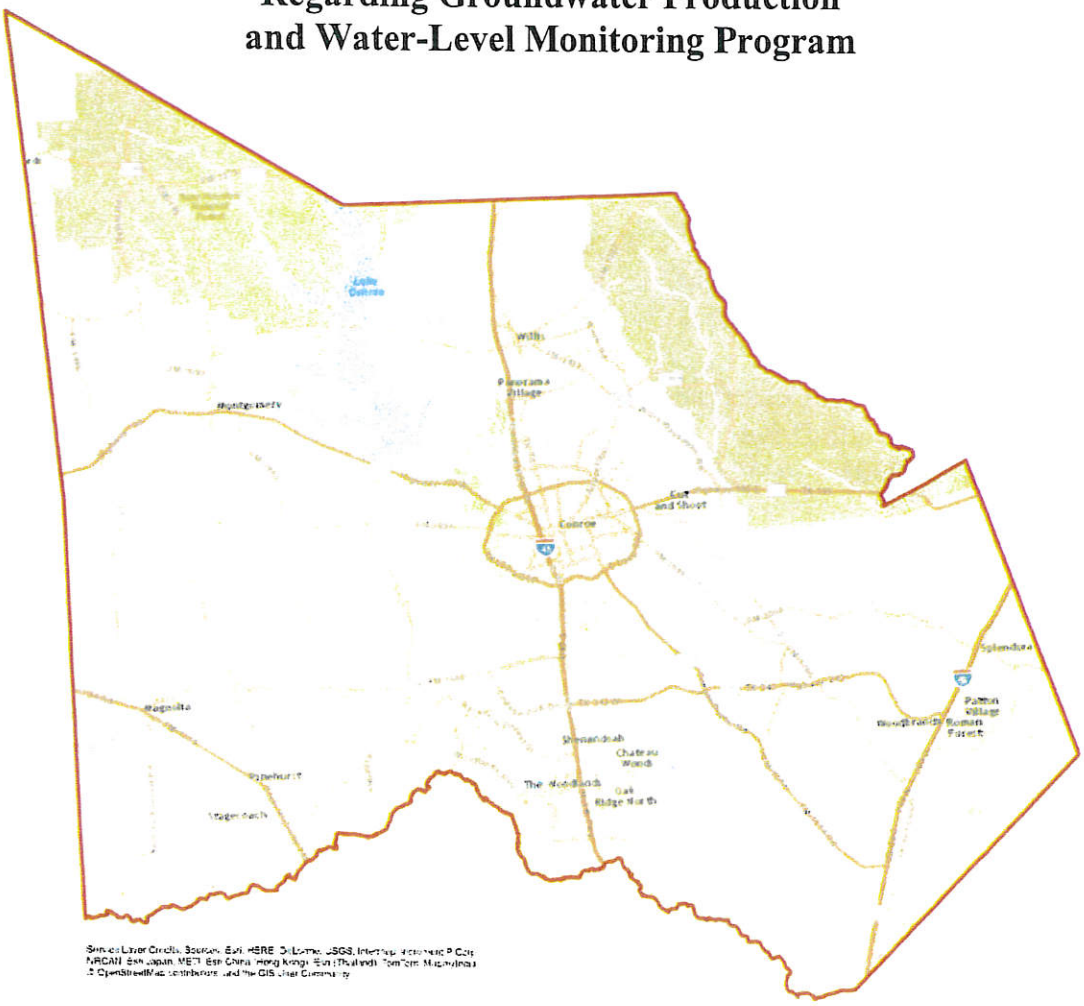
Technical Memorandum
Regarding Groundwater Production and Water-Level Monitoring Program



Prepared for

Lone Star Groundwater Conservation District

by

LBG-Guyton Associates
Professional Groundwater and Engineering Services
Texas Registered Engineering Firm F-4432
Texas Geoscientist Firm License No. 50111
11111 Katy Freeway, Suite 850
Houston, Texas 77079

September 2015

LBG-GUYTON ASSOCIATES
PROFESSIONAL GROUNDWATER AND ENVIRONMENTAL ENGINEERING SERVICES

11111 KATY FREEWAY
SUITE 850
HOUSTON, TX 77079
713-468-8600
FAX No.: 713-468-4956

September 4, 2015

Ms. Kathy Turner Jones
General Manager
Lone Star Groundwater Conservation District
655 Conroe Park North Drive
Conroe, Texas 77303

Dear Ms. Jones:

Enclosed is our technical memorandum regarding an evaluation of the adequacy of the well water-level monitoring and groundwater production data program within the Lone Star Groundwater Conservation District. The technical memorandum also includes an assessment of the initial reduction in groundwater pumping in part of north Harris County. An executive summary is included at the beginning of the technical memorandum. Comments received regarding the draft of the technical memorandum are addressed in the response to comments section at the conclusion of the technical memorandum or in the memorandum. This technical memorandum is presented in accordance with deliverables included in Task 1 of the Lone Star Groundwater Conservation District Strategic Water Resources Planning Study.

As you and others review the memorandum, please contact us with any questions.

Sincerely,

LBG-GUYTON ASSOCIATES

W. John Seifert, Jr., P.E.
Principal

LBG-Guyton Associates
F-4432

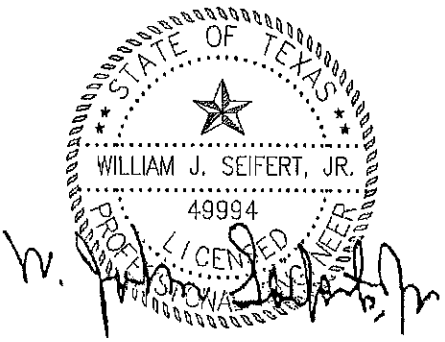


TABLE OF CONTENTS

FIGURES

TABLES

EXECUTIVE SUMMARY

- A study was performed to assess the adequacy of the current groundwater water-level monitoring network and groundwater production data within the Lone Star Groundwater Conservation District (LSGCD). The study also includes the evaluation of the response of aquifers in the north part of Harris County to a reduction in groundwater pumping in that area.

- The collection of groundwater production data was initiated by the LSGCD in 2002-2003 and provides a good accounting of total permitted pumping. Additional effort is recommended to correlate groundwater production by well with the source of the withdrawal, whether Chicot, Evangeline or Jasper aquifers. Groundwater production from the Catahoula Aquifer started about four years ago and is already being reported on a per well basis.

- The areal and temporal distribution of monitoring wells encompasses the Chicot, Evangeline, Jasper and Catahoula aquifers. The areal or spatial coverage of the wells within the LSGCD has improved in the last 10 years and provides reasonably good coverage over a large part of the LSGCD. Some areas of the county would benefit by the addition of 10 to 15 monitor wells per aquifer and/or the reallocation of monitor wells from areas with a greater number of wells to areas with a smaller number of wells. The aquifers of interest would be the Chicot, Evangeline and Jasper. The coverage of monitor wells for the Catahoula Aquifer is adequate and should increase as the area of pumping from the aquifer expands. A total of about 20, 5 to 10, and 3 shallow monitor wells are recommended for the outcrop areas of the Chicot, Evangeline and Jasper aquifers, respectively, to help assess changes in the water table and storage in those areas.

- Groundwater pumping reductions were initiated in the north part of Harris County in 2010 at a rate of about 14.8 million gallons per day (mgd) and that rate increased to about 26.6 mgd by 2014. In general, about 79 percent of the pumping reduction was from the Evangeline Aquifer, 12 percent from the Jasper Aquifer and 9 percent from

the Chicot Aquifer. The aquifers response in the area to the pumping reductions documents about 20 to possibly 60 feet of artesian head or well static water-level recovery in the Evangeline Aquifer over an area of about 80 miles^2 and a reduction in the rate of artesian head or well static water-level decline in the Jasper Aquifer from about 15 feet per year to a much reduced rate of decline of no greater than five feet per year. The measured static water levels (artesian heads) in wells screening the Chicot Aquifer in the peripheral area to the reduction in pumping have essentially not changed since the groundwater pumping reductions were initiated. Thus, the introduction of surface water and the reduction in groundwater pumping were effective in reducing static water-level (artesian head) declines that can contribute to subsidence.

- In the future a recovery in the aquifer artesian head or water levels in wells in Montgomery County should occur locally in areas where groundwater pumping is reduced. The amount of artesian head recovery or reduction in rate of head decline in each aquifer will principally be controlled by the amount of the pumping reduction in that aquifer. In Montgomery County, the initial major pumping reductions will occur from the Evangeline and Jasper aquifers and the static water-level recovery or reduction in rate of decline will occur principally in the south part of the county and in the City of Conroe area.

INTRODUCTION

The Lone Star Groundwater Conservation District (LSGCD) is conducting a strategic evaluation of potential opportunities for additional development of groundwater resources while ensuring long-term viability of the aquifers in Montgomery County. The evaluation/planning process includes a review of the adequacy of the current groundwater monitoring program to monitor and assess current aquifer conditions and to monitor the effects of the initial conversion to alternative water supplies in 2016. An initial phase of the study is to review the groundwater production and water-level data that have been collected over at least the past 10 years to help understand the response of the aquifers to pumping and also to gauge the areal coverage of the well water-level monitoring network and the program for collecting groundwater production data. Another objective is to evaluate the aquifers' response in terms of well water-level changes, principally within the north part of Harris County, to the initial conversion to surface water in that area where groundwater pumping was reduced beginning in 2010 when a supply of surface water was introduced. The aquifers occur under water table conditions in their outcrops and artesian conditions in the downdip areas where they provide large amounts of water. Water levels measured in wells in the downdip areas provide data on the artesian head fluctuations in the aquifers.

Some of the tasks for the technical memorandum include the collection and analysis of water-level and groundwater production data from numerous sources, both public and private, for the Chicot, Evangeline, Jasper and Catahoula aquifers. Water-level data also were collected in counties surrounding Montgomery County to help assess trends over the past decade and to see if wells were/are available to help review on a sub-regional basis, static water-level changes that have occurred as pumping in the general Montgomery and Harris county areas has fluctuated (TWDB, 2015, Database Reports).

Data were compiled and analyzed for both static water levels (water levels measured while a well is not actively being pumped) and groundwater production for an area in north Harris County up to about 16 miles in diameter where the initial conversion to surface water occurred at a rate that ramped up from about 14.8 mgd in 2010 to about 26.6 mgd by 2014 (NHCRWA, 2015). A map of Montgomery and surrounding counties is shown on Figure 1.

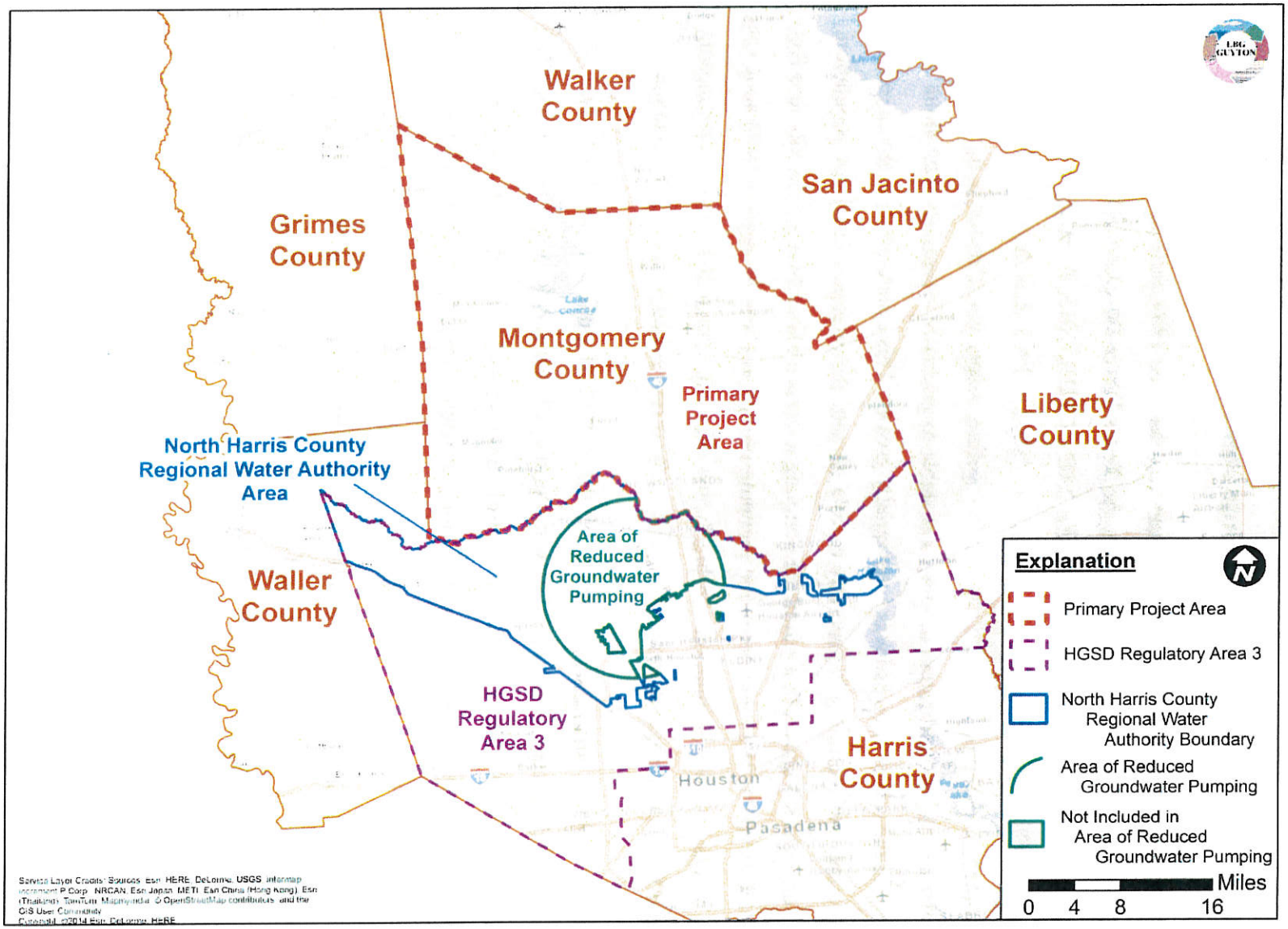


Figure 1. Montgomery and Surrounding Counties

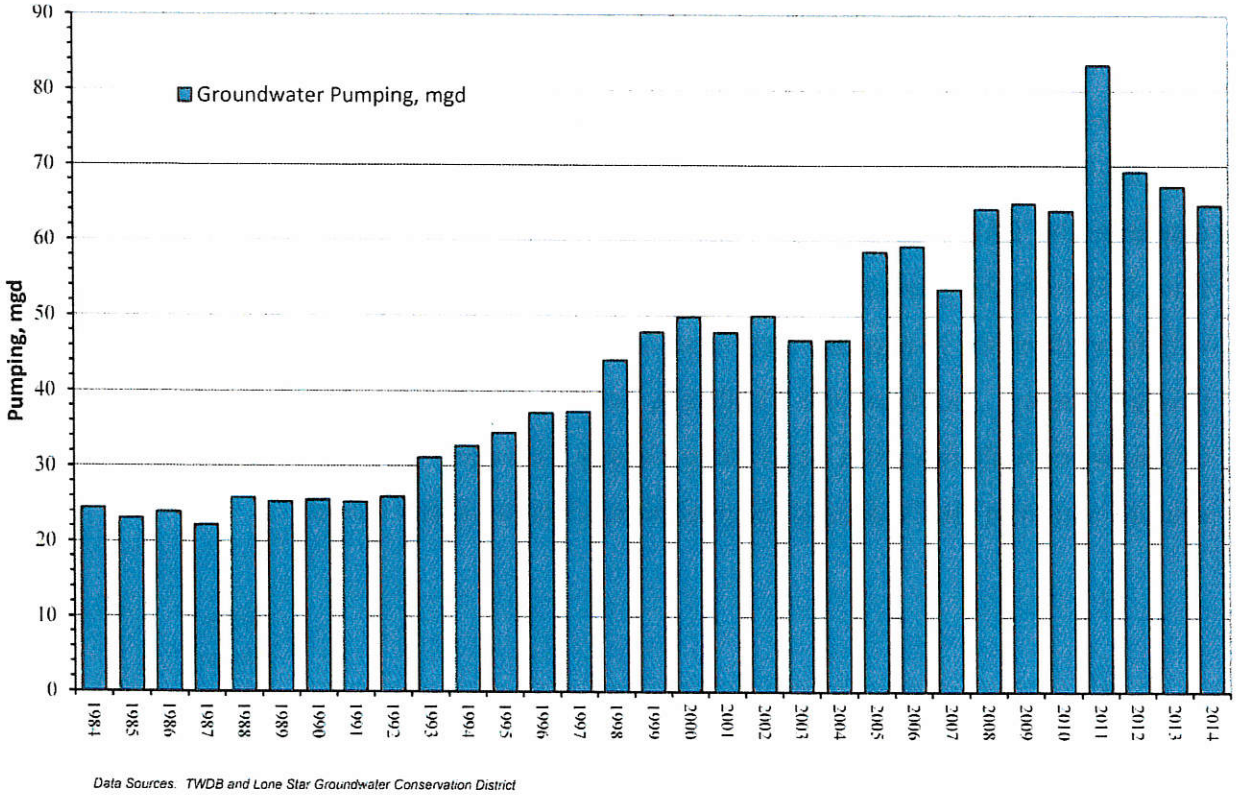
GROUNDWATER PUMPING

Montgomery County Historical Groundwater Pumping

Montgomery County groundwater pumping data for 1984 thru 2014 are shown on Figure 2. Pumping data were collected from the Texas Water Development Board (TWDB) county pumping inventory tables for 1984 thru 2002 (TWDB, 2015, Pumping Estimates) and from the LSGCD permitted pumping production data for 2003 thru 2014 (LSGCD, 2015). The data include pumping from the Chicot, Evangeline, Jasper and Catahoula aquifers. The data show that total groundwater pumping was stable to gradually increasing until about 1992 and after that the rate of increase was substantially greater. This acceleration in the increasing rate of groundwater pumping is generally correlated with the increases in county population. The data on Figure 2 shows that estimated pumping averaged about 24 mgd (26,883 acre feet per year (ac-ft/yr)) in 1984 and permitted pumping peaked at about 83 mgd (92,972 ac-ft/yr) in 2011, a year of low precipitation and high water demand. Since 2011 permitted pumping has ranged from an average of about 65 mgd (72,809 ac-ft/yr) to 69 mgd (77,298 ac-ft/yr).

Since 2000 a significant majority of the permitted pumping has been from the Evangeline and Jasper aquifers to provide water principally for public supply. Pumping from the Chicot Aquifer provides a limited amount of water, probably less than 10 mgd, with the water principally pumped by domestic wells for landscape watering, and a few public supply wells.

Pumping from the Catahoula Aquifer started in 2011 and increased from an average of 0.67 mgd (750 ac-ft/yr) in 2011, 1.48 mgd (4,681 ac-ft/yr) in 2012, and 2.09 mgd (2,341 ac-ft/yr) in 2013 to 2.72 mgd (3,046 ac-ft/yr) in 2014.



Data Sources: TWDB and Lone Star Groundwater Conservation District

Figure 2. Montgomery County Groundwater Pumping

Presently, a permittee in the LSGCD provides total pumping for a year by well or multiple wells and not pumping by aquifer, except for pumping from the Catahoula Aquifer. A number of permittees have multiple wells that screen the Chicot, Evangeline or Jasper aquifers and thus report total pumping, but do not report pumping by aquifer. The LSGCD is improving its database and reviewing/revising its reporting requirements so that future pumping information will be provided by aquifer.

The population in Montgomery County reported by the US Census Bureau was 184,066, 297,345 and 439, 298 in 1990, 2000 and 2010, respectively. Reported groundwater pumping in 1990, 2000 and 2010 was about 24.5, 50 and 63 mgd, respectively. The estimated gallons per capita per day (gpcd) usage using the available data was about 133, 168 and 139 gpcd in 1990, 2000 and 2010, respectively. If unreported domestic well pumping is added the gpcd would be slightly higher. In any event, the overall gpcd did not change substantially from 1990, 2000 and 2010 except in 2000 when precipitation was significantly below normal.

Groundwater Pumping in Surrounding Counties

Pumping is occurring around Montgomery County from the same aquifers that provide water to users in the LSGCD. There have been variations in the quantity of water that is pumped from neighboring counties for the period from 2000 to 2013. Groundwater pumping data from the TWDB for Grimes, Walker, San Jacinto, Liberty and Waller counties available from 2000 thru 2012 are shown on Figure 3. For Waller County the groundwater is mainly withdrawn from the Evangeline and Jasper aquifers; from the Catahoula and Jasper aquifers in Grimes County; and from the Catahoula, Jasper and Sparta aquifers in Walker County. Groundwater withdrawals in San Jacinto County are mainly from the Evangeline and Jasper aquifers and from the Chicot and Evangeline aquifers in Liberty County.

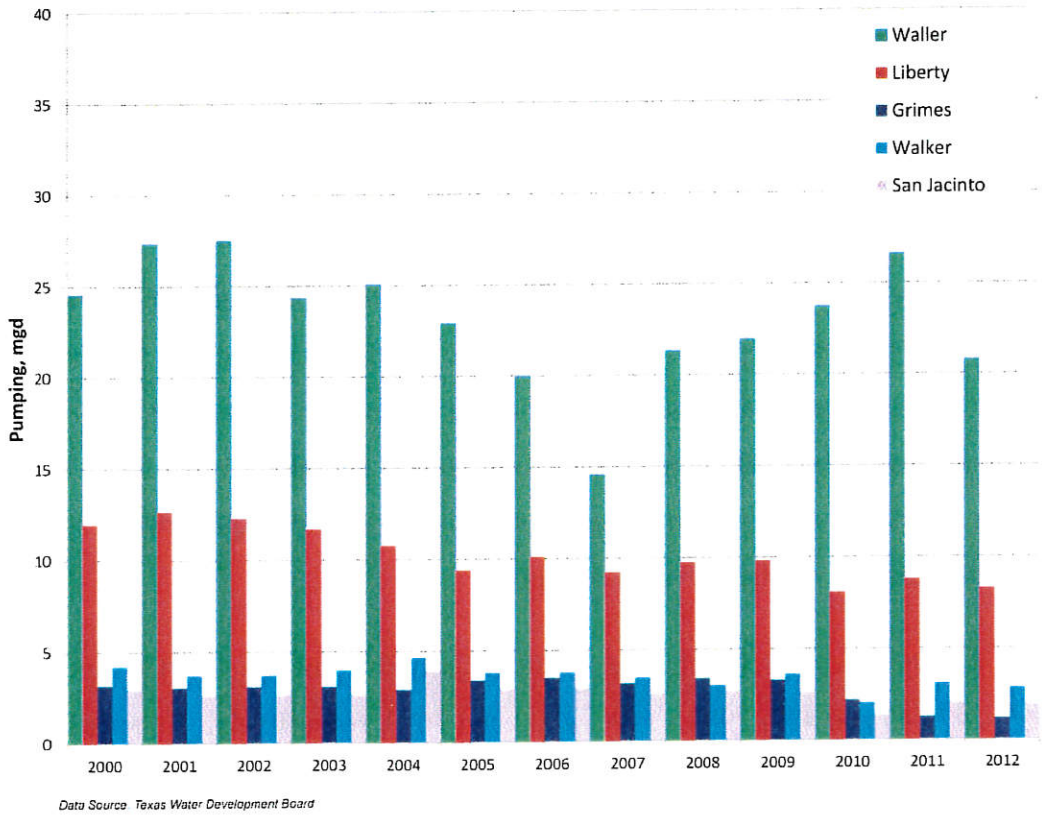


Figure 3. Groundwater Pumping by County

Pumping data from the Harris-Galveston Subsidence District (HGSD) (HGSD, 2015) are presented for Regulatory Area 3 for 2000 thru 2013, as shown on Figure 4. The significance of the data are that they show whether pumping in the area has increased, decreased or has been stable over the past twelve to thirteen years and is an indication of

whether the pumping from the area outside Montgomery County would have a significant influence on the changes in well water levels over the past 12 to 13 years in the aquifers in Montgomery County. For Harris County, the pumping data are exclusively for Regulatory Area 3 and the area location is shown on Figure 1.

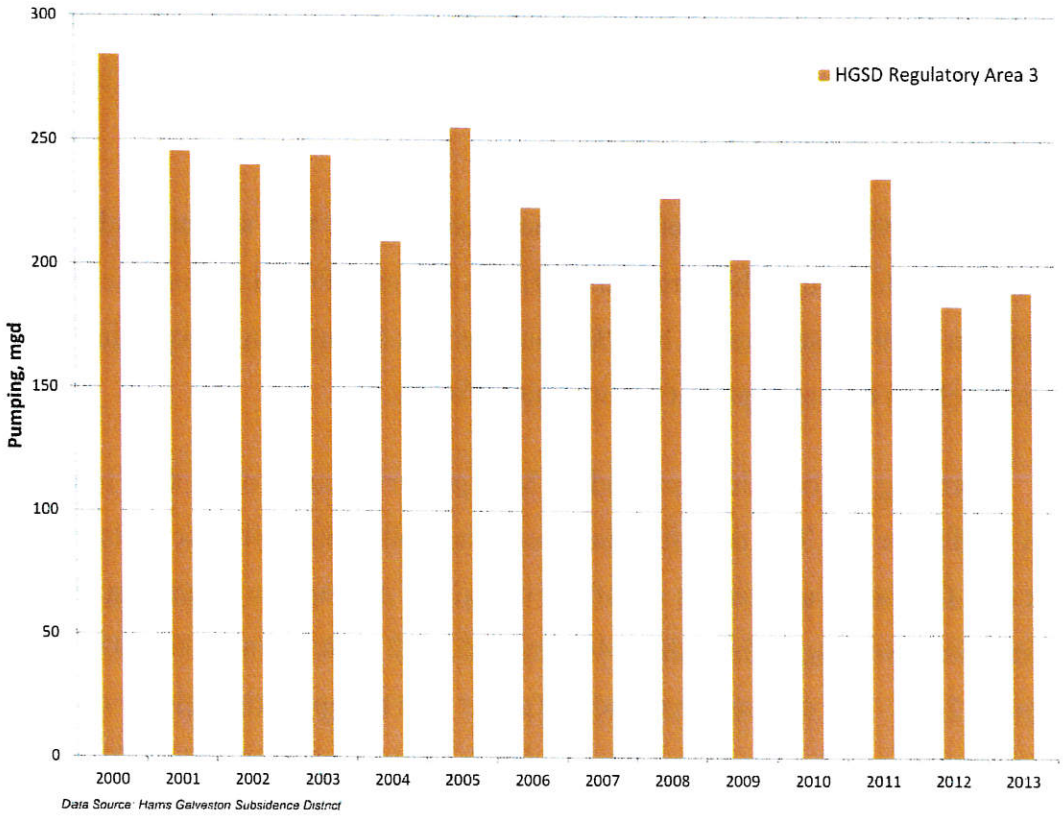


Figure 4. Groundwater Pumping in HGSD Regulatory Area 3

The data on Figure 4 show that the pumping from the Chicot, Evangeline and Jasper aquifers within Regulatory Area 3 ranged from about 284.5 mgd (318,640 ac-ft/yr) in 2000, a year with below normal precipitation, to about 189 mgd (211,680 ac-ft/yr) in 2013. The general trend in the amount of pumping in Regulatory Area 3 is slightly downward since 2008 with the exception of 2011 when below normal precipitation resulted in increased water demand and an increase in groundwater pumping to 235.1 mgd (263,312 ac-ft/yr). A significant majority of the pumping in Regulatory Area 3 is from the Evangeline Aquifer with much smaller amounts from the Chicot and Jasper aquifers. The pumping data for Regulatory Area 3 show a general downward trend while pumping data for Montgomery County show a general upward trend.

Increases in pumping cause artesian heads in an aquifer to decline while reductions in pumping cause the artesian heads to recover or have a lower rate of decline. The effects of increases or decreases in pumping on artesian heads are greatest in the immediate area of the pumping and decrease with increasing distance away from the pumping. Since 2000, permitted groundwater pumping in Montgomery County has increased from about 50 mgd to about 64 to 59 mgd in 2012 and 2014, respectively, as shown on Figure 2. At the same time, groundwater pumping in Regulatory Area 3 decreased from about 280 mgd in 2000 to about 180 mgd in 2012, as shown on Figure 4.

Since 1999, about 15 wells have been constructed that screen sands of the Jasper Aquifer and are located in the north part of Harris County. Pumping from the wells that were in service in 1999 is estimated to have had an effect on the artesian pressure in Jasper Aquifer screened wells in the south part of Montgomery County.

Pumping for counties surrounding Montgomery County other than Harris County is shown on Figure 3. The data illustrate combined pumping from the Chicot, Evangeline, Jasper and Catahoula aquifers in all of the counties. Average day pumping from all of the counties combined ranged from about 46.6 mgd (52,192 ac-ft/yr) in 2000 to 32.6 mgd (36,572 ac-ft/yr) in 2012. The data are provided in Table 1. Of the approximately 14 mgd (15,800 ac-ft/yr) of pumping reduction from 2000 to 2012, about 4 mgd (4,480 ac-ft/yr) occurred in Waller County and about 10 mgd (11,200 ac-ft/yr) occurred from Grimes, Liberty, San Jacinto and Walker counties combined. For Waller County the pumping ranged from 24.35 mgd (27,272 ac-ft/yr) in 2002 to 20.53 mgd (22,994 ac-ft/yr) in 2012.

Based on the locations of population in Grimes and Walker counties and irrigated acreage in Liberty County, a majority of the pumping is in the west part of Grimes County, at or north of Huntsville in Walker County, and in the central and south parts of Liberty County. For San Jacinto County, it is estimated that the limited pumping is distributed throughout the county and has averaged about 3 to 4 mgd (3,360 to 4,480 ac-ft/yr). In Waller County, the pumping is distributed through the county with the amount pumped for irrigation decreasing and the amount pumped for the increasing county population and commercial developments shifting to the south part of the county along Interstate Highway 10 (IH-10). The data show a

downward trend in pumping for the five counties and based on general observations, that a majority of the pumping is located at least 15 miles outside the LSGCD.

Table 1. Five Surrounding Counties Pumping

Year	Gulf Coast Aquifer Pumping in Grimes, San Jacinto, Liberty and Walker Counties, mgd	Waller County, mgd	Total, mgd
2000	22.23	24.35	46.58
2001	22	27.15	49.15
2002	21.71	27.30	49.01
2003	21.32	24.15	45.47
2004	22.16	24.86	47.02
2005	19.4	22.70	42.14
2006	20.31	19.74	40.05
2007	18.42	14.40	32.82
2008	18.78	21.14	39.92
2009	19.2	21.76	40.96
2010	9.76	23.47	33.23
2011	12.98	26.34	39.32
2012	12.03	20.58	32.61

In conclusion, there has not been a substantial increase, but general stability to a decrease in the groundwater pumping in the five counties surrounding Montgomery County over the past several years.

WATER-LEVEL DATA

Water-level data from the United States Geological Survey (USGS) (USGS, 2015), TWDB (TWDB, 2015) and private sources (GM Services, 2015) were collected for the Chicot, Evangeline, Jasper and Catahoula aquifers in Montgomery County and surrounding counties. The USGS has a program of measuring static water levels annually in 14, 76, 91 and 7 Chicot, Evangeline, Jasper and Catahoula aquifer screened wells, respectively, in Montgomery County. The data provide an indication of the aquifers response to pumping. An illustration showing the locations of USGS measured wells is shown on Figure 5. The

grid system used by the TWDB and USGS for identifying the locations of the well is superimposed on the figure. A list of the wells used to measure static water levels or aquifer artesian heads and the total depths of the wells is provided in Table 2. The wells can be located to the 2.5 by 2.5 mile grid using the well number and the grid map on Figure 5. Very few of the wells (6 to 9) are shallow and constructed in the water table part of the aquifers. The remaining 179 to 182 wells monitor water levels in the artesian part of the aquifers and are from a few hundred to 2,940 feet deep, based on data in Table 3. Water-level data for the wells represent a change in aquifer artesian head, not an unwatering of the sands screened.

Almost all of the wells used for monitoring also are pumped for water supply, thus when referring to monitoring wells the reference is to wells not solely used for providing water-level data.

Representative water-level hydrograph data are provided on Figure 6 for Montgomery County and on other figures for water wells in surrounding counties. The presentation of the data begins with the Chicot Aquifer and ends with the Catahoula Aquifer. The presentation of data regarding the Chicot, Evangeline and Jasper aquifers in Harris County will be provided in a later report section.

Chicot Aquifer Monitoring in Montgomery County

Areal Distribution of Wells

The areal distribution of wells screening the Chicot Aquifer and used for monitoring is provided on Figure 5. Shown on Figure 7 is the northwest extent of the Chicot Aquifer outcrop (Kazmarek, 2012). The distribution of the monitoring wells is about one well per 51 square miles with substantial areas of the county with no monitoring wells. Areas of the county where additional wells for water-level monitoring could be added are shown on Figure 8. An objective would be to use wells that have already been constructed or new wells that are constructed. Another objective would be to improve the areal coverage of the wells for monitoring aquifer response as pumping in the county is distributed over broader areas.

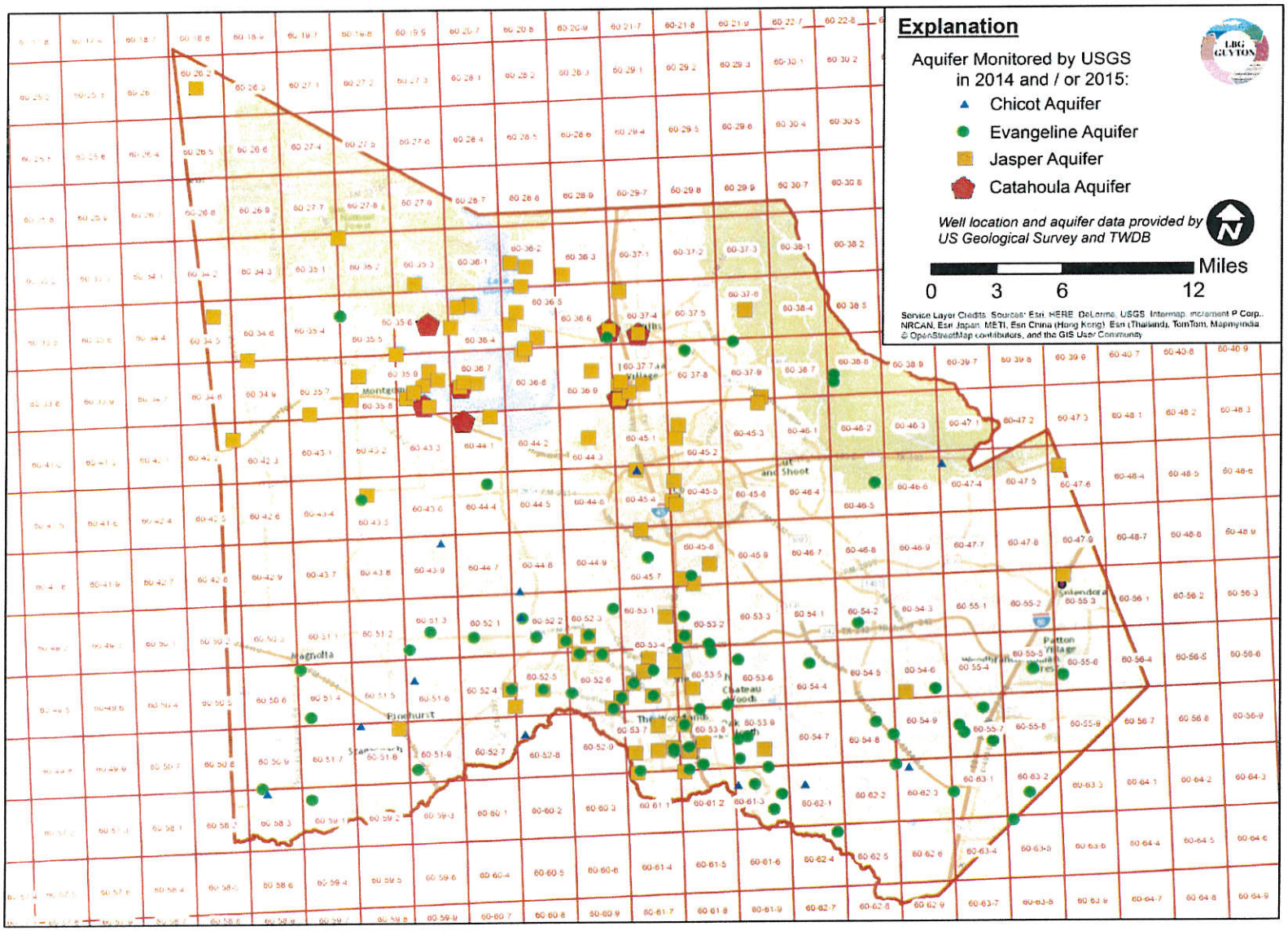


Figure 5. Areal Distribution of Monitoring Wells

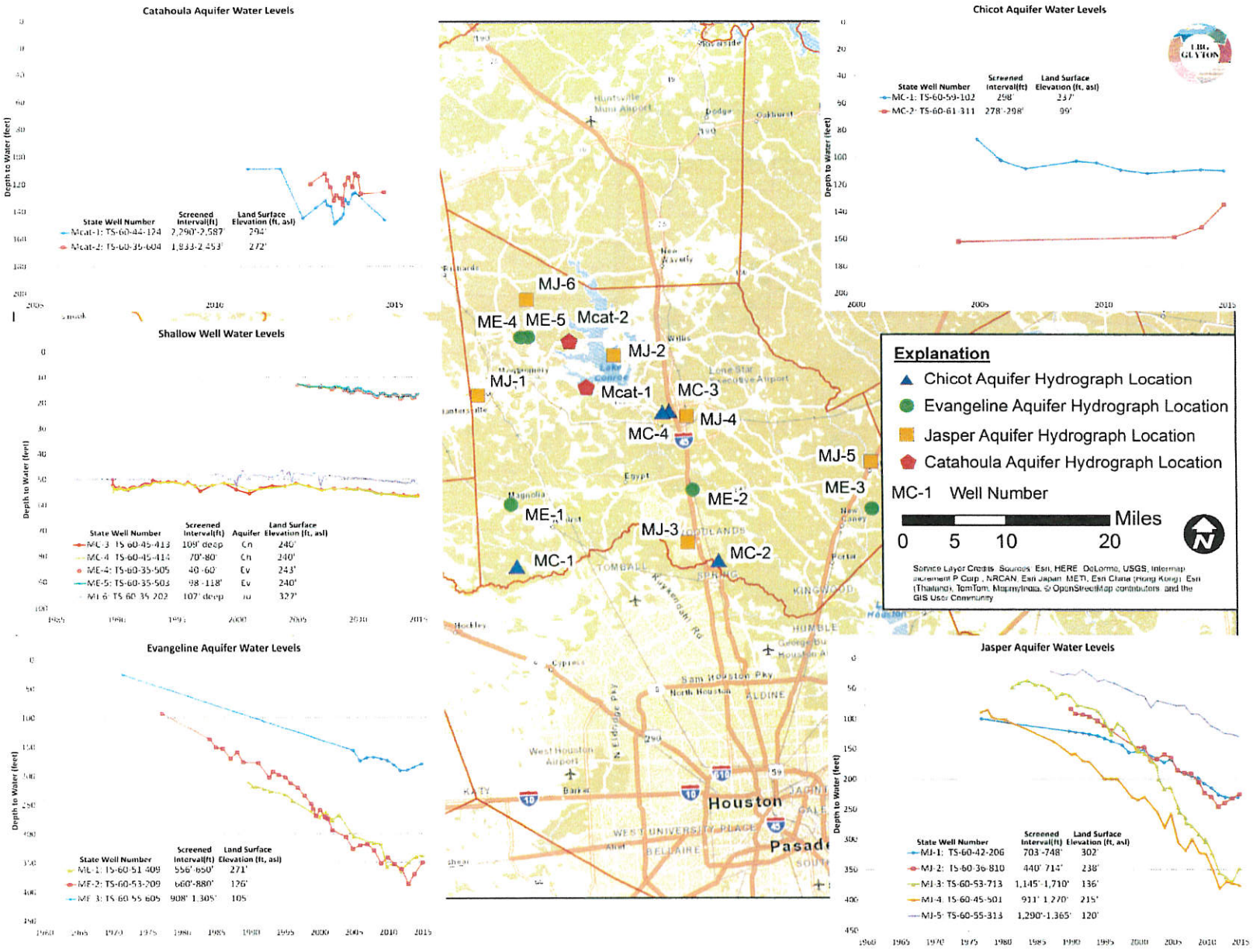


Figure 6. Montgomery County Water-Level Hydrographs

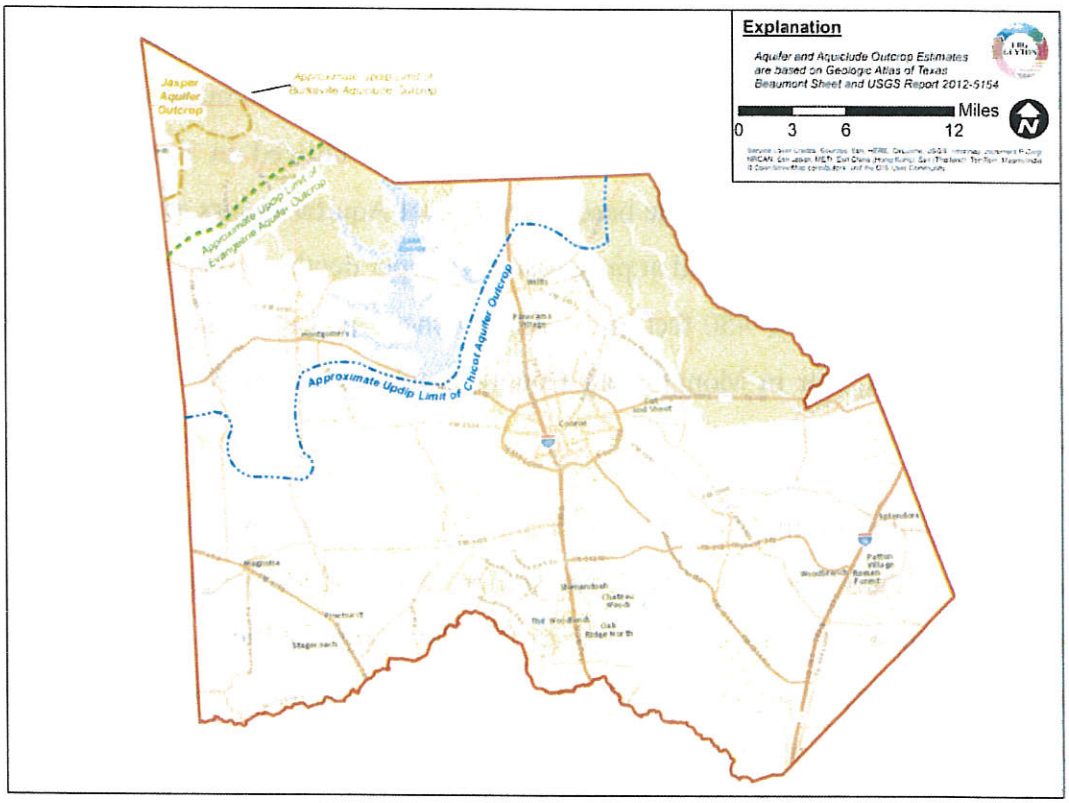


Figure 7. Aquifer Outcrops

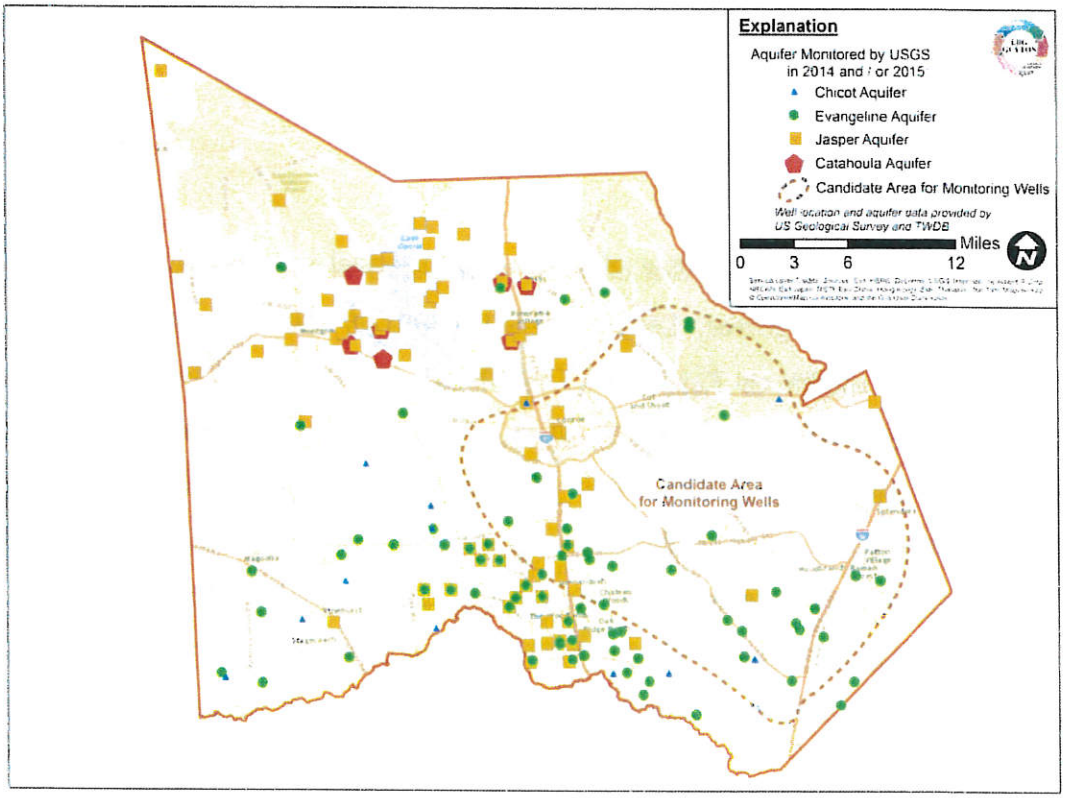


Figure 8. Area for Additional Wells for Monitoring Water Levels in the Chicot Aquifer

An additional 10 to 15 monitor wells spaced evenly over the area outlined on Figure 8 would increase the density of the water level observation locations. The additional wells to monitor aquifer artesian conditions could be important calibration/measured pumping effects targets as groundwater flow models are updated and utilized in future water resources planning/management efforts. The base of the Chicot Aquifer occurs at a depth of 50 feet or less at the Lake Conroe Dam and at progressively deeper depths to the southeast with the base at a depth of about 350 to 450 feet in the very southeast part of the county, thus the depth to the base of the aquifer in Montgomery County is relatively shallow compared to the other aquifers.

Only three of the Chicot Aquifer monitor wells are less than 120 feet deep and constructed in the water table part of the aquifer. Some additional monitor wells should be shallow, less than an estimated 80 feet deep, and thus represent monitoring of the water table or near water table part of the aquifer in the outcrop. The outcrop area, as shown on Figure 7, is very expansive and it would require probably 20 or so wells spaced over the outcrop to significantly expand the areal extent of monitoring water table conditions in the Chicot Aquifer. As part of monitoring the aquifer water table conditions, the LSGCD should work to identify existing candidate wells and, if funds are available, construct new, shallow monitoring wells.

Water-Level Hydrographs

There are a limited number of wells with historical water-level data available for the Chicot Aquifer in Montgomery County. The locations of wells with examples of water-level hydrographs are shown on Figure 6. The Chicot Aquifer generally occurs at depths too shallow for large-capacity wells and is mainly a source of water to 4-inch to 6-inch diameter domestic and small water system wells. The network of monitored wells in the county has increased since about 2004 as the result of an increase in cooperative efforts between the USGS, the LSGCD and well owners. As a result, data are available for Wells MC-1 and MC-2 beginning in about 2004. The static water levels in the wells show some stability to a modest rise since 2011 in one well (MC-2) and some initial decline and then water-level

stability in the other well (MC-1). Recent static water levels in the wells range from about 110 to 135 feet below ground level.

Also shown on Figure 6 are water-level data for two shallow non-pumped wells, 60-45-413 and -414, with water level measurements starting in about 1990. The data show a general downward trend from 1999 to 2001 and from 2005 to 2015, indicating water withdrawn from the water table part of the aquifer in proximity to the two wells. The withdrawal could be by pumping other nearby wells or by water in storage replenishing water pumped from the aquifer in other areas.

Evangeline Aquifer Monitoring in Montgomery County

Areal Distribution of Wells

Wells used to monitor water levels for the Evangeline Aquifer are distributed in Montgomery County, as shown on Figure 5. The monitor wells are spread over Montgomery County at an average density of about one well per 13 square miles. As shown on Figure 5, the distribution of monitor wells is concentrated in the south-central and southeast parts of Montgomery County where substantial urban development has occurred. Wells screened in the Evangeline Aquifer range in total depth from 60 to 1,315 feet. There is an area in the central and east part of Montgomery County where additional monitor wells should be located, as shown on Figure 9. An additional 10 monitor wells spread over the area would improve the areal coverage of the network. Also, as discussed with the Chicot Aquifer, additional monitor wells in targeted areas will provide calibration/measured pumping effects targets as groundwater flow models are updated and utilized in future water resources planning/management efforts. There also is the potential to reallocate LSGCD resources by discontinuing monitoring efforts in a few wells in the south-central part of the county and then establish new monitoring points in the areas with limited monitoring wells.

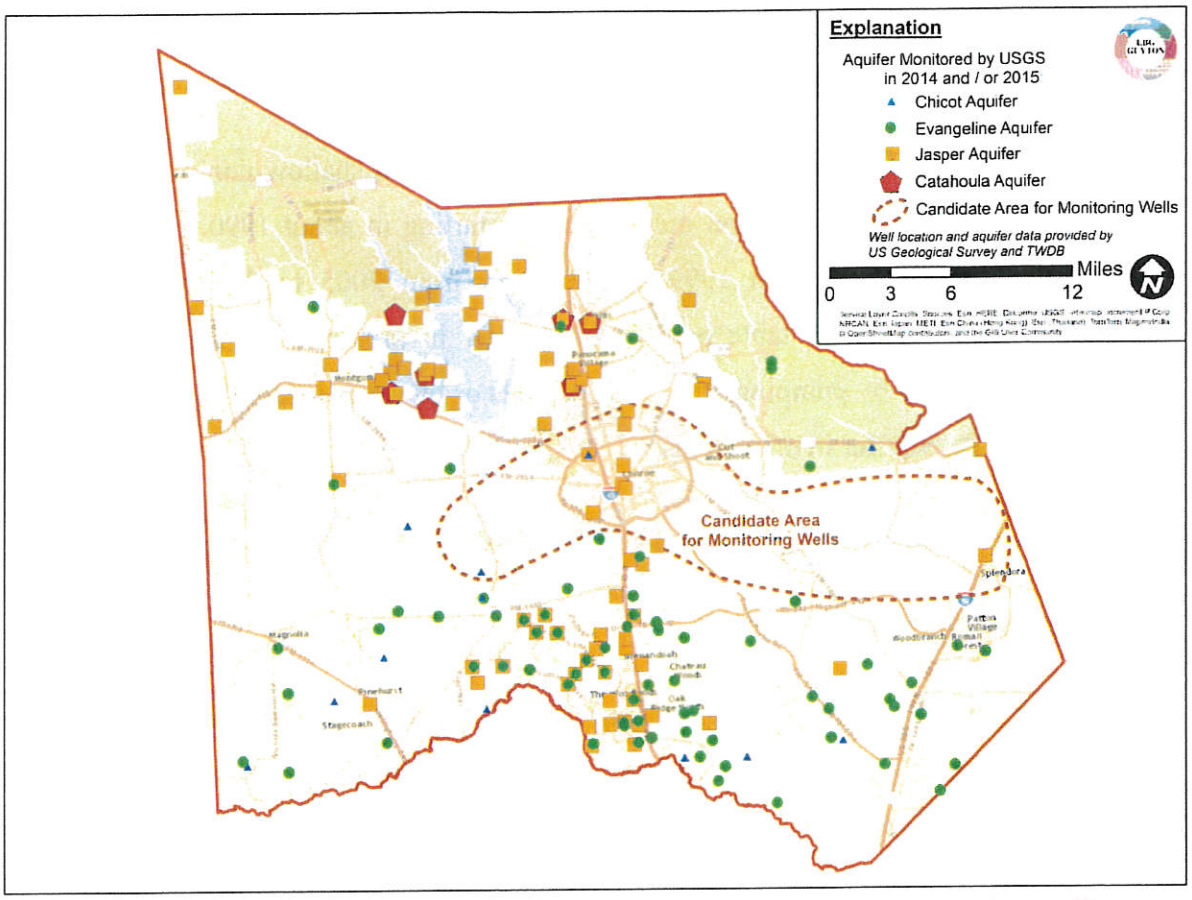


Figure 9. Area for Additional Wells for Monitoring Water Levels in the Evangeline Aquifer

Water-level monitoring in the outcrop of the Evangeline Aquifer shown on Figure 7 should be expanded with the incorporation of additional shallow monitoring wells, probably less than 80 feet deep into the LSGCD monitoring program. Initially, about five to ten wells could be added to the two existing shallow monitored wells and the additional wells spread over the outcrop area. An objective would be to identify shallow existing wells that could be used for monitoring and, if funds are available and sites can be secured, construct new shallow monitoring wells.

Water-Level Hydrographs

Static water levels in wells screened in the Evangeline Aquifer in southern Montgomery County have decreased about 150 feet over the past 25 years in response to stresses caused by increased pumping, as shown on Figure 2, and from pumping outside Montgomery County. The decrease in water levels is noted in wells that screen the major sands of the aquifer, as illustrated by two Evangeline Aquifer hydrographs on Figure 6. Two

hydrographs (ME-1) and (ME-2) show an overall downward trend ranging from an average decline of about 7.7 to 8.5 feet per year (2000-2011). Since 2011 there has been about 30 to 40 feet of water-level recovery in response to an overall reduction in pumping from the Evangeline Aquifer of at least a few mgd in Montgomery County. The reduction in pumping of about 14 to 22 mgd in the north part of Harris County since 2011 also has contributed to the recovery. The changes in well water levels representing aquifer artesian head fluctuations are principally due to the hydraulics of the aquifer and changes in the amount of pumping from the aquifer.

Also shown on Figure 6 are water-level data for two shallow non-pumped monitored wells, 60-35-503 and -505, constructed in 2004. The data show a general downward trend from 2005 to 2015 indicating water removed from the Evangeline Aquifer outcrop in proximity to them.

Jasper Aquifer Monitoring in Montgomery County

Areal Distribution of Wells

The water-level monitoring wells screening the Jasper Aquifer provide areal coverage in Montgomery County, as shown on Figure 5. The average density of the wells is about one well per 12 square miles. There are areas along the Interstate Highway 45 (IH-45) corridor and around Lake Conroe where the density is about one well per 3.5 square miles. At the same time, there is an area in the southwest and southeast part of the county with very few monitoring well screening sands of the Jasper Aquifer, as shown on Figure 10. It is recommended that a total of about 10 to 15 monitor wells be located in the two areas shown on Figure 10. These additional wells will be calibration/measured pumping effects targets as groundwater flow models are updated and utilized in future water resources planning/management efforts. Considering the density of the monitor wells along I-45 and in the Lake Conroe area, 10 to 15 of the wells in those areas could be reallocated in coordination with a LSGCD review of potential wells for monitoring at new locations in the areas outlined on Figure 10.

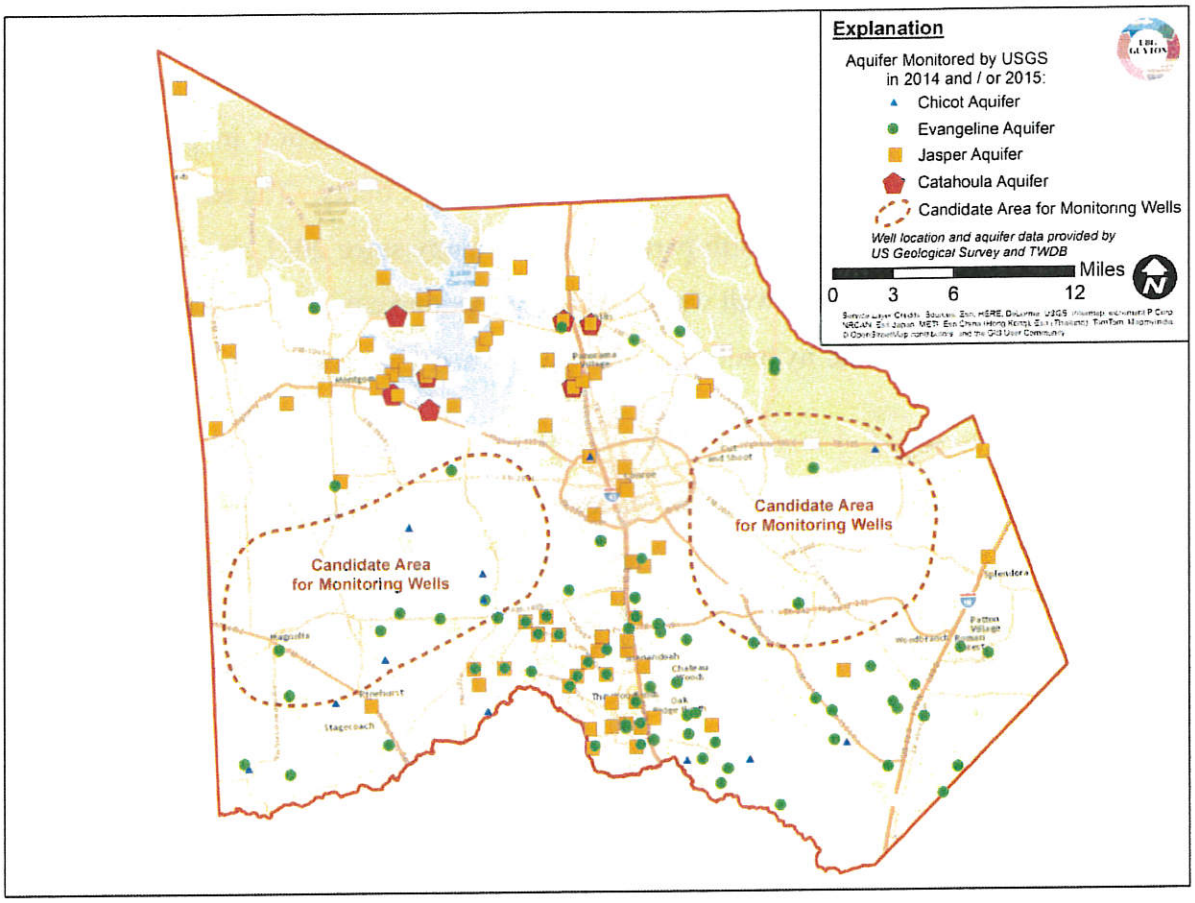


Figure 10. Area for Additional Wells for Monitoring Water Levels in the Jasper Aquifer

Water-level monitoring in the outcrop of the aquifer should be expanded with additional shallow monitoring wells probably less than 80 feet deep targeted. Initially, about three wells are recommended spread over the Jasper Aquifer outcrop area shown on Figure 7. An objective would be to utilize existing shallow wells and, if funds are available and locations can be secured, potentially construct a few new shallow monitor wells.

Water-Level Hydrographs

Static water levels of Jasper Aquifer screened wells have been monitored for at least four decades. The static-water levels in Montgomery County have declined over time in response to stress caused by increased pumping. The decline in water levels is noted in wells that screen the major sands of the aquifer, as illustrated by the five Jasper Aquifer hydrographs of Figure 6. The hydrographs in west Montgomery County (MJ-1), north Montgomery County (MJ-2) and east Montgomery County (MJ-5) show a similar downward

trend of about 70 to 80 feet from 2000 to 2015. The rates of static water-level decline have been greater in the south and central parts of Montgomery County where larger amounts of water are pumped. The water levels in south Montgomery County have experienced a greater amount of decline, about 310 feet since 1981 and of this about 290 feet of decline since 1990, due to the larger amount of pumping in the area. The rate of well water-level decline has not been as great in the City of Conroe area as in the south part of the county because the rate of increase in pumping has not been as high. If a water-level hydrograph includes measurements collected in the summer and winter, the summer measurements will show a deeper water level than the winter measurements due to a greater amount of pumping from the aquifer during that time.

Water-level data are available for shallow Well 60-35-202 about 107 feet deep and reported by the USGS to screen sands of the Jasper Aquifer. The location and water-level hydrograph is shown on Figure 6. The data show that the water level in the well rose from 1985 to 2005 and has declined since then. The data since 2005 show either a reduction in storage in the area in proximity to the well or a reduction in artesian pressure in the well.

Catahoula Aquifer Monitoring in Montgomery County

Areal Distribution of Wells

Water-level monitoring in the Catahoula Aquifer is mainly in the Lake Conroe area and to the southeast of it, as shown on Figures 5 and 11, as the areas are where wells have been constructed since 2010-2011. Prior to then there were no Catahoula Aquifer screened wells in the county. As additional wells are constructed, the areal coverage of water-level monitoring will expand. Additional wells constructed in the future should be equipped so that static water levels can reasonably easily be measured. The outcrop area for the Catahoula Aquifer is located to the north and west outside Montgomery County. If available, it is recommended that any water level data collected by the TWDB, USGS, or other groundwater conservation districts from wells located in the outcrop area be obtained and reviewed by the LSGCD.

Water-Level Hydrographs

The two hydrographs on Figure 6 show about a 40-foot reduction in the static water-level in MCat-1 since pumping began in about 2011 and approximately 10 feet of water-level decline in MCat-2 since 2012. A longer record of pumping and water-level changes will be developed during future years to enhance the understanding of the production potential of the aquifer. Currently no regional groundwater availability models exist for the Catahoula Aquifer for use in long-term planning. In the future when such a model is developed, adequate coverage of monitor wells with water-level hydrographs will be critical to the calibration of the model. The static water levels are still relatively shallow at about 130 to 150 feet below ground level.

ADDITIONAL MONITOR WELLS FOR MONTGOMERY COUNTY

Additional monitor wells are being recommended for Montgomery County to improve the water-level monitoring network. The proposed approach includes wells to measure water table changes in the aquifer outcrop areas and wells to measure artesian pressure changes where they exist generally in the downdip sections of the aquifers. The recommendations for the number of new wells for monitoring are provided in the following table.

Table 2. Summary of Monitor Wells Recommendations

Aquifer	Additional Monitor Wells in Artesian Areas of the Aquifers	Additional Shallow Monitor Wells in Outcrop Area
Chicot	10 – 15	20
Evangeline	10 [1]	5 – 10
Jasper	10 – 15 [1,2]	3
Catahoula	-	-

1 Potentially relinquish some monitor wells in areas with numerous, closely spaced wells and replace them with monitor wells in recommended areas

2 Utilize new wells for monitoring as they are constructed

The vast majority of the additional wells used for water-level monitoring will be constructed to supply water for various uses and equipped so that water levels can be measured on a periodic basis. As stated previously, utilizing pumped wells to monitor water levels has been successful for decades in the Montgomery and Harris county areas in assessing the aquifers response to groundwater pumping.

It also is recommended that available water-level data from wells constructed in either the water table or artesian areas of the aquifer in surrounding counties be periodically collected and evaluated.

Water-Level Monitoring in Surrounding Counties

Liberty County Water-Level Hydrographs

The USGS monitors water levels in a number of wells in western Liberty County that screen sands of the Evangeline Aquifer and water-level records are available for some of the wells since the 1940's and 1950s. The locations of the wells are shown on Figures 11 and 12. The data on Figure 12 show the water levels in the Evangeline Aquifer in Liberty County have only shown small fluctuations since about 1980 due to generally stable pumping in the area.

San Jacinto County Water-Level Hydrographs

The USGS monitors water levels in two wells in southwest San Jacinto County that screen sands of the Evangeline Aquifer and their locations are shown on Figure 12. The water-level records from the two wells date back to the mid 1970's and show the artesian head in the Evangeline Aquifer in San Jacinto County has a modest decline rate of about 1.4 feet per year up until 2005 as shown on Figure 12. Since 2005 the static water-level in SE-1 has fluctuated some, but has not shown any decline.

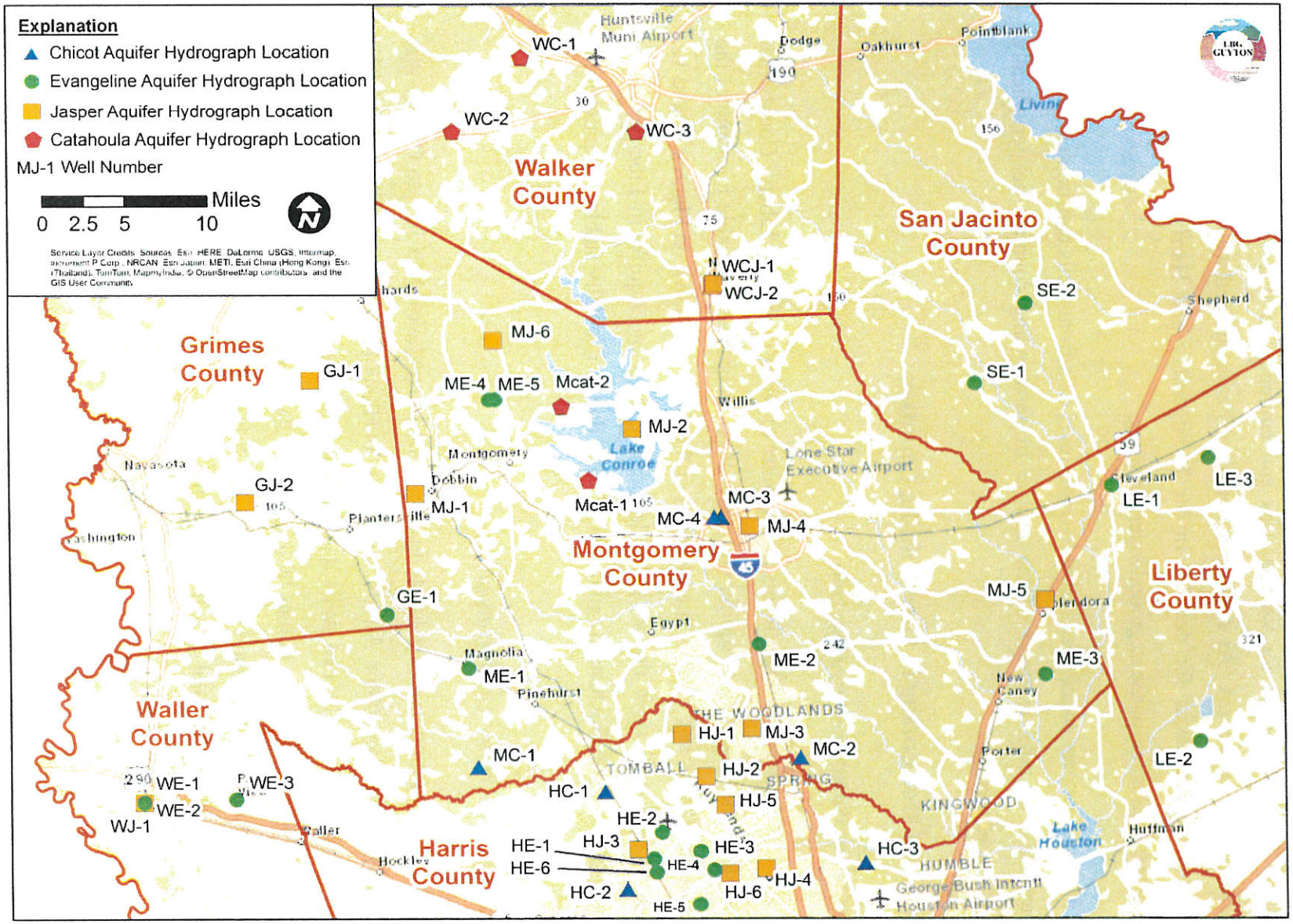


Figure 11. Static Water-Level Hydrograph Locations

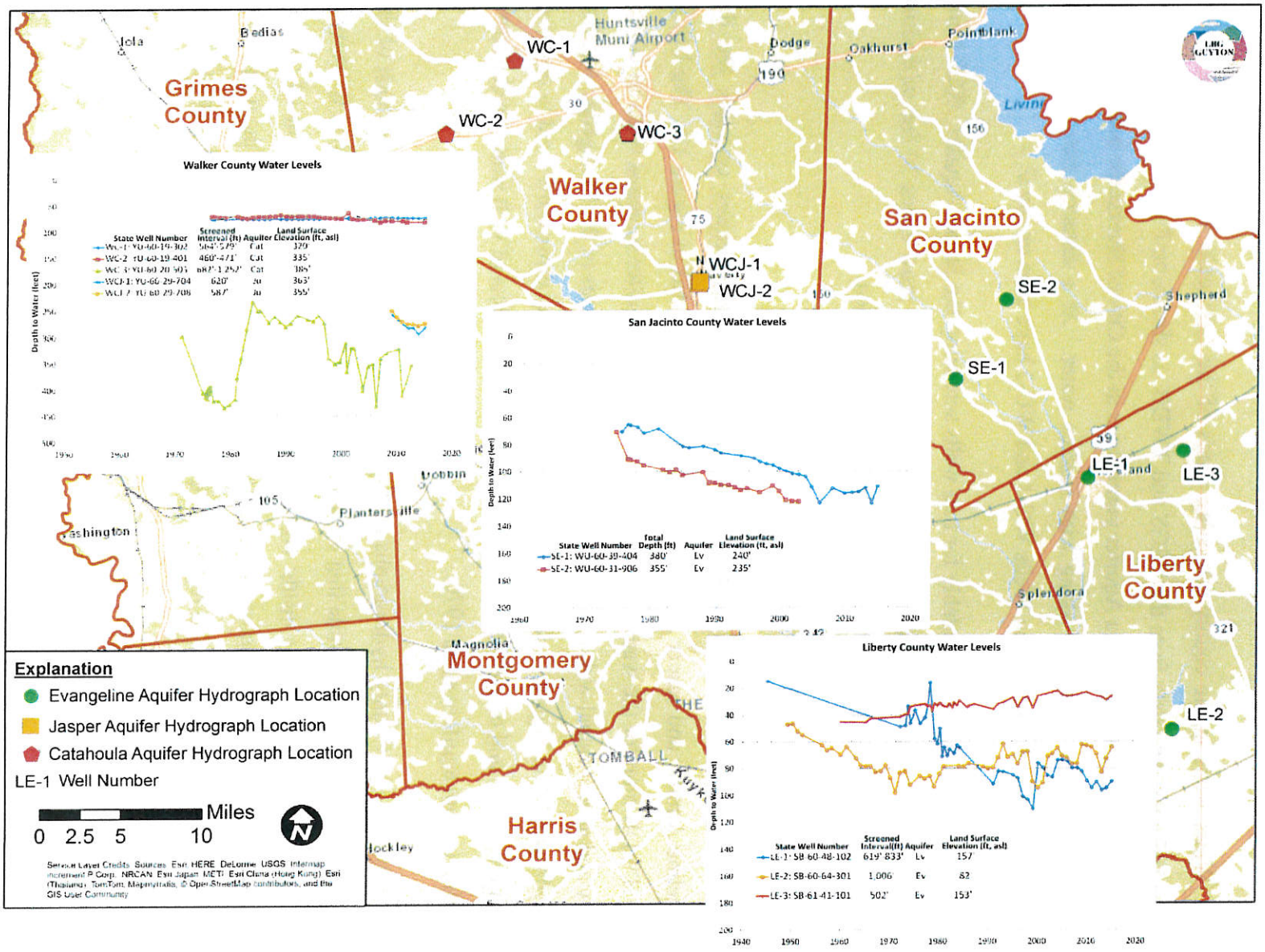


Figure 12. Liberty, San Jacinto and Walker County Static Water-Level Hydrographs

Walker County Water-Level Hydrographs

Water wells in the county screening sands of the Catahoula Aquifer have a history back to 1970 based on data from the USGS and TWDB, as shown on Figure 12. The primary area of any substantial Catahoula Aquifer pumping is in the City of Huntsville near Well WC-3 where the aquifer is utilized along with surface water. At a distance from the City of Huntsville water-level changes in Wells WC-1 and WC-2 have been minimal.

Water-level data are available for two wells screening the Jasper Aquifer, WCJ-1 and WCJ-2, located in the very south part of the county. The data show about 30 feet of decline from about 2007 to 2012 and 10 or less feet of recovery since then.

Waller and Grimes County Hydrographs

The presentation of water-level data for Waller and Grimes counties for the Evangeline Aquifer and Jasper Aquifer screened wells is provided in Figure 13. The USGS and/or TWDB monitor the water levels in three Evangeline Aquifer screened wells in Waller County and an additional well in Grimes County that screens sands of the Evangeline Aquifer. The hydrographs on Figure 13 for Waller County show a general downward trend in response to pumping inside and outside the county with about 85 to 100 feet of well water-level decline occurring in both aquifers since 1970.

The Grimes County hydrographs on Figure 13 for one well that screens sands of the Evangeline Aquifer and two wells that screens the Jasper Aquifer show a general downward trend in response to pumping inside and outside the county with the amount of decline ranging from about 25 to 50 feet since about 1960. The hydrographs for all of the wells show a downward trend through 2011, a higher pumping year and a small water-level rebound since then.

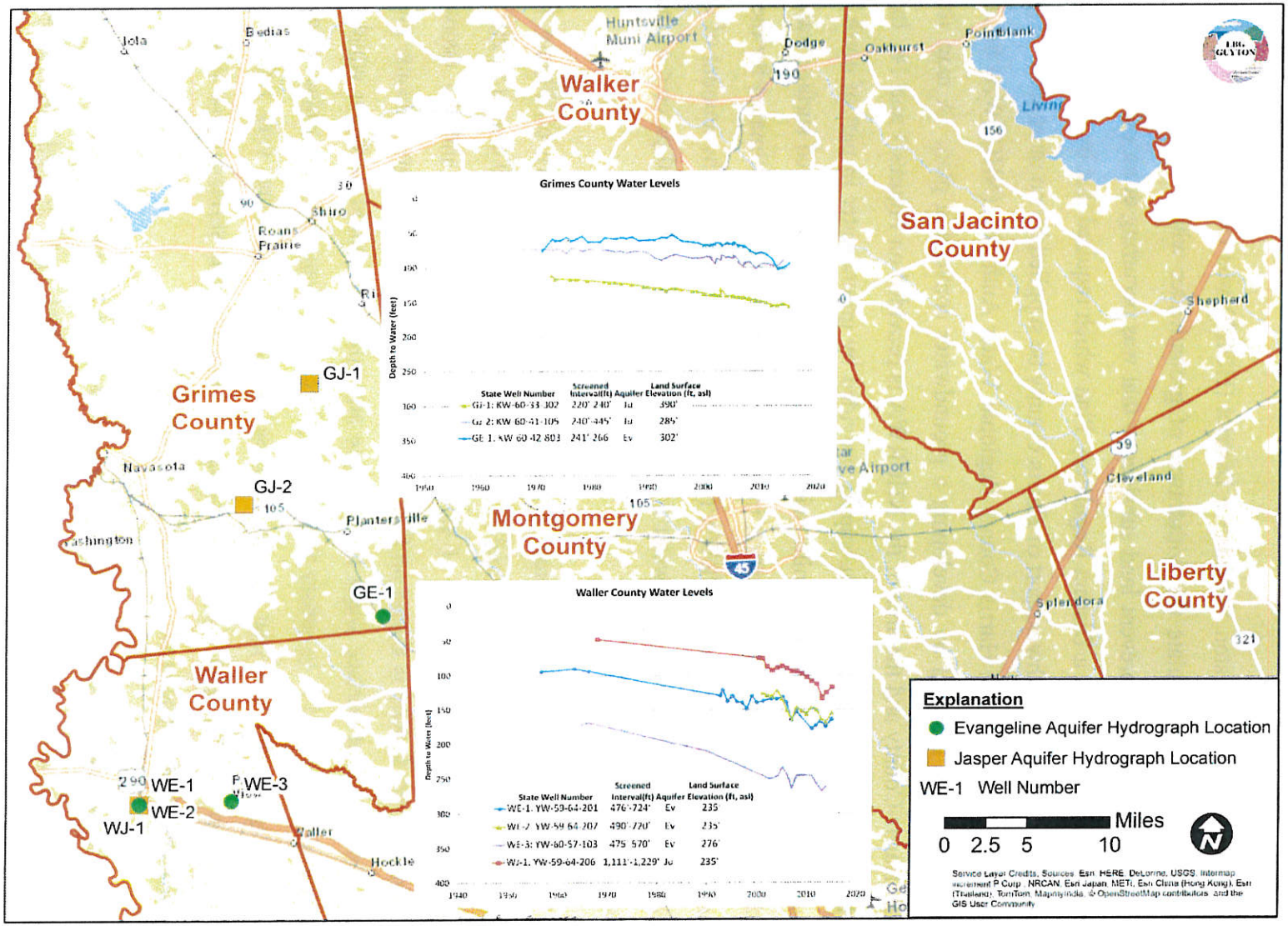


Figure 13. Waller and Grimes County Static Water-Level Hydrographs

AREA OF NORTH HARRIS COUNTY CONVERSION TO SURFACE WATER

History in Harris County

The Harris-Galveston Subsidence District (HGSD) was created in 1975 by the 64th State Legislature to regulate the withdrawal of groundwater within Harris and Galveston counties in an effort to prevent land subsidence that was occurring at an escalating rate. In 1999 the HGSD adopted a District Regulatory Plan which required that by 2010, the overall water demand in the northwest part of Harris County be supplied by no more than 70 percent groundwater. The North Harris County Regional Water Authority (NHCRWA) has helped the area achieve the goal by developing a groundwater conversion plan. A map showing north Harris County and the area of the NHCRWA is provided on Figures 1 and 14. In 2010, surface water replaced some of the supply provided by groundwater in part of north Harris County. An area up to about 16 miles wide where water districts received surface water also is shown on Figure 14. The reduction in groundwater pumping was estimated for the same area based on data from the NHCRWA (NHCRWA, 2015). By 2025 the amount of overall demand to be satisfied by groundwater is planned to be no more than 40 percent of the total water demand.

The amount of the reduction in groundwater pumping is shown on Figure 14 and started at an average of about 16 mgd in 2010 and increased to about 29.4 mgd in 2014. An illustration showing the amount of surface water that was utilized and the decrease in groundwater production is shown on Figure 15. With the reduction in groundwater pumping and introduction of surface water in the same area, the two should be about equal to one another when the goal is to satisfy 30 percent of the water demand with surface water. The data on Figure 15 show that this is the case except in 2011 when very below normal precipitation resulted in a significant increase in demand and surface water usage and a smaller than desired decrease in groundwater pumping.

Groundwater pumping decreased the most by 2014 from the Chicot, Evangeline, and Jasper aquifers at an average of about 3.3 mgd, 22.5 mgd, and 3.6 mgd, respectively. In general, the reduction in groundwater pumping was about 9 percent, 79 percent, and 12 percent from the Chicot, Evangeline, and Jasper aquifers, respectively.

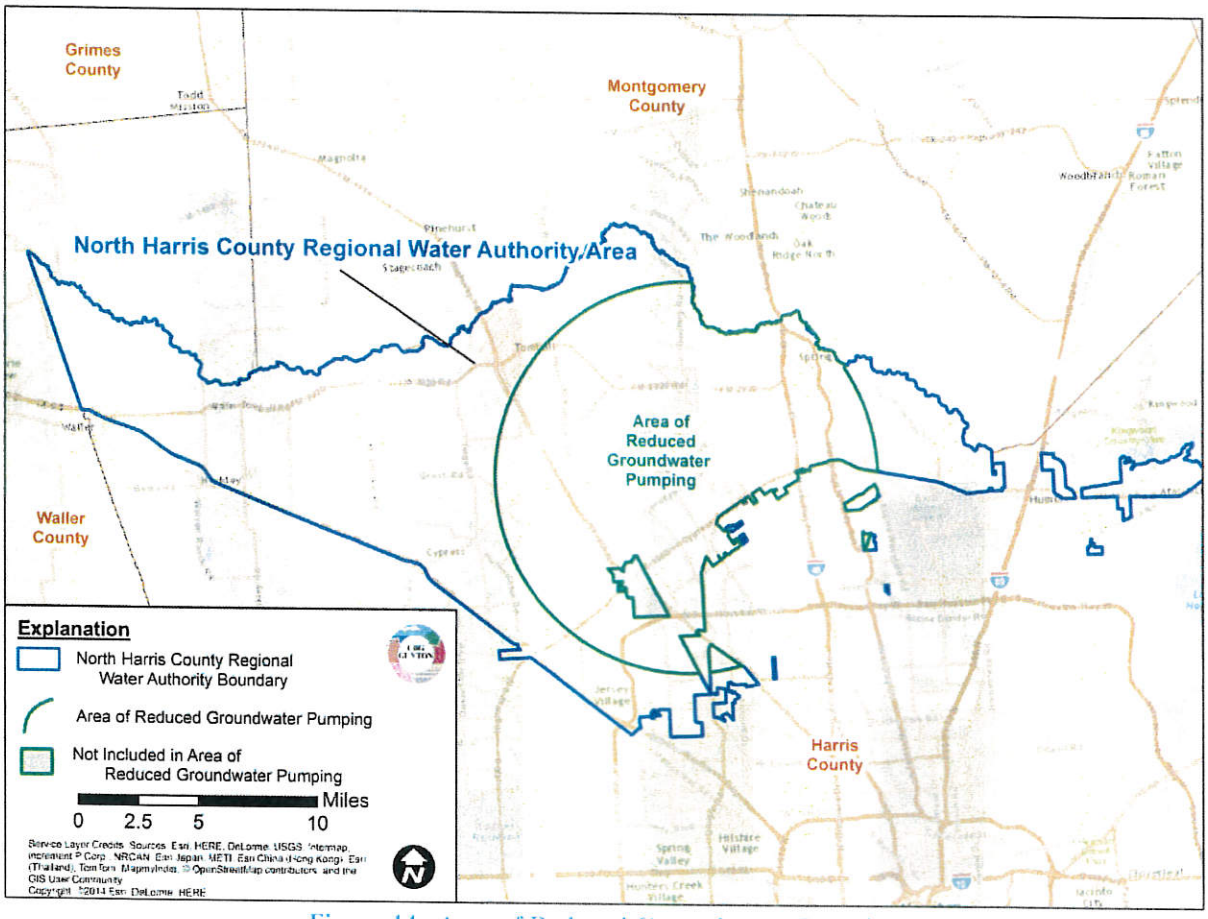
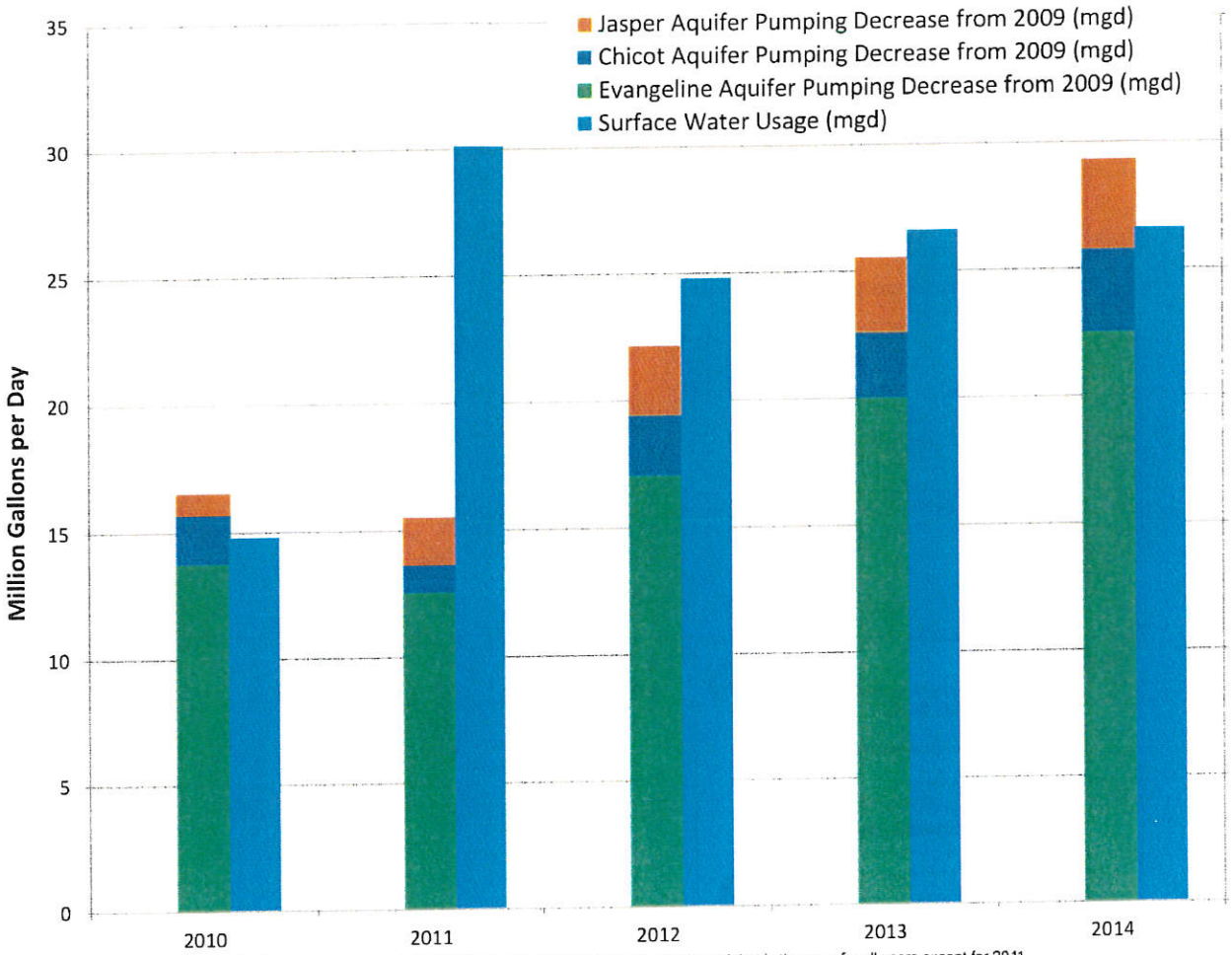


Figure 14. Area of Reduced Groundwater Pumping



The reduction in groundwater pumping in a year should about equal the surface water usage and that is the case for all years except for 2011. High water demand due to below normal precipitation lead to higher surface water usage.

Data Sources: North Harris County Regional Water Authority and LBG-Guyton Associates

Figure 15. Decrease in Groundwater Pumping Since 2009 and Surface Water Usage in the Area of Reduced Groundwater Pumping

Groundwater Pumping Outside Area of Surface Water Conversion

An objective of the study was to evaluate how water levels in wells screening the Chicot, Evangeline or Jasper aquifers responded to a reduction in pumping from the respective aquifers. The response of aquifers to a reduction in pumping is influenced by the amount of pumping within the area and the amount of pumping that is occurring outside the area and if those amounts of pumping are trending upward, staying the same or trending downward. In the case of the Gulf Coast Aquifer, reasonable proximity can be described as within about 10 to 15 miles of the area. A graph of the overall groundwater pumping within Regulatory Area 3 and in the southern part of Montgomery County is provided as Figure 16. Regulatory Area 3 covers about 1,050 miles^2 and the southern part of Montgomery County

about 240 miles^2 with the pumping concentrated along and west of IH-45. There are large differences in the amounts of pumping in the areas as Regulatory Area 3 had an estimated population of 2,250,000 in 2010 and the south part of Montgomery County had a population of about 225,000 in 2010 (Freese and Nichols, 2013). Part of the population in Regulatory Area 3 has treated surface water as a supply. The graph shows that between 2010 and 2011 there was a significant increase in pumping in Regulatory Area 3 because of the substantially higher than normal water usage. The fluctuation in the pumping in Regulatory Area 3 between 2010 and 2011 and 2011 and 2012 shows that the amount of the pumping change can be substantially higher than that recorded in southern Montgomery County. The data show that the small pumping fluctuations in southern Montgomery County should have had a very minimal effect on the static water-level changes that occurred in the Area of Reduced Groundwater Pumping. The proximal area changes in pumping were considered when estimating the response of the aquifers to the reduction in pumping within the area shown on Figure 14.

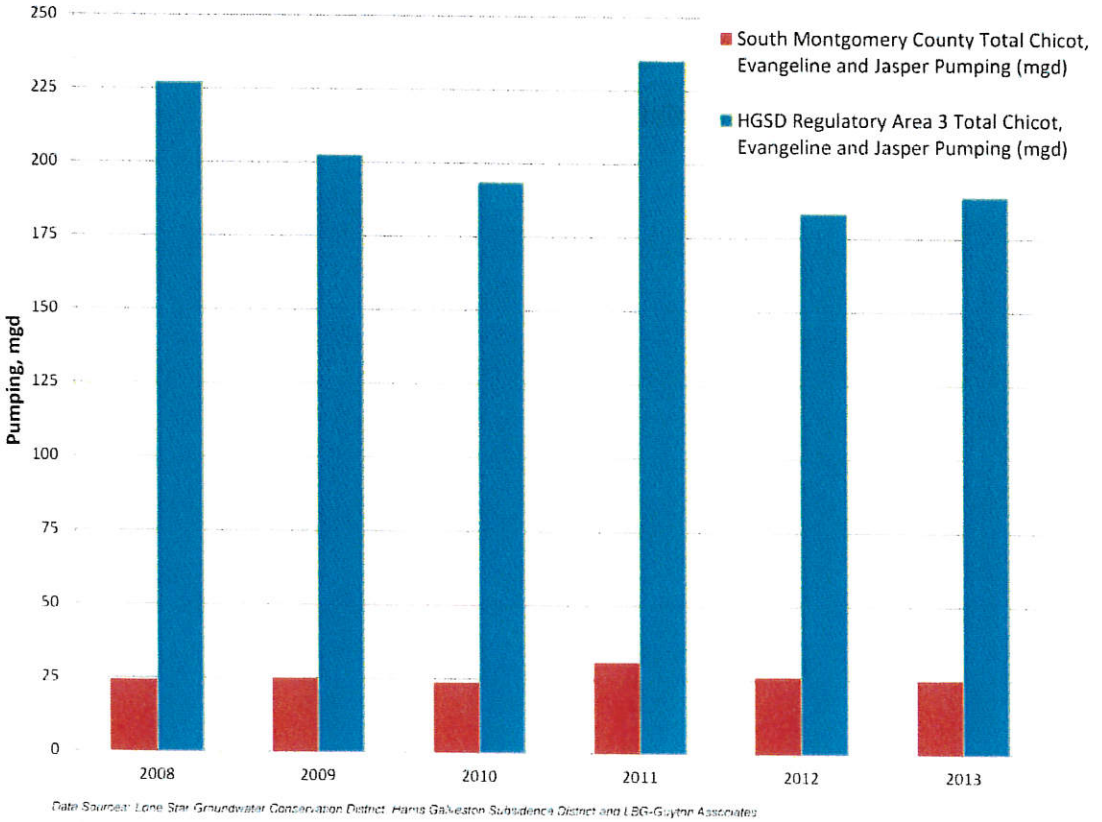
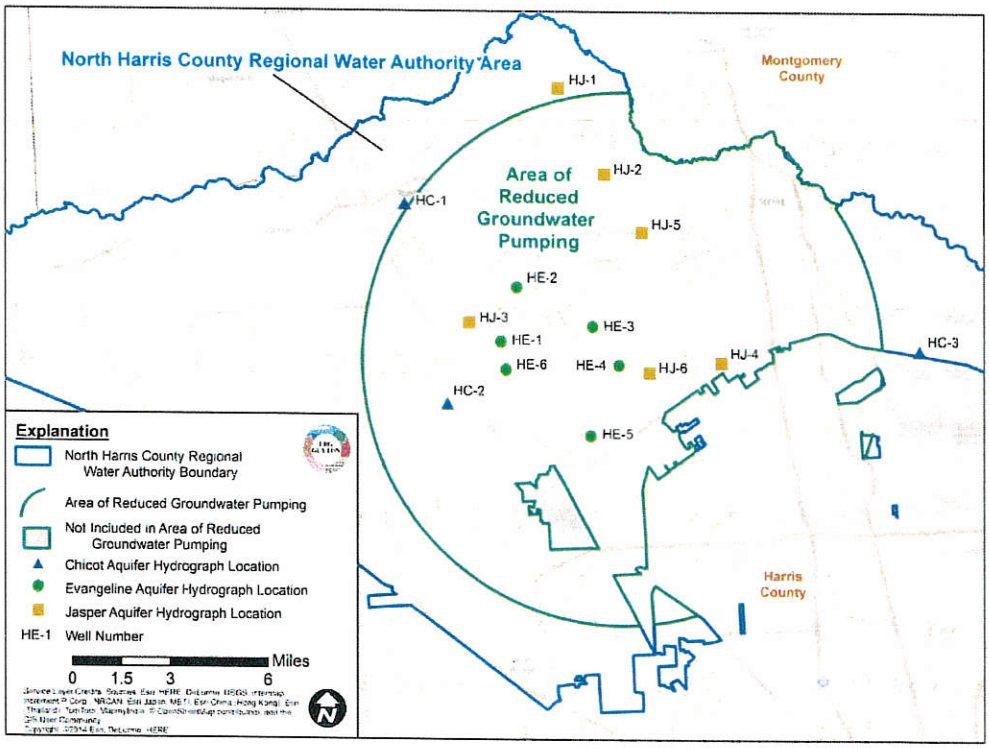


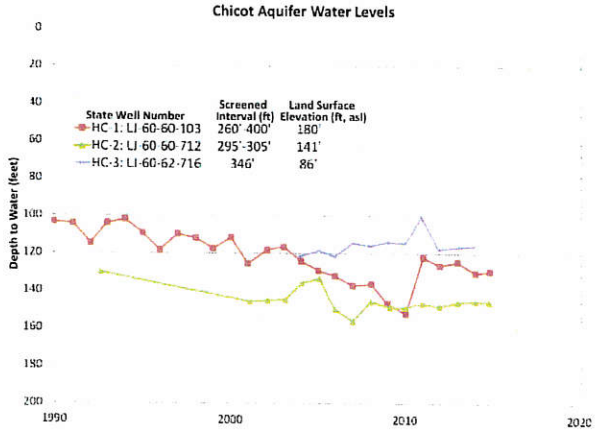
Figure 16. HGSD Regulatory Area 3 and South Montgomery County Groundwater Pumping

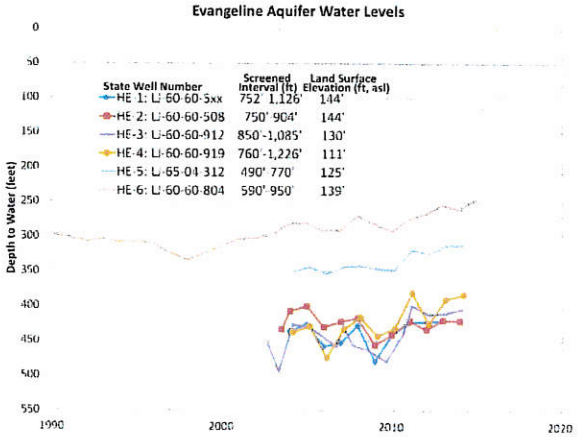
WELL STATIC WATER-LEVEL CHANGES

Chicot Aquifer

A limited number of hydrographs are available for wells that screen sands of the Chicot Aquifer in the area of interest. Water-level hydrographs available for three wells are shown on Figure 17 and their locations also are shown on Figure 17. The data show static water-level fluctuations, but for Well HC-1 the static water level recovered about 20 to 30 feet between 2010 and 2014. For Well HC-2 the rate of static water-level decline was arrested prior to 2010 and the static water level has remained stable. For Well HC-3 there has been a small net recovery in the static water level since about 2007. The reduced pumping from the Chicot Aquifer is estimated to have reached about 3.3 mgd by 2014. One reason for the observed static water-level response is that the observation wells are located somewhat peripherally to the area where a reduction in Chicot Aquifer pumping occurred and thus the magnitude of the water-level recovery is not as significant. This is evident when reviewing the well locations shown on Figure 17. It is probable that the amount of well water-level recovery is greater, but still limited in magnitude, in the interior of an area where the groundwater pumping was reduced about 3.4 mgd by 2014.







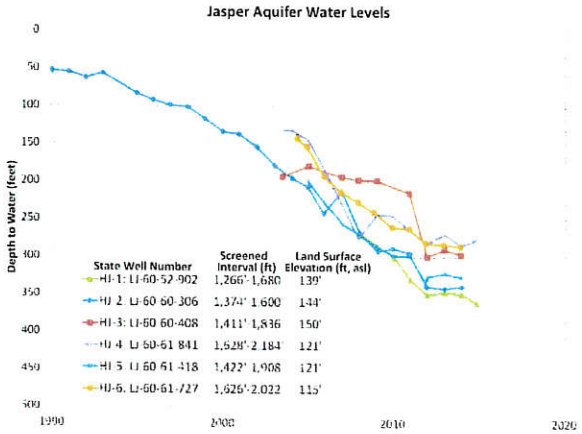


Figure 17. Static Water-Level Hydrographs in Area of Reduced Groundwater Pumping

Evangeline Aquifer

The data on Figure 17 show that from about 2003 to 2010 the static water levels in the Evangeline Aquifer in the area of interest fluctuated about 10 to 40 feet and most wells showed a downward trend from 2008 to 2009. Beginning in about 2010 when groundwater pumping from the Evangeline Aquifer was reduced initially by about 14 mgd, static water-level recovery started occurring and by 2014-2015 the water levels in the wells were from about 20 to 60 feet higher. This change is attributable to reduced groundwater pumping resulting from the introduction of surface water.

The center of the reduction in pumping from the Evangeline Aquifer is located about 8 to 9 miles south of Montgomery County. The effects of the reduction in pumping on static water levels in Evangeline Aquifer screened wells in Montgomery County is possibly 20 feet in the very south part of the county and smaller amounts of water-level recovery further to the north.

Jasper Aquifer

Well locations and water-level hydrographs for wells that screen sands of Jasper Aquifer are provided on Figure 17. The data show that from about 2005 until 2011 the rate of water-level decline averaged about 15 feet per year for most all of the wells. The data on Figure 17 show that, after about 2011, the rate of water-level decline substantially decreasing to no more than five feet per year for Wells 60-60-306 and -408 and for Well 60-61-418 there was essentially no static water-level decline. By 2014 pumping from the Jasper Aquifer was reduced by about 3.6 mgd. The reduction in the rate of static water-level decline is attributable to lower pumping from the Jasper Aquifer in the immediate area and possibly a small amount from a pumping reduction in Montgomery County.

AQUIFER RESPONSE TO REDUCTIONS IN GROUNDWATER PUMPING

The reductions in groundwater pumping in the north part of Harris County started at about 15 mgd beginning in 2010 and were up to about 29 mgd by 2014 and resulted in a reduced rate of water-level decline or stabilization of static water levels in the Jasper Aquifer

wells, the recovery of static water levels in the Evangeline Aquifer wells and some stabilization of static water levels in the Chicot Aquifer wells peripheral to the area of reduced pumping with an estimated few tens of feet of water-level recovery in the middle of the area of reduced pumping. For the Jasper Aquifer screened wells the rate of annual decline decreased from 15 feet per year to either a maximum of five feet per year or stable static water levels after 2011. If the magnitude of the reduction in pumping from the Jasper Aquifer had been larger, the positive effects on water levels would have been greater. For the Evangeline Aquifer wells the rise in static water levels has been about 20 to possibly 60 feet since 2010 in the area of reduced groundwater pumping.

FUTURE AQUIFER RESPONSE TO REDUCTIONS IN GROUNDWATER PUMPING IN MONTGOMERY COUNTY

As groundwater pumping reductions beginning in 2016 occur principally from the Evangeline and Jasper aquifers, there should be either a reduction in the rate of decline or a recovery in the aquifer artesian pressure or static water levels in wells in the areas of the pumping reductions. The amount of the artesian head or static water-level recovery or reduction in rate of decline in each aquifer will principally be controlled by the amount of the pumping reduction in that aquifer. The Chicot Aquifer provides substantially less water to wells in Montgomery County compared to the Evangeline or Jasper aquifers and therefore any pumping reductions from the Chicot Aquifer should be substantially smaller than the pumping reductions that occur in the other two aquifers.

REFERENCES

Freese and Nichols, Inc., 2013, Regional Groundwater Update Project: Harris-Galveston Subsidence District, 19 p.

G-M Services, 2015, Harris County Water-Level Data.

Harris Galveston Subsidence District, 2015, HGSD Regulatory Area 3 Groundwater Pumping Data.

Kasmarek, M.C., 2012, Hydrogeology and simulation of groundwater flow and land-surface subsidence in the northern part of the Gulf Coast aquifer system, Texas, 1891–2009 (ver. 1.1, December 2013): U.S. Geological Survey Scientific Investigations Report 2012–5154, 55 p.

Lone Star Groundwater Conservation District, 2015, Montgomery County Groundwater Pumping Data.

North Harris County Regional Water Authority, 2015, North Harris County Groundwater Pumping Data and North Harris County Surface Water Usage.

Texas Water Development Board, 2015, *Groundwater Database Reports: Well and Water Level Data*. Retrieved from: http://www.twdb.texas.gov/groundwater/data/gwdbrpt.asp.

Texas Water Development Board, 2015, *Groundwater Pumping Estimates*. Retrieved from: http://www.twdb.texas.gov/waterplanning/waterusesurvey/historical-pumpage.asp.

University of Texas, Bureau of Economic Geology, 1992, The Geologic Atlas of Texas, Beaumont Sheet, Scale 1:250,000.

U.S. Geological Survey, 2015, *Groundwater Levels for Texas*. Retrieved from:

http://nwis.waterdata.usgs.gov/tx/nwis/gwlevels.

TABLE

Table 3. List of Wells Used to Monitor Water Levels

State Well Number	Total Depth (ft)	First Measurement	Most Recent Measurement
Chicot Aquifer:			
TS-60-43-902	120	9/20/2006	2/2/2015
TS-60-44-805	161	2/8/2005	3/26/2015
TS-60-45-412	261	10/19/1989	3/31/2015
TS-60-45-413	109	10/19/1989	2/10/2015
TS-60-45-414	80	10/20/1989	3/31/2015
TS-60-47-408	210	6/28/2005	2/17/2015
TS-60-51-603	220	2/16/2006	2/10/2015
TS-60-51-816	210	6/3/2005	2/25/2014
TS-60-52-206	270	10/21/1986	3/3/2015
TS-60-52-811	143	9/24/2005	2/26/2014
TS-60-58-303	195	9/30/2005	2/6/2015
TS-60-61-311	300	5/13/2004	2/12/2015
TS-60-62-101	492	2/1/2010	2/27/2015
TS-60-62-306	260	9/20/2005	2/16/2015
Evangeline Aquifer:			
TS-60-35-503	118	2/8/2005	3/31/2015
TS-60-35-504	83	2/8/2005	1/13/2015
TS-60-35-505	60	2/8/2005	3/31/2015
TS-60-36-611	336	12/28/1977	1/6/2015
TS-60-37-806	350	2/17/2004	2/17/2015
TS-60-37-909	515	3/28/2000	12/9/2014
TS-60-38-806	600	2/7/2005	2/11/2015
TS-60-38-807	570	2/7/2005	2/11/2015
TS-60-43-511	394	9/1/1978	2/6/2015
TS-60-44-411	550	7/20/2006	1/7/2015
TS-60-45-716	710	1/15/2004	2/25/2014
TS-60-45-805	702	10/12/1964	2/9/2015
TS-60-46-505	345	5/17/1978	3/12/2015
TS-60-50-904	220	2/15/2006	3/2/2015
TS-60-51-310	454	5/21/2012	2/16/2015
TS-60-51-311	677	3/20/2013	2/16/2015
TS-60-51-409	662	3/1/2000	2/24/2015
TS-60-51-415	360	12/16/2009	2/6/2015
TS-60-51-907	720	10/21/1985	2/13/2015
TS-60-52-113	887	2/8/2011	2/18/2015
TS-60-52-210	976	2/4/2002	2/16/2015
TS-60-52-212	1,004	2/15/2005	2/6/2014
TS-60-52-215	718	3/3/2007	1/6/2015
TS-60-52-307	890	4/20/1999	2/16/2015
TS-60-52-309	836	7/20/2012	2/18/2015
TS-60-52-410	915	2/13/2008	2/16/2015
TS-60-52-502	906	4/4/2001	2/16/2015
TS-60-52-602	1,030	4/18/1999	2/5/2015
TS-60-52-605	1,064	4/20/1999	2/5/2015
TS-60-52-607	1,052	4/18/1999	2/3/2015
TS-60-52-609	1,120	5/6/1999	2/9/2015
TS-60-52-613	965	3/25/2006	2/17/2015
TS-60-53-208	820	4/19/1974	2/6/2014
TS-60-53-209	1,000	5/18/1977	2/17/2015
TS-60-53-215	256	2/15/2005	2/24/2015
TS-60-53-216	--	2/16/2005	12/8/2014
TS-60-53-407	1,005	4/18/1999	2/17/2015
TS-60-53-409	1,000	5/9/1999	2/3/2015
TS-60-53-417	1,094	4/26/2000	2/4/2015
TS-60-53-516	807	2/8/2005	3/26/2015
TS-60-53-517	265	4/22/2003	2/11/2015
Evangeline Aquifer (cont.):			
TS-60-53-520	360	9/23/2008	2/10/2015
TS-60-53-608	809	10/1/1978	2/19/2015
TS-60-53-709	944	10/5/1973	2/3/2015
TS-60-53-715	870	8/27/1982	2/12/2015
TS-60-53-718	246	2/26/2006	3/26/2015
TS-60-53-813	996	10/15/1970	1/20/2015
TS-60-53-820	500	2/6/2001	1/20/2015
TS-60-53-826	1,014	3/10/2000	3/4/2015
TS-60-53-827	570	2/9/2005	2/16/2015
TS-60-53-830	1,025	5/11/1999	2/3/2015
TS-60-53-831	910	7/12/1999	1/20/2015
TS-60-53-902	425	6/26/1980	2/13/2015
TS-60-53-903	558	2/16/2005	2/12/2015
TS-60-53-904	590	2/4/2012	2/12/2015
TS-60-54-209	320	9/3/2012	2/27/2015
TS-60-54-406	462	12/10/1999	2/19/2015
TS-60-54-614	1,102	4/10/2013	2/19/2015
TS-60-54-804	1,016	7/30/1980	1/20/2015
TS-60-54-808	516	2/14/2005	1/20/2015
TS-60-55-512	701	8/23/2012	2/16/2015
TS-60-55-605	1,315	2/9/2005	2/17/2015
TS-60-55-708	620	7/10/1984	2/16/2015
TS-60-55-710	600	2/8/2005	3/26/2015
TS-60-55-712	660	2/9/2005	2/16/2015
TS-60-55-714	590	2/9/2005	2/16/2015
TS-60-59-102	298	2/17/2005	2/12/2015
TS-60-61-307	506	10/30/1984	12/5/2014
TS-60-61-308	1,182	2/16/2005	3/4/2015
TS-60-61-309	1,066	1/26/2010	2/12/2015
TS-60-61-310	--	2/21/2005	12/5/2014
TS-60-62-201	634	2/22/2013	2/16/2015
TS-60-62-404	585	1/15/2010	2/27/2015
TS-60-63-109	777	2/26/1987	1/20/2015
TS-60-63-205	900	2/9/2005	2/13/2015
TS-60-63-507	1,190	2/1/2001	2/23/2015

Data provided by US Geological Survey and TWDB

Table 3. List of Wells Used to Monitor Water Levels

State Well Number	Total Depth (ft)	First Measurement	Most Recent Measurement
Jasper Aquifer:			
TS-60-26-208	172	3/3/2000	1/6/2014
TS-60-34-503	795	1/21/2002	12/3/2014
TS-60-34-605	404	11/3/2005	1/8/2014
TS-60-35-202	107	11/28/1952	3/31/2015
TS-60-35-303	348	2/20/2008	12/5/2014
TS-60-35-703	763	1/24/1983	12/3/2014
TS-60-35-812	783	3/2/2000	12/8/2014
TS-60-35-813	665	7/7/2005	4/22/2015
TS-60-35-907	490	5/14/1982	12/16/2014
TS-60-35-908	495	3/6/2000	12/16/2014
TS-60-35-909	648	7/1/1988	12/9/2014
TS-60-35-910	640	11/7/1990	12/16/2014
TS-60-35-911	742	2/13/2001	12/9/2014
TS-60-35-912	575	2/19/2004	12/5/2014
TS-60-35-913	654	2/13/2010	12/5/2014
TS-60-36-205	530	9/15/1972	12/8/2014
TS-60-36-207	470	3/17/1994	1/9/2015
TS-60-36-210	365	9/7/2011	1/7/2015
TS-60-36-305	478	3/10/1994	12/2/2014
TS-60-36-409	605	2/18/1988	12/16/2014
TS-60-36-410	467	3/27/1995	12/11/2014
TS-60-36-412	682	2/17/2004	12/11/2014
TS-60-36-413	451	3/1/2007	12/2/2014
TS-60-36-505	640	5/22/1972	12/2/2014
TS-60-36-509	652	10/1/1996	12/16/2014
TS-60-36-513	504	8/12/2011	1/7/2014
TS-60-36-612	984	1/12/2010	12/15/2014
TS-60-36-705	750	7/9/1973	12/16/2014
TS-60-36-706	750	2/15/1977	12/16/2014
TS-60-36-709	755	1/5/2010	12/16/2014
TS-60-36-809	740	6/22/1972	1/7/2015
TS-60-36-810	734	6/22/1989	3/3/2015
TS-60-36-812	581	7/6/1979	1/6/2015
TS-60-36-908	1,075	6/10/2010	2/11/2015
TS-60-37-402	912	12/9/1955	12/15/2014
TS-60-37-417	696	1/31/2008	2/16/2015
TS-60-37-603	1,500	1/17/2003	2/10/2015
TS-60-37-711	1,093	11/9/1976	2/26/2015
TS-60-37-714	1,132	3/9/2000	2/11/2015
TS-60-37-715	1,103	7/8/1964	2/18/2015
TS-60-37-716	882	4/8/1983	2/18/2015
TS-60-37-717	1,090	2/7/2001	2/18/2015
TS-60-37-911	1,056	2/8/2008	2/11/2015
TS-60-42-206	760	2/18/1977	12/3/2014
TS-60-43-514	1,050	3/9/2004	2/6/2015
TS-60-44-122	872	1/5/2010	12/16/2014
TS-60-44-318	1,184	5/22/1990	2/11/2015
TS-60-45-213	1,260	9/26/2007	2/11/2015
TS-60-45-214	1,290	6/16/2010	2/11/2015
TS-60-45-304	1,070	2/8/2008	2/11/2015
TS-60-45-402	1,150	1/12/1967	2/10/2015
TS-60-45-501	1,280	1/13/1967	2/10/2015
TS-60-45-503	1,332	4/20/1954	2/10/2015
TS-60-45-504	1,221	6/16/1956	2/10/2015
TS-60-45-507	1,280	12/16/1948	2/12/2015
TS-60-45-712	1,245	3/18/1974	2/12/2015
TS-60-45-812	1,260	4/1/1983	2/9/2015
TS-60-45-813	1,366	4/3/1996	2/9/2015
TS-60-45-814	1,276	10/1/2006	2/9/2015
TS-60-47-602	1,214	4/14/1994	2/17/2015
TS-60-51-815	1,644	1/22/2001	3/4/2015
TS-60-52-209	1,658	10/19/2000	2/16/2015
TS-60-52-306	1,594	4/19/1999	2/16/2015
TS-60-52-409	1,526	9/24/2007	2/16/2015
TS-60-52-411	1,649	5/12/2012	2/16/2015
TS-60-52-501	1,630	2/4/2002	2/17/2015
TS-60-52-603	1,650	4/18/1999	2/5/2015
TS-60-52-604	1,630	4/20/1999	2/5/2015
TS-60-52-606	1,680	4/18/1999	2/3/2015
TS-60-52-608	1,674	5/6/1999	2/5/2015
TS-60-53-111	1,572	2/9/2010	2/12/2015
TS-60-53-217	1,585	2/25/2009	2/17/2015
TS-60-53-406	1,620	4/18/1999	2/4/2015
TS-60-53-408	1,640	5/9/1999	2/4/2015
TS-60-53-416	1,656	4/26/2000	2/4/2015
TS-60-53-418	1,715	7/24/2003	2/5/2015
TS-60-53-420	1,628	5/2/2007	2/5/2015
TS-60-53-422	1,682	10/19/2007	2/17/2015
TS-60-53-519	1,661	6/3/2010	2/5/2015
TS-60-53-712	1,688	4/21/1999	2/3/2015
TS-60-53-713	1,710	1/20/1982	2/3/2015
TS-60-53-722	1,686	2/8/2001	2/12/2015
TS-60-53-726	1,568	12/2/2013	2/3/2015
TS-60-53-829	1,686	5/11/1999	2/3/2015
TS-60-53-832	1,718	2/9/2005	2/16/2015
TS-60-53-834	1,730	2/5/2010	1/20/2015
TS-60-53-905	1,640	6/13/2013	2/18/2015
TS-60-54-613	1,737	3/9/2004	2/19/2015
TS-60-55-313	1,639	3/7/1983	2/16/2015
TS-60-61-104	1,761	5/24/2006	2/12/2015
TS-60-61-214	622	11/4/2007	1/20/2015
Catahoula Aquifer:			
TS-60-35-604	2,473	11/29/2012	12/16/2014
TS-60-35-915	2,687	3/21/2013	12/9/2014
TS-60-36-615	2,685	4/17/2013	12/15/2014
TS-60-36-710	2,680	11/28/2012	12/16/2014
TS-60-37-418	2,940	4/24/2013	12/15/2014
TS-60-37-718	2,834	3/21/2013	2/18/2015
TS-60-44-124	2,607	2/28/2011	12/16/2014

Data provided by US Geological Survey and TWDB

Response to Comments Regarding the
"Draft Technical Memorandum Regarding Groundwater Production
and Water-Level Monitoring Program"

Comments from RW Harden & Associates, Inc.

1. *For now, we recommend that the report identify to the extent possible, pumpage by aquifer in Montgomery County and surrounding counties.*

   Response: General estimates of pumping by aquifer will be provided in the final report.

2. *We recommend developing a general grid spacing for monitor well locations in the artesian zone and perhaps a differing grid spacing be developed for the water table areas. Also recommend that there be more emphasis placed on monitoring of the water table.*

   Response: The expansion of the water-level monitoring program will depend on existing wells when available or new wells that are constructed and become available for water-level monitoring. The monitor wells will be spaced as evenly as possible, based on their availability, within the Lone Star GCD in lieu of trying to develop a grid system. The drilling of deeper monitor well is not planned due to budget constraints. The construction and utilization of shallow monitor wells by the Lone Star GCD is a possibility if funding is available and well sites can be obtained.

3. *We suggest indicating whether changes in static water levels are changes in artesian pressure or changes in water table storage, rather than using the more generalized term water level.*

   Response: The comment will be addressed in the final report. The final report will also be clarified to distinguish between static water-level changes and artesian pressure changes and the causes for artesian pressure changes.

Comments from Thornhill Group, Inc.

4. *The groundwater pumping is not reported by aquifer, it is only reported by county/geographic area.*

   Response: See response to Comment 1. Groundwater pumping is provided for the counties within the scope of work.

5. *Site specific pumping amounts and changes are not provided and this affects the evaluation of the water-level data.*

   Response: General groundwater pumping data associated with the changes in artesian head or water levels are provided. Well specific pumping data are not required to review the

adequacy of the water-level monitoring program, the primary objective of this task. An inventory of pumping counties away from the study area was determined to not be significant with respect to the scope of this study.

6. *Information for very few wells and limited areas is represented in the report. Also, pumping data for wells located near wells with hydrographs should be provided.*

   Response: The objective of this task in the integrated study is to show general water level or artesian head changes in the study area and review the adequacy of the Lone Star GCD's well monitoring program. It was never the intent of this study to provide all available historic well water-level monitoring data. Two additional water-level hydrographs will be provided for wells screening sands of the Jasper Aquifer to expand the areal coverage of hydrograph data in the areas of concentrated pumping. We do not agree with commenter's statement regarding the essentiality of numerous hydrographs and site specific pumping data to help evaluate general water-level trends and the adequacy of the water-level monitoring program and any recommendations for improvements. The pumping data for individual wells is not necessarily an indicator, at least on a regional basis, of what is influencing regional artesian head changes.

7. *Well completion information is not provided for monitoring wells.*

   Response: The final report will be amended to provide screened interval information, where available, for the wells with hydrographs discussed in the final report.

8. *LBG states that the majority of wells used as monitoring wells are production wells that are actively pumped.*

   Response: The monitoring system extends to the degree possible over much of Montgomery County where the only wells available for monitoring are pumped wells. General trends in static water-level or artesian head changes are representative using the available data. The hydrograph for MJ-3 (TS-60-53-713) will be discussed in the final report.

9. *There is reference to artesian head changes in the Jasper Aquifer due to 3.6 MGD of change in pumping in the north part of Harris County.*

   Response: Text addressing the aquifer response will be expanded in the final report.

10. *The monitoring network for both pumping and water levels should be spaced across the entire area affected by pumping in Montgomery County.*

    Response: Groundwater pumping and well water-level data are provided within the area covered by the scope of work, but not for counties exterior to the study area as that is not

necessary to evaluate the adequacy of the monitoring program and any potential improvements. Pumping is occurring in proximity to all of the Chicot, Evangeline, Jasper and Catahoula aquifer screened monitor wells and does not detract from the general water-level trends shown.

Comments from Lake Conroe Community Network

11. *Request that discussion of the relationship between population, water demand and water production be included in the report.*

    Response: The final report will be revised to include a general discussion; however a detailed analysis of population projections is clearly beyond the scope of Task 1.

12. *Request that all water-level data be recorded in reference to mean sea level.*

    Response: The water-level hydrographs will include land surface elevation at the well. The purpose of the hydrograph is to review historical water-level changes at a well and coupling that information with water-level data from other monitor wells to provide data on the aquifer response to pumping. Providing hydrographs showing depth to water relative to land surface is a standard approach when representing well water-level data.

13. *The comment referring to outcrop zones is requesting a significant expansion of the study effort to collect water-level data in outcrop areas of the aquifers, both inside and outside Montgomery County.*

    Response: Water-level data from USGS monitoring wells in Montgomery County is being utilized. An expansion of the monitoring program in the outcrop areas inside Montgomery County is already recommended as part of the report. As the Lone Star GCD has no regulatory authority over areas outside its jurisdictional boundaries (outside Montgomery County), any additional monitoring outside of Montgomery County would require a cooperative program with other governmental entities that have responsibility in those areas. Exploring this possibility will be recommended in the final report.

14. *Water-level data for additional Jasper Aquifer screened wells located in areas of concentrated pumping and less concentrated pumping should be presented and discussed. Additional water-level data showing seasonal changes should be provided along with other detailed information regarding pumping at wells or in proximity to them.*

    Response: Two additional water well hydrographs will be added and discussion of the aquifer response expanded for the three principal areas of concentrated pumping from the Jasper Aquifer. The request for additional detailed information goes beyond the scope of the

study in assessing the adequacy of the water-level monitoring program and where additional monitor wells should be located. The request for increased frequency of water-level measures could be considered as a recommendation at the conclusion of Task 1.

15. *Catahoula Aquifer monitoring. The comment is regarding additional emphasis being placed on the Catahoula Aquifer as a groundwater resource and its response to pumping including additional study in the artesian part of the aquifer and of the outcrop area and any monitor wells in the outcrop area and historical data regarding the wells. The requested work would occur inside and outside Montgomery County where the outcrop exists.*

    Response: General information is provided regarding the Catahoula Aquifer water-level monitoring, which is in conformance with one focus of Task 1. As additional pumping and well water-level data become available they will be integrated into the overall monitoring system. It will be recommended that monitoring data be periodically evaluated from Catahoula Aquifer screened wells located outside Montgomery County.

16. *Commenter believes that the Lone Star GCD monitoring system must account for both operating and outcrop components of each active aquifer.*

    Response: Additional improvements to the groundwater production reporting program and the number and locations of water-level monitoring wells both in the outcrop and downdip sections of the aquifers will be recommended in the final report.

Comments from Garry O. Dent

17. *The comment is that more focus needs to be applied to the analogy of the "half-full" part of the glass compared to the "half-empty" part of the glass when describing the groundwater resources.*

    Response: Work will be performed to address this comment during the performance of Tasks 2 and 3 as the potential for redistribution or an increase in groundwater pumping in the Lone Star GCD is studied.