the frequency of time that the non-firm supply is available. The non-firm supply is typically available except under the worst of drought conditions.

The results in Table 5 can be interpreted as follows. The firm yield estimate for Site A without non-firm supply diversions is 3,803 ac-ft per year (row 1). This is the maximum that may be diverted in all years regardless of storage content. Alternatively, 4,342 ac-ft per year may be diverted nearly 97% of the time if diversions can be curtailed to 3,039 ac-ft per year when storage content is very low and other water sources can be accessed (row 2).

Table 5. Examples of Non-Firm Supply and Firm Yield Combinations

Site	Max Elevation, feet	Storage Capacity, ac-ft	Non-Firm Supply, ac-ft/yr			Firm Yield, ac-ft/yr		
			Diversion, ac-ft/yr	Months Available	Whole Years Available	Diversion, ac-ft/yr	Months or Years Available	
A	416	17,162	*na*	*na*	*na*	3,803	100%	*Row 1*
A	416	17,162	4,342	96.6%	93.2%	3,039	100%	*2*
C	416	10,613	*na*	*na*	*na*	2,362	100%	*3*
C	416	10,613	2,634	97.3%	89.8%	1,844	100%	*4*
			Column V	*W*	*X*	*Y*	*Z*	

13. Refinement of Naturalized Flows

The standard WAM assumption of a drainage area ratio transfer of flows from the downstream USGS gage on the main stem of the Sabine River to the ungaged site on Grand Saline Creek serves as the basis for inflows to the proposed reservoir sites. Naturalized flows at Sites A and C are discussed in section 5 of this report. These synthetic naturalized flows also serve as the basis for triggering inflow passage under a hypothetical instream flow requirements applied on Grand Saline Creek. The firm yield estimates could be examined further by obtaining actual stream flow data at the dam sites or perhaps better statistical information regarding the relationship of Grand Saline Creek flows to flows at the downstream USGS gage near Mineola.

APPENDIX E: WATER RIGHTS CERTIFICATE OF ADJUDICATION FOR MILL CREEK RESERVOIR

CERTIFICATE OF ADJUDICATION

CERTIFICATE OF ADJUDICATION: 05-4675

OWNER: City of Canton
P. O. Box 245
Canton, Texas 75103

COUNTY: Van Zandt

PRIORITY DATES: April 19, 1954 and
January 5, 1970

WATERCOURSE: Mill Creek, tributary of the Sabine River

BASIN: Sabine River

WHEREAS, by final decree of the 188th Judicial District Court of Gregg County, in Cause No. 86-255-A; In Re: The Adjudication of Water Rights in the Upper Sabine River Segment of the Sabine River Basin dated June 9, 1986, a right was recognized under Permit 1712 and Permit 2529A authorizing the City of Canton to appropriate waters of the State of Texas as set forth below;

NOW, THEREFORE, this certificate of adjudication to appropriate waters of the State of Texas in the Sabine River Basin is issued to the City of Canton, subject to the following terms and conditions:

1. IMPOUNDMENT

Owner is authorized to maintain an existing dam and reservoir on Mill Creek and impound therein not to exceed 2261 acre-feet of water. The dam is located in the James Douthit Survey, Abstract 198, Van Zandt County, Texas.

2. USE

Owner is authorized to divert and use not to exceed 1550 acre-feet of water per annum from the aforesaid reservoir and from Mill Creek for municipal purposes.

3. DIVERSION

A. Location:

(1) At a point on Mill Creek in the J. Stockwell Survey, Abstract 760, Van Zandt County, Texas.

(2) At the perimeter of the aforesaid reservoir.

B. Rate:

(1) Maximum rate from the aforesaid reservoir: 3.33 cfs (1500 gpm).

(2) Maximum rate from Mill Creek: 0.89 cfs (400 gpm).

4. PRIORITY

A. The time priority of owner's right is April 19, 1954 for the diversion and use of 50 acre-feet of water per annum from Mill Creek.

B. The time priority of owner's right is January 5, 1970 for the impoundment and the diversion and use of 1500 acre-feet of water per annum from the aforesaid reservoir.

5. SPECIAL CONDITION

Owner shall maintain a suitable outlet in the aforesaid dam authorized herein to allow the free passage of water that owner is not entitled to divert or impound.

The locations of pertinent features related to this certificate are shown on Page 4 of the Upper Sabine River Segment Certificates of Adjudication Maps, copies of which are located in the office of the Texas Water Commission, Austin, Texas.

This certificate of adjudication is issued subject to all terms, conditions and provisions in the final decree of the 188th Judicial District Court of Gregg County, Texas, in Cause No. 86-255-A, In Re: The Adjudication of Water Rights in the Upper Sabine River Segment of the Sabine River Basin dated June 9, 1986, and supersedes all rights of the owner asserted in that cause.

This certificate of adjudication is issued subject to the obligations of the State of Texas pursuant to the terms of the Sabine River Compact.

This certificate of adjudication is issued subject to senior and superior water rights in the Sabine River Basin.

This certificate of adjudication is issued subject to the Rules of the Texas Water Commission and its continuing right of supervision of State water resources consistent with the public policy of the State as set forth in the Texas Water Code.

TEXAS WATER COMMISSION

Paul Hopkins

Paul Hopkins, Chairman

DATE ISSUED

DEC 31 1986

ATTEST:

Mary Ann Hefner

Mary Ann Hefner, Chief Clerk

APPENDIX F: WATER SUPPLY CALCULATIONS

	Water Supply Based on Proposed Grand Saline Creek Reservoir (Site A - 410.0')	MGD	Acre-Feet/Year
	Grand Saline Reservoir Firm Yield (Conservation Pool 410.0')	2.23	2503
+	Available from Mill Creek Reservoir (Per TCEQ)	1.34	1500
+	Available from Existing Wells (Per City)	0.43	482
+	Available by Proposed Indirect Reuse (2016 TWDB Group D Report)	0.29	323
	Potential Water Provided	**4.29**	**4808**
	Population Served (Using 2011 WUG Data)		19,152

	Water Supply Based on Proposed Grand Saline Creek Reservoir (Site A - 416.0')	MGD	Acre-Feet/Year
	Grand Saline Reservoir Firm Yield (Conservation Pool 416.0')	3.40	3803
+	Available from Mill Creek Reservoir (Per TCEQ)	1.34	1500
+	Available from Existing Wells (Per City)	0.43	482
+	Available by Proposed Indirect Reuse (2016 TWDB Group D Report)	0.29	323
	Potential Water Provided	**5.45**	**6108**
	Population Served (Using 2011 WUG Data)		24,330

City of Canton Population Projection

*Using 3.7% Growth Rate and a 224 GPCD Demand Rate

Year	Geometric	Water Demand (MGD)	Water Demand (ac-ft)
2017	3,581	0.80	899
2018	3,713	0.83	932
2019	3,849	0.86	966
2020	3,991	0.89	1,001
2021	4,138	0.93	1,038
2022	4,290	0.96	1,076
2023	4,448	1.00	1,116
2024	4,612	1.03	1,157
2025	4,782	1.07	1,200
2026	4,957	1.11	1,244
2027	5,140	1.15	1,290
2028	5,329	1.19	1,337
2029	5,525	1.24	1,386
2030	5,728	1.28	1,437
2031	5,939	1.33	1,490
2032	6,158	1.38	1,545
2033	6,384	1.43	1,602
2034	6,619	1.48	1,661
2035	6,863	1.54	1,722
2036	7,116	1.59	1,785
2037	7,377	1.65	1,851
2038	7,649	1.71	1,919
2039	7,930	1.78	1,990
2040	8,222	1.84	2,063
2041	8,525	1.91	2,139
2042	8,839	1.98	2,218
2043	9,164	2.05	2,299
2044	9,501	2.13	2,384
2045	9,851	2.21	2,472
2046	10,213	2.29	2,563
2047	10,589	2.37	2,657
2048	10,979	2.46	2,755
2049	11,383	2.55	2,856
2050	11,802	2.64	2,961
2051	12,236	2.74	3,070
2052	12,686	2.84	3,183
2053	13,153	2.95	3,300
2054	13,637	3.05	3,422
2055	14,139	3.17	3,548
2056	14,659	3.28	3,678
2057	15,199	3.40	3,814
2058	15,758	3.53	3,954
2059	16,338	3.66	4,099
2060	16,939	3.79	4,250
2061	17,562	3.93	4,407
2062	18,209	4.08	4,569
2063	18,879	4.23	4,737
2064	19,574	4.38	4,911
2065	20,294	4.55	5,092
2066	21,041	4.71	5,279
2067	21,815	4.89	5,474
2068	22,618	5.07	5,675
2069	23,450	5.25	5,884
2070	24,313	5.45	6,100

City of Canton Population Projection (Forney Growth Rate)

*Using 6.2% Growth Rate and a 224 GPCD Demand Rate

Year	Geometric	Water Demand (MGD)	Water Demand (ac-ft)
2017	3,581	0.80	899
2018	3,801	0.85	954
2019	4,035	0.90	1,012
2020	4,283	0.96	1,075
2021	4,547	1.02	1,141
2022	4,826	1.08	1,211
2023	5,123	1.15	1,285
2024	5,438	1.22	1,364
2025	5,773	1.29	1,448
2026	6,128	1.37	1,537
2027	6,504	1.46	1,632
2028	6,904	1.55	1,732
2029	7,329	1.64	1,839
2030	7,780	1.74	1,952
2031	8,258	1.85	2,072
2032	8,766	1.96	2,200
2033	9,305	2.08	2,335
2034	9,877	2.21	2,478
2035	10,485	2.35	2,631
2036	11,130	2.49	2,793
2037	11,814	2.65	2,964
2038	12,541	2.81	3,147
2039	13,312	2.98	3,340
2040	14,131	3.17	3,546
2041	15,000	3.36	3,764
2042	15,922	3.57	3,995
2043	16,901	3.79	4,241
2044	17,941	4.02	4,502
2045	19,044	4.27	4,778
2046	20,215	4.53	5,072
2047	21,459	4.81	5,384
2048	22,778	5.10	5,715
2049	24,179	5.42	6,067
2050	25,666	5.75	6,440
2051	27,245	6.10	6,836
2052	28,920	6.48	7,256
2053	30,699	6.88	7,703
2054	32,587	7.30	8,176
2055	34,591	7.75	8,679
2056	36,718	8.22	9,213
2057	38,977	8.73	9,780
2058	41,374	9.27	10,381
2059	43,918	9.84	11,020
2060	46,619	10.44	11,697
2061	49,486	11.08	12,417
2062	52,530	11.77	13,180
2063	55,760	12.49	13,991
2064	59,189	13.26	14,851
2065	62,830	14.07	15,765
2066	66,694	14.94	16,734
2067	70,795	15.86	17,763
2068	75,149	16.83	18,856
2069	79,771	17.87	20,015
2070	84,677	18.97	21,246